AUTOMOTIVE BATTERIES

CARE AND MAINTENANCE

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1. GENERAL

1.01 This section includes general information about the construction of automotive batteries and about the chemical action within a lead-acid battery. This information is provided as supplementary information to the recommended care and maintenance procedures covered in the section.

1.02 An automotive battery produces the electrical energy used by the cranking motor and the ignition system as the engine is started. In addition, the battery operates lights and accessories when the generator output is below the demand. It also acts as a voltage stabilizer in the electrical system.

1.03 The lead-acid storage battery generates electrical energy through chemical reaction between the active materials of the battery plates and the sulfuric acid of the electrolyte. Since satisfactory operation of a car or truck depends upon the electrical energy supplied by the battery, proper battery care and maintenance are necessary for trouble-free operation throughout battery life.

2. BATTERY DESCRIPTION

CONSTRUCTION OF A BATTERY

2.01 A typical lead-acid storage battery consists of a specific number of elements placed in individual cells in a hard-rubber battery case. A hard rubber cover fits over the element in each cell, and the cells are connected in series by cell connectors which are welded to terminal posts on the elements. Construction of a typical 12-volt battery is illustrated in Fig. 1. The battery is filled with electrolyte, which contains sulfuric acid, that reacts with the sponge lead and lead oxide of the plates to produce current flow.

2.02 The elements consist of plates (Fig. 2) that are either negative plates, which contain sponge lead, or positive plates, which contain lead oxide. The plates are assembled into plate groups, either negative or positive, by welding a number of similar plates to a plate strap that holds the plates apart and provides a terminal post. The plates of the opposite polarity plate groups are interspaced so negative and positive plates alternate. Separators, which complete the element assembly, are used to keep the plates from touching each other.

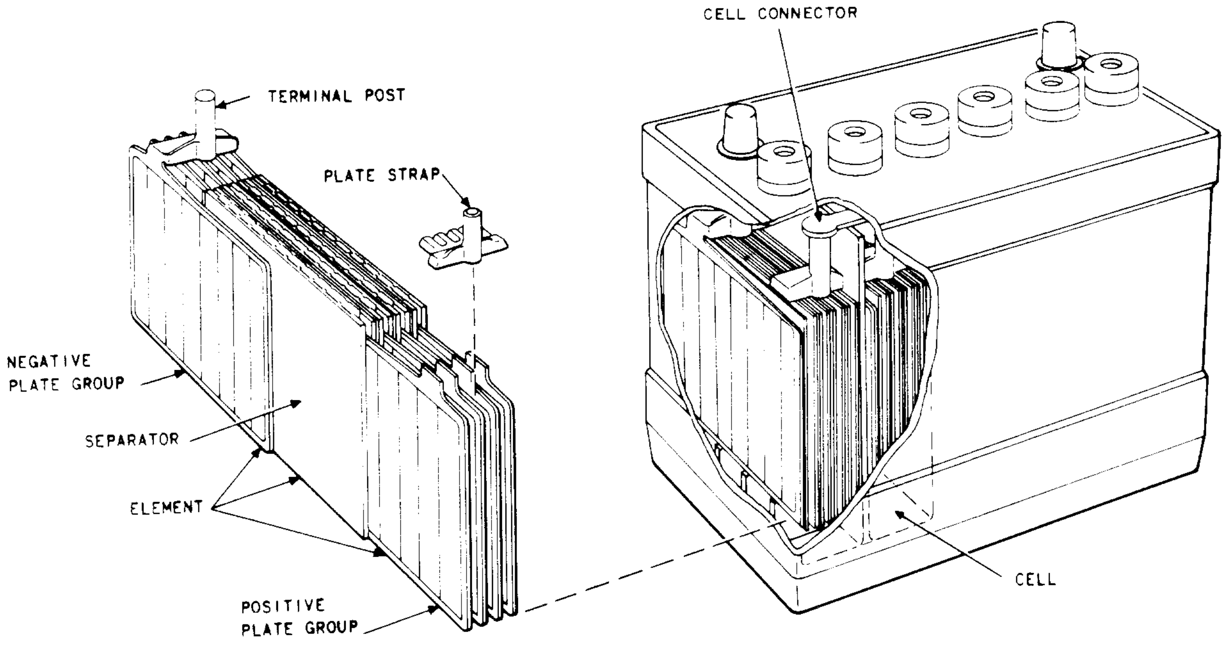
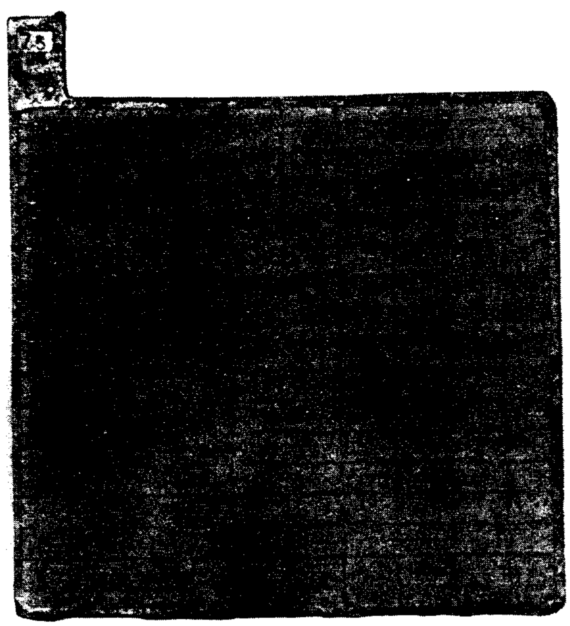


Fig. 1—Construction of a Typical Storage Battery



ACTIVE MATERIAL IS CONTAINED IN CAST GRID OF A LEAD-ANTIMONIAL ALLOY

Fig. 2—Typical Battery Plate Prior to Assembly into Plate Group

2.03 The electrolyte is a solution of sulfuric acid and water. The percent of acid in the solution may vary slightly depending upon the make or rating of the battery but most solutions contain no more than 40 percent acid. A typical example of a fully charged battery is one with the electrolyte consisting of approximately 36 percent sulfuric acid and 64 percent water. This solution will have a specific gravity of approximately 1.270 at 80° F. As the state of charge of a battery decreases, the amount of sulfuric acid in the solution will decrease proportionally. Since the specific gravity of the solution is directly related to the acid content, testing with a hydrometer will give a fairly accurate indication of the state of charge of the battery. By taking specific gravity readings and making corrections for temperature (add 0.004 to specific gravity reading for each 10 degrees above 80° F, and subtract 0.004 for each 10 degrees below 80°F), the state of charge of a battery can be determined as shown in the following list. Specific gravity readings in the list have been corrected for temperature variation.

Specific Gravity	State of Charge of Battery
1.265-1.290	Fully charged
1.235-1.260	Three-fourths charged

1.205-1.235	One-half charged
1.170-1.205	One-fourth charged
1.140-1.170	Barely charged
1.110-1.140	Completely discharged

2.04 The battery case is made with separating partitions or cells that hold the elements. In the bottom of the case, sediment chambers are formed by supports on which the elements rest. The cell covers incorporate vented caps that provide a means for gas to escape during charging and facilitate checking the electrolyte level and adding water.

2.05 Each cell in a lead-acid storage battery has a potential of approximately 2 volts. Thus, batteries with three cells connected in series are 6-volt batteries, and batteries with six cells connected in series are 12-volt batteries.

CHEMICAL ACTION IN A BATTERY

2.06 Electrical energy produced by a charged battery is a result of chemical reaction between the negative and positive plates and the sulfric acid of the electrolyte. During discharge, oxygen in the positive active material combines with hydrogen in the electrolyte to form water, while the lead in the positive active material combines with the sulfate radical of the sulfuric acid in the electrolyte to form lead sulfate. A similar reaction takes place at the negative plate where lead of the negative active material combines with the sulfate radical to form lead sulfate. As the discharge continues, dilution of the electrolyte and accumulation of lead sulfate in both plates causes the reaction to stop and cell voltage to drop since voltage depends upon the chemical difference of the negative and positive plates. When the cells no longer produce the desired voltage, the battery is discharged.

2.07 To restore the battery to a charged condition, the chemical energy must be restored by reversing the current through the battery. This causes chemical reactions that are essentially the reverse of those occurring during discharge. The lead sulfate on both the negative and positive plates is separated into lead and sulfate. The sulfate leaves both plates and combines with hydrogen in the electrolyte to form sulfuric acid. At the same time, the oxygen in the electrolyte combines with the lead at the positive plates to form lead dioxide, and the negative plate returns to the original form of lead.

3. CAUSES OF BATTERY FAILURE

3.01 Most of the electrical problems that lead to premature battery failure can be avoided or minimized by proper care and maintenance of the battery and the charging and other electrical systems. Since the battery is a part of the charging, cranking, ignition, and accessory systems, deterioration of the battery can have an adverse effect on the systems. Conversely, failures in components of the electrical systems can cause deterioration of the battery.

3.02 Overcharging, which can be caused by a defective voltage regulator or a regulator setting that is too high, can damage the plates to the point of disintegrating the plate grid wires. A battery that has been subjected to overcharging for extended periods will not deliver maximum current. An example of plate damage caused by overcharging is shown in Fig. 3.

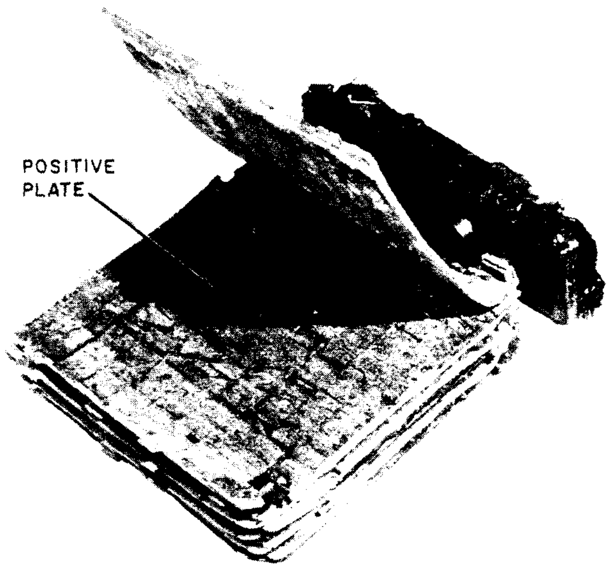


Fig. 3—Plate Damage Caused by Overcharging

3.03 Repeated discharging and recharging, called cycling, causes material to shed from the positive plates. Shedding results in decreased battery performance, and if continued, will result in battery failure. Cycling can be caused by insufficient generator output. An example of damage to positive plates caused by cycling is shown in Fig. 4.

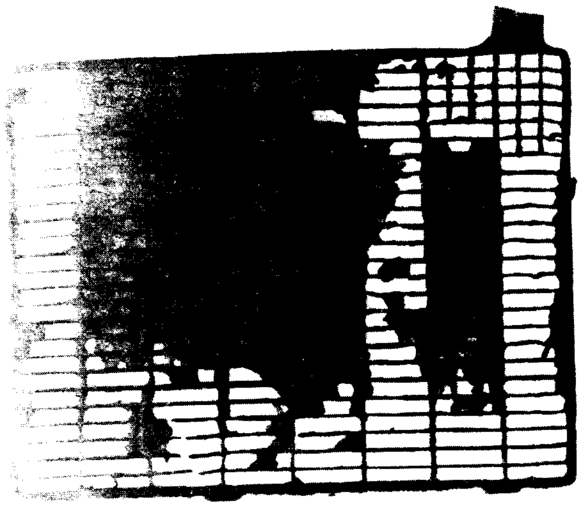


Fig. 4—Plate Damage Caused by Cycling

3.04 Freezing damage can occur in cold weather in an undercharged battery. Since the freezing point of electrolyte is dependent upon its specific gravity, the lower the state of charge the higher the freezing point. Some examples of freezing temperatures of electrolyte at various specific gravities are given in the following list:

Value of Specific Gravity (Corrected to 80°F)	Freezing Temperature (Degrees Farenheit)
1.100	18
1.120	13
1.140	8
1.160	1
1.180	-6
1.200	-17
1.220	-31
1.240	-50
1.260	-75
1.280	-92
1.300	-95

3.05 Low electrolyte level shortens battery life and causes poor performance. The active plate material above the electrolyte level becomes hardened and chemically inactive, while the plate material below the electrolyte level deteriorates more rapidly because of the higher concentration of acid. A place damaged by low electrolyte level is shown in Fig. 5. Overfilling causes loss of electrolyte and excessive corrosion of terminal posts and cell covers. Loss of electrolyte results in poor performance and early failure.

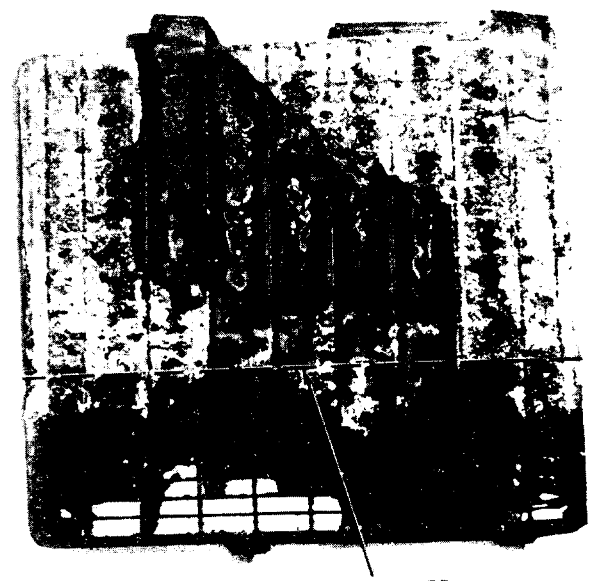


Fig. 5—Plate Damage Caused by Low Electrolyte Level

3.06 Vibration of the battery resulting from loose battery carriers or hold-downs can shake the active material from the plates as shown in

Fig. 6. Battery capacity and life are reduced when a battery is subjected to excessive vibration.

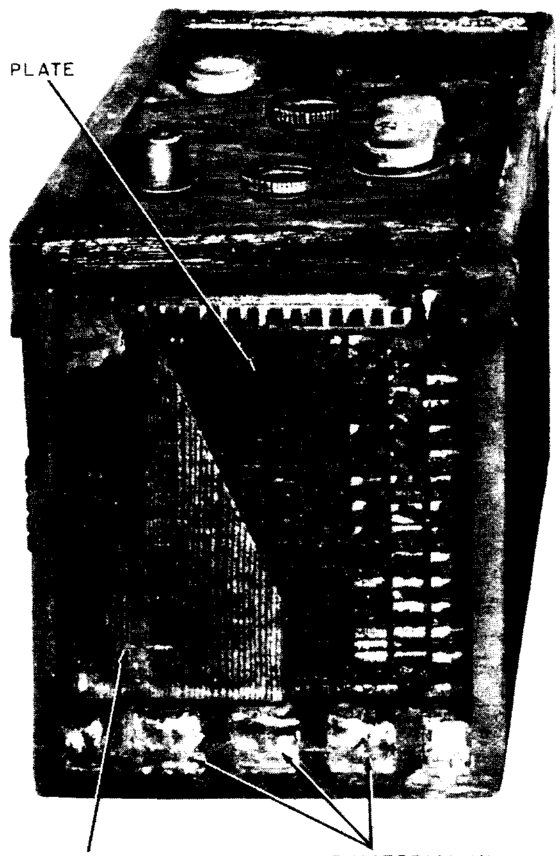


Fig. 6—Battery Damage Caused by Excessive Vibration

4. SAFETY PRECAUTIONS

4.01 Batteries on charge emit explosive gas from the vent openings. Charge batteries in a well ventilated area away from open flame. Avoid the creation of sparks, including those caused by static electricity.

4.02 Standard eye protection must be worn when servicing, testing, or handling batteries. In addition, gloves and an apron should be used when handling electrolyte or cells containing electrolyte.

4.03 Wrenches and other tools for use when removing or replacing a battery or when making battery connections should be insulated. Do not change battery connections while cells are gassing.

4.04 Immediately neutralize any electrolyte that is splashed or spilled on clothing or comes in contact with the skin by flushing the affected area with a soda solution. On clothing, a solution of one part household ammonia and two parts water may be used to neutralize acid and avoid white spots left by soda. However, ammonia must be handled with care since ammonia or its concentrated vapor can injure the eyes and nose. Also, ammonia fumes may adversely affect the commutation of dc machines. If electrolyte gets into the eyes, immediately flush with clear, clean water. Delay in flushing the eyes could result in permanent eye damage.

5. BATTERY MAINTENANCE ON THE VEHICLE

5.01 If the state of charge is found to be low when inspecting or testing a battery, the battery should be fully recharged by the slow charge method before it is returned to service. Also, it is important that the reason for the low state of charge be determined and any necessary adjustments or repairs be made. A low state of charge could result from a faulty regulator or generator, faulty wiring, or from other mechanical or electrical troubles. It may be that the lights or accessories were used under conditions that did not allow sufficient time for the generator to recharge the battery. It is also possible that the generating equipment is not adequate for the electrical load or operating schedule of the vehicle.

PERIODIC INSPECTION

5.02 At least once each month, or at some comparable interval that coincides with other periodic maintenance on the vehicle, a complete inspection of the battery and battery connections should be made. When making the inspection, it is advisable to record the specific gravity readings and the amount of water (in ounces) required to raise the electrolyte to the proper level. These records can be used as an aid to determine the state of charge of the battery, to indicate the cause of potential troubles, and to predict the remaining useful life of the battery.

5.03 At the regular inspection interval, check the specific gravity of one or two cells.

Readings should be corrected to 80° F, so a thermometer and a hydrometer or a combination unit is needed. In warm months a specific gravity reading of approximately 1.220 or higher indicates a satisfactory state of charge. In freezing weather, the specific gravity reading should be no less than 1.230 to provide sufficient energy for cranking and to protect the electrolyte from freezing.

5.04 Check the electrolyte level in all cells. The level should be up to the indicator. If there is no indicator, the electrolyte should be approximately 3/8-inch above the plates and separators. Add approved water as required using a syringe or other device that will provide a convenient means of measuring the amount of water added. In general, average water usage should not exceed four ounces for a 12-volt battery or two ounces for a 6-volt battery during approximately 2000 miles of driving. A battery that has consistently high water usage indicates a possible overcharging condition. If one or two cells require considerably more water than the others, check for leaks in the case, cell covers, or sealing compound, or for broken or missing vent caps. Less than normal water usage indicates an undercharged condition. Allowing the battery to remain undercharged for long periods can cause plate sulfation and permanent damage. Never add acid to a battery in service. An overconcentration of acid will cause premature battery failure.

5.05 Make a thorough visual inspection of the battery carrier, hold-downs, and cable clamps to be sure they are tight and secure. Inspect the cables for corrosion or wear and replace those that are damaged.

5.06 Remove excessive dirt and corrosion from the battery, cable clamps, and battery posts. If necessary, scrub with a solution of water and table soda, washing soda, or Bell System pyrophosphate. Before scrubbing, be sure the vent caps are in place so the solution does not enter the battery. After scrubbing, rinse the battery thoroughly with clear water. Dry the post contact area thoroughly, scrape or sandpaper to a bright finish, and apply an approved corrosion retardant.

LIGHT LOAD TEST

5.07 When a battery is new the voltage difference between cells is negligible. After the battery is placed in service, the voltage difference between cells gradually increases with each month of use until the life of the battery is expended. By performing the Light Load Test at periodic intervals and plotting the maximum cell voltage differences on a chart, a trend will be established that can be used to effectively anticipate remaining battery life. Usually, when the maximum cell voltage difference reaches 0.05 volts, the battery can be expected to fail within a short time, approximately one month.

5.08 The Light Load Test can be performed on batteries with individual cell covers. An expanded scale voltmeter, one that has 0.01 volt per scale division, is needed for the test. Before starting the test, check the electrolyte level and add water as required. Condition the battery for the test by cranking the engine for three seconds. If the engine starts, stop it immediately. If the Light Load Test is applied to a battery that is fully charged, defective cells may pass the test giving a false indication of battery condition.

5.09 Turn on the headlights to low beam, wait one minute, and, with the headlights on, read the voltage of each battery cell noting the exact voltages. The voltage readings may be interpreted as follows:

(a) If all the voltage readings are 1.95 volts or more and the difference between the highest and lowest reading is less than 0.05 volts, the battery is in good condition and sufficiently charged.

(b) If the voltage readings are both above and below 1.95 volts, but the difference between the highest and lowest reading is less than 0.05 volts the battery is in good condition but requires charging.

(c) If the voltage reading of any cell is above 1.95 volts, but the difference between the highest and lowest reading is 0.05 volts or more, the battery is near the point of failure.

(d) If the voltage reading of all cells is below 1.95 volts, the state of charge is too low for an accurate test, and the battery must be given a boost charge and the Light Load Test repeated. Twelve-volt car and light truck batteries should be charged at 50 amps for 20 minutes (1000 ampere minutes), and all 6-volt and larger 12-volt batteries should be charged at 60 amps for 30 minutes (1800 ampere minutes). If none of the cells come up to 1.95 volts after the boost charge, repeat the charge and the test. Batteries that do not come up after the second boost charge should be replaced. A battery that meets the requirements of the Light Load Test after a boost charge, should be fully recharged before being placed in service.

REMOVING AND REPLACING

5.10 Before removing the battery, mark the clamps on the cables with a plus or minus, according to battery polarity, to ensure that the replacement battery will be installed with correct polarity.

5.11 Remove the ground cable first to prevent the possibility of accidental grounding from contact of a tool with electrical ground. Remove the cable clamps from the battery posts with a tool designed especially for that purpose. Do not hammer or pry the clamps or posts. This could damage the post seals or cell covers and ruin the battery as well as void any battery warranty that may be in effect.

5.12 After removing the cables, remove or loosen the battery hold-down and lift the battery by its case. Never lift a battery by its posts.

5.13 The replacement battery should be of the same size and ampere-hour rating as the battery that was removed. Before installing the replacement battery, make a thorough inspection of the carrier and hold-down and make any necessary repairs. Place the battery in the carrier so the cables can be connected with correct polarity, and secure the hold-down, but do not overtighten. Overtightening can distort or crack the battery case.

5.14 Complete the battery replacement by connecting the cables. Connect the ground cable last to prevent the possibility of arcing. When connecting the cables, open the clamps sufficiently to allow them to slip onto the battery posts with only a slight amount of pressure. Never hammer the clamps onto the battery posts. When the replacement is complete, apply a coat of approved corrosion retardant to the clamp and post connections.

6. BATTERY MAINTENANCE IN THE SHOP

6.01 When the condition of a battery in service becomes doubtful, it should be removed from the vehicle and completely inspected and tested to determine whether or not it can be recharged and returned to service. In general, the procedure for inspecting and testing the battery should be to visually inspect the battery, perform the Light Load Test, fully charge the battery, perform the full charge hydrometer test, and perform the high rate discharge test. If the battery should fail any one of the tests, it should be considered defective.

BATTERY INSPECTION

6.02 Visually inspect each battery brought to the shop. Inspect for cracked or damaged case, broken cell covers, loose posts, or other damage. Damaged batteries should not be returned to service. If there is no visible damage, clean the battery by scrubbing with a solution of 1/2 pound soda to one gallon of water. Do not allow solution to enter cells. Rinse well after cleaning.

LIGHT LOAD TEST

6.03 Check the electrolyte level in each cell. Add water as required, but do not overfill. Remove any excess electrolyte with a syringe. Condition the battery for the Light Load Test by placing a load on the battery using a carbon pile and ammeter across the terminal posts. Apply a 150-amp load for three seconds, then reduce the load to 10 amps and allow the battery to discharge for one minute. With the load still applied, read the voltage of each cell with an expanded scale voltmeter. Compare the readings as covered in 5.09(a) through (d). If a boost charge is required, do not fully charge the battery as this may temporarily hide a defect. Limit the charge on 12-volt car and light truck batteries to 1000 ampere minutes and on larger 12-volt batteries and 6-volt batteries to 1800 ampere minutes. To determine correct charging time, divide the charger's ampere output into the desired ampere minutes. The quotient is the charging time in minutes. A battery that will not come up to 1.95 volts in at least one cell after a second boost charge is defective and should not be returned to service.

BATTERY CHARGING

6.04 A battery that meets the requirements of the Light Load Test should be fully charged at the slow charge rate for further testing and future use. When using a current-limiting charger, the charging rate should be set to not exceed 7 percent of the ampere-hour rating of the battery. If the ampere-hour rating is not known, a charge rate of 5 amperes for passenger car batteries and 9 amperes for heavier batteries is acceptable. More than one battery at a time may be charged by connecting batteries in series and setting the charge rate so it does not exceed 7 percent of the ampere-hour rating of the smallest battery. Charging periods of 24 hours or more may be required for batteries with a low state of charge. Batteries that have been in a discharged condition for a long period may require 3 to 4 days of slow charging to be restored to a fully charged condition. Batteries that are permanently sulfated cannot be recharged.

6.05 Periodically while the battery is charging, measure the temperature of the electrolyte. If the temperature reaches 125°F, either the charge rate must be reduced or charging must be temporarily halted to avoid damaging the battery. Never allow the electrolyte temperature to exceed 125° F. After a reasonable charging period, check the specific gravity of each cell. After a one-hour interval make another check of the specific gravity of each cell and compare the readings with those made from the previous check. If all the cells are gassing freely and no change occurs in the specific gravity over the one-hour period, the battery is fully charged and should be removed from the charger. If more than one battery is on charge and the smallest battery is removed, the charge rate may be increased to 7 percent of the next highest rated battery still on charge.

FULL CHARGE HYDROMETER TEST

6.06 To perform the full charge hydrometer test, measure the specific gravity of each cell after the battery has been removed from the charger. If the specific gravity of any cell is less than 1.230, corrected for temperature, the battery is near the point of failure. If the specific gravity readings are between 1.230 and 1.310, the battery is in good condition and ready for the high rate discharge test. Any cell with a specific gravity above 1.310, corrected for temperature, has an excessively high concentration of acid. The electrolyte may be replaced with new electrolyte of the proper specific gravity, but this will not correct the damage that has already been done even though the rapid deterioration caused by the concentration of acid will be stopped. It should be noted that batteries for use in hot climates may have an initial specific gravity lower than 1.265. In these cases the full charge hydrometer test readings must be lowered accordingly to be of significant value.

HIGH RATE DISCHARGE TEST

6.07 Fully charged batteries that are in good condition, as indicated by the full charge hydrometer test, should be given the high rate discharge test as a final test. For this test to be effective, the battery should be fully charged and at a stable temperature within the range of 70° to 90° F. If the test is performed on a battery with a low state of charge, a battery defect may be falsely indicated. There are two types of testers commonly used, the carbon pile type and the cell type. When using the carbon pile type, connect the test leads to the battery terminals and adjust the load to two times the ampere-hour rating for 6-volt batteries or three times the ampere-hour rating for 12-volt batteries. After the load has been applied for 15 seconds, measure the terminal voltage. Terminal voltage should be above 4.5 volts for 6-volt batteries and 9 volts for 12-volt batteries. If lower, the battery is defective. When using the cell type test, each cell is tested individually. On either 6-volt or 12-volt batteries, if any one cell measures below 1.5 volts the battery is defective.

6.08 Before returning any battery to service or placing it in storage, thoroughly clean the battery to remove any electrolyte that may have spilled during charging and testing.

7. BATTERY STORAGE

7.01 The self-discharging characteristic of all batteries that contain electrolyte can cause a battery in storage to become discharged to the point where it cannot be recharged and returned to service. To retard self-discharging, store batteries in a cool dry place. Do not store batteries on floors that may be damp. This dampness can cause a moisture film on the battery which will increase the self-discharge rate.

7.02 To maintain stored batteries in a fully charged condition, they should be recharged for about 3 hours each week at 7 percent of their ampere-hour capacity. The "trickle" charge method is acceptable if the batteries are not left on charge for extended periods. Overcharging, even at low rates, can cause damage that will shorten battery life appreciably.