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AUTOMOTIVE DIESEL MAINTENANCE 2. UNIT XIII, BATTERY SERVICE AND TESTING PROCEDURES--PART II.

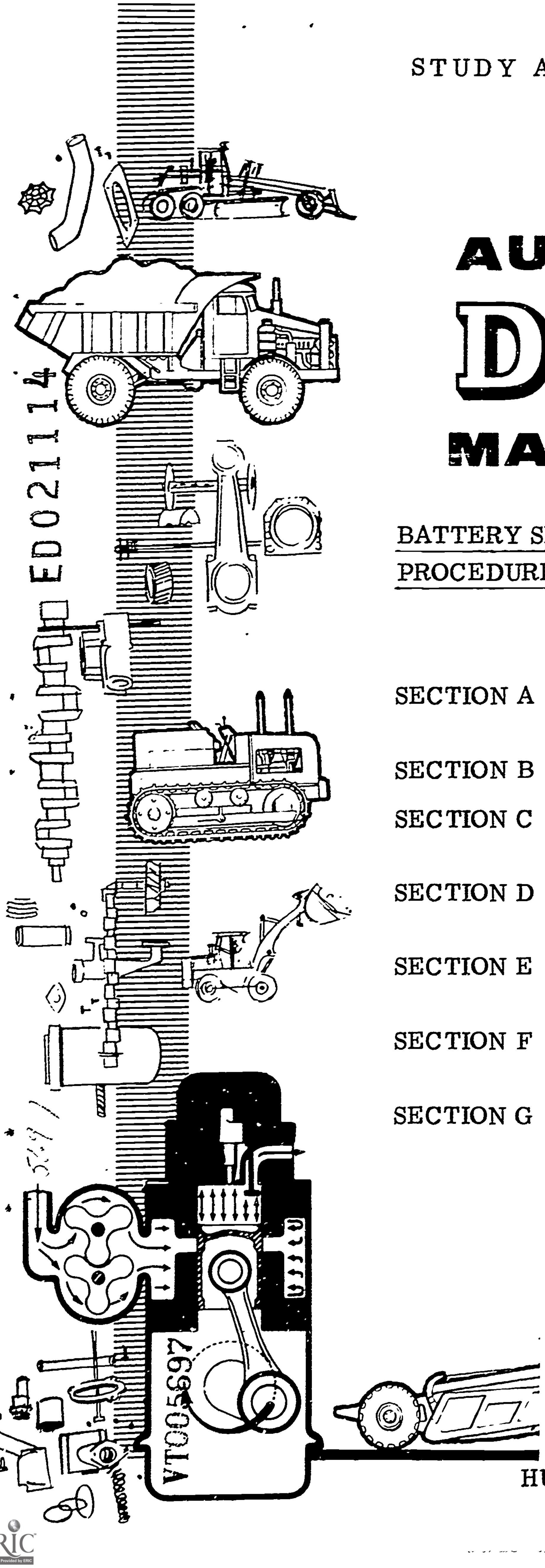
HUMAN ENGINEERING INSTITUTE, CLEVELAND, OHIO

REPORT NUMBER AM-2-13 PUB DATE 8 SEP 67

EDRS PRICE MF-$0.25 HC-$1.88 45P.

DESCRIPTORS- *STUDY GUIDES, *TEACHING GUIDES, *TRADE AND INDUSTRIAL EDUCATION, *AUTO MECHANICS (OCCUPATION), *ELECTRICAL SYSTEMS, DIESEL ENGINES, MOTOR VEHICLES, EQUIPMENT MAINTENANCE, ADULT VOCATIONAL EDUCATION, INSTRUCTIONAL FILMS, PROGRAMED INSTRUCTION,

THIS MODULE OF A 25-MODULE COURSE IS DESIGNED TO FAMILIARIZE THE TRAINEE WITH PROCEDURES FOR SERVICING LEAD-ACID STORAGE BATTERIES USED ON DIESEL POWERED EQUIPMENT. TOPICS ARE (1) ELECTROLYTE AND SPECIFIC GRAVITY, (2) BATTERY CHARGING, (3) STORAGE BATTERY TYPES AND DESIGN, (4) BATTERY CAPACITY RATINGS, (5) BATTERY INSTALLATION, SERVICING, AND TESTING, (6) FACTORS AFFECTING BATTERY LIFE, AND (7) SAFETY PRECAUTIONS. THE MODULE CONSISTS OF A SELF-INSTRUCTIONAL PROGRAMED TRAINING FILM "AUTOMOTIVE BATTERIES II--BATTERY SERVICING AND TESTING PROCEDURES" AND OTHER MATERIALS. SEE VT 005 685 FOR FURTHER INFORMATION. MODULES IN THIS SERIES ARE AVAILABLE AS VT 005 685 - VT 005 709. MODULES FOR "AUTOMOTIVE DIESEL MAINTENANCE 1" ARE AVAILABLE AS VT 005 655 - VT 005 684. THE 2-YEAR PROGRAM OUTLINE FOR "AUTOMOTIVE DIESEL MAINTENANCE 1 AND 2" IS AVAILABLE AS VT 006 006. THE TEXT MATERIAL, PROGRAMED TRAINING FILM, AND THE ELECTRONIC TUTOR MAY BE RENTED (FOR $1.75 PER WEEK) OR PURCHASED FROM THE HUMAN ENGINEERING INSTITUTE, HEADQUARTERS AND DEVELOPMENT CENTER, 2341 CARNEGIE AVENUE, CLEVELAND, OHIO 44115. (HC)



STUDY AND READING MATERIALS

AUTOMOTIVE DIESEL 2 MAINTENANCE

BATTERY SERVICE AND TESTING PROCEDURES -- PART II

UNIT XIII

SECTION A	ELECTROLYTE AND SPECIFIC GRAVITY
SECTION B	BATTERY CHARGING
SECTION C	STORAGE BATTERY TYPES AND DESIGN
SECTION D	BATTERY CAPACITY RATINGS
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HUMAN ENGINEERING INSTITUTE

SECTION A -- ELECTROLYTE AND SPECIFIC GRAVITY

The lead and lead peroxide of the battery plates are referred to as the "active" materials. However, they cannot become active until they are covered with electrolyte (the name given to a solution of sulfuric acid and water). Electrical energy is produced by a chemical action between the active materials of the plates and the sulfuric acid of the electrolyte. The electrolyte also is the carrier for the electric current as it passes through the separators to the plates. The framework of the grids then becomes the conductor which carries the current to the external connectors.

Electrolyte usually contains approximately 36% sulfuric acid by weight, or about 25% by volume. This is comparable to a specific gravity of 1.270 at 80 F. The acid content is adjusted to other varied mixtures to meet the requirements of temperature extremes or particular design characteristics.

The sulfuric acid supplies the necessary sulfate. Whenever the circuit is completed at the battery terminals, the sulfate combines with the active materials of the positive and negative plates, changing the active materials to lead sulfate, and releasing electrical energy in the process.

THE MEANING OF SPECIFIC GRAVITY -- Any discussion on the electrolyte of a storage battery automatically leads into a discussion of specific gravity. SPECIFIC GRAVITY is a method of measurement for determining the sulfuric acid content of the electrolyte. If we were to put exactly one pint of water on a simple balance scale with exactly one pint of electrolyte (equal volumes), the scale would go down on the electrolyte side.

This indicates that the electrolyte is heavier than the water. Water has arbitrarly been assigned a value of 1.000; therefore, all other liquid compounds on a comparative basis will either be heavier than water or lighter than water. Pure sulfuric acid has a specific gravity of 1.835 (spoken of as: eighteen thirty-five). Commercial electrolyte prepared by the industry for resale in servicing batteries usually has a specific gravity of 1.400 (fourteen hundred). This must be diluted with water which is free from mineral content, in order to get a specific gravity of 1.260 (twelve-sixty), which is the recommended specific gravity for many 12 volt batteries used on today's vehicles. This simply means that electrolyte is 1.26 times as heavy as water.

The specific gravity varies with temperature and the state of charge. In order to obtain any accurate indication of the condition of the battery, it must always be corrected to the standard temperature of 80 F. Examples of temperature correction will be covered later in this Unit.

Since the strength of the electrolyte varies directly with the state of charge of the cell, it offers a convenient basis for estimating the state of charge. To determine approximately the state of charge and how much energy is available from the battery, it is necessary only to measure the specific gravity of the electrolyte.

Specific gravity can be measured by means of a battery hydrometer. The hydrometer is a bulb type syringe which will extract electrolyte from a cell. A calibrated float is placed inside the glass barrel of the syringe. It is weighted to sink into the electrolyte. The distance it sinks depends on the density of the solution.

A letter or number scale is incorporated within the float so that it may be easily read and translated by the mechanic into a state of charge condition of the battery. The float scale is read on the letter or number at the point where it intersects the upper surface of the electrolyte. The scale is calibrated and is designed so that when the float rides high in the electrolyte, the specific gravity reads high. If the float sinks low into the electrolyte, the specific gravity reads low. Most hydrometers used today have a built-in thermometer to compensate for the changes in temperature. No reading is correct until these corrections for temperature have been made.

TEMPERATURE CORRECTION -- Hydrometer floats are calibrated to give a true reading at one fixed temperature only. A correction factor must be applied for any specific gravity reading attempted on an electrolyte whose temperature is not 80 F. (In some instances a reference temperature of 60 F is used.) Temperature compensation is required because of the fact that acid volume will rise when heated and contract when cooled. When heated, the electrolyte will be less dense; therefore the hydrometer float will sink further down into the solution -- giving a lower specific gravity reading. On the other hand, a cooled electrolyte shrinks in volume and holds the float up higher in the solution, for a higher reading.

Regardless of the reference temperature (60 F or 80 F) used as a standard, the correction factor of .004 gravity points is used for each 10 degree change in temperature. Four points of gravity are added to the indicated reading for each 10 degree increment above 80 F. Four points are subtracted for each 10 degree increment below 80 F.

BATTERY TEMPERATURE CORRECTIONS -- Let's suppose that a gravity reading of 1.234 at 120 F is obtained. Since the temperature is 40 degrees above the standard (80 F), four points must be added for every 10 degrees, a total addition of 16 points. The corrected reading is, therefore, 1.250. Suppose the gravity reading of 1.282 at 0 F is obtained. Since the temperature is 80 degrees below the standard (80 F), four points must be subtracted for every 10 degrees, total deduction of 32 gravity points. The corrected reading, therefore, is 1.250. See Figure 1.

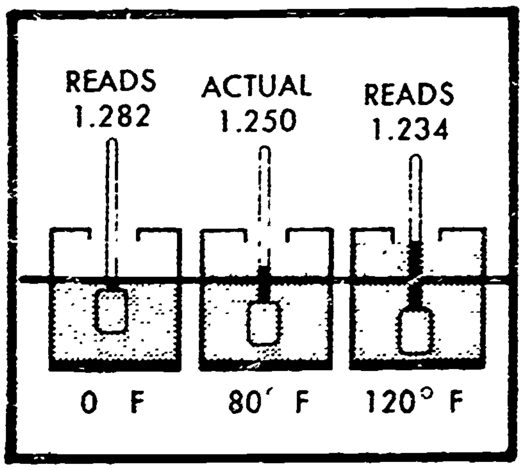


Fig. 1 Temperature versus specific gravity

There are at least three instances where a reading could be misleading to the mechanic. Readings are inaccurate if taken:

1. Immediately after adding water to the electrolyte.
2. While a hot battery is being charged.
3. Immediately after a battery has been subjected to a high rate of discharge (e.g. prolonged cranking).

A more accurate reading will be obtained if the acid is allowed time to diffuse from the plates and into the surrounding electrolyte. The acid will mix slowly if the battery stands idle for a few hours or will mix more rapidly if placed on a charger adjusted at a slow rate of charge.

ELECTROLYTE UNDER TEMPERATURE EXTREMES -- Most batteries used in temperate climates are placed in service with a nominal specific gravity of 1.260 to 1.270. These batteries are designed to function at maximum efficiency under these conditions. The electrolytes used in batteries that are prepared for tropical or arctic conditions will deviate somewhat from the specific gravity strengths mentioned above.

TROPICAL CLIMATES -- Electrolyte with a specific gravity of 1.225 (fully charged) is used in areas where temperatures are never cold enough to freeze water. This milder strength of acid is considered less harmful to the plates and separators.

ARCTIC CLIMATES -- Batteries that are prepared for use under extremely cold weather conditions make use of an increased strength of electrolyte. In some instances, a specific gravity of 1.290 to 1.300 would not be considered excessive. Generally speaking, lower specific gravities favor longer battery life, whereas higher specific gravities will produce greater 20 hour capacity and cold capacity.

An electrolyte temperature of 32 F makes a battery approximately 65% effective in cranking power, and at zero F it is only about 40% effective. Sub-freezing climates require that many other precautions be observed in the realm of light lubricating oils, pre-warming, garaging or sheltering vulnerable areas of the vehicle, etc.

The important thing for you to remember is that the nearer a battery approaches a state of discharge, the quicker it will freeze. From a service standpoint, a battery should never be allowed to operate below a 75 percent charge condition. A longer service life can be expected if the battery is not subjected to deep-cycling effects or allowed to approach freezing conditions.

A chart showing the approximate freezing point of the electrolyte is provided in Figure 2.

STATE OF CHARGE -- Since the efficiency of a battery and its ability to produce electrical energy is affected by the amount of...

1. Active materials in the positive plates,
2. Active materials in the negative plates,
3. Sulfuric acid present in the electrolyte,

and since the sulfuric acid is absorbed by the plates during discharge, it is possible to calculate the remaining electrical potential of the battery by determining the remaining acid content left in the electrolyte.

State of charge is the term used to identify the battery's internal condition

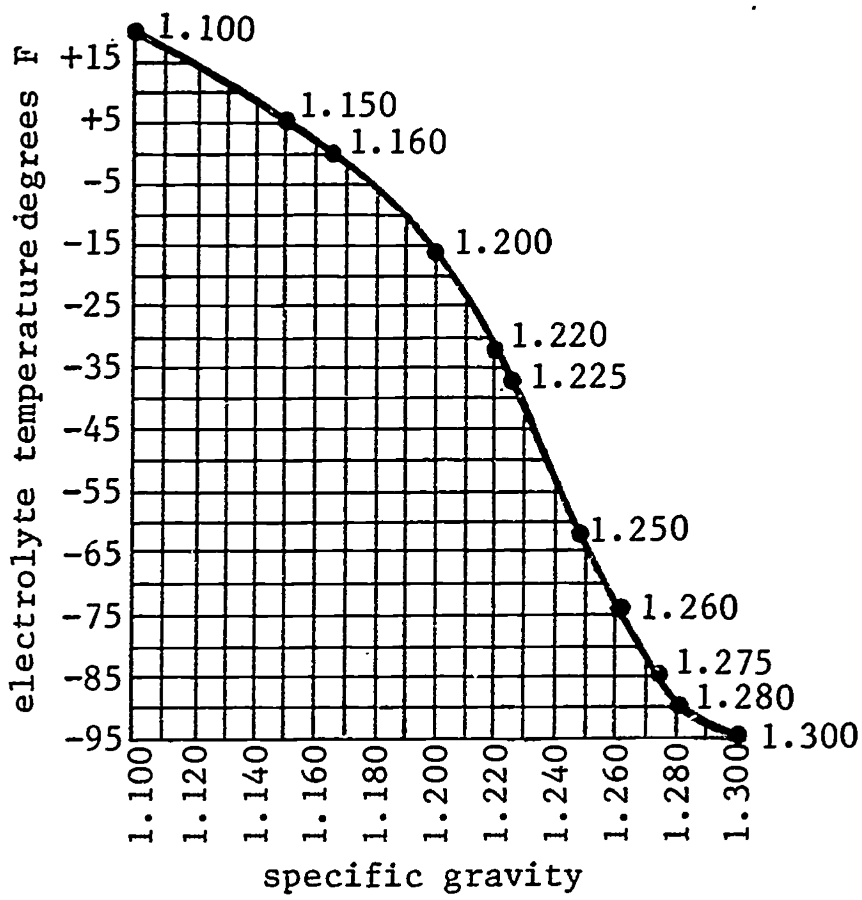


Fig. 2 Specific gravities

in relation to a fully charged unit. It is usually expressed as percentage of a fully charged battery.

The specifications for full charge usually fall between 1.260 and 1.300 specific gravity. The chart in Figure 3 is provided to show the approximate specific gravity readings of a partially charged cell. Each separate cell of a battery should have the same specific gravity when fully charged and in good condition.

% Charged (20-hour rate)	1.260 Initial Full Charge	1.280 Initial Full Charge
100	1.260	1.280
75	1.230	1.250
50	1.200	1.220
25	1.170	1.190
Discharged	1.110	1.130

Fig. 3 Percent charged

SECTION B -- BATTERY CHARGING

There are two methods of recharging batteries -- the slow charge method and the fast charge method. As the names imply, they differ in the length of time the battery is charged and in the amount of charging current supplied.

Before recharging any battery, the cells should be checked, and water added if necessary to bring the electrolyte to the proper level. Periodically during the charging process, the temperature of the electrolyte should be measured. If the temperature exceeds 125 F, the charge rate must be reduced or temporarily halted to avoid damage to the battery. Never allow the electrolyte temperature to exceed 125 F.

The slow charge method supplies the battery with a relatively low charging rate for a long period of time. The charging rate should be about 7% of the ampere-hour rating of the battery. Example: If the ampere-hour rating is 60 AH, the charge rate should be 4.2 amperes, or for all practical purposes 4 amperes.

If the ampere-hour rating of the battery is unknown, use a charge rate of 5 amperes for passenger car type batteries, and 9 amperes for the heavier batteries. Charging periods of 24 hours and more may be needed to bring the battery to full charge. The battery is fully charged when the cells are gassing freely and no change in specific gravity occurs over a one hour period. See Figure 4.

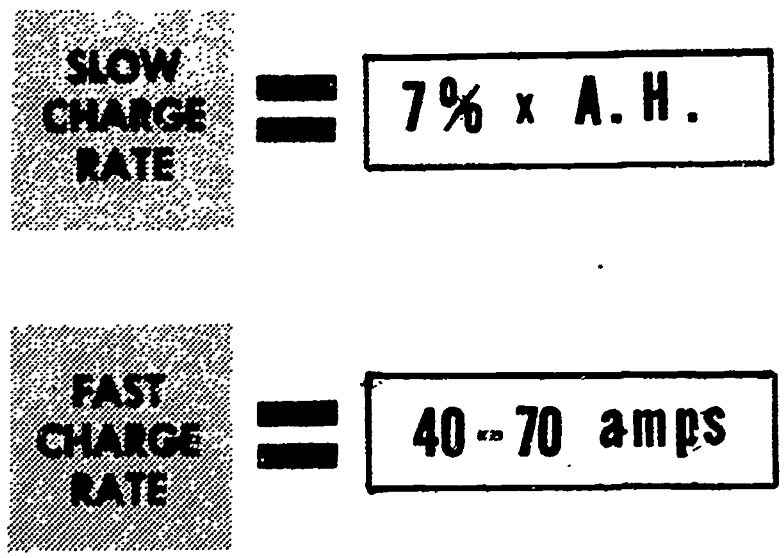


Fig. 4 Two charging rates

A sulfated battery, that is, a battery which has stood in a discharged condition for long periods of time without recharging, may require three to four days of slow charging in order to bring it to a fully charged condition. Batteries which are permanently sulfated can never be restored to a normal operating condition, regardless of the rate of charge or the length of time the charge is applied.

The fast charge method supplies the battery with a high charging rate for a short period of time. Charging rates of 40 to 70 amperes are common, with charge periods varying from 1 1/2 to three hours, depending on battery type and size. The high charging rate may be continued for as long as there is no electrolyte loss and the electrolyte temperature does not exceed 125 F.

Because of the charging period and the high charging rate, the plates are not fully converted to lead peroxide (PbO_2) and sponge lead (Pb). This means that the battery cannot be fully recharged by the fast charge method, although it can be substantially boosted or recharged. To completely recharge the battery, the fast charge procedure should be followed with a slow charge for a few hours. When using fast chargers, never ignore the safeguards built into the charger by the manufacturer, as these safeguards are intended to protect the battery from damage.

It is important to remember that an explosive mixture of hydrogen gas and oxygen is formed beneath the cell covers when any battery is being charged. As the mixture escapes through the vent caps, normal air circulation usually carriers the explosive mixture away. But if circulation is poor, or if the battery is being heavily charged, the explosive mixture may accumulate near the battery. Since a spark or flame can ignite the mixture and cause an internal battery explosion, care should be taken to avoid sparks and flame near the battery. Remember that removing or connecting battery cables while the battery is on charge or discharge can cause a dangerous spark.

SECTION C -- STORAGE BATTERY TYPES AND DESIGN

There are two types of batteries -- the wet charged type and the dry charged type. The wet charged battery is manufactured in a "standard" manner, and when shipped from the factory contains a full supply of electrolyte in each cell.

The dry charged battery is shipped from the factory with no electrolyte in the cells. In the manufacture of this type of battery, the cell elements, consisting of positive and negative plates and separators, are charged, and then each cell element is thoroughly washed, completely dried, and assembled into the battery case. The dry charged battery will remain in a fully charged condition for as long as moisture is prevented from entering the cells. The battery can be placed in service simply by adding electrolyte to the cells.

WET CHARGED BATTERY STORAGE -- As explained in the previous section, wet charged is the term used for a battery that is fully charged and completely activated at the factory. This type of battery contains electrolyte from the time of manufacture. Even though the wet charged battery is not in use, a slow reaction takes place between the plate materials and electrolyte to cause the battery to discharge slowly. This is called "self-discharge," and occurs at a much faster rate at higher temperatures. A fully charged battery stored at a room temperature of 100 F will be almost completely discharged after a storage period of 90 days. The same battery stored at 60 F will be only slightly discharged after 90 days. Wet charged batteries, therefore, should be stored in as cool a place as available, as long as the electrolyte does not freeze. See Figure 5.

DRY CHARGED BATTERY STORAGE AND ACTIVATION -- Dry charge is a name designating a completely charged battery that contains no electrolyte until it is activated for service.

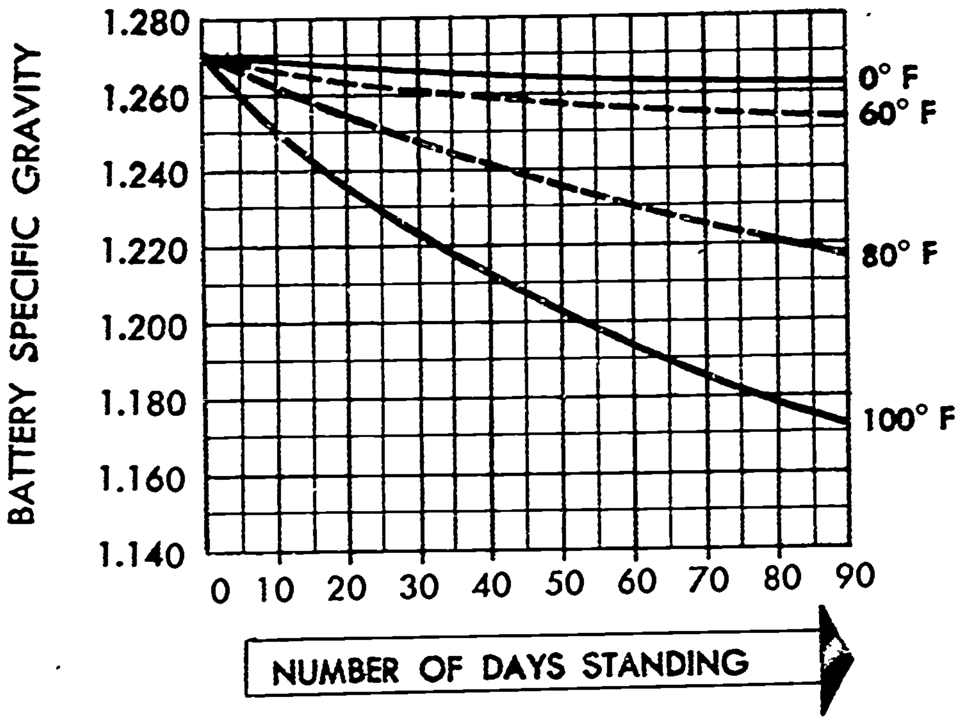


Fig. 5 Temperature versus time

A dry charge battery when packaged for shipment has reached the end of a factory control program. Temperature and moisture control will, of necessity, be less rigid during the period when batteries are stored on the dealer's shelf. As a result of this lack of control, there will be a lack of uniformity in the dry charge capacity in battery plates in any given dealer's stock. Except in rare cases, this margin of variation will have no effect on the life of the battery. It will, however, affect activation and charging procedures.

The American Association of Battery Manufacturers recommends the following:

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

2. When the manufacturer recommends filling to gravities of 1.250 or higher, boost charge 12 volt batteries at 30 to 40 amps, (6 volt batteries at 60 to 70 amps) until the specific gravity of the electrolyte is 1.240 or higher and electrolyte temperature is at least 80 F. BOTH CONDITIONS MUST BE MET. If the electrolyte bubbles

violently while charging, reduce charging rate until excessive bubbling action subsides, then continue charging until 1.240 and 80 F are reached. (In tropical climates, lower specific gravities are recommended.)

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

4. Install battery in vehicle. Turn on lights or other accessories and be sure ammeter shows discharge. For vehicles not having ammeters, check manufacturer's manual for proper polarity. Check battery after one week. After battery has been in service, add only approved water. DO NOT ADD ACID. Following these instructions will assure proper activation and satisfactory service life, regardless of temperature and conditions of storage.

DELCO REMY recommends the following procedure for activating Delco dry charged batteries:

Although the Delco dry charge battery may be put into service immediately after activation, to insure good battery performance the following tests are recommended for batteries only. (Energizers need not be subjected to the following tests.)

After adding electrolyte, check the open circuit terminal voltage of the battery. Less than 5 volts on a 6 volt battery, or less than 10 volts on a 12 volt battery indicates a reverse cell or an open circuit, and the battery should be replaced. The specific gravity of each cell should be checked. If the readings, corrected to 80 F, show more than thirty (.030) points drop from the 1.265 filling electrolyte, the battery should be fully recharged before use. Also, the battery should be recharged if one or more cells should gas violently after addition of electrolyte. For best performance, when the temperature is 32 F or less, or when the battery and electrolyte are not at 60 F or above at time of activation, the battery should be warmed by boost charging as indicated below.

Boost charge 6 volt batteries and 12 volt heavy duty batteries for a minimum of 10 minutes at 30 amperes. Boost charge all other 12 volt batteries for a minimum of 10 minutes at 15 amperes. If the minimum boost charges do not bring the battery electrolyte temperature up to 60 F, then continue charging until the temperature is above 60 F.

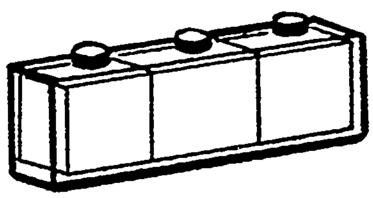
SECTION D -- BATTERY CAPACITY RATINGS

The two most common battery ratings are the 20 Hour Rating at 80 F and the Cold Rating at Zero F. The 20 hour rating indicates the lighting and accessory load capacity of the battery, and the cold rating indicates the cranking load capacity.

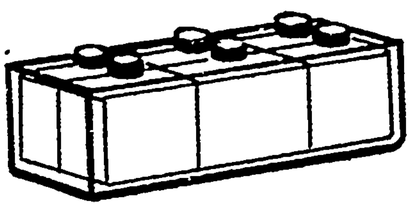
The 20 hour rating in ampere-hours is determined by laboratory testing the battery under controlled conditions. The test is begun with the battery fully charged and at a temperature of 80 F; the battery is then discharged at a constant rate for 20 hours, at the end of which time the average cell voltage must be 1.75 volts or above. This is equivalent to 5.25 volts on a six volt battery and 10.5 volts on a 12 volt battery. A battery capable of supplying 3 amperes under these conditions would qualify for a rating of 60 ampere-hours (3 amperes x 20 hours = 60 ampere-hours). A battery capable of supplying 6 amperes would qualify for a 120 ampere-hour rating.

The cold rating is obtained by discharging a fully charged battery at zero F at a constant rate of 150 or 300 amperes, depending upon the voltage and ampere-hour rating of the battery. The rating is then indicated in two values. One is the voltage obtained after 5 or 10 seconds of discharge, and the other is the time in minutes required for the battery to reach the end voltage test. A 12 volt battery having a 10 second voltage rating of 7.6 volts at 300 amps will maintain a voltage of 7.6 volts or higher for 10 seconds. Also, the same battery having a time rating of two minutes will operate under the above conditions for two minutes before the terminal voltage falls to the end voltage, which may be 5.0 volts for this particular battery. The higher the 10 second voltage rating and the higher the time rating, the greater will be the cranking capacity of the battery.

It is interesting to compare the ratings of 6 volt batteries with 12 volt batteries. Consider a 6 volt battery having a rating of 70 ampere-hours, with 11 plates (total of positive and negative) in each of 3 cells. When 3 more identical cells are added to form a 12 volt battery, the ampere rating remains at 70 ampere hours. However, there is one significant difference between the performances of the two batteries, as shown in Figure 6.



3 cells;
11 plates per cell
6 volts



6 cells;
11 plates per cell
12 volts

plates per cell	number of cells	battery voltage	ampere hour rating	20 hour discharge rate in amperes	battery voltage after 20 hours
11	3	6	70	3.5	5.25
11	6	12	70	3.5	10.5

Fig. 6 Capacity ratings

The significant difference is in the voltage at which the current is supplied by the battery. Since power is equal to voltage times amperes, the potential power of the 12 volt battery is twice that of the 6 volt battery. As an example, when the battery voltage is 12 volts and the discharge rate is 3.5 amperes, the power output is 42 watts (12 volts x 3.5 amperes = 42 watts). The 6 volt battery power output at the same discharge rate, however, is only 21 watts (6 volts x 3.5 amperes = 21 watts). See Figure 7. The important point to note here is that the 6 and 12 volt batteries may have the same ampere hour rating, but the 12 volt battery is capable of producing twice the amount of power as the 6 volt battery.

Some manufacturer's batteries are rated in watts, which is in effect a measure of the cranking ability of the battery at cold temperature. The wattage rating is determined by laboratory testing, and is obtained by multiplying the voltage by the current. The peak wattage is used in rating batteries at the temperature involved. Thus, by comparing wattage ratings, an immediate comparison of the cranking abilities of various batteries is obtained.

$$P = E \times I$$

WATTS VOLTS AMPERES

Fig. 7 Watts versus ampere-hour

Ampere-hour ratings have a useful application in determining the appropriate slow charging rate for a given battery. Some manufacturers are reluctant to use the recommended charging rate of "one ampere per positive plate per cell." They feel that this rate would cause overcharging on some batteries. Instead, they recommend a charging rate of seven percent of the published ampere-hour rating (to the nearest ampere).

SECTION E -- BATTERY INSTALLATION, SERVICING AND TESTING

While the battery is designed to satisfactorily withstand normal operating conditions, excessive mechanical abuse leads to early failure. One area in which mechanical abuse often occurs is during installation. The following recommendations are important to properly install a battery:

1. Be sure the battery carrier and hold-down are clean and that the new battery rests level when installed.
2. The hold-down should be tightened until it is snug; however, it should not be drawn tight enough to distort or crack the battery case.
3. Be sure that the cables are in good condition and that the terminal clamps are clean.
4. Clean the battery terminals with a wire brush before attaching the cable clamps. Do not pound the clamps onto the battery terminals. When tightening cable nuts, use the wrench carefully, to prevent twisting and cell cover damage.
5. Make sure that the cable terminals are clean and tight at the engine or frame and also at the cranking motor switch and solenoid.
6. Before installing the battery, check for proper battery polarity with respect to the vehicle specifications. Ground polarity usually is indicated. Reverse polarity during installation can be avoided by marking cables as to their polarity when removing the old battery. Reverse battery polarity may cause serious damage to the electrical system. Note that the positive terminal post is larger than the negative terminal post.
7. When installing batteries, the grounded cable at the battery terminal should be disconnected first and reconnected last to avoid damage to the battery and wiring by accidental grounds with tools.

BATTERY SERVICING -- The importance of periodic battery service cannot be overemphasized. With a reasonable amount of attention and care, the useful life of the battery can be appreciably extended. In contrast, neglect and abuse will invariably cause shorter life. In any servicing and maintenance program, attention should be given to the following areas.

Inspect thoroughly for defective cables, loose connections, corrosion, cracked cases and covers and loose hold-downs. The electrolyte level should also be checked periodically, particularly in hot weather; and colorless, odorless drinking water should be added if necessary to bring the liquid level to the bottom of the split ring in each cell.

Overfilling should be avoided, as this will cause loss of electrolyte, resulting in excessive corrosion, reduced battery performance and shorter battery life. Conversely, allowing the electrolyte level to drop below the top of the plates will cause the exposed plate material to become dry, and chemically inactive. Also, the high concentration of electrolyte remaining in the battery will cause permanent damage to the plate area below the electrolyte level. This will result in poor battery performance and shorter life.

If the battery requires the addition of an excessive amount of water in normal service, an overcharged condition is indicated. Some water usage is normal, usually 1 to 2 ounces per cell per one thousand miles of service (1 to 2 ounces per cell per 24 hour operating period on vehicles equipped with engine hour meters, such as off-highway vehicles) depending on type of service and prevailing temperatures.

If the water usage becomes excessive, high battery temperatures or a high voltage regulator setting should be suspected as the most likely causes. If no appreciable use of water occurs over three or four thousand miles, or three or four 24 hour operating periods of service, an undercharged battery may be indicated. Allowing the battery to remain in an undercharged condition for excessive periods of time may result in plate sulfation and permanent damage. The cause of the undercharged condition should be immediately corrected, in order to ensure maximum battery life.

Periodically, the battery top, posts, cable clamps, carrier, and hold-down should be cleaned with a diluted ammonia or soda solution to remove corrosion and other foreign material. After cleaning, flush with clean water, and apply a thin coating of petroleum jelly to cable clamps and posts to retard corrosion. Tighten the hold-down so the battery will not shake in the carrier, but avoid overtightening as this may cause damage to the battery case.

BATTERY TESTING -- The battery may be tested to determine if it is in good condition, or if it is defective or worn out and must be replaced. Before performing any electrical checks, a visual inspection should be made to reveal any obvious defects. If the case or cover is cracked or if the battery has unusual odors or is otherwise damaged, it should be replaced.

The Light Load Test and Full Charge Hydrometer Test are to be used on conventional batteries. Testing procedures for Energizers and other similar batteries are covered later in the Unit.

The LIGHT LOAD TEST should be performed on batteries having individual cell covers. This test is simple, quick and accurate and should be applied to batteries before they are charged. Otherwise, defective cells may pass the test and give a false diagnosis. An expanded voltmeter -- one that has .01 volt per scale division -- is needed for this test.

To check the electrical condition of battery cells using the light load test, first check the electrolyte level in each cell. If needed, adjust it to the proper level by adding colorless, odorless drinking water, or distilled water if available. Then, if the battery is in the vehicle, place a load on the battery by holding the starter switch ON for three seconds or until the engine starts. If the engine starts, turn off the ignition IMMEDIATELY. If the battery is out of the vehicle, place a 150 ampere load on it for three seconds.

Next, turn on the headlights (low beam) or if the battery is out of the vehicle, place a 10 ampere load on the battery. After one minute, with the lights still ON, or with 10 ampere load still connected, read the voltage of each battery cell with a voltmeter, noting the exact voltages. It is necessary to remember only the highest and lowest voltages.

The condition of the battery can be determined by noting the difference in voltage readings between the individual cells as follows: (See Figures 8, 9, 10 and 11.)

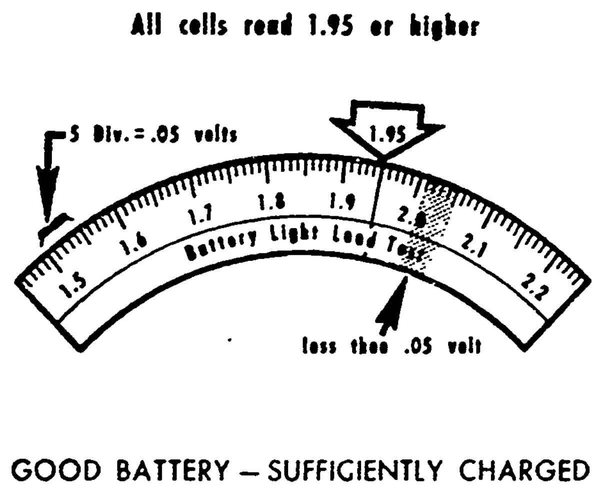


Fig. 8 Cell voltmeter readings

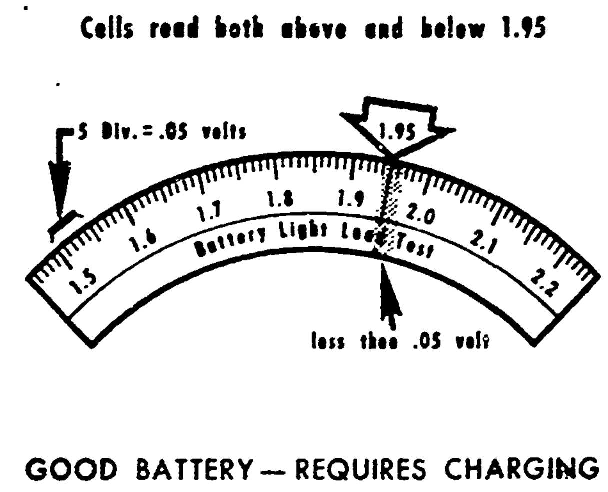


Fig. 9 Cell voltmeter readings

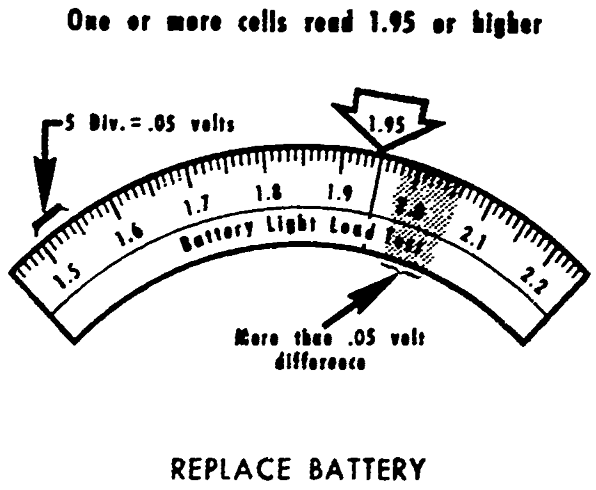


Fig. 10 Cell voltmeter readings

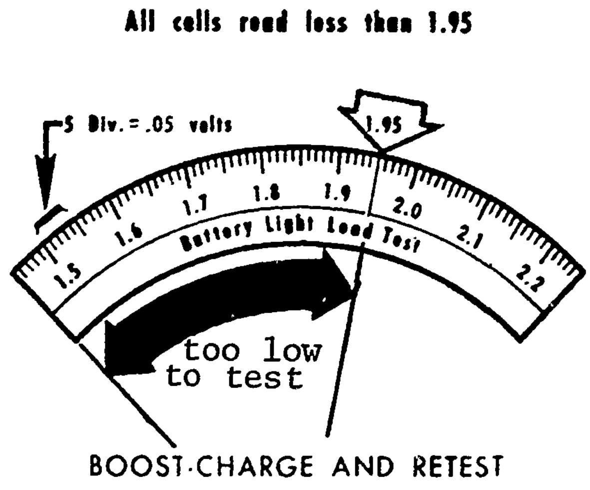


Fig. 11 Cell voltmeter readings

1. If all cells read 1.95 volts or more and the difference between the highest and the lowest cell is less than .05 volt (5 divisions), the battery is good and sufficiently charged.

2. If cells read both above and below 1. 95 volts and the difference between the highest and lowest cell is less than . 05 volt (5 divisions), the battery is good, but requires charging.

3. If any cell reads 1. 95 volts or more and there is a difference of . 05 volt (5 divisions) or more between the highest and lowest cell, the battery is defective, damaged or worn out and should be replaced.

4. If all cells read less than 1. 95 volts, the battery state of charge is too low to test accurately; boost-charge and repeat the light load test. Boost charge all 12 volt batteries rated at 100 ampere-hours or less at 50 amperes for 20 minutes (1000 ampere-minutes). Charge all other batteries, both 6 and 12 volt, at 60 amperes for 30 minutes (1800 ampere-minutes). If none of the cells comes up to 1. 95 volts after the first boost charge, the battery should be given the second boost charge. Batteries which do not come up after the second boost charge should be replaced

If the charger being used will not give the rate specified, charge for an equal number of ampere-minutes at the next lower rate available. For purposes of the light load test, do not boost battery more than the amount indicated.

If the battery is found to be good after boosting, it should be fully re-charged by the slow charge method before being placed in service.

The FULL CHARGE HYDROMETER TEST should be used on batteries that have tested good by the light load test, but which subsequently fail in service. In order to perform the full charge hydrometer test, THE BATTERY MUST BE FULLY CHARGED BY THE SLOW CHARGE METHOD. This method consists of charging at a rate in amperes equal to 7% of the ampere-hour rating of the battery. Example: Charge a 100 ampere-hour battery at a 7 ampere rate. The battery is fully charged when cells are gassing freely and no change in specific gravity occurs over a one hour period. Due to the low rate, charge periods of 24 hours and more often are required. When the battery is fully charged, measure the specific gravity in each cell. If any cell reads less than 1. 230, corrected for temperature (except batteries that are prepared for tropical or arctic conditions), the battery should be replaced. If the hydrometer readings are between 1.230 and 1.310, the battery is in good condition and may be returned to service.

If any cell reads above 1.310, corrected for temperature, the battery may be returned to service, but its useful life has been shortened due to damage caused by the high-gravity electrolyte. Adjusting the gravity to lower levels may not correct the damage that has already been done.

PREDICTING BATTERY LIFE -- When the battery is new, all cells are in good condition and the voltage difference between cells approaches zero or is negligible. As the battery accumulates months and years of service, the voltage difference between cells increases. This is normal, as all lead-acid storage batteries are perishable items. When the maximum difference between cell voltages reaches .05 volts, the useful remaining life of the battery is very short, and immediate replacement is advisable.

The light load test can be used to predict the time at which a battery will eventually wear out and fail. By performing the light load test at periodic intervals and plotting the maximum difference in cell voltages on a chart, a trend can be observed and the useful remaining battery life anticipated.

Although each battery in service will have its own "life curve," the curve of one battery is illustrated in Figure 12. By plotting points on the graph at 3-month intervals, a curved line can be drawn through the points to form the life curve. As the maximum voltage difference between the highest and lowest cell approaches .05 volts (the point of imminent failure), more frequent recordings should be made in order to replace the battery before the failure occurs.

ENERGIZERS AND OTHER ONE-PIECE COVER DESIGN BATTERIES -- The "421 Test," the specific gravity cell comparison test, and the full

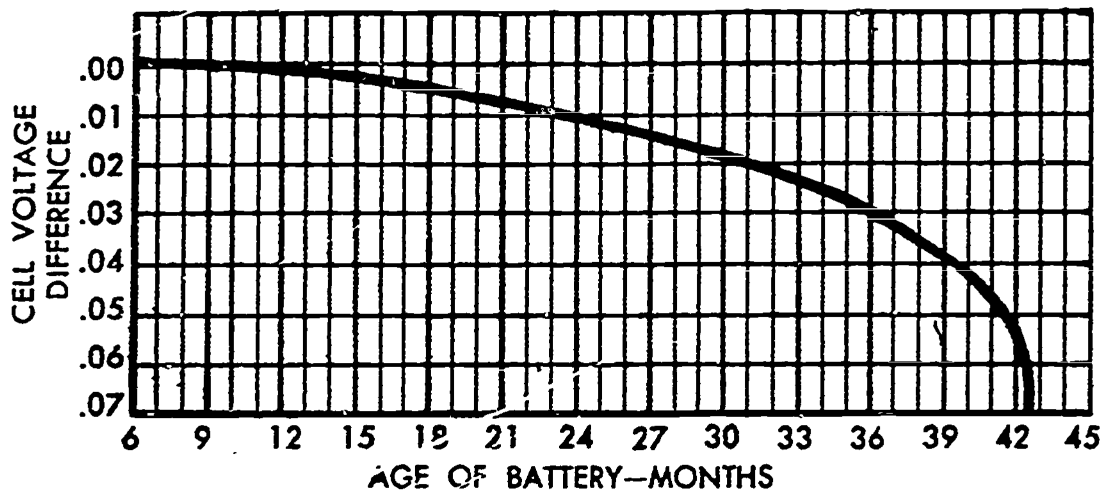


Fig. 12 Age of battery -- months

charge hydrometer test may be used on Energizers.

THE 421 TEST is a specific, programmed test procedure consisting of a series of timed discharge and charge cycles that will determine the condition of the Energizer with a high degree of accuracy in a very short period of time. The 421 Testers are manufactured by a number of suppliers, and these testers automatically subject the Energizer to the programmed 421 Test.

The 421 Test is the procedure that is the most accurate for checking Energizers, and therefore is the preferred procedure. When using one of these testers, the procedure recommended by the tester manufacturer should be followed. If a tester is not available to perform the "421 Test," the Specific Gravity Cell Comparison Test may be used, but with a sacrifice in testing accuracy.

Specific Gravity Cell Comparison Test: Measure the specific gravity of each cell, regardless of state of charge, and interpret results as follows: If specific gravity readings show a difference between the highest and the lowest cell of .050 (50 points) or more, the Energizer is defective and must be replaced.

The Full Charge Hydrometer Test is conducted on Energizers the same as for conventional batteries as mentioned earlier in the Unit.

SECTION F -- FACTORS AFFECTING BATTERY LIFE

There are many factors which affect battery life. Besides periodic cleaning of the battery top, post and cable clamps, probably the four most important factors are:

ELECTROLYTE LEVEL -- The regular and systematic addition of approved water to the cells, in order to maintain the electrolyte level at the manufacturer's prescribed level, is very important to battery life. Underfilling increases the concentration of electrolyte and causes exposed plates to harden and become chemically inactive. The high concentration of electrolyte remaining in the cells also causes the plates to deteriorate more rapidly. Overfilling causes loss of electrolyte and heavy corrosion on the battery posts and cell covers. Loss of electrolyte will result in poor performance and early battery failure.

OVERCHARGING -- Overcharging causes a loss of water by disassociating the water of the electrolyte into hydrogen and oxygen gases. The gas bubbles wash active materials from the plates, and reduce the battery capacity. If not replaced, this loss of water will cause the electrolyte level to fall below the tops of the plates, with the resulting damage as suggested above. Overcharging also causes high internal heat and the oxidation of the positive plate grids, resulting in loss of cell capacity and early failure.

UNDERCHARGING -- A battery which is consistently undercharged will develop sulfated plates. The sulfate normally formed in the plates will become dense, hard and chemically irreversible if allowed to remain in the plates for extended periods. The lowered gravity levels make the battery more susceptible to freezing. Also, undercharged batteries tend to fail to crank in cold weather because of the loss of the reserve capacity which results from undercharging.

CYCLING -- A cycle consists simply of a discharge and recharge. If operating conditions subject the battery to heavy and repeated cycling, its life will be shortened, as cycling causes the positive, active plate material to shed and to fall into the sediment chambers in the bottom of the battery.

In order to obtain the maximum life from batteries, rigid and highly controlled manufacturing techniques are employed. Also, regulator voltage settings are very accurately set and adjusted by the manufacturers to minimize the effects of undercharge or overcharge. Microporous rubber separators, along with glass mats on some battery models, prevent excessive shedding on batteries subjected to cycling in normal service.

While the battery is a perishable item and will eventually serve its useful life, it is important to remember that its life can be prolonged with a reasonable amount of care.

SECTION G -- SAFETY PRECAUTIONS

Numerous safety precautions have been mentioned throughout this Unit in the various areas where they are applicable. The principle hazards in servicing batteries occur under charge conditions or when handling acid. Here is a listing of these safety rules which **MUST BE OBSERVED** when handling or charging batteries:

1. When mixing battery electrolyte, it is important to pour the acid into the water and NOT the water into the acid.
2. When working with acid, such as filling batteries, splash-proof goggles should be worn. (Other articles of protective clothing may be advisable if many batteries are handled.)
3. When adding water or electrolyte, non-metallic containers and/or funnels must be used.
4. Acid must not be stored in excessively warm locations or in direct sunlight.
5. Acid burns resulting from contact with skin or eyes should be rinsed immediately with clear water. Except for eye injuries, a solution of baking soda and water should be placed on the affected area following the water rinse. If discomfort continues, the victim should seek medical aid. A supply of neutralizing agents should always be kept close by for immediate use.

6. Manufacturer's recommendations should be closely followed to hold the charging rate at a limit that prevents rapid generation of hydrogen gas. Hydrogen gas is extremely explosive.

7. Open flames or smoking should not be allowed when batteries are being charged.

8. Exercise care to keep tools or other metallic objects from falling across the battery terminals.

9. NEVER break a live circuit at the battery terminals. A spark usually occurs whenever charged leads or booster cables are disconnected. Any spark could ignite the accumulated hydrogen gas.

10. Use fender covers to protect the vehicle finish from any possibility of acid spillage, and to reduce splashing of any acid on the fender.

DIDACTOR PLATES FOR AM 2-13D

ACTIVATING THE DRY-CHARGED BATTERY

1. Follow manufacturer's instructions.
2. Place battery on bench or work table. Do not attempt to activate in the vehicle. Remove vent caps from all cells.
3. Remove seals according to manufacturer's instructions.
4. Fill each cell with ELECTROLYTE of specific gravity rating recommended by the manufacturer. Fill to recommended level.
5. Warm battery with a "boost charge" if activating electrolyte temperature is below that recommended by manufacturer. Do not allow electrolyte temperature to exceed 125 F.
6. Check electrolyte level after "boost charge". If below recommended level, refill with activating ELECTROLYTE (NOT water).
7. Replace vent caps securely.
8. Install battery in vehicle or place in temporary storage as desired. Once activated, follow storage principles for wet charged battery.

Plate I

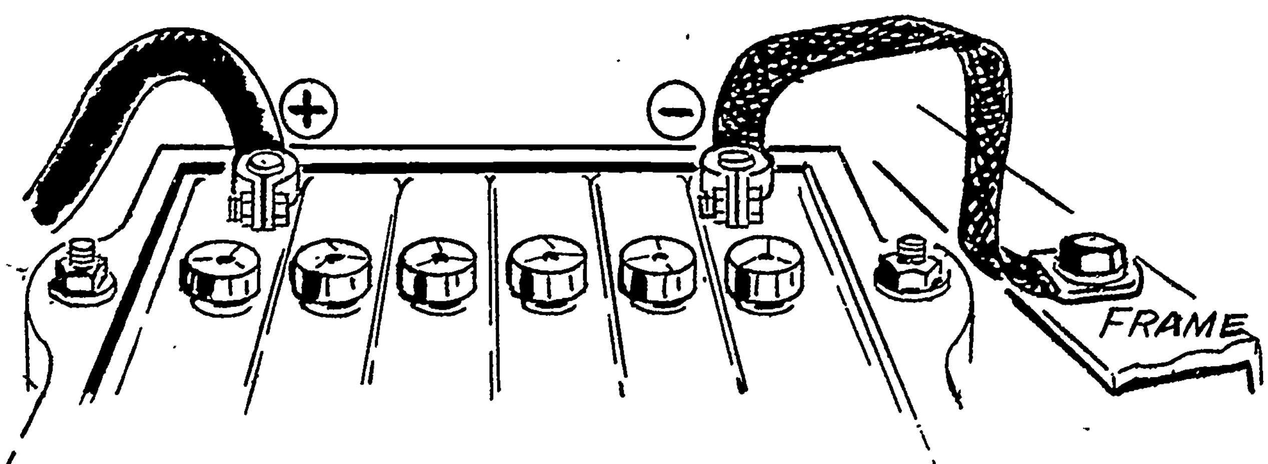


Plate II

CONDITION	POSSIBLE CAUSE(S)
Cracked or buckled battery case or cover	1. Hold-down too tight 2. Hold-down too loose -- vibration damage 3. Excessively high temperature: a. Around battery -- near engine, etc. b. Inside battery -- overcharging 4. Clogged vent caps; no escape route for hydrogen and oxygen gases formed during charging 5. Open flame or spark near battery "gassing" while on charge 6. Electrolyte frozen (75% or more state of charge prevents freezing)
Raised cell covers	1. Battery in prolonged state of charge later subjected to prolonged over-charging
Acid deposits (corrosion) on cover, terminal, posts, cables or cable clamps	1. Leakage -- due to cracks, overfilling, failure to repair holes in sealing compound made by pointed voltmeter probes 2. "Gassing" due to excessively high rate of charge.
Cables frayed or broken; stretched	1. Wrong gauge or length of cables being used 2. Corrosion 3. Cables "chafing" against battery top or vehicle frame, etc.
Damaged terminal posts, cell covers, sealing compound	1. "Hammering on" cable clamps 2. Careless use of cable wrench 3. Improper removal of cable clamps 4. Tools or wires "flashed" across terminals 5. Improper connection of charging equipment

Plate III Battery Visual Inspection Troubleshooting Chart

Plate III Battery Visual Inspection Troubleshooting Chart (cont'd.)

CONDITION	POSSIBLE CAUSE(S)
Electrolyte discolored or with odor of rotten eggs	1. Excessively high charging rate 2. Battery subjected to prolonged deep cycling 3. Impurities in electrolyte -- polluted water used to refill cells 4. Battery aged -- approaching end of its useful service life
Electrolyte level too low	1. Level not checked periodically 2. Excessive charging rate due to: a. improper voltage regulator setting b. excessive tightness of generator pulley belt

Battery state of charge	Electrolyte specific gravity*	Open circuit cell voltage**	Electrolyte freezing point
100%	1.260	2.10	-70 F
75%	1.230	2.07	-39 F
50%	1.200	2.04	-16 F
25%	1.170	2.01	-20 F
Discharged	1.110	1.95	+17 F

* (Corrected to 80 F) ** (For batteries not charged within the past 16 hours)

Plate IV Approximate specific gravity, open circuit cell voltage and electrolyte freezing temperature at various states of charge

0

AM 2-13D
9/20/67

AUTOMOTIVE BATTERIES II --
BATTERY SERVICING AND TESTING PROCEDURES

Human Engineering Institute

Minn. State Dept. of Ed. Vocational Education

Press A 1

Check to see that timer is OFF.

1

An automotive battery is a perishable item -- it will not last forever. But a reasonable amount of care and periodic servicing can contribute greatly to attaining the maximum useful life built into each battery.

In this film we will discuss battery servicing and testing -- we'll see what the automotive electrician can do to extend the useful life of the batteries he services.

Press A

1-1 2

2

With regard to batteries, the job of the automotive electrician is to ___________ their useful life as much as possible, but to replace them _________ they fail completely.

Decide on the best word to fill each blank and then press A. 3

1-2

3

We hope you chose "extend", "lengthen" or "prolong" (or some similar word) for the first blank, and "before" for the second:

As an automotive electrician, your job is to EXTEND the useful life of the battery as much as possible. But since the battery will wear out eventually, your job also is to replace the battery BEFORE it fails completely.

Press A 4

1-3

4

Before we get into specific testing procedures, let's take a look at some guidelines to the proper servicing and handling of lead-acid batteries. We'll talk briefly about STORING batteries first.

You probably already know that there are two basic types of automotive batteries -- the WET CHARGED type and the DRY CHARGED type.

Wet charged batteries are ___________________.

A. filled with electrolyte at the factory 6

B. filled with electrolyte just before installation in the vehicle 5

1-4

5

No.
The DRY CHARGED battery is the type that is filled with electrolyte at the time of installation.

Wet charged batteries are filled with electrolyte at the factory and are fully charged and activated before shipment.

Press A 6

1-5

6

OK.
Although fully charged and activated at the factory, the wet charged battery begins to lose some of its charge and useful life before ever being used.

This is due to a slow reaction that takes place between the plate materials and the electrolyte during shipping and storage. This is called self-discharge or standing loss.

1-6

Press A 7

7

SELF-DISCHARGE varies with temperature. The higher the temperature, the greater the loss due to self-discharge will be.

Therefore, it is important that wet charged batteries be stored in a cool, dry place. The cooler the better, as long as the electrolyte does not freeze.

Also important is periodic checking of the electrolyte level and periodic recharging, to bring the stored battery back to a fully charged condition.

Press A 8

1-7

8

A wet charged battery stored in a dry room at 90 F will discharge itself ______________ an identical battery stored in a dry room at 65 F.

A. slower than 9
B. at the same rate as 9
C. faster than 10

1-8

9

You are incorrect.

Remember that the rate of self-discharge increases as the temperature goes up.

A wet charged battery stored at 90 F will self-discharge FASTER than one stored at 65 F.

Press A 10

1-9

10

OK.
DRY CHARGED batteries should also be stored in a cool, dry place. No routine maintenance is required during storage, as long as moisture and air do not enter the cells. Moisture and air cause the negative plates of dry charged batteries to lose their charge.

Seals are placed in the battery vent cap holes to protect the cells until the battery is activated.

Press A 11

1-10

11

See Plate I. These are basic guidelines to follow when activating a dry charged battery. Electrolyte temperature and specific gravity recommendations can vary among manufacturers. Follow the procedures and specifications indicated for the particular battery.

If the activating electrolyte level falls below the recommended point during the activation of a dry charged battery. the level should be "topped up" with ______________.

A. distilled water 12
B. electrolyte 13

1-11

12

Incorrect.

At the time of activation, the dry charged battery will be in a relatively full state of charge.

Adding water to the cells during activation will LOWER the initial specific gravity of the electrolyte, a factor which will shorten the useful life of the new battery.

Press A 13

1-12

13

OK.
The dry charged battery should be put in service in a full state of charge. The temperature and specific gravity of the activating electrolyte are important factors in assuring the battery a good start in life.

If you would like to review wet charged and dry charged batteries, press A 4

Otherwise, press B. 15

X(C)-14

2-13

14

OK.
Refilling the cell with ACTIVATING ELECTROLYTE helps to assure that the dry charged battery will begin its service life in a full state of charge.

Since you made an error or two on the questions so far, let's quickly review wet charged and dry charged batteries.

When you answer all the questions correctly, we'll talk about battery installation and removal.

Press A 4

1-14

15

BATTERY INSTALLATION AND REMOVAL

Batteries are designed and built to withstand normal operating conditions; but improper handling and mechanical abuse can lead to premature failure.

Mechanical damage and other problems can result from careless installation or removal of a battery. Let's look at some recommendations for proper battery handling during installation and removal.

Press A 16

2-15

16

Before removing a battery, it is important to note which terminal post (positive or negative) is connected to the GROUNDED battery cable (the one connected to the vehicle engine or frame).

See Plate II. The battery illustrated is a ____(1)____ volt, ____(2)____-ground battery.

A. (1) six (2) positive 17
B. (1) six (2) negative 18
C. (1) twelve (2) positive 18
D. (1) twelve (2) negative 19

2-16

17

You are incorrect. (See Plate II.)

Each cell in an automotive battery develops approximately two volts. How many cells are there in the battery in Plate II? (How many vent caps do you see?)

Also, which terminal post is connected to the GROUNDED cable (the cable connected to the frame)?

Press A 16

2-17

18

Only part of your answer is correct.

Each cell in a lead-acid storage battery develops approximately two volts. How many cells are there in the battery in Plate II ? (How many vent caps are there?)

The "ground" of a battery is determined by noting which terminal post is connected to the grounded cable which, in turn, is connected to the frame.

Press A 16

2-18

19

Good.
The grounded cable should be disconnected FIRST during battery removal. This will prevent short circuits, and damage to the battery and wiring caused by accidental grounding with the cable wrench or other tools.

Press A 20

2-19

20

Once both terminal cables are disconnected, the old battery may be removed.

Batteries should be held as level as possible while being carried. Before setting the new battery in place, the battery carriage and hold-downs should be cleaned, if necessary. They should be free of rust and corrosion.

The new battery should rest level when it is installed.

Press A 21

2-20

21

The new battery must be installed in the carriage so that the grounded cable can be connected to the proper terminal post. Reversing the polarity can cause serious electrical system damage.

Cables must be checked for wear and corrosion. Frayed, oil-soaked or worn cables should be replaced.

The grounded cable should be replaced if it is broken or corroded because ____________.

A. there will be the danger of a short circuit otherwise 22

B. there will be abnormal resistance in the cable if not replaced 23

2-21

22

No.
The electrical circuit is completed through the grounded cable. There is no danger of a short circuit there.

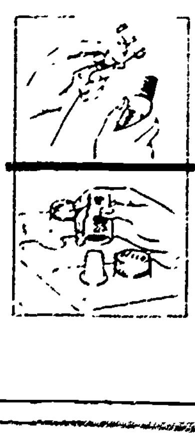
However, the resistance in the grounded cable will be increased if it is broken or corroded. This reduces its effectiveness as a part of the electrical system.

Press A 23

2-22

23

OK.
The cable clamps and the battery terminal posts should be cleaned with a wire brush prior to connection.



The cable clamps should NOT be pounded onto the terminal posts with a hammer. This can cause internal damage and provide a path for electrolyte leaks.

Loosen the cable nuts, and spread the clamps, if necessary.

Press A 24

2-23

24

When installing the new battery, the cables should be connected in REVERSE order to what was done when the old battery was removed.

When installing a battery, the ______________ cable should be reconnected first.

A. grounded 25
B. ungrounded 26

2-24

25

Incorrect.

When the old battery was removed we disconnected the grounded cable first, to prevent short circuits caused by accidential grounding with tools.

When INSTALLING a battery you reverse this procedure -- reconnect the UNgrounded cable first, also to prevent accidential short circuits.

Press A 26 2-25

26

OK.
The cable terminals should be tightened snugly around the terminal posts to insure good electrical contact. Use the cable wrench carefully to avoid twisting and damage to the cell covers and terminal posts. Excessive pressure can cause damage to internal connections and shorten the life of the battery.

Overtightening the hold-downs also causes damage -- distortion and cracking of the battery case can occur.

Press A 27 2-26

27

The exposed areas of the terminal posts and the cable clamps should be coated with a film of non-metallic grease (or petroleum jelly if non-metallic grease is unavailable). This helps to prevent corrosion.

If corrosion had already occurred, it can be removed by scraping and/or washing the part with a dilute solution of baking soda or household ammonia.

Battery corrosion is caused by the action of __________ on metals.

A. hydrogen gas 28
B. heat 28
C. electrolyte acid 29 2-27

28

No.
Although heat tends to speed up the corrosive action. the acid in the electrolyte is primarily what attacks the metal parts and causes battery corrosion.

Press A 29 2-28

29

OK.
Corrosion prevention is one good reason to avoid overfilling and overcharging the battery.

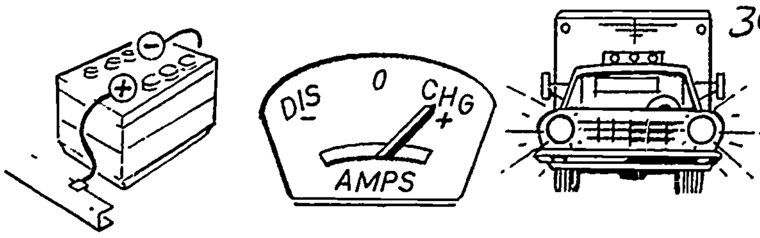
****

The TEST for proper battery installation is to turn on the vehicle lights and check the ammeter or other such indicator in the vehicle.

If the ammeter shows DIScharge, the battery is installed properly.

If it shows charge, the polarity is reversed and the battery cables are improperly connected. DO NOT start the engine! Reverse the connections and test again. Press A 30 2-29

30



A new battery has just been installed in a vehicle with a 12 volt negative ground electrical system. Above are illustrated some parts of the vehicle. The engine is not running. Is anything wrong here?

A. No. The battery is installed correctly. 31
B. The operator has left the lights on. 32
C. The battery polarity is reversed. 33 2-30

31

Your answer is incorrect.

In the illustration, the grounded cable is connected to the POSITIVE terminal post of the battery.

The ammeter is reading CHARGE. Take another look at the preceding frame and then try the question again. Read carefully.

Press A 29 2-31

32

It is true that the lights were ON, but in this case it was no accident.

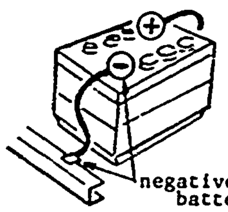
In the illustration, the grounded cable is connected to the POSITIVE battery terminal and the ammeter is reading CHARGE.

Take another look at the preceding frame and then try the question again.

Press A 29 2-32

33

Good. The battery must be reversed in its carriage so that the negative battery post is connected to the grounded cable, as shown here. Then the installation will be correct, since the vehicle has a NEGATIVE ground system.



If you would like to review battery installation and removal, press A. 15
Otherwise, press B. 35

X(C)-34 3-33

34

OK.
The battery should be reversed in its carriage so that the NEGATIVE battery post can be connected to the grounded cable. The vehicle has a NEGATIVE ground electrical system.

Let's have a quick review of this section on battery installation and removal, since you had trouble with a question or two. Press A 15

2-34

35

VISUAL INSPECTION

Although not a substitute for instrument checks, periodic visual inspection of the battery is an important part of service and preventive maintenance.

Battery manufacturers usually provide some means of indicating the installation date of the battery. This date is important, since it can indicate whether a particular condition is premature, or is the result of normal degeneration.

Press A 36 3-35

36

See Plate III, the "Battery Visual Inspection Troubleshooting Chart." Study this chart carefully.

The battery must be inspected periodically for corrosion, cracked cases and covers, loose hold-downs, loose connections and corroded or defective cables.

Electrolyte level should be checked periodically (MORE frequently in summer months). Distilled water or colorless, odorless drinking water ONLY should be used to fill the cells to the required level.

3-36

Press A 37

37

If the vent holes in the battery vent caps are clogged with dirt or other foreign material, __________ may result.

A. corrosion deposits 38
B. gassing 39
C. a cracked or buckled battery case 40

(Refer to Plate III for help in answering.)

3-37

38

Not necessarily.

A battery that has been neglected long enough for the vent caps to become clogged may have corrosion problems too. But, the primary danger from clogged vent caps is that the battery case may rupture from the pressure of gases formed during charging.

Press A 40

3-38

39

Your answer is incorrect.

Gassing is likely to occur in any battery as it reaches a full state of charge. At any point during the charge cycle, hydrogen and oxygen gases are being liberated at the plates.

Clogged vent caps prevent the gases from escaping to the atmosphere as the battery reaches full charge. This can result in a cracked or buckled battery case or cover. Press A 40

3-39

40

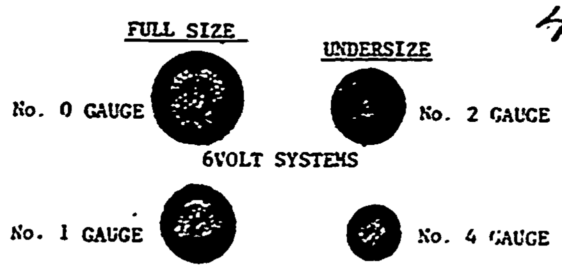
OK.

The condition and size of the battery cables also is important. The electrical system places a high current demand on these cables.

During a visual inspection, the size of the cables being used should be checked and compared with the manufacturer's recommendations.

Press A 41 3-40

41

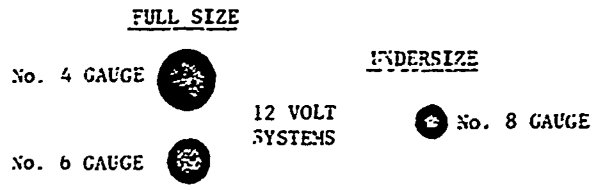


In 6 volt applications, number "0" gauge or number "1" gauge cables are generally recommended.

Press A 42

3-41

42



For 12 volt systems, number "4" gauge is recommended. The number "6" gauge is also used in some applications.

Twelve volt systems use ________ gauge cables than 6 volt systems.

A. finer 44
B. heavier 43

For another look at the previous frame before answering, press C. 41 3-42

43

Incorrect.

Twelve volt electrical systems use FINER gauge cables than 6 volt systems.

Press A for a look at why this is true. 44

3-43

44

OK.

A 6 volt battery supplies only half as much emf as a 12 volt battery. Larger diameter cables are needed in 6 volt systems to provide a low resistance path for the current.

A 12 volt battery on the other hand supplies sufficient emf to allow smaller diameter cables to be used. The smaller the cable diameter, the greater its resistance will be.

Press A 45 3-44

45

You already know that water plays an important part in the reactions that take place in a storage battery.

Controversy has long existed over what kind of water is best to use in the battery. Colorless, odorless drinking water is considered safe by many experts. But no one can really deny that DISTILLED water is actually best.

Battery water should be stored in a ___ ________ container.

A. metallic 46
B. non-metallic 47 3-45

46

You are incorrect.

Water stored in a metallic container will pick up small amounts of the material from which the container is made.

Impure water will shorten the life of the battery. Store battery water in non-metallic containers.

Press A 47 3-46

47

OK.

Extremely small amounts of solid or organic material in the water can make it unfit for use in a battery. The iron content, for example, can be no more than FIVE PARTS PER MILLION to be considered safe.

A sign that impure water has been used in a battery is ______________.

A. corrosion on the terminals 48
B. electrolyte level too low 48
C. discolored or foul-smelling electrolyte 49

(Refer to Plate III if needed.)

3-47

48

Not necessarily. (See Plate III.)

The "symptom" you chose does not indicate directly that impure water has been used in the battery.

But discolored or foul-smelling electrolyte (with the odor of rotten eggs) is an indication that impure water may have been used.

Press A 49

3-48

49

OK.
In some areas the municipal water supply has been approved for use in batteries. Even where tap water is approved however, run the faucet for several minutes before filling the container. This will help eliminate water that either has been in the pipes long enough to pick up any metal content, or has accumulated sediment along the way.

Press A 50

3-49

50

Corrosion can be removed from the surfaces of the battery, the terminals, the hold-downs and the cables with a wire brush.

Corrosion may also be removed by washing the battery with a dilute solution of ______________ or household ammonia.

A. salt 51
B. vinegar 51
C. baking soda 52

3-50

51

No.
Corrosion is best removed after wire brushing by washing the area with a dilute solution of BAKING SODA or household ammonia.

Press A 52

3-51

52

OK.
After washing, the area or part should be rinsed with clear water, and dried. Care should be taken not to get the washing solution into the battery cell. Be sure the vent caps are snug.

Dirt, grease or acid deposits on the surface of the battery cover may form a path for current to flow between the battery terminals. This will increase the battery's ____________________.

A rate of self-discharge 54
B. state of charge 53
C. tendency to gas 53

3-52

53

No.
Remember that as soon as a battery is activated with electrolyte (regardless of whether it is a wet charged or dry charged battery), it slowly begins to lose some of its charge.

Any completed path between the terminal posts will increase this SELF-DISCHARGE rate.

Press A 55

3-53

54

OK.
Remember to spread a light coating of non-metallic grease of petroleum jelly over metal parts that have been cleaned of corrosion.

Visual inspection plays an important part in overall battery maintenance.

If you would like to review this section, press A. 35
Otherwise, press B. 56

3-54

X (C)-55

55

OK.
The battery cover, case, terminals and hold-down must be kept free of corrosion.

Since you made an error or two on the questions in this section, let's review visual inspection.

When you answer all the questions correctly, we'll get into some specific testing procedures.

Press A 35

3-55

56

There is really no substitute for instrument tests when it comes to determining the condition or state of charge of an automotive battery.

Two of the most useful instruments for the automotive electrician are the HYDROMETER and the VOLTMETER.

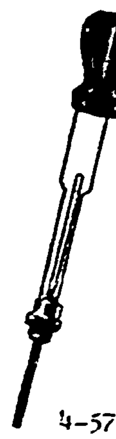
Let's look at the hydrometer first.

Press A 57

4-56

57

The hydrometer may be used to ESTIMATE either the condition of a battery (its ability to store and deliver power), or the battery's state of charge (the amount of power in the battery).



The hydrometer measures the SPECIFIC GRAVITY of the electrolyte in the cells. The higher the hydrometer float rides in the electrolyte sample, the higher the specific gravity will be. Press A 58

4-57

58

The specific gravity of the electrolyte varies directly with the state of charge.

The electrolyte in a battery with a high state of charge will have relatively __________ specific gravity.

A. low 59
B. high 60

4-58

59

Incorrect.

State of charge and electrolyte specific gravity are DIRECTLY proportional.

A high state of charge means relatively HIGH specific gravity.

Press A 60

4-59

60

OK.
Temperature also has an effect on the specific gravity of the electrolyte. Temperature and specific gravity are inversely proportional.

As the temperature of the electrolyte in a battery goes up, its specific gravity ________________.

A. remains constant 61
B. decreases 62
C. increases 61

4-60

61

No.
Remember that the temperature and the specific gravity of electrolyte are INVERSELY proportional.

This means that as the electrolyte temperature INCREASES, specific gravity DECREASES.

Likewise, as the electrolyte cools, its specific gravity increases.

Press A 62

4-61

62

OK
As electrolyte is heated, it expands and becomes less dense, and its specific gravity is lowered.

This fact can cause inaccuracies in estimating the state of charge of a battery. Most specific gravity charts are based on electrolyte temperatures of 80 F as a standard.

Readings taken at other temperatures must be corrected to the 80 F level. Press A 63

4-62

63

The electrolyte temperature will seldom be exactly 80 when you take specific gravity readings. Unless the hydrometer you use has its own conversion scale, you will have to make the temperature correction yourself.

For every 10 degrees of electrolyte temperature ABOVE 80 F, four gravity points (.004) must be ADDED to the reading you get.

If the electrolyte temperature is 90 F, and you obtain a reading of 1.226 on the hydrometer, the corrected specific gravity will be __________.

A. 1.222 64
B. 1.626 65
C. 1.230 66

4-63

64

Incorrect.

You must have subtracted four gravity points (004) instead of adding.

The electrolyte temperature is 90 F (one unit of 10 degrees ABOVE the 80 F standard). This means that .004 must be ADDED to the original reading of 1.226. In other words:

1.226 PLUS .004 equals 1.230

Press A 66 4-64

65

You are incorrect. You seem to have the right idea, (adding). But "four gravity points" means .004, NOT .400.

The electrolyte temperature is 90 F (one unit of 10 ABOVE the 80 F standard). This means that .004 must be added to the original reading of 1.226. In other words:

1.226 PLUS .004 equals 1.230

Press A 66 4-65

66

OK.
The corrected reading will be 1.230.

Now. if the electrolyte temperature is below 80 F, four gravity points (.004) must be SUBTRACTED from the reading you get for every 10 degrees of electrolyte temperature.

If the electrolyte temperature is 60 F. and you obtain a hydrometer reading of 1.248. the corrected reading will be ____________.

67 A. 1.256
69 B. 1.240
68 C. 1.244

4-66

67

You are incorrect. You had the right number of specific gravity correction points (.008 for two units of 10 degrees BELOW 80 F), but you added instead of subtracting.

Since the electrolyte temperature (60 F) is BELOW 80 F. you must SUBTRACT the specific gravity correction points:

1.248 MINUS .008 equals 1.240

Press A 69 4-67

68

Incorrect. You had the right idea (subtracting). but you did not subtract enough correction points.

The electrolyte temperature was given as 60 F This is TWO units of 10 degrees below 80 F (80 minus 10 minus 10 equals 60).

This means that .008 (2 times .004) must be subtracted from the original reading of 1.248:

1.248 MINUS .008 equals 1.240.

Press A 69 4-68

69

OK. The corrected reading is 1 240.

A hydrometer test is not complete until you take readings from all the cells. correct them for temperature. and record your findings

The information you record will allow you to make certain assumptions about the battery Let's see how to interpret the hydrometer readings you get

Press A 71 X(C)-70 4-69

70

OK
The corrected reading is 1.240.

Before we go into interpreting hydrometer readings. let's quickly review specific gravity and state of charge and temperature correction. You had some trouble with the questions on those topics.

Press A 56 4-70

71

HYDROMETER TEST INTERPRETATION

If all the cells read 1.215 or above (temperature corrected). the state of charge is probably good. This can be confirmed by the voltmeter test which we will cover later.

If the difference between the highest and lowest cell readings is LESS than .050 (fifty gravity points). the battery is serviceable. Recharge according to the manufacturer's specifications and retest.

Press A 72 4-71

72

Here are the corrected specific gravity readings obtained from the cells of a 12 volt battery:

1.250	1.248	1.225
1.248	1.235	1.210

The difference between the highest cell reading and the lowest cell reading is ___(1)___ than .050, so the battery should be ___(2)___.

A. (1) less (2) used as is 73
B. (1) less (2) recharged 75
C. (1) more (2) replaced 74

4-72

73

Only part of your answer is correct. The difference between the highest reading (1.250) and the lowest reading (1.210) IS less than .050.

What does this indicate to the automotive electrician?

Look at the preceding frame again and try the question once more.

Press A 72

4-73

74

You are incorrect.

The specific gravity readings given were:

1.250	1.248	1.225
1.248	1.235	1.210

The difference between the highest reading (1.250) and the lowest reading (1.210) is .040. What does this indicate to the automotive electrician? Take another look at the previous frame and then try the question again. Press A 71

4-74

75

OK. The battery should be recharged if the difference between cells is less than fifty gravity points (.050).

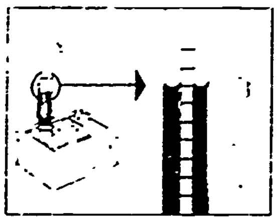
If all the cells had read above 1.215 and their specific gravities had been EQUAL, no recharge would be necessary.

If the difference in specific gravity readings between any two cells is MORE than .050, the value of a recharge is doubtful. The battery probably is nearing the end of its useful life and you should recommend replacement, to avoid an unexpected failure. Press A 76

4-75

76

In taking a specific gravity reading, it is important to allow the float to ride free in the electrolyte. It must not be allowed to touch the top, sides or bottom of the tube. Read the scale at eye level. Be careful that no electrolyte drops on your hands, your clothes or on another person.



Here are some hydrometer readings taken from a 6 volt battery: 1.240, 1.170, 1.230.

This battery should be ________.

A. left in service 77
B. recharged 77
C. replaced 78

4-76

77

Your answer is incorrect.

The readings were: 1.240, 1.170, 1.230.

The difference between cell readings here is MORE than .050 in two cases -- 1.240 minus 1.170 equals .070
1.230 minus 1.170 equals .060.

When the difference between any two cells is MORE than .050 REPLACEMENT is recommended.

Press A 78

4-77

78

OK The battery should be replaced.

Specific gravity readings will be inaccurate if they are taken within one hour of the addition of water to the cells A gassing battery on charge will also show inaccurate readings. Allow gas to escape from your sample before reading.

If you want to review temperature correction and hydrometer test interpretation, press A. 56
Otherwise, press B. 80

4-78

B(A) - 79

79

OK.
The battery should be replaced.

You have made an error or two on the questions covering hydrometer test interpretation, so we will have a brief review now.

If you would like to review electrolyte temperature correction also, press A. 56

Press B is you want to review only hydrometer test interpretation. 71

4-79

80

We mentioned earlier that another important tool for the automotive electrician is the voltmeter.

Just as individual cell specific gravities offer an idea of the condition and state of charge of a battery, individual cell OPEN CIRCUIT VOLTAGES also provide indications of these factors.

Let's see how we can test a battery using an expanded scale voltmeter.

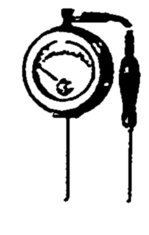
Press A 81

5-80

81

An expanded scale voltmeter is one in which the smallest division on the voltage scale is 0.01 volt. This is a sensitive instrument and must be read accurately.

Batteries with individual cell covers can be tested with a voltmeter through the LIGHT LOAD TEST. Essentially, the light load test uses 1.95 volts as the reference point, and 0.05 volts as the limit of variation.



Press A 82

5-81

82

The light load test is made with the voltmeter probes in parallel with the individual cell terminals (positive to positive; negative to negative).

The condition of the battery is determined by noting the difference (if any) in the readings of the individual cells.

The smallest scale division on an expanded scale voltmeter is __________ volt.

A. 0.10 83
B. 0.01 84
C. 0.05 83

5-82

83

Incorrect.

The smallest scale division on an expanded scale voltmeter is 0.01 volt (one-hundredth of a volt). Scale divisions that are this accurate are needed for the light load test.

Press A 84

5-83

84

OK.
The light load test may be performed either in the vehicle or in the shop. For bench testing, a HIGH RATE LOAD TESTER may be applied to simulate the action of cranking the engine and turning the lights on low beam. We'll outline the test, using the in-vehicle method.

Press A 85

5-84

85

To perform the light load test:

1. Adjust the electrolyte level in the cells, if necessary, by adding approved water.
2. Turn the starter switch ON and hold for three seconds or until the engine starts. Shut the engine off IMMEDIATELY if it starts (150 amps for three seconds for bench test).
3. Turn headlights on low beam. Wait one minute before starting the test. Leave the lights on during the test (10 amp load for bench test).

5-85

Press A 86

86

Cranking the engine removes the surface charge from the battery plates and conditions them for the test. It helps amplify any voltage difference between the cells.

Turning the lights on low beam allows the discharge current to reduce cell voltage in proportion to the true capacity of the cell.

Low beam lights are __________ during the light load test.

A. turned off XX
B. left on 87

5-86

(Only the correct answer will move the film.)

87

OK.
With the low beam lights ON, test each cell with the voltmeter and record your findings.

LIGHT LOAD TEST INTERPRETATION

If all the cells read LESS than 1.95 volts, the battery is too low to test properly. It should be given a "boost charge" (usually at 60 amperes for 30 minutes for heavy duty batteries). Then the test can be made again. A battery that does not come up after a second boost charge should be replaced.

Press A 88

5-87

88

If all the cells read 1.95 volts or more, and the difference between the highest cell and the lowest cell is LESS than 0.05 (five scale divisions), the battery is sufficiently charged.

From a 6 volt battery, these original cell voltage readings were obtained: 1.80 volts, 1.94 volts, 1.90 volts.

This battery should be ____________________.

A. used as is 89
B. replaced 89
C. given a boost charge and retested 90

5-88

89

Your answer is incorrect.

The cell voltages obtained in the original light load test were: 1.80 volts, 1.94 volts, 1.90 volts.

Note that ALL the cells read LESS than 1.95 volts. This means that the battery should be given a boost charge and retested.

Press A 90

5-89

90

OK.
Light load test cell voltages were obtained from a 12 volt battery. The readings are as follows:

1.99	2.01	1.99
2.02	2.00	1.98

The difference between the highest and lowest reading is __(1)__ than 0.05 volt, so the battery __(2)__.

A. (1) less (2) should be replaced 91
B. (1) more (2) is sufficiently charged 91
C. (1) more (2) should be recharged 92
D. (1) less (2) is sufficiently charged 93

5-90

91

Only part of your answer is correct.

In the example given, all the cells read more than 1.95 volts. The difference between the highest reading (2.02 volts) and the lowest reading (1.98 volts) is 0.04 volts (LESS than 0.05).

That means that the battery is sufficiently charged.

Press A 93

5-91

92

Your answer is incorrect.

The individual cell voltages obtained were:

1.99	2.01	1.99
2.02	2.00	1.98

All the cells read more than 1.95 volts. The difference between the highest cell (2.02 volts) and the lowest cell (1.98 volts) is 0.04 volts (LESS than 0.05 volts).

That means that the battery is sufficiently charged.

Press A 93

5-92

93

If the cell readings obtained in a light load test are both ABOVE and BELOW 1.95 volts, and the difference between the highest and lowest cell is LESS than 0.05 volt, the battery is serviceable, but requires recharging.

If any cell reads 1.95 volts or more, and the difference between the highest and lowest reading is MORE than 0.05 volts, the battery is defective or worn out. It should be replaced.

Press A 94

5-93

94

Here are some light load test cell voltages:

1.98	1.97	1.94
1.97	1.96	1.94

This 12 volt battery should be ____________________.

A. returned to service without further maintenance 95
B. recharged, and then returned to service 96
C. replaced immediately to avoid unexpected failure 95

5-94

95

Your answer is incorrect

The cell voltages given were:

1.98	1.97	1.94
1.97	1.96	1.94

Note that the difference between the highest and lowest cell is 0.04 volt (LESS than 0.05) and that the cells read both ABOVE and BELOW 1.95 volts (1.98 to 1.94)

Take another look at the previous frame and try the question again.

Press A 93

5-95

96

Good.
A 6 volt battery gave these readings during the light load test: 2.01 volts, 1.97 volts, 1.84 volts. This battery ______.

A. probably is defective and should be replaced 98
B. is serviceable and should be recharged 97
C. is sufficiently charged to return to service 97

5-96

97

Your answer is incorrect.

Perhaps you missed information that would help you answer the question.

The voltages obtained were: 2.01 volts, 1.97 volts, 1.84 volts.

What is the difference between the highest cell and the lowest cell -- more or less than 0.05 volts?

Press A 93

5-97

98

OK. The difference between the highest and lowest cell reading was 0.17 volt (2.01 minus 1.84). Since this is MORE than 0.05, the battery should be replaced to avoid an unexpected failure.

The light load test has certain advantages over the hydrometer test in that:

1. The maintenance man does not have to handle electrolyte
2. No temperature corrections have to be made

Press A 100 X(C)-99

6-98

99

OK.
Since the difference between the highest and lowest cell readings is more than 0.05 volts, the battery should be replaced.

You have made an error on one or more questions in this section, so let's review the voltmeter and the light load test.

We'll continue when you answer all the questions correctly.

Press A 80

5-99

100

The light load test does have certain DISadvantages however:

1. It cannot be applied to batteries that have just been charged. Defective cells may acquire enough surface charge to give false high readings.
2. It cannot be used on batteries that have a one piece cover. Hydrometer tests, or specially programed charge-discharge tests, must be used for hard cover batteries.

If you would like to review voltmeters and the light load test, press A. 80

Otherwise, press B. 101

6-100

101

LOW TEMPERATURE OPERATION

At sub-zero temperatures, the cranking ability (capacity) of a fully charged battery is only about 30 percent of its capacity at 80 F. In effect, a battery is "smaller" during cold weather than it is during the warmer months.

Press A 102

6-101

102

Electrolyte in a storage battery will freeze at a temperature determined by its specific gravity. This, in turn, means that the freezing temperature of the electrolyte also depends on the state of charge of the battery, since state of charge and electrolyte specific gravity are directly related.

At low states of charge, electrolyte specific gravity is relatively ______.

A. low 104
B. high 103

6-102

103

Incorrect.

Earlier in this film we said that state of charge and electrolyte specific gravity are DIRECTLY proportional.

This means that when the state of charge is low, electrolyte specific gravity will also be LOW

Press A 104

6-103

104

OK. See Plate IV. This chart shows the approximate electrolyte freezing points at various states of charge. The corresponding specific gravities and approximate open circuit cell voltages are shown also.

A battery with a 75 percent state of charge will freeze when the electrolyte temperature reaches approximately ____________.

A. 39 F 105
B. -70 F 105
C. - 39 F 106

6-104

105

Your answer is incorrect. (See Plate IV.)

Reading across in the 75 percent state of charge line, we find that the electrolyte freezing point is MINUS 39 F (39 degrees BELOW zero) at 75 percent charge.

Press A 106

6-105

106

OK. That means that when the outdoor temperature reaches about 40 below zero, a battery might freeze even if it is three-fourths charged!

The electrolyte specific gravity in each cell must be slightly higher than __________ to protect a battery from freezing in "40 below" weather.

A. 1.170 XX
B. 1.260 XX
C. 1.230 107

6-106

(Only the correct answer will move the film.)

107

OK.
Of course, if there is danger that the temperature will drop even lower than -40 F, still higher specific gravities will be required to protect the battery, and to provide adequate service.

A half-charged battery will be in danger of freezing as soon as the temperature drops to about ________.

A. -20 F 108
B. -16 F 109
C. -39 F 108

6-107

108

You are incorrect.

We were looking for the freezing point for electrolyte in a half-charged battery (50 percent state of charge). Referring to Plate IV, we find that a half-charged battery is in danger of freezing at temperatures of -16 F or below.

Press A 109

6-108

109

Will a battery with electrolyte specific gravity of about 1.110 perform well at sub-zero temperature?

A Yes 110
B. No 111

6-109

110

You are incorrect. (See Plate IV.)

When the specific gravity reaches 1.110, the battery is in a discharged condition, and each cell produces only about 1.95 volts. In this condition the electrolyte freezing point is 17 degrees ABOVE zero.

Press A 111

6-110

111

OK.
If local temperatures are expected to drop to the -30 F to -40 F range, batteries must be maintained in a constant __________ state of charge in order to be protected and to provide adequate current.

A. 75-100 percent 113
B. 25-50 percent 112
C. 50-75 percent 112

6-111

112

That would not be enough to be safe.

At 40 below zero, even a battery in a 75 percent state of charge may be in danger of freezing, and may not provide adequate service.

In order to protect batteries adequately at temperatures lower than -30 F, it is necessary to keep them well within the 75-100 percent state of charge range.

Press A 113

6-112

113

OK.
Temperature is an extremely critical factor in determining the condition and performance of a lead-acid storage battery.

If you would like to review low temperature operation, press A. 101

Otherwise, press B. 115

X(C)-114

6-113

114

OK. Batteries must be maintained in a constant high state of charge, in cold weather applications.

Since you made an error or two on the questions, let's review low temperature operation.

Press A 101

6-114

115

Congratulations!

You have completed this film on "Battery Servicing and Testing Procedures."

We hope that what you have studied here will help you obtain maximum useful life from the batteries you service.

Press REWIND.

6-115

INSTRUCTOR'S GUIDE

Title of Unit: BATTERY SERVICE AND TESTING PROCEDURES (PART II) Code: AM 2-13 9/8/67

OBJECTIVES:

1. To assist all personnel engaged in servicing of storage batteries. It also is intended as a reference guide to the training information available from other manufacturers on the subject of automotive type lead-acid storage battery.
2. To familiarize the student with procedures recommended by The American Association of Battery Manufacturers in battery installation, servicing and testing.
3. To introduce information to the student about factors affecting battery life, and methods of predicting battery life.
4. To let the student become aware of the hazards involved in working with and around batteries. (Safety Precautions)

LEARNING AIDS suggested:

Visual Aids: Delco-Remy training charts and manuals No. DR 5133-B, Storage Batteries

Models: Any cells, elements, plates or complete batteries prepared in advance for the purpose of classroom demonstration. (Acid removed and plates etc. washed and dried). Demonstration in use of hydrometer, voltmeter and other test equipment used on batteries.

QUESTIONS FOR DISCUSSION AND GROUP PARTICIPATION:

1. What is necessary to make battery plates become "active materials?"
2. What is the name of the solution surrounding the plates of an activated battery?
3. What is the solution mentioned in question #2 composed of?
4. How are the following related? Specific gravity; temperature; state of charge.
5. What is the meaning of specific gravity as associated with batteries?
6. What effect does temperature have on the specific gravity reading of a battery?
7. What important determination may be made from the specific gravity readings of a battery?
8. What is a nominal specific gravity reading for a battery placed in service for temperate climates? (New and fully charged)

9. What effect does the specific gravity reading on batteries prepared for Arctic Climates have on the capacity and the life expectancy of the battery?
10. What is meant by the term "state of charge?"
11. What are the two most common methods for charging batteries?
12. What happens to battery plates if left in an uncharged condition?
13. What is the basic difference between the wet charged type and the dry charged type batteries?
14. After a battery has been placed in service, what should be added to the cells if the electrolyte level is low? Water or acid?
15. What are the two most common battery ratings used and discussed? (As mentioned in the Unit.)
16. Is polarity important when installing batteries, new or used? Why?
17. Is periodic battery service important? Why?
18. When taking hydrometer readings to determine the state of charge, if any cell reads above 1.310, corrected for temperature, what effect will the high hydrometer reading have on the life of the battery?
19. What is meant by the statement, "lead-acid storage batteries are perishable items?"
20. What is meant by the term "cycling?"