Bulldog Battery

SERVICE MANUAL

Unleash The Power

bulldog-battery.com

UNLEASH THE POWER

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ESOP

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INTRODUCTION

Batteries have been so much a part of our life style for so long that many people tend to take them for granted. They expect batteries to perform reliably and trouble-free with little or no attention. In plant environments, where many materials must be moved, this lack of proper attention can result in reduced battery life, inefficient materials handling, damage to lift truck equipment, and a poor return on capital investment. Because they play such a vital role in materials handling in virtually every segment of industry, batteries should receive a great deal of attention in any plant program of care and maintenance.

Ideally, batteries should be handled by trained and skilled personnel—not only because of the financial investment involved, but also because of the inherent dangers involved with battery handling and maintenance. The purpose of this manual is to help the person(s) responsible for this care and maintenance to get the most efficient service from their batteries, and work with procedures that provide the safest possible environment. The design of charging rooms vary widely depending on space limitations. Contact your local Bulldog Battery representative or write Bulldog Battery for recommendations based on your specific needs.

CAUTION

The experienced battery maintenance and repair person is aware of the dangers involved with the handling of lead-acid industrial batteries, and with the acid and gases which are ever present with such batteries. As a reminder to this battery specialist and particularly to plant personnel who may not fully understand these dangers, Bulldog Battery labels each battery they ship with the following warning label:

DANGER	DANGER
DO NOT smoke or use an open flame. **DO NOT** create arcs or sparks, and **DO NOT** use other sources of ignition near this battery· **HYDROGEN GAS**, which may explode if ignited, is produced by this battery, especially when on charge. Good ventilation will reduce the explosion hazard.	**SULFURIC ACID,** which is corrosive and may cause burns, has been diluted with water to form the liquid in this battery. Keep it away from the eyes, skin and clothing. In case of contact, flush immediately with water. Always obtain medical attention when the eyes are affected.

Additional precautions and safety measures to be observed by those handling batteries are covered in the section entitled "Safety." Before handling or repairing batteries we strongly recommend this section be read.

Description and Theory

How a Battery is Constructed

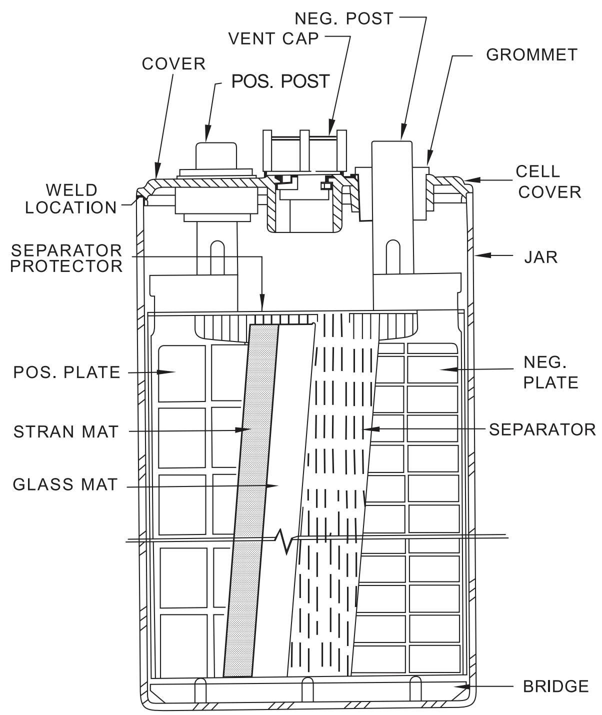
A lead-acid motive power battery is a portable power source for supplying direct current (DC) electricity to electric vehicles. It consists of six or more cells connected in series and assembled into a metal or fiberglass tray. This type of battery comes in a wide variety of shapes, voltages, and ampere hour capacities.

Each cell of a battery contains a group of positive and negative plates, interleaved so that positives and negatives alternate. The negative plates outnumber the positives by one. The positive plate consists of the active material, lead peroxide, held within the positive grid structure. In the Bulldog Industrial Battery, the active material is held firmly against the grid framework with a retention system consisting of glass mat, a fiberglass mat and a sleeve separator.

The negative active material is held by the thinner negative grid. No retention system is used because there is only slight shedding of the active material throughout its normal service life.

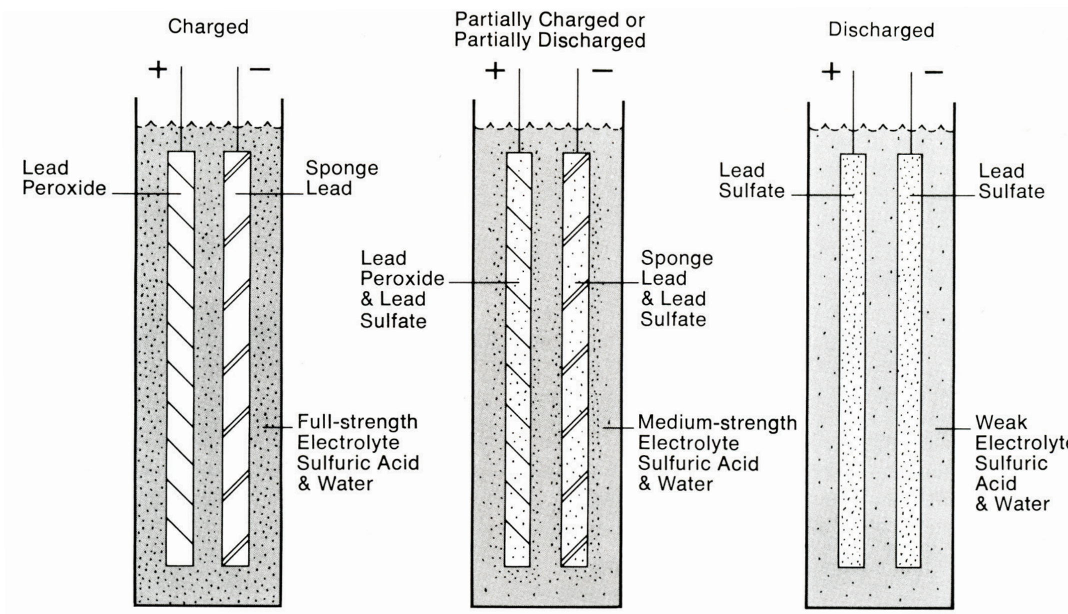
The plates are insulated from each other by the sleeve separator. All the positive plates are connected to the positive strap and the negative plates to the negative strap. The positive and negative plates and separators are submerged in a solution of sulfuric acid and water, called electrolyte, and are held in an acid-proof container called a jar.

Each cell has a nominal voltage of 2 volts. Thus, a 6-cell battery is called a 12-volt battery, and an 18-cell battery a 36-volt battery, etc. Increasing or decreasing the number of plates or the size of the cell has no effect on its voltage. It does, however, affect its capacity.



How a Battery Works

A battery releases power by the reaction of the electrolyte with the positive and negative plates (electrodes). A fully charged battery reflects the following internal condition: the positive active material is lead peroxide (PbO2); the negative active material is sponge lead (Pb); and the electrolyte, which has a specific gravity of about 1.280, is a solution of sulfuric acid (H2SO4) and water. The open circuit voltage is approximately 2.12 volts per cell.



The chemical reactions of charging and discharging batteries are reversible.

The Discharging Battery

When a battery is placed in use (connected to an electrical load), the stored chemical energy is re leased in the form of DC electrical energy. During the process, the internal components of the battery cells undergo a chemical change. The sulfuric acid (H2SO4) combines with the lead peroxide (PbO2) of the positive plates, and the sponge lead (Pb) of the negative plates and transforms them to lead sulfate (PbSO4).

The reversible reaction is shown as follows:

Pbo_2	**+ Pb**	**$+2H_2SO_4$**	**discharge** $\longleftarrow$	**$2PbSO_4$**	**$+ 2H_2O$**
lead peroxide	**+ sponge lead**	**-sulfuric acid**	$\longrightarrow$ **charge**	**lead sulfate**	**+ water**

As the battery discharges, the electrolyte approaches the specific gravity of water (1.000) with a simultaneous decrease in voltage. The specific gravity of a discharged battery reads between 1.100 to 1.160, depending on the type of battery, and the open circuit voltage reads from 1.98 to 2.01. The exact figures can be determined from manufacturer's specifications. The graph on page 15 shows the final discharged specific gravities of various types of Bulldog Batteries.

The Charging Battery

The chemical energy in the battery is restored by charging the battery, thereby reversing the discharge reaction. During the charge and especially toward the end of it, hydrogen and oxygen gas are produced by the electrolysis of water. Chemically, the reaction is:

$2H_2O$	$\longrightarrow$	**$2H_2$**	**$+ O_2$**
water	**electricity**	**hydrogen**	**+ oxygen**

How a Battery is Rated

The vehicle configuration, application and type of work to be performed by the vehicle usually determine the battery voltage and ampere hour capacity selected. A battery is rated by its capacity to deliver or discharge electrical energy over a period of time, and the capacity is expressed in ampere hours. For example, a battery rated at 300 ampere hours at a 6-hour rate means that it can deliver 50 amperes continuously for 6 hours before it reaches a discharged condition. The 6-hour rate is the time standard used by the battery industry when measuring battery capacity. A variety of factors that include the plate size, the number of plates in a cell, the specific gravity of the electrolyte and the discharge rate, all help to determine the ampere hour capacity.

Another measure of battery capacity takes both the ampere hours and voltage into consideration. This measure of capacity is called watt hours or kilowatt hours (watt hours 1000). Kilowatt hour (KWH) capacity indicates the power a battery can deliver under certain conditions. This relationship is explained by the definitions of battery capacity terms and the explanation of battery capacity testing.

Ampere Hour (AH)

Ampere Hour Rating = current (in amperes) X time (in hours)

Examples:

300 amperes for 1 hour = 300 ampere hours (at one-hour rate)

100 amperes for 6 hours = 600 ampere hours (at 6-hour rate)

Kilowatt Hour (KWH)

Watt Hour Rating = current (in amperes) X time (in hours) X average voltage = ampere hours X average voltage, as designated by the battery manufacturer.

Kilowatt Hour Rating = watt hour rating /1000
= ampere hours X average voltage /1000

Example:

What is the KWH rating of an 18 cell, 600 ampere hour battery with an average discharge voltage of 34.95 volts?

KWH Rating = 600 ampere hours X 34.95 volts/1000
= 20.97 KWH

Standard Test Conditions

Time—6 hours

Final Battery Voltage—1.70 volts per cell X number of cells in the battery

Temperature—77°F (average)

Capacity Discharge Test

A capacity discharge test determines if a specific battery delivers its rated capacity. "Capacity Testing" is explained on page 21.

Ampere Hours per Positive Plate

This term is defined as the rating of a specific size or type of positive plate expressed in ampere hours at the 6-hour rate. There is one more negative plate than positive plates in a cell. Therefore to calculate the ampere hours per positive plate in a specific type of battery, first subtract one from the total number of plates in the cell and then divide by two.

Example:

Determine the ampere hours per positive plate in a type 18-85B-17 battery which is rated at 680 ampere hours. The "17" indicates there are seventeen plates per cell.

17- 1 = 16

16 / 2 = 8 positive plates per cell

680 ampere hours / 8 positive plates = 85 ampere hours per positive plate

Safety

A lead-acid motive power battery can be an extremely useful, safe source of electrical power. On the other hand, if improperly used, it can be an extremely dangerous piece of equipment. The difference between the two conditions is determined by the care and safety procedures exercised in handling batteries. Before considering the safety procedures, first consider the hazards inherent to a lead-acid battery.

The Hazards

A lead-acid battery, by its very construction, exposes working personnel to four potentially dangerous elements: sulfuric acid, explosive gases, electricity and heavy weight.

A ***sulfuric acid*** solution is used as the electrolyte in lead-acid storage batteries, and has a concentration of approximately 37% by weight of sulfuric acid in water. Even in this diluted state, sulfuric acid is a strong oxidizing agent and can burn the skin and eyes; and "eat" holes in clothes made of many common materials such as cotton and rayon.

An ***explosive mixture*** of oxygen and hydrogen is produced in a lead-acid storage battery during the charging process. The two gases can combine explosively if a spark or flame ignite them. Because hydrogen is so light, it normally floats away and disperses into the air before it can collect into an explosive mixture. However, if it accumulates into gas pockets, it will explode when ignited.

Electricity is produced by the battery on discharge, and while most persons cannot "feel" voltages through their bodies below 35 or 40 volts, all motive power batteries should be regarded as potentially dangerous. A lead-acid battery is capable of discharging at extremely high rates, and under conditions of direct shorting can cause much damage and serious injury.

The ***weight*** of these heavy batteries can crush hands and feet if care is not taken when changing and handling them. Adequate and proper handling equipment should be provided. The average lift truck battery weighs over 2000 pounds.

The Safety Procedures

In 1970, Congress passed the Occupational Safety and Health Act (OSHA). The act established the minimal acceptable standards for safe and healthful working conditions. The act not only pinpoints the responsibility of employer and employee, but also establishes the penalties for disregarding the standards. It would be well to remember that OSHA standards are minimum requirements. The safety procedures suggested in this manual have been compiled from standards developed over the years by professional and technical organizations and by battery manufacturers and users who have had the experience necessary to create the most effective safety standards. They exceed the minimum standards of OSHA for personnel safety, and include procedures for safeguarding equipment as well.

For the purposes of making the information easier to find, the safety procedures have been grouped according to where they would logically be needed while working with batteries or charging equipment. The groups are identified as (1) Handling and Changing Batteries, (2) Charging Batteries, (3) Handling Acid, and (4) Repairing Batteries.

Note:
The information presented is of a general nature. It should NOT BE CONSTRUED AS A LEGAL OPINION.

Handling and Changing Batteries

Wearing Jewelry

Personnel who work around batteries should not wear jewelry made of conductive material. Metal items can short circuit a battery, and in the process become hot enough to cause a severe burn.

Removing Batteries

If a battery is to be removed from a truck, (1) open the electrical circuit of the truck (turn key or switch off), (2) set the brakes or chock the wheels, and (3) unplug the battery. The same procedure applies if the battery is to be charged in the truck. Never try to move a battery by pulling its cables. Batteries should be changed or charged only by personnel who are trained and authorized to perform these jobs.

Protected Chain Hoists

For handling batteries, chain hoists should be equipped with a chain container or bucket to prevent a dangling chain from shorting the battery. If a container or bucket is not available, the battery may be covered with a non-conducting material such as plywood or plastic. An insulated battery lifting beam can be used with any type of overhead hoist. A description of the adjustable, insulated battery lifting beam appears on the back cover.

Protective Eyeglasses and Headgear

The use of safety glasses and safety hats made of a non-conducting material is suggested when batteries are being handled or serviced.

Lifting Batteries

Steel trayed batteries have holes or eyes for lifting. The eyes used in conjunction with an insulated battery lifting beam and an overhead hoist is the recommended way to lift a battery. If a battery is lifted with two chains attached to a hoist at a single, central point forming a triangle, the procedure is unsafe and can damage the steel tray.

Battery as a Counterbalance

In most industrial trucks, a battery is used as a counterbalance for a carried load. Before installing a new or different battery, check the manufacturer of the truck for the recommended range of battery weight. The battery service weight is usually stamped into the battery top lead on the same intercell connector with the battery serial number. A battery with the wrong weight can change the center of gravity of the truck and cause it to upset.

Charging Batteries

Charging Rooms

Plants that change batteries at the end of each shift should have one or more centralized areas designated for battery charging. These battery charging areas should be equipped with overhead hoists, conveyors, and cranes or their equivalents for handling batteries safely and conveniently.

Battery charging areas should be adequately ventilated, either through natural or forced ventilation. "Adequate ventilation" is difficult to define as it is dependent on a variety of factors such as: number and size of batteries being charged at one time, room size, ceiling height, air-tightness of the building, etc.

No Smoking, No Open Flame

Because an explosive mixture of gas can exist in and around charging batteries, anything that could ignite the gas, such as open flame, an arc, spark, or smoking should be prohibited in battery charging. It is recommended that "No Smoking" sign be posted prominently in charging areas.

Insulated Battery Charging Racks

When batteries are charged in racks, the racks should be insulated to prevent the possibility of sparking. The supports on which a battery rests should be made of non-conductive materials or be suitably insulated.

Charger Connections

Before connecting a battery to, or disconnecting it from a charger, the charger should be turned off. Live leads can cause sparking and arcing, plus undesirable pitting of the contact surfaces of plugs or connectors.

Firefighting Equipment

In addition to automatic sprinkler equipment that might be present, charging areas should be equipped with suitable hand-operated fire extinguishers. Consult local fire authorities or your insuring carrier for the class and size needed, and recommended locations for mounting them.

Ventilation

The ventilating system in a charging room should conform to local codes and ordinances. If the average hydrogen concentration throughout the charging room does not exceed 1.5 percent by volume, or exceed 2 percent by volume in any one location, the ventilation is considered to be satisfactory. (Concentrations between 4% and 74% are explosive.) A variety of instruments such as combustible gas indicators and flammable vapor indicators are commercially available for continuous and automatic analysis of hydrogen concentrations in the air. Contact Bulldog Battery if more information on these indicators is desired.

When charging an enclosed or covered battery, whether it remains in the truck or is placed on the rack, always keep the battery tray cover and the truck compartment cover open throughout the entire charging period. Opening the covers will help cool the battery and disperse the gases.

Battery Gassing

The gases given off by a lead-acid storage battery on charge are due to the electrolytic breakdown (electrolysis) of water in the electrolyte to produce hydrogen and oxygen. Gaseous hydrogen is Gaseous hydrogen is produced at the negative plate, while oxygen is produced at the positive. Hydrogen is the gas which creates the problem. It will burn explosively when ignited if the air contains between 4 percent and 74 percent of it (less than 4% or more than 74% hydrogen will not explode). Hydrogen, which is the lightest known gas, is fourteen times lighter than air, and rises and disperses very rapidly.

Normally, insignificant quantities of gases are released by a battery during the first part of the charge, as most of the charging current is used in charging the battery. Only during the last stages of the charge does the process become inefficient, so that an increasing portion of the current is used up by the creation of heat and gases.

If, instead of being used to charge the battery, an ampere-hour of charge is used completely to produce gas, it will create 0.01474 cubic feet, or 0.418 liters, of hydrogen per cell at standard temperature and pressure. Stated another way, 68 ampere hours of charge, used completely to produce gas, will create approximately one cubic foot of hydrogen per cell.

To determine exactly how much hydrogen is released by a battery at any moment of the charge is rather difficult, as each case will be different. However, the total amount released may be approximated by the following method. It is based on the concept that a completely discharged 100 AH battery requires 100 AH of charge to bring it to full charge, plus overcharge needed to make up for inefficiencies of charging such as heating and gassing. The calculation assumes all the overcharge is used to produce gas.

K equals the number of cells in the battery.
W equals percentage overcharge assumed to be given to the battery. Assume this is 20% unless the actual percentage is known. This is the percent of the charge which is "wasted" in creating heat and gas. Further, assume it is all used to create gases.

B equals the volume of hydrogen produced by one ampere hour of charge. Use 0.01474 to get cubic feet. Use 0.418 to get liters.

C equals rated 6-hour capacity of the battery in ampere hours. This is also the number of ampere hours a fully discharged battery must accept to be fully charged.

H equals the volume of hydrogen produced during the charge.

(H) equals (K) times W/100 times (B) times (C)
$H = KWBC/100$

For example:

How many cubic feet of hydrogen are released while charging an 18-75B-15 (18 cell) battery (525 AH capacity) if it receives 20% overcharge?

H = KWBC/100

H = (18) (20) (0.01474) (525)/100

H = 27.9 cubic feet of hydrogen
Assume this gas is released during the last four hours of an 8-hour charge; then calculating a rough rate of hydrogen release is possible.

Example:

27.9/4 equals approximately 7 cubic feet per hour.

Eye-wash and Emergency Shower Facilities

The kinds of equipment available for eye-wash and acid neutralization vary widely as to capability and cost. Regardless of the equipment selected, it should be located in the immediate work area. The three most popular types of equipment are described below.

- *Chemical Burn Station*—This is the lowest cost type of safety equipment. It consists of a plastic squeeze bottle containing a buffering solution for the relief of acid burns on skin, clothing or in the eyes. The bottle usually holds about a quart of solution. It is held in a brightly-colored, molded receptacle about 1 1/2 feet square that can be mounted on the walls of the battery charging areas or battery repair shops. Its use is practical in smaller battery charging areas and at battery repair shops where acid with a specific gravity of 1.400 or higher is not handled. Before installing chemical burn station equipment, check to see if it is acceptable to your company Safety and Medical Departments.
- *Eye-wash Fountain*—A water fountain-type of device with two openings that facilitate washing both eyes at once. This type of safety equipment is useful when 1.400 specific gravity acid is regularly used for gravity adjustment, etc.
- *Deluge Shower*—This is a shower-type of device with a handle or foot treadle for turning it on full force. When high specific gravity sulfuric acid (above 1.400) is handled regularly, it is recommended that a deluge shower and an eye-wash station be installed.

Vent Caps Stay In

Keep the vent caps in the cells at all times, except when removal is necessary to service or repair the cells. This precaution reduces the probability of electrolyte splash, and prevents foreign matter from entering and damaging the cells.

Handling Acid

Acid Splash in the Eyes

Acid splashing into the eyes is the most dangerous condition possible while handling higher specific gravity acid or electrolyte. If it happens, the eyes should immediately be flooded gently with running water for at least 15 minutes, followed as quickly as possible with an examination by a physician. Special care should be taken to check for persons wearing contact lenses. The lenses should be removed if acid gets into the eyes, then the eyes thoroughly rinsed with water.

WARNING: Do not place a buffering or neutralizing

Acid Splash on Skin

Acid or electrolyte spilled or splashed on the skin should be washed off under running water. If a burn develops, it should be reported to a supervisor and treated medically.

Acid Splash on Clothing

When acid is splashed on clothing, use a weak solution of bicarbonate of soda to neutralize the acid. When clothes are soaked or splashed over large areas, they may be removed, the acid neutralized with bicarbonate of soda, and/or rinsed in running water until free of acid. The sooner the clothing is rinsed, the less chance of damage to the material.

Care should be taken not to spill acid into acid-resistant boots. Boots should be checked prior to each wearing to make sure that they are dry and that no acid or chemical has been left inside.

Protective Clothing

Normal work clothing can be worn in battery charging and battery repair areas for routine battery work. Acid resistant clothing is not as susceptible to acid damage as garments made of cotton, rayon or similar materials. If sulfuric acid with specific gravity higher than 1.400 is handled during gravity adjustment, etc., the following protective clothing and equipment can be used:

- Acid resistant gloves
- Acid resistant arm gauntlets
- Acid resistant apron
- Acid resistant boots
- Plastic face shield

Pouring Acid

A carboy filter or safety siphon shall be used when acid is removed from a carboy container. A venting device in a carboy will provide uninterrupted flow and prevent splashing. Never move a carboy of acid without its protective box. Store acid carboys in a cool place, and keep them out of the direct rays of the sun.

Mixing Electrolyte

Always add acid to water. Never pour water into strong acid. When mixing electrolyte, add the sulfuric acid to the water slowly, while stirring the mixture. The mixing container should be heat and acid- resistant.

Using sulfuric acid above 1.400 specific gravity is seldom required and is not recommended. Concentrated acid is extremely dangerous. When it must be used, special precautions must be followed and supervisory personnel should oversee the operation.

Storing Acids and Electrolyte

The floors in battery and charger rooms should be sloped toward a sump. Acid spillage should be neutralized before discharging into a sewer. Even though the floor is protected with an acid-resistant coating, it should be washed down with water after an acid spillage. It is recommended that local ordinances be checked to see if discharging any flow into the sewer complies with their regulations

Neutralizing Acids and Electrolyte

Sulfuric acid can be neutralized with several different chemicals. All should be handled with care.

1. Bicarbonate of soda or baking soda ($NaHCO3$) is a relatively harmless chemical with no marked effect on the skin or clothing. As it neutralizes it releases bubbles of carbon dioxide. When the bubbling action stops, the acid neutralization is complete.
2. Soda ash or sodium carbonate ($Na2CO3$) is also relatively harmless and has no marked effects on skin or clothing. It also releases carbon dioxide bubbles while neutralizing.
3. Caustic soda or sodium hydroxide ($NaOH$) is a strong chemical that requires special equipment and care in handling. When properly used it is an effective neutralizing agent. Since no carbon dioxide bubbles are released to indicate when neutralization is complete, pH (acidity) control equipment is recommended. The use of caustic soda is usually restricted to large installations with automatic neutralizing equipment.

NOTE: All of these neutralizing chemicals can be purchased from chemical supply firms.

Repairing Batteries

Disconnect the Battery

A battery should not be handled or repaired while on charge or discharge. Disconnect the battery from the truck or charger first.

Remove the Gas Before Working

Before working on a battery, remove all of the vent caps and flush each cell with a gentle stream of air by fanning each vent opening with a stiff piece of cardboard or other suitable non-conductor on charge or discharge. Disconnect the battery from the truck or charger first.

Sealing Compound

When melting sealing compound in a melting pot, be careful not to puncture the top section of unmelted compound with a sharp or pointed object. A build-up of pressure from the melted compound in the lower section of the pot, may cause liquid compound to squirt and inflict a severe burn.

Insulated Tools

Use insulated tools whenever possible when working on batteries. If possible, cover the terminals and connectors of a battery with a sheet of plywood or other insulating material.

Installation

Receiving a Battery

Inspecting the Shipping Container— Immediately upon receiving a battery, inspect the outside of the corrugated container (or crate) and the pallet. Look for wet spots on the sides and bottom. Wet spots generally indicate that the battery jars are broken, or that the battery was tipped over in transit.

Making a Claim—Shipments are generally made FOB, Bulldog Battery Plant or stocking location. Therefore, making a claim to the carrier is the responsibility of the customer. If there is evidence that the battery was damaged in shipment, a proper claim should be filed with the carrier. The services of a professional industrial battery repairman may be required to evaluate the extent of the damage. Contact Bulldog Battery or the nearest Bulldog Battery representative.

Lifting Batteries—The ideal rig for lifting batteries is an overhead hoist equipped with an adjustable, insulated battery lifting beam as illustrated on page 5. When attached to the lifting "eyes" of a battery, the lifting beam exerts a vertical pull on the eyes. This method prevents damage to a battery that would occur using lifting methods that tend to squeeze or stretch the battery tray. If there is a possibility that the chain or cable of the hoist might come in contact with the battery post, cover the battery with a piece of plywood or another type of non-conducting material.

Immediate Repairs to Damaged Batteries—If the electrolyte level in a particular cell drops quickly after water is added, the jar in this cell is leaking and should be replaced. When service facilities and personnel are available, replacement of the leaking jar should be made within one week of discovery. (See section on "Battery Repairs," page 26.) If repairs cannot be made, contact the nearest Bulldog Representative or Authorized Service Location for other arrangements.

Treatment for Repaired Cells—After the element is installed in a new jar, fill the jar with electrolyte of the same specific gravity as the rest of the cells in the battery at the time of the spillage. Charge the battery at the finishing rate (refer to "The Charging Process" in the Routine Maintenance Section, page 14, until the battery specific gravity stops rising. If the specific gravity in the cell being repaired is lower or higher than the normal reading for a fully charged battery, follow the instructions outlined in "Acid Replacement and Adjustment of Specific Gravity," page 28.

Placing a Wet Battery in Service

After determining that a battery was not damaged in shipment, give it a freshening charge of three to six hours, then install the battery. (See "Freshening Charge" for more details, page 14.)

Installing the Battery

The battery compartment of the vehicle must be well ventilated to allow the heat generated by the battery during discharge to dissipate. The battery compartment should also have drain openings in the floor. Most vehicle manufacturers are aware of both these needs and have provided the necessary louvers, slots and/or holes in the battery compartment. If the battery is to be installed in a metal compartment, make sure the compartment is clean and dry prior to installation.

Seat the battery in the compartment firmly and evenly. Then block it in position. Many vehicles adjustable clips for blocking the battery into place. 1/ 4" to 1/2" clearance between the block (or clip) and the battery tray. Do not wedge the battery into the compartment because some room is needed for expansion.

All vent caps must be in place. Uncapped cells will allow the electrolyte to splash and cause corrosion to the tray and vehicle.

Routine Maintenance

Today's industrial battery is designed and built to give anywhere from 1000 to 2000 operation/ charge cycles, depending on the application and the operating environment. If such a battery were to complete one cycle per work day, the life expectancy would be 4 to 8 years. Exactly how much life a battery will provide depends to a great extent on how well you take care of your battery. The following maintenance procedures, properly carried out at the proper time, will go a long way toward prolonging the life of the battery and making it more efficient.

Routine battery maintenance consists of four functions:

- Properly charging the battery
- Adding water as needed
- Cleaning as required
- Maintaining battery at proper temperatures

Instruments for Inspecting Batteries

Three testing instruments are required to check batteries accurately and efficiently: a voltmeter, hydrometer and thermometer. All three testing instruments appear in "Accessories and Testing Equipment" on the back cover. The specify gravity and open circuit voltage readings are normally in direct proportion to each other; therefore, a voltmeter or hydrometer can be used to check the battery. The use of the voltmeter is a faster method of approximating the individual cell state of charge, and can reduce dramatically the time required for routine battery checking. When using the voltmeter method of battery checking, take specific gravity readings on the two cells having the highest and lowest voltage readings. This will confirm both cells' state of charge and accurately pinpoint the difference in the state of charge between them. The voltmeter is used when on-charge or on-discharge voltage readings are needed.

A battery thermometer is read like any normal thermometer. If the thermometer does not have specific gravity corrections marked on its scale, refer to the "Temperature Correction Chart" on the next page to determine the specific gravity correction.

The Bulldog Hydrometer has an extra-long scale to make reading more accurate. For ease of correcting for temperature, the specific gravity corrections are marked on the scale of the Bulldog thermometer. The Bulldog Cell Tester (voltmeter) is a digital meter for more accurate readings.

Specific Gravity Temperature Correction Chart

Electrolyte Temperature °F	Point Correction
140°	+21
137°	+20
134°	+19
131°	+18
128°	+17
125°	+16
122°	+15
119°	+14
116°	+13
113°	+12
110°	+11
107°	+10
104°	+9
101°	+8
98°	+7
95°	+6
92°	+5
89°	+4
86°	+3
83°	+2
80°	+1
77°	No Correction
74°	– 1
71°	– 2
68°	– 3
65°	– 4
62°	– 5
59°	– 6
56°	– 7
53°	– 8
50°	– 9
47°	– 10
44°	– 11
41°	– 12
38°	– 13
35°	– 14
32°	– 15
29°	– 16
26°	– 17
23°	– 18
20°	– 19
17°	– 20
14°	– 21

Specific Gravity Correction Chart. For an accurate specific gravity reading, the temperature point correction must be added to or subtracted from the hydrometer reading.

Battery Charging

By far, the most important part of routine maintenance is the proper charging of the batteries. Generally speaking, lead-acid batteries may be charged at any rate of current which does not cause excessive "gassing" of the electrolyte, and does not produce temperatures in excess of 115°F (125°F is acceptable for infrequent, short periods). Fortunately, today's automatic voltage controlled chargers, like the Bulldog Battery Charger, take the guess-work out of charging. Providing the battery is well maintained, as described later in this section, all that is necessary for routine charging is knowledge that the charger is functioning properly. This is accomplished by periodic inspection and adjustment of the equipment. Periodic inspection and adjustment of the charging equipment can be performed by an outside professional charger repairman. Contact your Bulldog Battery representative.

However, a basic knowledge of what is involved in the charging operation, plus a brief description of the more important types of charging and when they should be used, should provide valuable information in the event of automatic charger malfunction, or for charging operations not using fully automatic equipment.

Types of Charging

There are a number of different charging methods, but for purposes of this manual, only three need explanation. These are: Cycle Charge, Equalizing Charge, and Freshening Charge.

Cycle Charge

This is the complete recharge of a battery after it has been fully or partially discharged during normal operation. Typically, a cycle charge is based on an 8- hour charging cycle, but can, depending on need, be extended.

Equalizing Charge

Each cell of a battery has slight differences in uniformity of construction and content. These slight differences cause some cells to take less charge than the other cells in the battery. After a time, the state of charge of the cells which require more charge than the others will drift back in capacity, and the battery will not deliver its full capacity. To bring the cells with a lower state of charge up to the same level as the others, the battery is given an "equalizing charge." The cells with a higher state of charge will be overcharged somewhat, in order to bring the cells with a below normal state of charge up to full charge.

Years ago, when lift trucks and mine locomotives were used lightly or sometimes stored during slack seasons, frequent equalizing charges (sometimes weekly) were recommended by battery manufacturers. Today, this inflexible kind of equalizing schedule is not recommended. Instead, the recommended frequency of equalization is dependent upon how often the batteries are cycled, and the depth of the cycles. The frequency of equalization can dramatically affect the operational costs of the vehicle. Unnecessary equalizing charges, in addition to consuming electricity, can result in significant loss of battery life caused by unnecessary overcharge. The following examples will give you a good idea of a reasonable battery equalizing schedule for a specific battery operation.

- For batteries that are cycled only once or twice a week to an average depth of 30 to 60 percent, a monthly equalizing charge is sufficient to keep them fully charged.
- Batteries that are discharged regularly—three or more cycles per week, and to an average discharge depth of 60 to 80 percent of their rating—can,be kept healthy by equalizing them every two months.
- Batteries that are cycled four to eight times a month at any depth require equalizing about every month to keep them in a healthy condition.
- Batteries that are cycled five or more times a week at an average discharge depth of 60 to 100 percent never need equalizing charges unless stored.

Freshening Charge

A freshening charge is used to bring a battery to a fully charged condition before it is placed in service, or when it has been standing idle for a short period. It takes about three hours at the finish charge rate (3 to 6 amperes per 100 ampere hours of the battery's 6- hour capacity rating).

The Charging Process

When a battery is placed on charge, the opposite action of battery discharge takes place; that is, the sulfate in the active material of the plates is driven back into the electrolyte. This reduces the sulfate in the plates and increases the specific gravity of the electrolyte, an electrochemical process which continues until the on-charge cell voltages reach 2.50 to 2.70 volts per cell, dependent upon the type of charging equipment used. The illustration and formula on page 2 explains the charging process in more detail.

Finish rate or "normal" rate is that current which can be used safely any time charging is required, and which can be continued after the completion of the charge without causing excessive gassing or high temperature resulting from overcharge. The finish rate is shown on the nameplate of Bulldog Batteries. Generally speaking, it is 5 amperes per 100 hours of the battery's 6-hour rate capacity.

A partially, or completely discharged battery can safely handle currents much higher than the finish rate, but as it approaches full charge, whatever charging rate is used must be reduced to the finish rate.

Note that after approximately 5 hours of charge, when the battery is about 85% of its nominal full charge, the charging current is reduced sharply to a level which is maintained until charging is complete. When the battery is fully charged, the current is stopped or should be reduced to a very low rate.

Determining if a Battery is Properly Charged

If the battery charging equipment is the counter voltage sensing type and is functioning properly, and if the battery is in a healthy condition, there is little chance for an improperly charged battery. If some doubt about its operation exists, the following checks are a quick way of determining a proper, fully charged battery:

- Charging current readings will level off to the finishing rate
- Charging voltage stabilizes
- No rise in specific gravity
- Normal gassing (excessive gassing is defined on the next page under "Gassing.")

Overcharging

An excessive amount of charge results in high battery temperature, reducing the battery's service life.

Overheating

To obtain maximum service life from a battery, it should be charged and operated at temperatures below 115°F. Above this temperature, overheating occurs. Overheating can damage the battery and shorten its normal expected service life. The extent of the damage and service life loss depend on how high the temperature, how often the overheating occurs, and how long the batteries are subjected to high temperatures.

A healthy battery charged on a properly functioning charger will have a 10 to 20°F rise in temperature when fully charged from a completely discharged state. What causes a battery to go beyond this range and overheat? The temperature rise is affected by several variable factors:

- Age and condition of the battery
- Battery temperature compared to ambient temperature
- Start, intermediate and finish rate of the charger
- The amount of overcharge given the battery

In lift truck operations, a battery can overheat because of the operating requirements of the truck, as well as the operating environment. If a lift truck requires almost continuous current draws that are higher than normal, the temperature will rise. Ideally, for this operation, a "cool" battery whose temperature is 90°F or lower should be installed in the truck.

However, if the lift truck operation starts with an overheated battery whose temperature is above 115°F, the continuous high current draws will tend to make the temperature rise even higher and battery damage is likely. Typical working environments where batteries must operate in an overheated condition are in a foundry, where ambient temperatures reach 120°F and higher; and in heavy-duty operations where they must be changed every 5 to 6 hours with no time for cooling before a charge. The latter problem can often be alleviated by having more than two batteries per truck. For the former, an inexpensive way to cool the battery is by directing a fan over its intercell connectors and since they conduct about 60% of the heat out of the battery, the battery will cool rapidly. Charge with battery covers open.

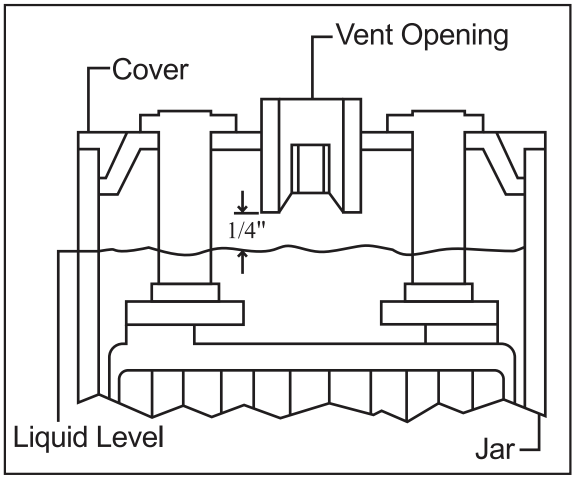
Operating and charging batteries at elevated temperatures is a frequent cause of battery damage and reduced service life. An experienced lift truck battery person, given the levels of operating and charging temperatures, and the time span for which they are held, can estimate the percentage of service life lost. The estimated loss expressed as a percent, can serve as the basis for deciding whether to invest in extra batteries, higher capacity batteries or battery cooling equipment. If this kind of professional judgment is not available in your plant or operation, contact your nearest Bulldog Battery Sales Office or Service Location.

Gassing

When a battery is charging, the electrolytic breakdown of the water in the electrolyte produces oxygen on the positive plate and hydrogen on the negative plate. This is normal. However, if a high charging rate is continued after the battery has been brought to its gassing voltage, the gassing becomes excessive, and abnormally large amounts of hydrogen and oxygen gases are produced. The best indication of excessive gassing is very noticeable "bubbling" action of the electrolyte and high electrolyte temperature.

Keyed Connectors

Sometimes, batteries of several different voltages and ampere-hour capacities are charged at the same centralized location. Precautions must be taken to make sure that batteries are charged on chargers with matching voltages and ampere-hour ratings. Rather than rely on the persons placing the batteries on the chargers, we recommend the use of plugs and connectors of different types or the use of keyed and color-coded connectors. Contact the nearest Bulldog Battery Sales Office or Service Location, if more information on the various kinds of charging plugs and connectors is desired.



The electrolyte level must be kept between the "high watering level" and the separator protector is shown in the sketch. Caution—Do not overfill. Moisture on the tops of the batteries indicates overfilling has occurred.

Hydrogen is a highly combustible gas and will explode on ignition when its concentration in air reaches any battery the concentration is too weak; above 74% there is not enough oxygen left in the air to support combustion.) If you have reason to suspect excessive gassing, troubleshoot the battery and charging equipment. An unusually high usage of water indicates that excessive gassing is occurring. A list of eight probable causes and possible remedies are outlined in the "battery overheats during charge" section of the "Troubleshooting Chart" on page 24. A section entitled "Battery Gassing" on page 8 shows how to calculate the rate of hydrogen release for a specified battery.

Undercharging

Undercharging a battery, even to a small degree, if continued, leads to excessive "sulfation." The same is true of batteries which have been left standing in an uncharged state for an extended period. High temperatures rapidly accelerate sulfation when batteries are left standing in a partially charged condition. The cells of a sulfated battery will give low specific gravity and open circuit voltage readings. On charge, voltage readings will be unusually high. The battery will not become fully charged after a single normal charging when sulfation has taken place over a prolonged period.

Treatment of Sulfated Batteries

Careful attention to the following steps often will restore a sulfated battery to a good operating placed on equalizing charge two or three times.

1. Thoroughly clean the battery. See page 16 for cleaning instructions.
2. Bring the electrolyte level to proper height by adding water.
3. Put battery on charge at the prescribed finishing rate until the rated ampere-hour capacity has been returned to the battery. Record the voltage and specific gravity readings. Correct the specific gravity readings using the chart shown on page 11. If temperature at any time during these procedure exceeds 115°F, stop the charger and allow the battery to cool to 90°F or below, before continuing the charge. Continue charging the battery until the specific gravity shows no change during a 4-hour period taking hourly readings. With automatic charging equipment, the battery may have to be placed on equalizing charge two or three times. I-f a battery is badly sulfated, the specific gravity may rise only 30 or 40 points (.030 to .040) during this first condition.
4. Place the battery into service and discharge it to a fully discharged condition. The chart on the opposite page shows the specific gravity of a 100 percent discharged battery. (The battery can be discharged through a bank of resistors, if desired.)
5. Charge the battery again until the specific gravity shows no change during a 4-hour period.
6. Repeat the charge/discharge process until the specific gravity rises to within 30 points of a fully charged battery. Then place the battery back into normal service. Although the specific gravities may be lower than normal, they should not vary other than sulfation may be present. If the spread between the highest and lowest specific gravity readings is 50 points (.050) or more, refer to the "Troubleshooting Chart" on page 24-25 to help identify the problem. If the battery has not responded to the above treatment, it should be replaced.

Adding Water

Generally, a certain amount of water loss is normal in all batteries, and it should be replaced with "pure" tap water or distilled water. In some areas around the country, tap water may contain chemicals or other impurities harmful to batteries. If in doubt about the suitability of the local tap water, read the information entitled "Water Suitability and Water Analysis." If water is needed, add just enough to bring the electrolyte to the proper level as illustrated in the *'Ten Commandments of Good Battery Care" available upon request.* Batteries should be filled only at the end of can cause tray corrosion and loss of capacity. Since that corrosion can cause EXTENSIVE DAMAGE to batteries and vehicles, extreme caution must be taken to avoid overfilling the batteries. The information in "Tray Corrosion" below identifies the cause and effects, and how to prevent it. The information in Watering Schedule" page 18, can help you Establish a reasonable and economical watering schedule.

Water Suitability and Water Analysis

Most tap water in the United States is suitable as replacement water in lead acid storage batteries. There are a few locales where certain quantities of specific impurities will reduce battery life significantly enough to justify the use of distilled or a more "pure" water. The NEMA recommendation for battery replacement water lists the following maximum allowable impurities (parts per million):

Total solids	350 ppm
Chlorides as Cl	25 ppm
Nitrates as NO_3	10 ppm
Iron as Fe	4ppm

Occasionally tap water has a small amount of nickel, manganese, chromium or copper contamination. Depending on the quantity, these contaminants also can significantly affect battery life.

If the suitability of the tap water for watering batteries in your locale is questionable, Bulldog Battery can provide a water sample analysis test. For details and the cost of the test, phone or write the nearest Bulldog Battery Representative.
If the Bulldog analysis indicates that the tap water in your locale is not suitable for batteries, it is possible that a more suitable tap water might be found within a reasonable distance and transported to your location more economically than purchasing distilled water or water purifying equipment.

Tray Corrosion

Most trays for motive power batteries are made of steel that is protected with an acid resistant coating. Regardless of how good the coating is, if a break in the coating exposes the steel tray to the sulfuric acid spilled from the battery, the acid will corrode the tray. How quickly the tray corrodes depends on how much and how often acid is spilled on top of the battery, and how often the battery is cleaned.

The major cause of tray corrosion is over-watering or overfilling a battery. When overfilled, the electrolyte will spill on top of the battery. Although the water in the electrolyte will evaporate, the highly concentrated acid solution remains and gives the appearance of dampness. If the acid is not removed, the tray will eventually corrode. To prevent corrosion, batteries should be cleaned any time the accumulation of dampness or acid becomes significant.

The only way to prevent overfilling is by not exceeding the level pointed out in "The Ten Commandments of Good Battery Care." A good technique to follow in watering batteries is to use a flashlight focused on the vent hole being watered. Visually, watch the level of the electrolyte rise, and stop the watering the instant the proper level is reached. Each cell is filled in the same way. Cell filling equipment that automatically fills batteries to the proper level is available. Contact the nearest Bulldog Battery Service Location for details.

In addition to causing tray corrosion, the accumulation of acid in conjunction with the corrosion can cause grounds. Two significant grounds can create an external short through the case of the battery. As a result, some or all of the cells will continually discharge. And as the current carrying ability of the multiple grounds increases, further complications such as jar leakage, overheating, cell failure, etc., can occur. Furthermore, grounds can also cause serious problems or failures in the electronic controls or electrical components of the vehicle.

To test for a ground in a battery, set the voltmeter to handle the full open circuit voltage of the battery being tested. Place the positive probe on the positive terminal of the battery and the negative probe on a spot of the steel tray where bare steel is exposed.

Make sure that the negative probe penetrates the general cleaning at this time, the moisture can be removed with rages or paper towels. (These could be immediately disposed of.) The frequency of a general cleaning depends upon paint to the steel. To detect the location of the ground, move the positive probe from intercell to intercell connector until the lowest voltage reading is found. This will be the grounded cell.

To clear the ground, clean the top of the battery of acid and corrosion and dry. If the ground is still present, remove the cell and check for leaks. Reseal using the Bulldog Plastic Welder, if necessary,

Watering Schedule

Most tap water in the United Low electrolyte level in a cell can cause the plates to oxidize and shorten the life of the cell and the battery. To prevent this needless and wasteful damage, water should be added often enough to keep the electrolyte level above the perforated separator protectors. Ideally, a watering policy or schedule should be adopted and followed strictly. One of two systems can be used. In the first, the electrolyte level of two or three cells is checked each time the battery is charged. In the second, water is added to all of the batteries assigned to each charging area on a regular time schedule. The electrolyte levels are also spot checked periodically to determine if the proper levels are being maintained, if the second method is used.

Determining a reasonable and proper battery watering time schedule could be easy or difficult, depending on how widely the following three factors vary:

- Frequency of charge (daily, 1 1/2 times a day, three times a week, etc.)
- Water storage capacity of the specific cell type
- Age and condition of the battery

Older batteries and those in poor condition will consume water more rapidly than newer batteries and those in good condition. Also some cell types have a greater water storage capacity than others.

Depending on the preceding variable factors, the batteries assigned to a specific charging area will require watering at different intervals. The frequency of watering is best determined by first-hand experience.

EXAMPLE: If some batteries have low electrolyte levels when a weekly watering schedule is followed, change the schedule to twice a week.

Cleaning

To prevent tray corrosion and the resultant problems, batteries must be cleaned and dried routinely.

Sometimes minor spills or overflows of electrolyte occur due to overfilling. Instead of giving the battery a two factors:

- How quickly dust, dirt, oil and other foreign matter accumulate on the top of the battery; and
- How quickly the electrolyte spillage accumulates.

When the top of a battery is "dirty" or looks damp, it is ready for a general cleaning. It could be as often as every two weeks or as infrequent as every six months, depending on the battery's environment and the care it receives. The average battery needs a general cleaning every three months.

To give a battery a general cleaning, use hot water (130° to 170°F) with a neutralizing detergent solution. The neutralizer/detergent solution is made by mixing 1/2 pound of baking soda, or 1/2 pint of household cleaning ammonia, with the recommended amount of detergent for general cleaning with one gallon of clear water.

Apply the solution with a clean paint brush to the top of the battery, working it under the intercell connectors and the terminals to loosen the grime and neutralize the acid. If baking soda is in the solution, apply the mixture until the "fizzing" action stops. (An ammonia solution will not "fizz.") Then rinse the battery with clear, hot water from a low pressure hose to remove all traces bf the solution and loose dirt. Cold water works, but hot water cleans better.

DURING ANY CLEANING, BUT PARTICULARLY WHEN USING A NEUTRALIZER / DETERGENT SOLUTION, MAKE CERTAIN THAT ALL VENT CAPS ARE TIGHTLY IN PLACE.

A Few DOs and DON'Ts for Effective Battery Maintenance

As is true with almost any piece of industrial equipment, proper maintenance not only keeps it operating to its design specifications, it also helps prolong the service life of that equipment. Industrial batteries are no exception. The following maintenance tips, if followed, can help achieve top performance over thousands of hours of operation.

1. **DO** maintain the proper electrolyte level. Avoid overfilling, as this damages the battery.
2. **DO** charge properly. Check charger controls and instruments periodically. Calibrate meters as needed.
3. **DO** repair damage promptly. Major damage means an idle investment; minor damage, if not quickly repaired, can soon lead to major damage.
4. **DON'T** overcharge. Many batteries deliver short service life from too much charge.
5. **DON'T** discharge over 80% for maximum battery life. Over-discharging is one cause of less than normal battery life. And, as a battery nears complete discharge, its operating efficiency decreases substan**tially.**
6. **DO** use batteries according to the manufacturer's recommendations. Using a smaller capacity battery than is called for is a sure way of ruining an expensive investment.
7. **DON'T** place metal objects on a battery. They can "arc" or short circuit the battery.
8. **DO** replace at 80% of capacity. When a battery cannot deliver more than 80% of its normal capacity after a charge, it's time to replace it. A battery in poor condition can cause low voltage operation in the vehicle and result in substantial damage to its electrical components.
9. **DO** keep accurate records. They not only provide an accurate history of the battery and permit replacement of worn units in time to forestall production stoppages, they also indicate whether a battery is being abused.
10. **DO** give periodic equalizing charges as described on page 13.
11. **DO** check batteries periodically-cell voltages, specific gravities and electrolyte levels.
12. **DO** make regular visual inspections to determine spillage, corrosion, damage to the case, and similar problems.
13. **DO** keep idle batteries charged. When stored for extended periods, batteries should be given a freshening charge periodically and immediately before use.

Periodic Battery Inspection Adding Water

The investment in motive power batteries can be considerable. To protect this investment, it is recommended that both batteries and chargers be inspected periodically. This general type of inspection, which is a form of preventative maintenance, should not be confused with the inspection carried out for troubleshooting a battery to pinpoint a specific problem.

If minor problems in batteries and charges can be identified early, then adjusted or repaired, battery damage can be avoided. A battery inspection often reveals improper routine maintenance and operational procedures, which can lead to extensive battery and vehicle damage. Inspection can also identify batteries in poor or bad condition so that they can be replaced immediately or at some suitable time in the future.

Establishing a battery inspection timetable suitable for all users is difficult, because battery usage and the quality of routine maintenance differ from one plant to the next. However, if routine maintenance is average, and the batteries are cycled once a day, five days a week, an annual inspection should be frequent enough to identify the problems.

With rare exception, few vehicle repairmen have the necessary training and experience to identify and correct the subtle battery and charger problems that can occur. But, it is relatively easy for the experienced professional serviceman equipped with special instruments and tools to identify the problems. If your organization does not have a trained battery and charger repairman, we recommend that you contact the nearest Bulldog Battery Service Location to inquire about the cost of these periodic inspections by a professional.

A troubleshooting procedure, chart and list of diagnostic hints appear in the "Troubleshooting" section of this manual on pages 20 through25.

How to Inspect a Battery

The more complex and extensive battery inspecting, testing and diagnostic work is often best handled by experienced motive power battery technicians. This manual is not intended to be a complete source for the training of a battery technician, although it provides a good foundation. The following instructions can show an electrician or vehicle repairman how to gather and record basic information that can help him to pinpoint the source of a battery problem.

1. If the battery is still in the vehicle, turn off the power switch and disconnect the battery by unplugging it from the vehicle.

2. Allow the battery to remain on open circuit (without charging or discharging) for 30 minutes or longer.

3. Prepare a form similar to the illustrated "Battery Inspection Form." Fill in the necessary data on the top of the form, i.e., battery type, serial number, etc.

4. Read and record the specific gravity and open circuit voltage (cell volts) for all cells of the battery. The positive terminal cell of the entire battery is recorded as cell No. 1, etc., following the intercell connectors to the last cell which is the negative terminal cell of the battery.

5. Read and record the pilot cell temperature. If the battery is being tested on charge or discharge, record the "reading at . . . . . . amps."

6. If desired, record the temperature corrected specific gravity readings in the "Positive Cadmium" columns. Use a temperature correction thermometer, or refer to the "Specific Gravity Temperature Correction Chart" on page 12 to correct the specific gravity reading for temperature. Use the pilot cell temperature for the temperature correction of all the battery's cells. It is not necessary to read the temperature of every cell unless the temperature difference between the center cells of the battery and the outside cells of the battery is 12°F or more.

Troubleshooting and Testing

There might be times when a battery does not perform to expectations; or times when a specific symptom such as overheating, high water usage, etc. indicate that a problem exists or indicates the possibility of impending trouble. To help identify conditions, pinpoint problems and offer solutions is the purpose of the Troubleshooting and Testing Section. Diagnostic hints, detailed instructions for capacity and cadmium electrode testing plus a troubleshooting chart can go a long way in helping to correct minor problems before they become major expenses.

Some Diagnostic Hints

These hints can help pinpoint the source of battery problems:

1. While a battery is on charge, feel the intercell connectors. A hot connector usually indicates an overheated battery, defective cell or a bad connector burn.
2. An accumulation of moisture and/or tray corrosion on the bottom of a battery or a vehicle battery compartment often indicates that one or more jars are leaking.
3. Unequal cell specific gravities in a newer battery indicate that the battery might have been tipped over and the cells with the lower specific gravities have lost electrolyte.
4. If a battery is inspected shortly after it is watered and prior to charging, the specific gravity readings may be low and uneven. The specific gravities will level out after it is fully charged.
5. Watering to the proper level is the most difficult procedure to control in routine battery maintenance. Over-watering causes tray corrosion and results in the multiple problems discussed on pages 17 and 18.
6. A defective or out-of-adjustment battery charger can create considerable damage before the cause is discovered. Vehicle operators should be trained to report "hot" batteries; battery maintenance personnel should report to their supervisors chargers that do not reduce the charging rate at the end of every charge.
7. Continual over discharge dramatically shortens battery life. Avoid over discharging by using battery protectors in the lift trucks; or, obtain more batteries with higher capacity, if possible—and charge them more frequently.
8. If the spread between the lowest and highest cell specific gravity in an older battery is .050 or more, the battery will probably deliver less than 80% of its rated capacity and may need to be replaced. (Read "Capacity Testing" for more details.)
9. As a battery ages, the positive plates "grow" in length and push the post of the battery up until it becomes noticeable. The positive post of every cell cover in the battery will be higher than the negative post, and the covers appear to be tilted. When the positive posts of all the cell covers are 3/16" to 1/4" higher than the negative posts, the battery is probably worn out and beyond economical repair.
10. Most battery problems can be avoided or corrected by following strictly the "Ten Commandments of Good Battery Care."

Capacity Testing

A capacity test is sometimes desirable to determine the actual capacity that a battery delivers as compared to its rated capacity. If all other testing methods fail, this test can help determine if a battery should be replaced. When a battery delivers less than 80% of its rated capacity, the remaining capacity will rapidly decrease with each additional cycle. Logically therefore, it should be replaced before some of its cells fall and cause low voltage operation of the vehicle and result in damage to its electrical system.

A capacity test is performed by discharging a fully charged battery at a fixed rate while carefully following specific test conditions, methods and procedures.

EXAMPLE:
A fully-charged 600 ampere-hour battery, at 77°F, at the 6-hour rate, is discharged at 100 amperes (600 ampere hours by 6 hours) until it reaches a final battery voltage of 1.70 volts per cell times the number of cells in the battery. If this final battery voltage is reached in five hours, the battery delivered 83.3% of its rated capacity.

5 hours/6 hours X 100% = 83.3%

It is essential that, unless the battery's electrolyte temperature is between 70°F and 85°F a temperature correction be made to the required time.

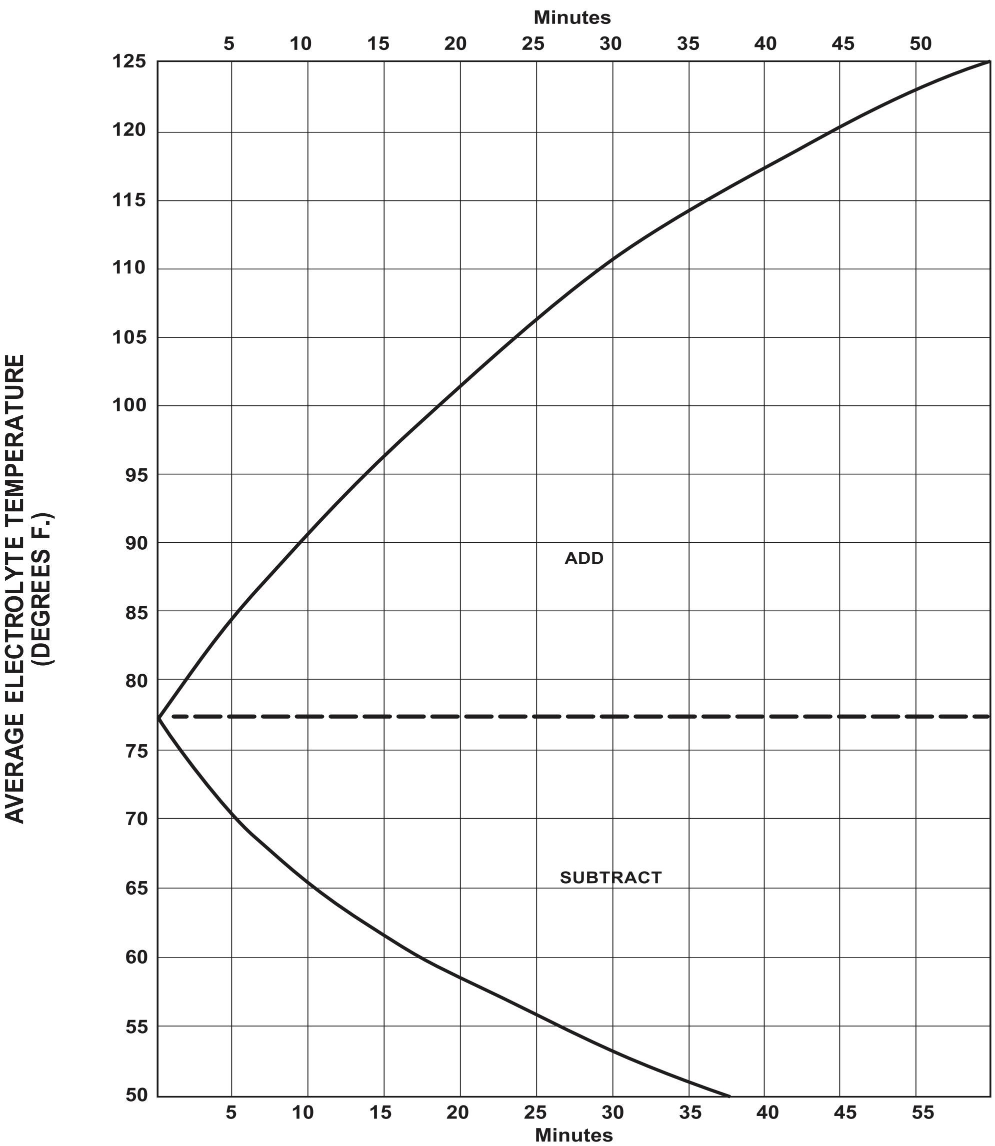
This is a simplified example of discharge per the graph below.

If tests are to be made, it is recommended that the test conditions, methods and procedures specified in NEMA Standards Publication No. IB2-1974 entitled "Determination of Capacity of Lead Acid Industrial Storage Batteries for Motive Power Service," be followed. Copies of this standard publication can be obtained at a nominal cost.

Address inquiries to:

National Electrical Manufacturers Association
Department of Engineering and Safety Regulations
2101 L Street, NW
Washington, D.C. 20037

The rated capacity of a Bulldog Battery is indicated on the nameplate. If it is not legible, contact the nearest Bulldog Battery Sales Office or Service Location.



Cadmium Electrode Testing

Cadmium electrode testing is a more detailed test of a cell, and is used to determine whether internal inspection or repair of the cell is required. The cadmium electrode test is given at the end of the charge while the battery is still on charge at the finish rate.

If any doubt exists as to whether a cell should be removed from the battery for inspection or repair, the cadmium electrode test can help make the decision.

In order to prepare the surface of a new cadmium electrode, it should be soaked in sulfuric acid for several days. If it was stored dry before use, re-soak it for at least thirty minutes so that the readings will be accurate.

To take the positive cadmium reading of a cell, connect the cadmium electrode to the negative lead of a voltmeter with a 0-3 volt full scale range.

Connect the positive lead of the voltmeter by probe to the positive terminal of the cell. Immerse the cadmium electrode in the electrolyte of the cell (see photo) and move it around frequently to prevent the formation of gas bubbles and provide a good, positive cadmium reading.

Take and record the positive cadmium readings for all the cells of the battery while on charge. Record the on-charge cell voltages and specific gravities of all cells of the battery for future use.

By way of illustration, the example below shows the positive cadmium readings of the cells of a battery in a fully-charged condition at a temperature of 77°F.

Cell Number	On-Charge Voltage	Positive Cadmium	Negative Cadmium
1	2.65	2.45	-.20
2	2.45	2.50	+.05
3	2.66	2.51	-.16
4	2.45	2.26	-.19
5	2.65	2.45	-.20
6	2.65	2.45	-.20

Referring to the table, note that cell number 4 has a low on-charge voltage of 2.45. This fact, plus the fact that the positive cadmium reading is also quite low, is an indication that the cell should be inspected internally for trouble.

Cell number 2 also shows a lower than normal on-charge voltage. Notice that in both cases, a problem is indicated by a cell voltage reading being out of line with the other cell voltage readings in the battery. However, in the case of cell number 2, the positive cadmium reading is normal, suggesting possible trouble with the negative plates.

Several conditions such as contaminated electrolyte can cause this. The “Unequal Cell Voltage” section of the Troubleshooting Chart on page 25 lists other possible causes of a below-normal cell voltage.

Troubleshooting Chart

Symptom	Probable Cause	Possible Remedy
Battery overheats during charge	1. Malfunctioning charging equipment. 2. Charging equipment out of adjustment. 3. Weak or defective cell(s). 4. Battery beyond economical repair. 5. High resistance connection within the battery. 6. Low electrolyte level. 7. Battery charged in the vehicle with battery compartment closed. 8. Battery over 115°F when placed on charge	1. Replace or repair defective charger parts (timer, voltage sensitive relay, control board, etc.). 2. a. Adjust start and/or finish charging rates. b. Adjust charge termination, voltage sensitive electronic device or relay. 3. Replace or repair problem cell(s). (See page 26.) 4. Replace battery. (See page 26.) 5. Check for hot wires, cells, intercell connectors, charging plugs, etc. Repair or replace defective component. 6. Water battery to proper level and charge immediately after cooling. 7. Open the compartment during charge or charge the battery out of the truck with the tray cover opened. 8. Allow battery to cool below 90°F before charging. Use cooling fans to speed the process.
Battery overheats during discharge	1. Any probable cause listed under 2. "Battery overheats during charge". 3. Worn out bearings, brakes dragging or other vehicle problem causing high current draws. 4. Overdischarge of battery.	1. Any possible remedy listed under "Battery Overheats During Charge." 2. Repair or replace defective lift truck parts. 3.a. Require drivers to return battery for recharge when vehicle begins to slow down. b. Install battery protector on vehicles.
Battery not completing full work shift	1. Battery not fully charged before placed into operation 2. Leaking, weak or defective cell(s) in the battery 3. Shorts or grounds in the battery 4. Battery beyond economical repair. 5. Battery too small for the job 6. Mechanical or electrical problems in vehicle	1. See that battery has reached full charge specific gravity before placing into operation. Full charge gravity is 1.280 corrected for temperature variations. 2. Repair or replace battery. (See page 26.) 3. Replace battery with equal or higher capacity battery. 4. a. Replace battery with batteries having higher capacity. b. Purchase extra batteries with higher capacity if possible. 5. Troubleshoot vehicle and repair.

Symptom	Probable Cause	Possible Remedy
Low electrolyte level	1. Broken or cracked jar(s). 2. Cell missed when watered. 3. Weak or defective cell(s). 4. Frequent overcharge. 5. Battery not regularly watered.	1. Replace jar(s) and adjust gravity. 2. More careful attention when watering. 3. Repair or replace cell(s). (See page 26.) 4. See items 1 and 2 in "Battery overheats during charge," on opposite page. 5. Water battery regularly. (See page 18.)
Unequal cell voltages	1. Grounds in battery. 2. There is a "tap" off the battery for auxiliary equipment. 3. Battery sluggish due to lack of work. 4. Leaking cover or cell. 5. Weak or defective cell(s). 6. Battery beyond economical repair. 7. Acid loss in a few cells by tipping battery over. 8. Frequent over watering causing electrolyte loss due to flooding.	1. a. Change location of the battery "tap" periodically. b. Equalize battery regularly. 2. a. Give battery a deep discharge and equalizing charge. b. Equalize the battery periodically. 3. Replace jar or cover and adjust gravity. 4. Repair or replace defective cell(s). (See page 26.) 5. Replace battery. 6. Adjust specific gravity. (See page 28.) 7. Fill to proper level (see page 15.)
Unequal specific gravities between cells	1. Any probable cause listed under "Unequal cell voltages". 2. Battery just watered and water not mixed with electrolyte. 3. Improper gravity adjustment after a cell change	1. Any possible remedy listed under "Unequal cell voltages" above. 2. Place battery on charge and read 1 hour after it begins to gas. 3. Adjust gravity. (See page 28.)

Battery Repairs

Repair vs. Replacement

There are times when a decision to repair or replace a damaged battery is clear cut. Frequently, however, a decision either way is debatable. The following information is offered as a guideline to help decide when to repair and when to replace.

The normal service life that can be expected of a fork truck battery in a specific operation can be determined by experience and by keeping life records. A service life of 6 years or 1800 cycles is not unusual when the depth of cycle, operating temperatures, quality of maintenance, etc. are properly controlled.

A good, general rule is this: If a battery has one or two years of one cycle per day service, and has not been exposed to overcharging, over-discharging, high operating temperature or other misuse, and the repair costs do not exceed 50% of the replacement cost, it is probably more economical to repair it than to replace it. Remember, that a physically damaged battery or one that is damaged by overcharge may have hidden damage.

Before undertaking major repairs, give the battery an equalizing charge and read all of the specific gravities. Instructions on "How to Inspect a Battery" are on page 20. If all of the undamaged cells are within .030 points of specific gravity of a fully charged battery, the battery is probably economically repairable.

An older battery, or one that has extensive damage, requires a closer look at the economics of repair versus replacement. A battery that has 900 to 1500 cycles (or 3 to 5 years of service) and requires repairs totaling 25% or more of the replacement cost, probably should be replaced instead of repaired. The determination depends mainly on how many more cycles or years of service the battery can be expected to deliver after the repairs are completed. This kind of estimate can be made by an experienced industrial battery repairman If you do not feel confident in making this judgment, contact your local Bulldog Battery Service Location. A professional battery serviceman can estimate the remaining service life expected of the battery if the necessary repairs are made.

After estimating the remaining service life, the final decision to repair or replace is made by arithmetic. For example, if the estimated cost of repairing the battery is $200 and its replacement cost is $1200, the estimated remaining service life must exceed 1 year (or 300 cycles) to justify the repair. Otherwise it is more economical to replace the battery.

Disassembly and Reassembly Instructions

Caution:

Repairs attempted by inexperienced personnel can be dangerous because they expose personnel to several potentially dangerous elements. Therefore, the "Safety" section of this manual should be reviewed before handling the battery or beginning repairs. If the slightest doubt exists about the ability of the personnel to perform the repairs, play it safe. Call your nearest Bulldog Battery Sales Office and arrange to have the battery repaired at an authorized Bulldog Battery Repair Facility, or at your plant by professional battery repairmen.

Disassembling and reassembling battery components are described in a step-by-step procedure.

Removing Connectors

1. Using a connector drill, drill out the cover post holes.

2. Lift off the connector with a pair of trimmer or channel lock pliers.

Removing a Complete Cell

1. Remove the connectors (see "Removing Connectors" above).

2. Cut the compound to isolate the cell from the

adjacent cells using a putty knife or similar tool. Make sure to cut the compound at the jar line, and not at the cover line.

3. When the walls of the jar are free, the cell can be lifted out by using a cell puller on the negative posts.

4. With the cell out of the tray, neutralize any acid in the tray with a soda solution and clean up the residue.

Removing the Element

1. Remove the connectors (see "Removing Connectors," opposite page).

2. Using cell pullers, pull the cell-complete with cover, out of the jar.

3. Cut the jar below the cover locating pins.

4. Examine the cover and jar for cracks and leaks.

5. Examine the positive and negative plates and separators for damage. Also check for particles of materials, which may cause short circuit.

6. Any work done on the element must be done as quickly as possible. Unless the repairs can be made within 20 minutes, the element must be covered with wet cloths to prevent heating. If repair of the cell is delayed more than 1 hour, store the element in electrolyte of the same specific gravity as in the cell.

Note: Elements exposed to air can be damaged by oxidation of the negative plates

Reassembling the Battery

Plastic Welding

1. If the element was removed from the jar, insert the element into the jar. Check for correct polarity.

2. Using ammonia as a neutralizing agent, clean and neutralize the jar, especially in the area to be welded. Allow to thoroughly dry.

3. Observing the correct polarity, install the replacement cover onto the cell. At this time the grommets should be seated only deeply enough to hold the cover in place during the welding operation. Again, observe correct polarity indication.

NOTE: The welding operation may be easier if the cell is in a horizontal position. To prevent leakage of residual electrolyte, raise the cover end slightly. A block of wood placed under the cover end of the jar will suffice.

4. Plug the welder into a 120 VAC grounded outlet, the compressor will begin operating. Turn on the switch to the heating element and allow the welder to warm-up for three or four minutes.

5. Cut a length of 1/8 inch or 5/32 inch polypropylene welding rod. The rod should be at least four inches longer than the length of the weld. Cut the end of the rod to a 60° angle with cutting pliers.

6. Preheat the cover and the jar at the start of the weld by fanning the heat 1/2 inch from the surface.

NOTE: Do not start the weld on or near the jar corners. Hold the rod perpendicular to the joint of the jar and cover, continue the fanning motion, and press the rod to the joint. Heat the tip of the rod and the starting point of the joint until they become tacky. Press the end of the welding rod firmly into the joint with the point of the rod away from the direction of the weld. Start heating the welding joint and rod together with a fanning motion in line with the direction of the weld. Maintain a firm downward pressure on the welding rod at a right angle to the work. The rod will begin to move forward. The welder is fanned at a 45° angle between the welding rod and the joint. This heats all surfaces equally. Only the outer surfaces of the rod, jar and cover are heated. As the welding continues, a small bead should be forming along both sides of the welding bead, and a small roll forming under the welding rod, both of which would continue along the weld.

7. At the end of the weld, overlap the start of the road at least 1/4 inch, then, cut away the excess

rod with rod pliers.

8. At this time, seat the grommets. The cell should then be air pressure tested for leaks. This can be done with a radiator tester modified to accept a vent cap. The cell should withstand a pressure of four PSI for fifteen seconds.

Complete Battery Assembly

1. Insert the complete cell (element and jar) into the battery tray if the complete cell has been removed from the tray. Check for correct polarity.

2. Fill the cell with an electrolyte that has a specific gravity approximately the same as the surrounding cells.

3. Flush the cell and its surrounding cells with a gentle stream of air to eliminate trapped hydrogen gas. (See "Remove the Gas Before Working", page 10).

4. Next, heat the asphalt sealing compound and pour it into the channel between the cells and tray wall battery. Use a flame from a source such as hydrogen, natural gas or acetylene and oxygen. Be careful not to melt the plastic jar or destroy the coated surfaces of 6.

5. Now, fill the channel to the top with compound. Gently flame it around the top to seal the cell and burning nut.

6. Rebuild the terminal posts with a post mold and a burning nut.

7. Install the connectors to the terminal posts. Melt the connectors to the post with a torch or a carbon arc.

Acid Replacement and Adjustment of Specific Gravity

Under normal circumstances, a battery should never require the addition of acid to increase the specific gravity of the electrolyte. However, when upsets, jar breakage, over flushing or careless use of the hydrometer cause a loss of electrolyte and a corresponding loss of battery capacity, the lost acid should be replaced.

Caution:

Before adding acid to a cell or to an entire battery with low specific gravity readings, try to raise the specific gravity by charging as described on page 16 under "Treatment of Sulfated Batteries." Only if the charging is unsuccessful should an attempt be made to increase the specific gravity with acid.

To replace acid, use the following procedure with a sulfuric acid having a specific gravity of 1.400.

1. Battery must be in fully charged condition, topped off with an equalizing charge (see page 11 for definition and description), with the electrolyte freely gassing.

2. Add the acid slowly to the cell while it is still charging and gassing so that the acid mixes thoroughly. If added too fast, the acid will drop to the bottom of the cell. The acid will not diffuse immediately and the specific gravity reading will be inaccurate, i.e., on the low side. Further additions of acid can be harmful especially when the battery is returned to service and complete diffusion results in a high specific gravity. About 1/4" of 1.400 specific gravity acid will increase a cell's specific gravity about 5 points (0.005).

3. After adding the high specific gravity acid, leave the battery on charge for one hour so that the higher specific gravity acid is thoroughly mixed with the electrolyte. Read and record all the cells' specific gravities. If the specific

gravity readings are too low, corrected for temperature, use an acid-proof syringe to remove the electrolyte down as far as the perforated separator protector to provide the necessary space for more high specific gravity acid. Add a quantity of high gravity acid to each cell as required to bring the specific gravity to the proper level.

4. Continue to remove electrolyte and add high gravity acid until all cells of the battery reach the proper, full charged specific gravity (1.280). The final specific gravity of all the cells in the battery should be adjusted to within ±.005 (5 points) of proper, full charge specific gravity.

Example:

The specific gravity of a battery with a proper, full charge specific gravity of 1.280 should range between 1.275 and 1.285. Correct the gravity for temperature variation by using the "Specific Gravity Temperature Correction Chart" on page 12.

5. If the specific gravity in a cell is too high, remove the electrolyte with an acid-proof syringe and replace it with water. Charge the battery for one hour at the finish rate. Read the cell specific gravity and correct for temperature if necessary. If the specific gravity is still too high, repeat the process until it reaches the proper full charge specific gravity.

Notes:

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