Autolite

BATTERY SERVICE
and
TESTING PROCEDURES

Autolite Battery Care

the ABC's of proper battery maintenance

foreword...

This manual has been prepared to assist all personnel engaged in the sale and servicing of wet storage batteries. It is also intended to serve as a permanent reference guide to the training information available by attending an *Autolite-Ford Field Service Training Clinic,* on this subject.

Although the information contained in this publication is concerned primarily with automotive batteries, the theory . . . principles . . . and procedures apply to all installations that depend upon electrical storage battery power.

contents...

The last six pages of this manual describe AUTO TECH—WHAT IT IS . . . HOW IT WORKS . . . WHAT IT PROVIDES. We encourage you to read about this low-cost correspondence training program which carries a money-back guarantee. A registration form is included for your convenience.

The procedures, descriptive data, and specifications contained in this Manual were in effect at the time the publication was approved for printing. The Autolite-Ford Parts Division of Ford Motor Company reserves the right to alter its product line at any time, or change specifications or design without notice and without incurring obligation.

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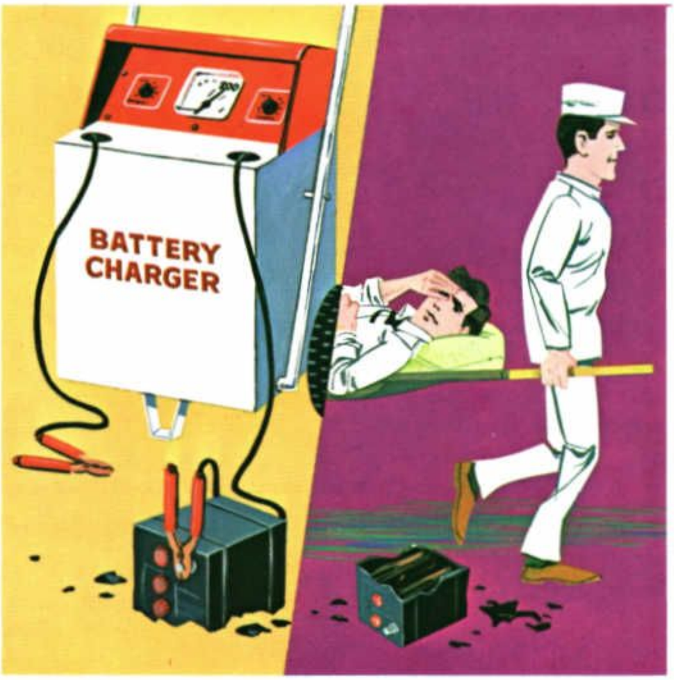
1
Introduction

Safety Precautions



Numerous safety precautions will be mentioned throughout the text in the various areas where they are applicable. The principal hazards in servicing batteries occur under charge conditions or when handling acid. The following is a listing of these safety rules which must be observed when handling or charging batteries:

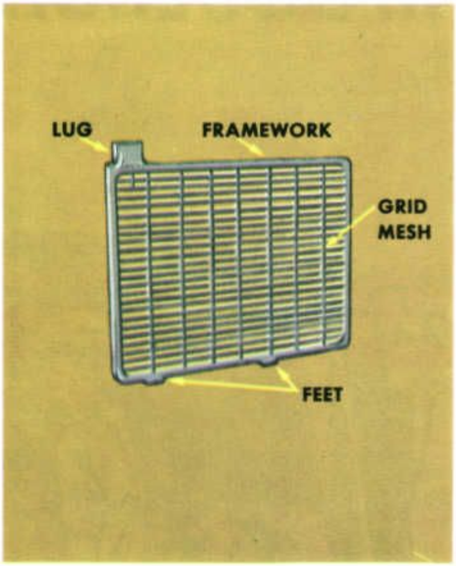
1. When mixing battery electrolyte, it is important to *pour the acid into the water* and not the water into the acid.
2. When working with acid, such as filling batteries, splash-proof goggles should be worn. (Other articles of protective clothing may be advisable if many batteries are handled.)
3. 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. Excepting 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. This gas is extremely explosive!
7. Open flames or smoking should not be allowed when batteries are being charged.
8. Exercise care to avoid tools or metallic objects from falling across the battery terminals.
9. Never break a live circuit at the battery terminals. A spark usually occurs whenever charger leads or booster cable leads 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.

Battery Construction

The internal design features will be considered first in order to give you fundamental background information about the materials which take part in the chemical reactions inside a battery. A more thorough understanding of test results . . . and the corrective action they indicate . . . will be derived from a familiarity with the operation and construction of these components.

Each will now be covered separately . . . beginning with basic plate grid construction and progressing through to the point where the battery will be illustrated as a cutaway view of the complete assembly. The callouts on the assembly will help to relate the installed position of all parts.

PLATE GRID

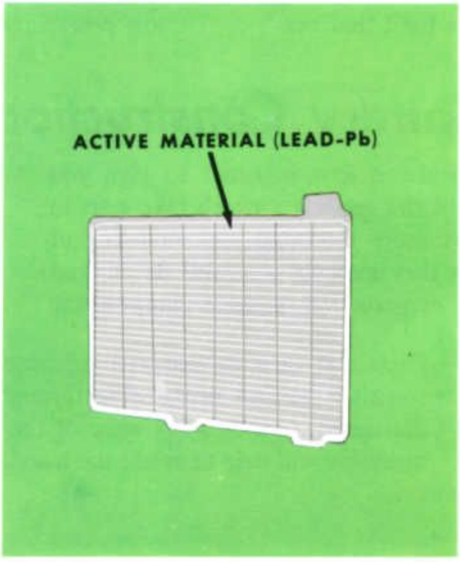


This is the name given to the supporting framework or "backbone" of the plates. The grid serves to conduct current to and from the active materials of the positive and negative plates. They are made of an alloy of lead and antimony. The antimony strengthens and stiffens the soft lead while keeping the overall battery weight to a minimum. The borders are usually heavier than the inner wire mesh. "Feet" are incorporated on the bottom edge to support the plate on the tops of the element rests.

POSITIVE PLATE

The positive plate is an assembly which results when the plate grid is united with its active material. The active material, in this instance, is in the form of a lead oxide paste which is applied to the grid. After the plate is assembled into the cell and given an initial forming charge, the lead oxide changes into lead peroxide. Lead peroxide is a dark brown, crystalline material composed of very small grains or particles which provide a high degree of porosity. This allows the electrolyte to freely penetrate the plate.

NEGATIVE PLATE



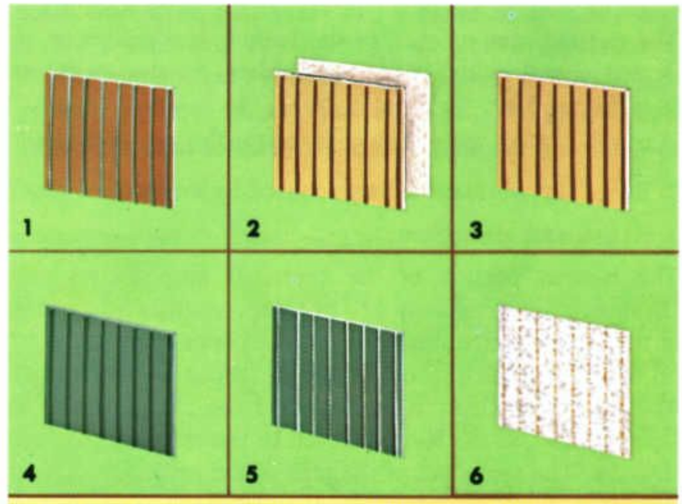
The negative plate is an assembly which results when the grid is filled with a porous mass of lead in sponge form, which allows the electrolyte to penetrate freely. The active material also contains "expanders" which prevent the sponge lead from contracting and reverting to a dense inactive state.

SEPARATORS

Positive and negative plates which are allowed to touch each other will quickly lose their potential energy. Thin sheets of non-conducting, micro-porous material called separators are placed between each plate to prevent this contact. The material used includes:

1. Resin impregnated cellulose fiber
2. Wood
3. Rubber
4. Plastics

These materials are used alone or in combination with fiber-glass sheets. The sheets help to retard the loss of active materials from the positive plate, as well as protect the separator from oxidation. Separators with vertical ribs on one side are placed next to the positive plate to provide greater acid volume for the surface of the positive plate. This arrangement improves efficiency and aids electrolyte circulation throughout the cell.

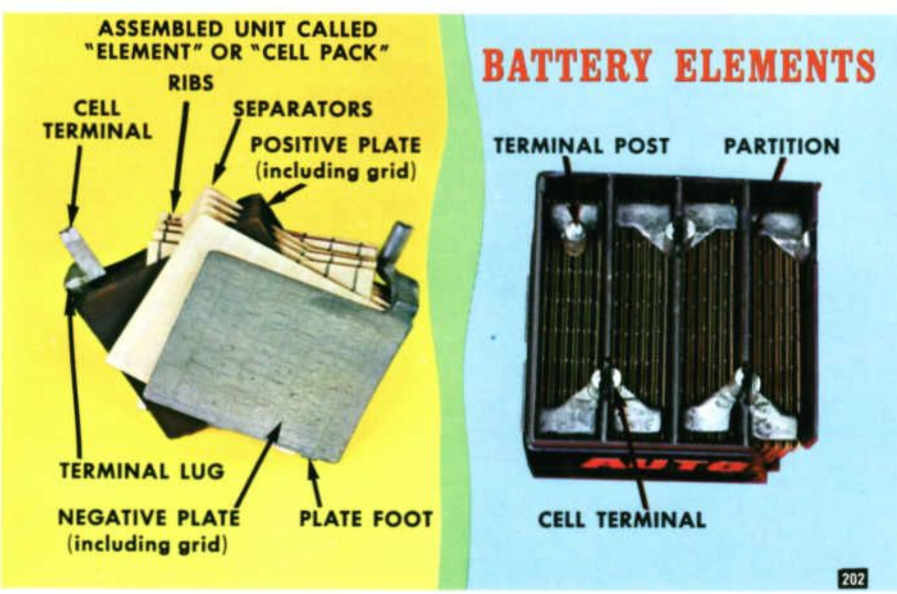


1. Resin Impregnated Cellulose Fiber Separator with Plastic Ribs.
2. & 3. Resin Impregnated Fiber Separators, with and without Fiber-Glass Retainer Mats.
4. Microporous Rubber Separator.
5. Microporous Rubber Separator with Plastic Ribs.
6. Fiber-Glass Mat Separator with Microporous Backing Attached.

PLATE GROUPS

A plate group is formed in one of the two following ways:

1. The lugs of each similar plate (positive and negative) are welded (lead-burned) to a plate strap. The plate strap includes a terminal post for connecting the group in *series* with the plate groups of adjacent cells. The assembled positive and negative groups are then positioned together with separators placed between each plate.
2. A stack of alternate positive and negative plates—with separators between each plate are built up. Grooved faces of the separators are placed next to the positive plates. The terminal straps (with posts) are then welded to the plate lugs. One for the positive group and one for the negative group. The negative group always contains one more plate than the positive group to improve efficiency.



ELEMENTS

The assembly which results when these plate groups, with separators, are positioned together is a single unit known as an element. Any number or size of plates may be used, depending upon the desired capacity. The *greater* the plate *surface area per element*, the *higher* the *voltage* will be during *high rates of discharge* and *low temperatures*. One thing to remember, however, is that the open circuit voltage potential of a single cell, regardless of the size or number of plates used, will only be a little over 2-volts. Accordingly, the 12-volt battery has 6 cells, and the 6-volt battery has 3 cells.

INTRODUCTION

CONTAINER

The outside case or shell of the battery is a one-piece, molded, rectangular-shaped container made of hard rubber, plastics, or bituminous composition. It is designed to:

1. Withstand the temperature extremes of heat and cold.
2. Resist the vibration damage caused by mechanical shock.
3. Resist acid absorption.

The bottom portion of the container incorporates four element rests or "bridges", approximately 1/7 of total container height, running the full length of the case. As mentioned earlier, the plates are constructed with "feet" on the bottom edge, which sit on these rests. (Positive on 1 and 3—negatives on 2 and 4). The plates sit at right angles to the element rests and in some battery designs, we find the feet anchored to the rest itself to insure against vibration damage. The space below the tops of the rests acts as a sediment chamber for collecting the dislodged active material of the plates. This loss of plate material is a part of the natural wear process caused by repeated cycling (charging and discharging). By the time the sediment spaces fill up, the life of the cell is spent, as the shedded material will eventually form an electrical path between the bottoms of the positive to negative plates. A direct *SHORT CIRCUIT* results!

CELL COVERS

Usually made of hard rubber and they are constructed to provide an acid-tight seal, as well as accommodate openings for the two terminal posts, intermediate connectors, and various designs of vent plugs and openings. The construction and location of the vent openings help to baffle the gases and the electrolyte that is splashed or sprayed against the underside of the cover.

One-piece cover designs incorporate three types:

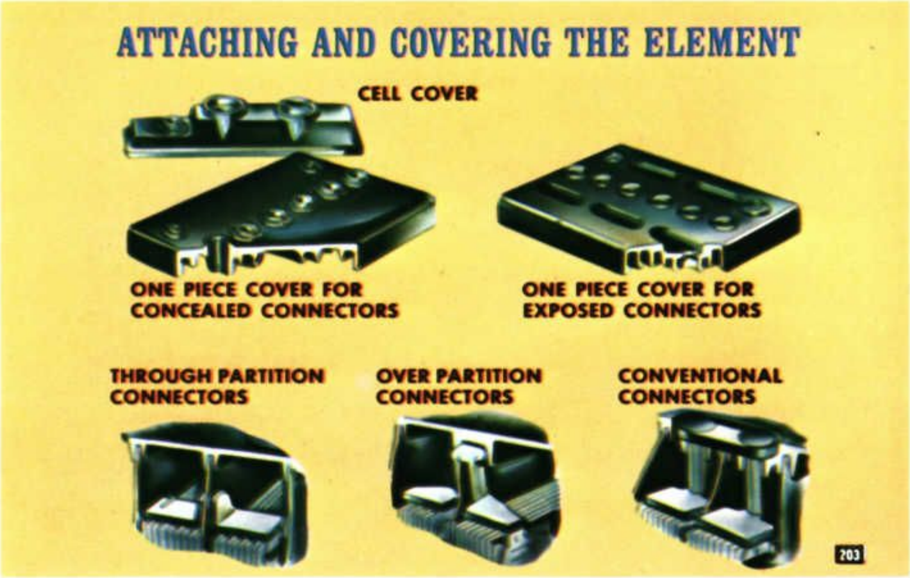
1. Connectors molded in covers with openings to burn connector buttons.
2. Recessed for cell connectors.
3. Grooved to fit over all inter-cell connectors and sealed after the intercell connections are complete.

CELL CONNECTORS

So that the elements may be connected in *SERIES*, they are positioned alternately positive and negative in the cells. The positive terminal of one cell connects to the negative terminal of the next. Three cells make up a 6-volt unit and six cells constitute a 12-volt unit. Cell connectors are placed over the protruding terminal posts and are welded to them. These connectors must be heavy enough to carry the required high starting current without overheating. Later construction techniques employ a method of joining the terminal posts in series either *through* the cell partitions or *over the tops* of the partitions before the cover is placed on the battery. This type of construction not only provides an acid-tight seal between the cells but also assures minimum voltage losses from cell to cell.

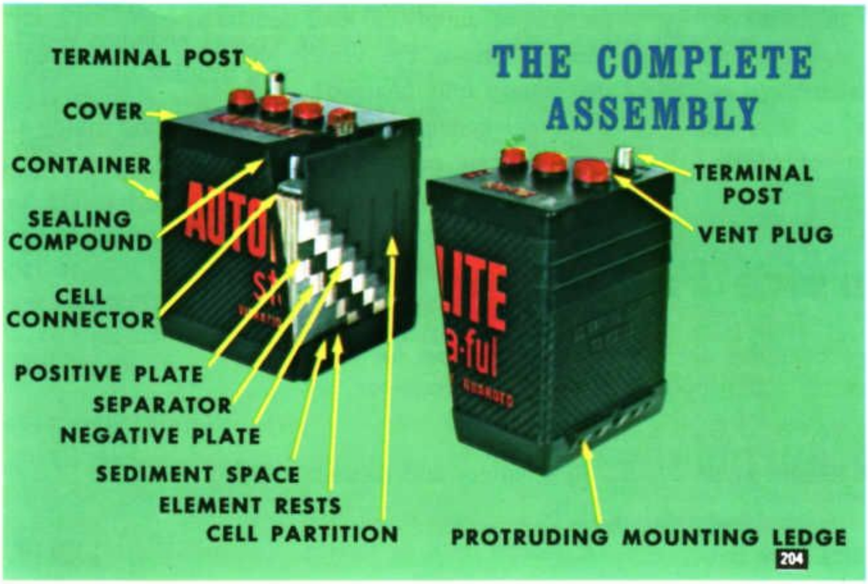
TERMINAL DESIGN

The battery manufacturing industry has agreed that the tapered terminal sizes be consistent so that all cable clamps will fit interchangeably (one size for the positive and another size for the negative). The positive terminal is $11/16''$ at the top while the negative terminal is $5/8''$ at the top. Minimum length of the taper is specified at $5/8''$.



SEALING COMPOUNDS

Along with one-piece cover designed batteries came the epoxy resin seals. This type of seal is permanent and cannot be removed by heating. The conventional type seals used over past years are a blend of specially processed bituminous compositions that have resistance to flow in summer and resistance to cracking in winter. The primary purpose of any seal is to provide an acid-tight bond between cell covers and containers.



THE COMPLETE ASSEMBLY

The accompanying illustration shows the internal battery components as they are assembled into their relative positions. The latest design of one-piece cover is shown. Note the plastic ribs of the separators that touch the positive plates. Note also the over-the-partition type of cell connector. The positive and negative plates are easily distinguished by the darker color of the positive plate.

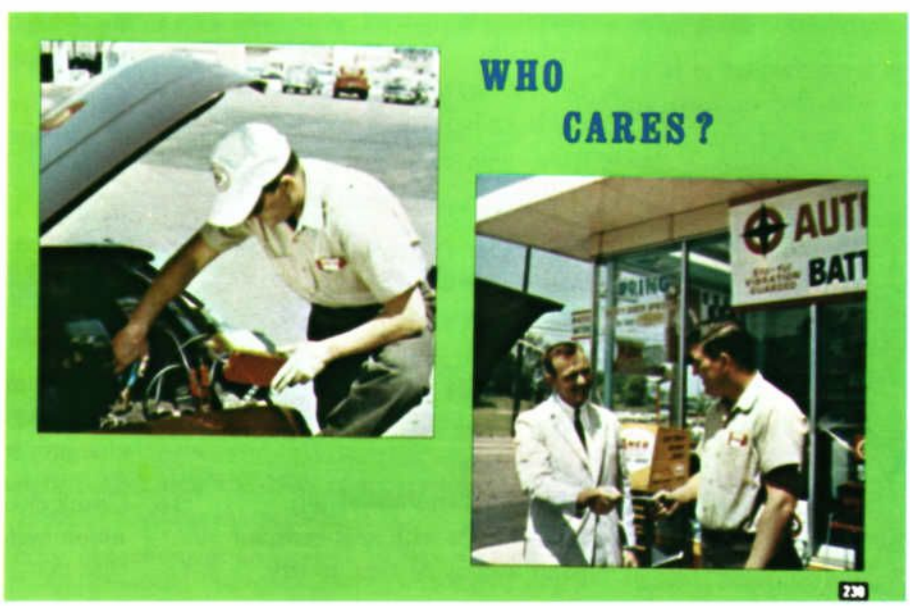
An exploded view of a battery assembly is provided in Section 6, "Useful Information." Refer to Page 43 for the additional detail that this illustration offers.

2
Preventive Maintenance

Preventive maintenance in battery servicing is precisely what the name implies —to perform those service operations that contribute to maximum service life and operating efficiency. Most electrical troubles caused by battery failures can be prevented by systematic battery care.

Premature battery failures can be reduced considerably by:

1. Proper selection; the ampere hour capacity must be balanced with the electrical load. An undersized battery will result in poor performance or premature failure.
2. Proper activation procedures.
3. Correct installation procedures; avoid physical abuses and overtightening.
4. Periodic servicing; the customer should be made to realize that the battery is a perishable item and requires frequent attention. Satisfactory life can only be obtained when these services are performed regularly.



Routine Procedures

Perhaps the single most important service operation affecting battery life is keeping the cables and top of the battery clean and free from corrosive deposits. Battery manufacturers have designed the one-piece covers to help alleviate the problem of acid seepage on the tops of batteries. Further, the cleaning is very simple and many vehicle owners prefer to do it themselves, while others rely on the competent technician to care enough to see that the battery is properly serviced. The technician, of course, realizes that cleanliness is only part of the maintenance program. Several other contributing factors must be considered. These are:

1. Vehicle application–is the battery big enough to do the job of supplying load demands?
2. Charge rate–is the vehicle charging system keeping the battery fully charged?
3. Electrical system operation–is the starting motor and circuit wiring performing properly?

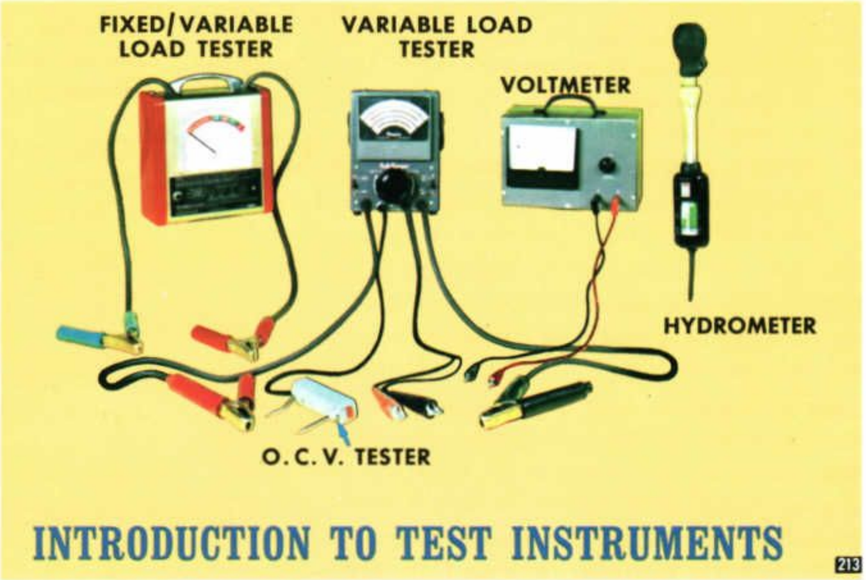
Service Procedures

The following Service Procedures are offered as a refresher for automotive electrical technicians and as a step-by-step guide for the beginner:

1. Raise hood and put fender cover in place.
2. Remove battery cables from battery posts (negative first).
   a. Clean cable terminals with acid neutralizing solution and wire brush.
   b. Replace cables and/or cable clamp bolts as required.
3. Remove hold-down clamps.
4. Remove battery from vehicle.
5. Place battery over suitable drain.
6. Wash entire exterior of battery with acid neutralizing solution. (Ammonia or baking soda and water.)
   a. Do not allow neutralizer to get inside cells.
   b. Rinse with clear water.
   c. Dry with compressed air.
7. Wash cradle (battery tray) with neutralizing solution.
   a. Rinse with clear water.
   b. Scrape off excess corrosion or rust deposits.
   c. Open water drain holes in bottom of tray.
   d. Dry with compressed air.
   e. Paint cradle with acid-resistant paint and allow time to dry.
8. Test battery and recommend that it be:
   a. Placed back in service.
   b. Recharged before placing back in service.
   c. Replaced.
9. Clean battery posts with wire brush.
10. Adjust electrolyte level, if required.
11. Place battery back in vehicle.
12. Tighten hold-down (Do not over-tighten).
13. Place cables back on battery posts (positive first).
   a. Coat with mineral grease or vasoline (not the contact surfaces).
   b. Make sure felt washers were replaced, if used.
14. Start engine and allow it to reach operating temperature.
15. Read battery terminal voltage to determine overall condition of charging system.
16. Check charging system and/or ignition system if battery tests indicate that there is still a problem.

Testing as a Part of Maintenance

Step 8 on Page 6 brings out the fact that TESTING a battery is a portion of the complete battery servicing sequence. The detailed procedures applicable to each test are covered in the "Test Procedure" section of this manual. The test instrument that will quickly and accurately diagnose a battery is covered in the "Trouble-Shooting" section which follows. The question that remains is WHEN to test and WHAT course of corrective action to take.



WHEN

With due consideration to any extenuating circumstances, a battery test may be in order whenever . . .

1. The car stops at the refueling island.
2. The car is brought in for lubrication services.
3. The car requires tune-up services.
4. The car accumulates a given mileage.
5. The seasonal changes alter electrical load requirements.
6. The car suffers from a specific malfunction.
7. The customer is dissatisfied with performance.

WHAT

The conclusions to be drawn from positive test results will point to one of three directions . . .

1. The battery is to be placed back in service.
2. The battery is to be recharged before placing back in service.
3. The battery must be replaced.

Some Reasons for Battery Neglect

1. The battery is often taken for granted without an awareness on the customer's part that they do wear out, and do require looking after.
2. The time-honored custom of waiting until the battery fails still prevails in some areas.
3. Few vehicle owners realize that the battery represents the highest cost for a single replacement item on the vehicle.
4. High volume service operations often neglect battery service in the mistaken interest of saving time.

Some Reasons for Combating Neglect

Now let's take a look at a couple of forces that tend to show trends in the opposite direction–that is, some reasons why batteries *are* being serviced.

1. More service shops are beginning to realize that the day of guessing in diagnosis is over. They are willing to invest in quality test instruments to provide the services demanded by the customer.
2. Today's consumer is price-conscious and is, therefore, receptive to service suggestions that will save him money.

The idea of service to the customer cannot be overemphasized. The entire service business is built around the principle of the satisfied customer and repeat business depends on it.

Let's take a closer look at the opportunities that present themselves for battery service. The most frequent maintenance interval, of course, is the refueling stops. This we can call "underhood" checks. At this time, one can recognize abnormal conditions as shown by low electrolyte level, excessive corrosion deposits, frayed cables, or other tell-tale visual clues. This maintenance interval could range from 200 to 1,000 miles of driving. Installation dates could also play an important part in maintenance. At least it could help the servicing technician to understand why a particular battery would not hold a charge or deliver its rated capacity.

In addition to the routine underhood checks, the vehicle is often brought in for correction of a specific malfunction. In this instance the technician must begin with the customer's complaint as a starting point in his diagnostic procedure. From there he either road-tests the vehicle to confirm the customer's observations or makes use of the instruments at his disposal.

Customers are usually aware of preventive maintenance items when preparing for extended trips, such as vacations or business trips, but are usually found to neglect their vehicles in the routine atmosphere of driving to and from work everyday. Many service shops are beginning to recognize this fact and are slowly accepting the responsibility of making routine checks themselves and keeping the customer informed as to his needs. By this, it is meant that an item such as the battery is automatically serviced whenever the vehicle is left for other periodic services such as, lubrication, tune-up, or other minor repairs. The concept of selling the customer only those parts and/or services that he needs has been found to pay dividends in the long run. Whether these routine services are based on accumulated mileage, change in seasons, worn-out parts, or performance that is not up to par, the customer appreciates a technician who calls needed services to his attention. A direct sale is not always immediately apparent, but is often the end result when this technique of informing the customer is employed. He is confident that his automobile is in the hands of someone who cares.

Another contributing factor to battery maintenance and important enough to consider alone, is the tension of the fan belt. This tension requirement is critical and very often overlooked by many service technicians–not that they don't know better–only a simple maintenance item that is taken for granted.

A slipping generator/alternator drive belt can cause:

1. A battery to be in a constant low state of charge.
2. A glazed fan belt, which:
   a. May squeal and squeak
   b. Can only be cured by replacing with a new belt.

On the other hand, a belt which is overtightened will cause:

1. Belt stretching–which also necessitates replacement.
2. Premature bearing failure.

It is suggested that a belt tension gauge be used in belt-tightening, rather than the older, "rule-of-thumb" of tightening until a 1-inch deflection is attained. This is necessary on recently built automobiles because of the shorter distances between drive pulleys.

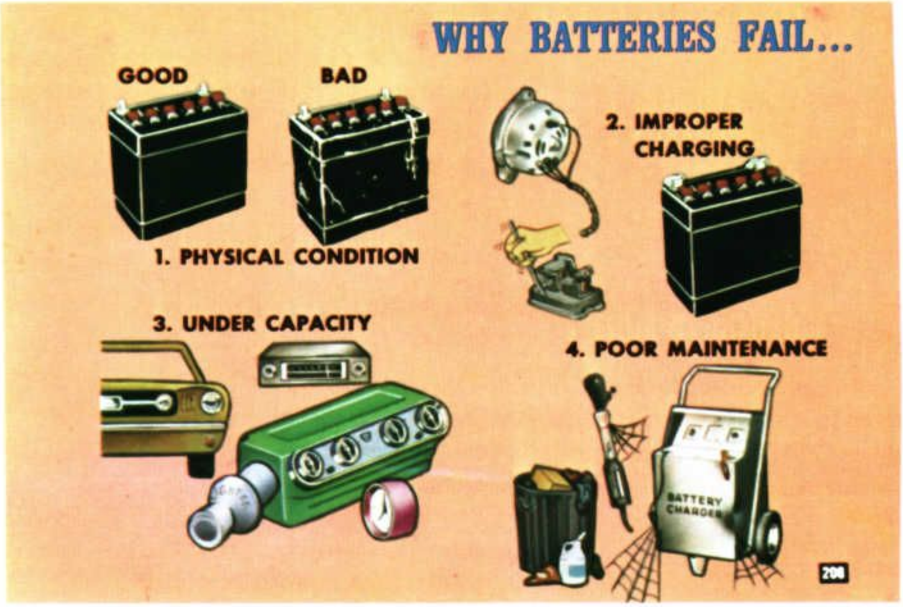
If a belt-tension gauge is not available, the following procedure is recommended:

1. Tighten belt until fan pulley cannot be turned by hand.
2. Run engine for approximately 15-minutes.
3. Stop engine and adjust again until the fan pulley will not slip with hand pressure applied.

This simple procedure pre-stretches the belt and assures full bearing and belt life–thus sufficient charging current to maintain the battery.

3
Trouble Shooting

Why Batteries Fail



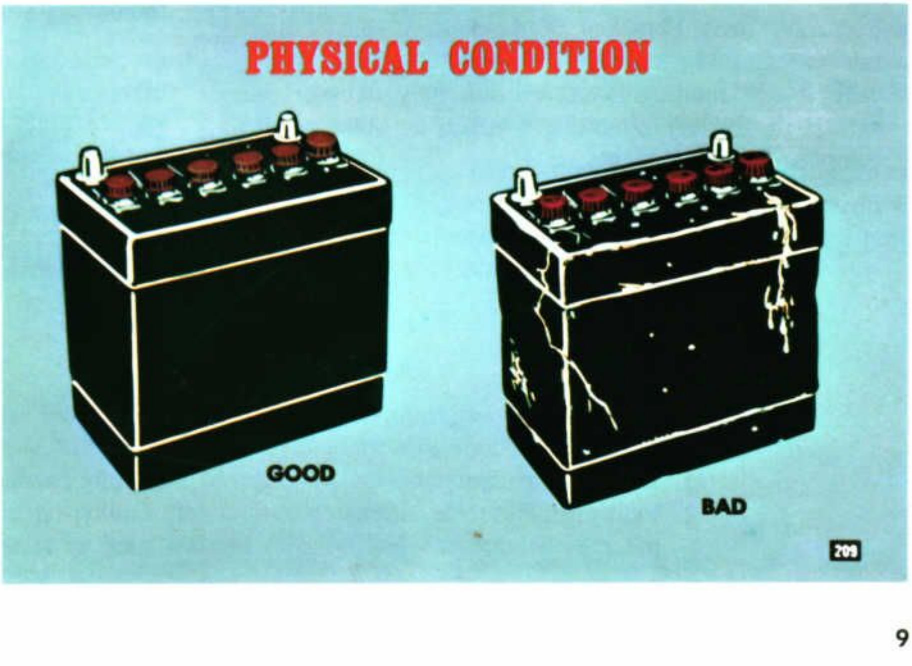
There are four general reasons for battery failure–

- Poor physical condition.
- Prolonged undercharging or overcharging.
- Under-capacity application.
- Lack of proper maintenance.

POOR PHYSICAL CONDITION

The physical condition of a battery is an obvious but nonetheless important factor in its performance.

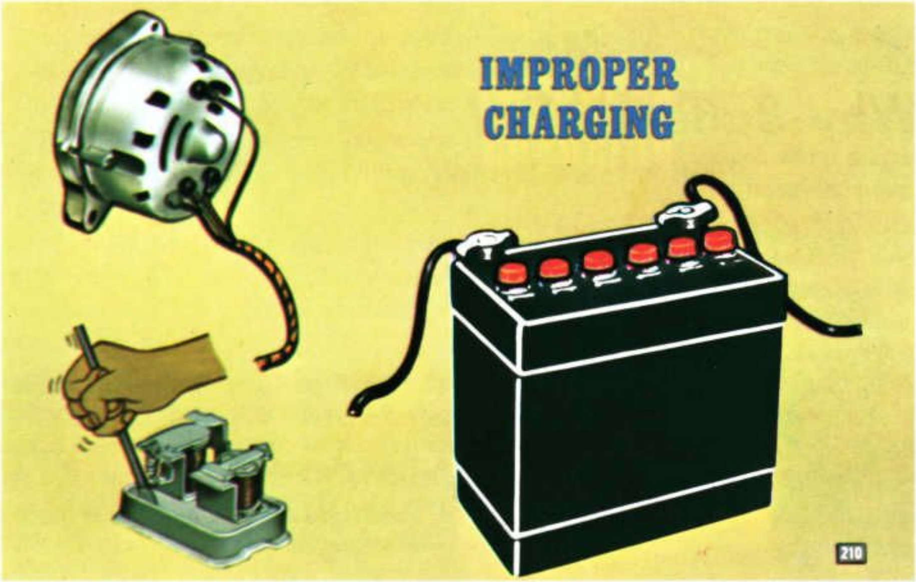
Among the causes for a poor condition, we must include the normal deterioration which accompanies the aging process. The repeated charging and discharging cycles slowly wear-away the active materials in the plates and deposit them in the sediment area beneath the element rests. A point is eventually reached where the surface area of the plates which is available for reaction with the electrolyte is insufficient to allow restoration to a state of full-charge.



A low supply of electrolyte will cause a premature deterioration of the active material in the battery plates. If this should happen, it is possible that there will not be enough plate area remaining to produce the power needed to accommodate the load which might be placed on the battery.

Other factors contributing to inferior physical condition include damage, manufacturing defects, and inadequate preventive maintenance.

IMPROPER CHARGING



An insufficient or excessive supply of charging power can be equally damaging in the effect it has on a battery. This applies to the car's charging system, just as it applies to an external charging device. Typical results of each are as follows:

Overcharging

- Severe corrosion of positive plates.
- Decomposition of water into gaseous hydrogen and oxygen which tends to break down the active material in the plates and "boil-out" acid from the cells.
- Excessive heat, which intensifies all normal chemical reactions, with resulting damage to plates, separators, case, and sealing compounds.
- Severe positive plate warpage and related separator perforations. (This damaging affect is most likely to occur if overcharging follows a period of undercharging.)
- Electrolyte may blow out of the battery cells if high rate charging is excessive. The spray of acid from the cells, if not thoroughly neutralized, may damage the cables, the battery mounting bracket, or other engine compartment components.

Undercharging

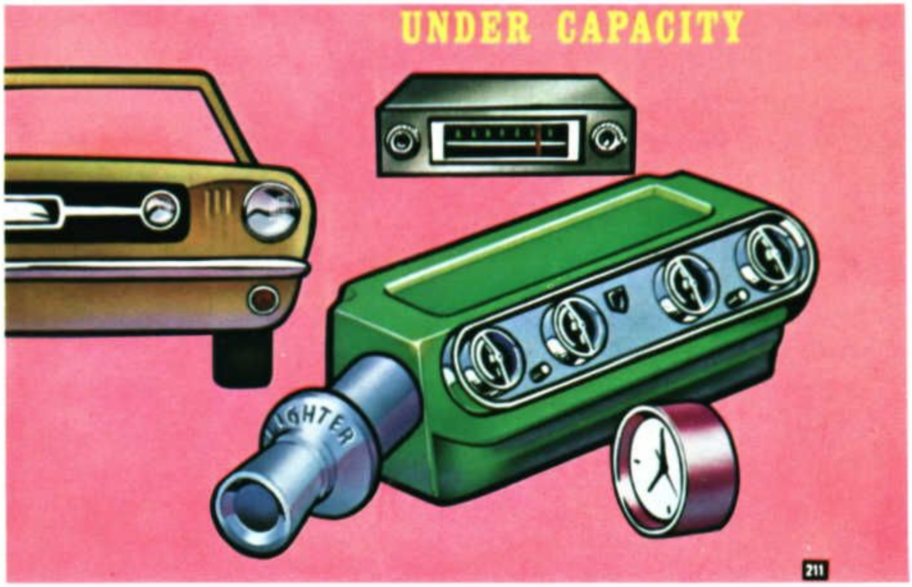
- Undercharging causes the density of sulfate on the plates to increase. This heavier sulfate resists the normal electro-chemical reaction which occurs when the the battery is being charged.
- Prolonged periods of undercharging disturb the solubility relationship between lead sulfate and electrolyte. In time, lead particles may form in the separators causing minute short circuits between the positive and negative plates.
- An undercharged battery has a high water content in the electrolyte. During cold weather, this increases the possibility of freezing.

The causes of an improper charge may include one or more of the following:

1. Faulty regulation.
2. Faulty generator or alternator output.
3. Faulty conductors in the circuit.
4. Faulty circuit control components such as relays, solenoids, switches.

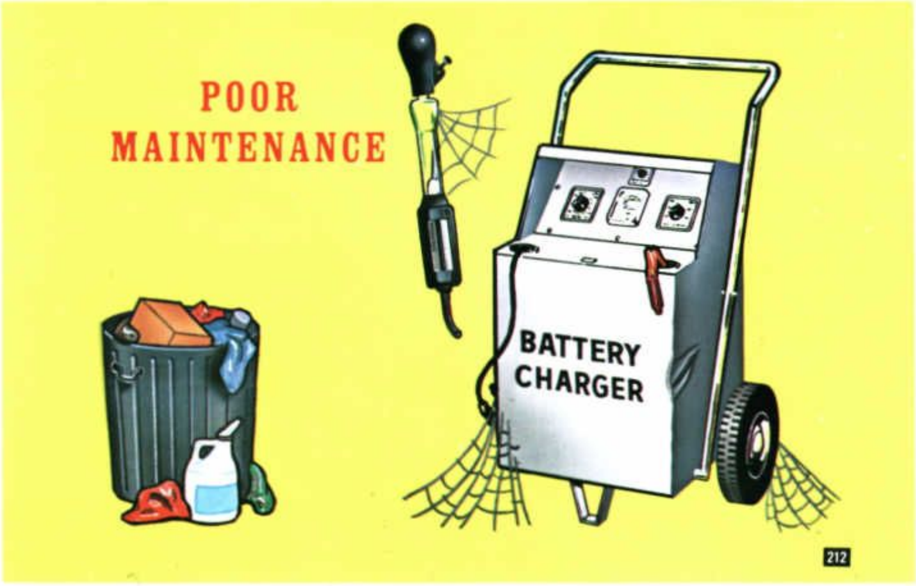
IMPROPER CAPACITY

When an automobile manufacturer specifies a battery of a given capacity as original equipment, this capacity rating takes into consideration the known demands which starting, accessory operation, etc. will place upon the unit. The continuing adequacy of this rating assumes that demand potential will not change.



Several factors which might alter battery requirements are:

1. Poor ignition continuity causing excessive battery drain when starting the engine. (Starting is a prolonged effort.)
2. An electrical equipment circuit problem or an excess of electrical components is causing excessive drain. (The results of damage or an improperly operating electrical component are self-evident. The indiscriminate addition of electrical accessories which the charging circuit cannot support within the limits of battery capacity could lead to very gradual discharge and probably repeated incidents of battery failure.)



LACK OF MAINTENANCE

The results of improper maintenance are closely related to poor physical condition—a cause for failure which we have covered previously in this section. In this instance, however, we are referring to the PREMATURE degeneration of a battery.

The routine procedures and suggested testing operations related to preventive maintenance are provided in the preceding section. Refer to Page 5.

The service technician who has a solid background in the operation of charging system components will be a better qualified trouble shooter. Since the battery is an integral part of proper charging system operation, maintenance of each is equally important. Remember that even a new battery cannot function correctly for very long without an electrical balance between the charging component and the battery.

The Shortest Route

Knowing WHY batteries fail is a basic store of knowledge which a service technician should possess to perform the responsibilities of his job effectively. Knowing HOW to accurately confirm a given reason for failure is equally as important. The "HOW" portion of this two-headed objective is covered under "Test Procedures".

There is no reason to rely on guess-work when trouble-shooting a battery problem. The wide selection of battery test instruments which are on the market today supersede the question . . . *"Should I test this battery?"* Now the question is . . . *"What should I use to test this battery?"* The answer, of course, is to select the test device which will do the job accurately, completely, and quickly. In other words, follow *"the shortest route"* . . .

The basic reason for battery testing is to arrive at a valid conclusion as to whether the unit is serviceable or whether it should be replaced. In arriving at this objective, there are several questions to answer . . .

- What is the present state-of-charge of the battery?
- Is the problem a recurring condition?
- Will it respond satisfactorily to service?
- Is the battery designed specifically for this vehicle?
- Is the battery actually the origin of the problem?

Let's consider the questions separately and look to where the answers are to be found.

1. *Determining the present state-of-charge of a battery* . . . The hydrometer is the instrument with industry-wide recognition as the device which will record the state-of-charge. If other than a hard cover unit is involved, an O.C.V. tester will serve the same purpose.

   Both instruments have comparative advantages and disadvantages. The more obvious disadvantage in using a hydrometer is the problem it poses in the handling of an acid solution. The greatest disadvantage of the O.C.V. tester is its limited application to soft-cover batteries.

   Then, there is the disadvantage common to both instruments wherein calculation is required to convert individual cell values into total battery potential. Finally, the hydrometer requires temperature correction to obtain a true specific gravity reading.

2. *A recurring condition* . . . can only be determined by talking to the vehicle owner. In some instances a maintenance record (case history) is kept on services performed by the shop. In either case, knowing that an undesirable condition occurred more than once is a valuable asset when analyzing the battery's present condition. For example, a constant low state-of-charge would lead you directly to a battery capacity test. If satisfactory, a check would then be made on the vehicle charging system.

3. *Determining whether the battery will respond satisfactorily to service* . . . requires a combination of knowledge from many areas; i.e., age of battery, conditions of service, load demands, specific charging rates, internal condition of components, etc . . . The technician must make use of information supplied to him by the

vehicle owner, service specification publications and specific test results. Further, knowing which combination of testing device to use helps him to trouble-shoot in the shortest time possible. Thus, matching a given symptom to a particular piece of test equipment will shorten diagnosis time considerably. In other words, it is not necessary to make *every* known test on a battery before reaching a decision as to whether or not the battery is serviceable. As an example, if the state-of-charge and capacity tests are satisfactory, then the charge acceptance test would probably be unnecessary.

4. *To determine whether the battery capacity is large enough to support the vehicle load requirements . . .* a quick survey must be made to see how many electrical accessories are on the vehicle. After some experience in this area, the technician can quickly sum up the maximum number of amperes the battery could be asked to deliver at one time. Then a comparison can be made with application recommendations of the manufacturer.

5. *To determine whether the battery is actually the cause of trouble . . .* more often than not, it is condemned when some other electrical system component is at fault. Most electrical system failures can be traced to excessive voltage losses, current leakage, or improper adjustment of the voltage limiting devices of the charging circuit. The technician who becomes proficient in the use of the test instrument designed to do a particular job is performing a service to both himself and his customer.

   Isolating the problem quickly is money in his pocket in time saved and applying the proper corrective action —the first time—saves not only money for his customer, but inconvenience and frustration caused by unexpected battery failure.

The "Test Procedures", Section 4, which follow gives you detailed instructions as to how to use a particular instrument and how to interpret the readings obtained.

It will not tell you which instrument you should use. It will not tell you whether you should use it only when requested by the customer, when he stops for gasoline and underhood checks, or whether you should check his battery when he leaves his car for other maintenance services. Obviously a battery cannot be tested for all conditions at one time. These are common-sense decisions that you must make based on your knowledge of battery operating principles, charging system operation, load requirements, previous performance, etc. . . . Your decisions are often influenced by available time for servicing a battery—both yours and the customer's. For example, it is sometimes more economical in the long run to replace a questionable battery than to tie up a customer's automobile for 24 hours for charging purposes. Again . . . take the shortest route to profits and customer satisfaction.

In order to aid you in your task of analyzing battery performance, a suggested "Battery Test Sheet" is provided at the end of the "Test Procedures" section of this manual. Take the time to fill in the information it asks—get in the habit of looking up application data and service information—and applying this information to solving your battery problems. True, at first glance, it may appear too time consuming, however, the elimination of guess-work is well worth the effort expended. It is hoped that you will agree that, everything considered, a systematic approach is the SHORTEST ROUTE.

4
Test Procedures

Visual Inspection

A visual inspection cannot be expected to effectively substitute for an instrument check when diagnosing a battery problem or evaluating its condition. An inspection will, however, uncover tell-tale clues which can direct the service technician toward the selection of instrumentation which will most efficiently test a battery under a given set of conditions.

Where there is an indication that there is a need for further service, it is advisable that the technician check the installation date. (Length of service could be a factor—it would certainly be an aid in determining whether trouble is premature or the result of normal degeneration.)

The standard practice of battery manufacturers is to provide a predetermined location for this date . . . it may be the top surface of the negative battery post . . . a date-coding ring is the stamping tool used for marking . . . or a special surface area may be set aside for date-coding.

This code is also approaching industry standardization:

1. The letters "A" through "M" (excluding the letter "I") identify the months of the year in chronological order.
2. The numerals "O" through "9" identify the terminal digit of the year.

Accordingly, the code "A3" would signify that a given battery was placed in service in *JANUARY* of *1963*.

The following are items ' visually checked for : trouble in-the-making:

- The condition of the and its 1-piece cover cell covers.
- The top surface of t acid accumulation.
- The color and odor o lyte in the battery.
- A gassing condition wl ing circuit is operating
- The condition and size
- Corrosive deposits.
- All surfaces of the b: indications of abuse.
- Missing vent plugs.
- The level of the batter

Now, let's consider the items suggested as visual inspection check points in a little greater detail.

CONDITION OF CASE AND COVER

1. Check for cracks or buckling which could result from one of the following:
   a. Excessive tightening of hold-down attachments
   b. Hold-down attachments too loose, causing vibration damage.
   c. Excessive temperatures
      (1) in the engine compartment
      (2) internally, due to a high charging rate
   d. Buckled plates as a result of the battery standing in an under-charged condition for long periods of time.
   e. Excessive loads (as a reminder . . . never use the starting motor to propel the vehicle.)
   f. Clogged vent caps which prevent expansion of the hydrogen and oxygen gases during charge.
   g. Freezing of the electrolyte. (A battery with ¾ state of charge is in no danger of freezing. Refer to "Electrolyte and Specific Gravity", for more information about electrolyte under temperature extremes.)
2. Check the cell covers; they could be raised as a result of operating an under-charged battery over a long period of time–then subjecting it to prolonged over-charging.
3. Again, check the cell case and cover, one or both could be broken as a result of an open flame or spark being brought too close to a "gassing" battery.

EVIDENCE OF ACID ON COVER

If acid deposits are noted on the cover, it is that leakage, spill-over, or gassing due to a rate is a contributing cause. (A voltmeter ‹ termine whether leakage is taking place.) I tions are not serviced, they can result in : the rate of self-discharge.

COLOR AND ODOR OF THE ELE

Separately or in combination, discoloratior clear electrolyte and/or the presence of ar to that of "rotten eggs" suggests one or following:

1. The existence of an excessively high charging rate
2. The adverse affects of deep cycling
3. The presence of impurities in the electrolyte solution.
4. An aged battery which is approaching the end of its useful life.

SIGNS OF ABUSE

Surface indications of abuse to the battery are a clue to the cause of some troubles. Check for the following:

1. Battery posts which have been damaged as a result of:
   a. Hammering.
   b. Flashing tools or wires across the terminals.
   c. Stretching short cables on applications that require longer lengths.
   d. Improper cable removing techniques.
   e. Improper connections of booster or charging equipment.

2. Sealing compounds which have been damaged as a result of:
   a. Excessive probing with pointed testing devices which have not been followed-up with repair.
   b. Placing copper objects on the top of the battery.

ELECTROLYTE LEVEL

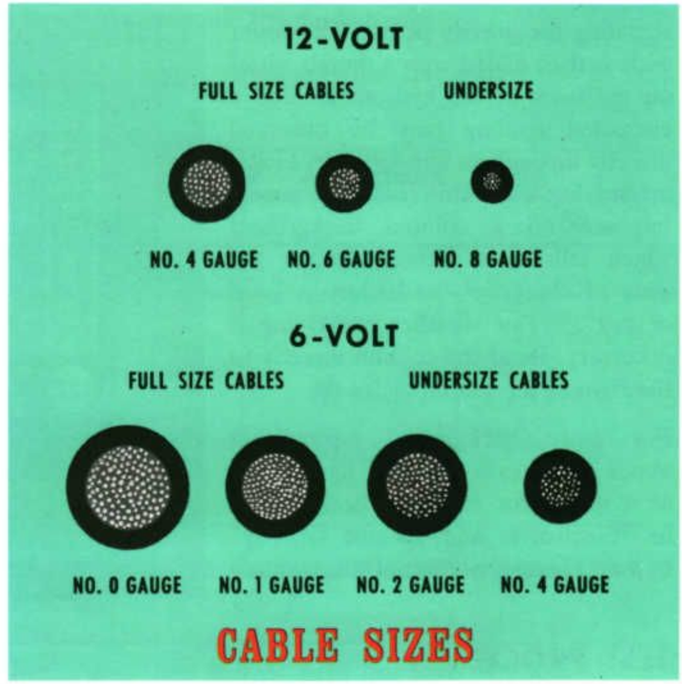
Battery capacity is reduced in direct proportion to the amount of active plate material which is exposed to the air. If inspection reveals a low supply, pure water should be added to restore its level to ¼″ to ½″ above the top of the plates. (Most batteries have a level indicator near the base of the filler opening. If such an indicator is provided, it should be used.)

Water consumption at a rate up to two ounces per cell per 1000 miles of driving is considered to be acceptable. The need to add water in excess of this amount, suggests the need to check and adjust the voltage limiter. (A running record of mileage and water consumption will aid in determining the adequacy of voltage limiter operation.)

CONDITION AND SIZE OF CABLES

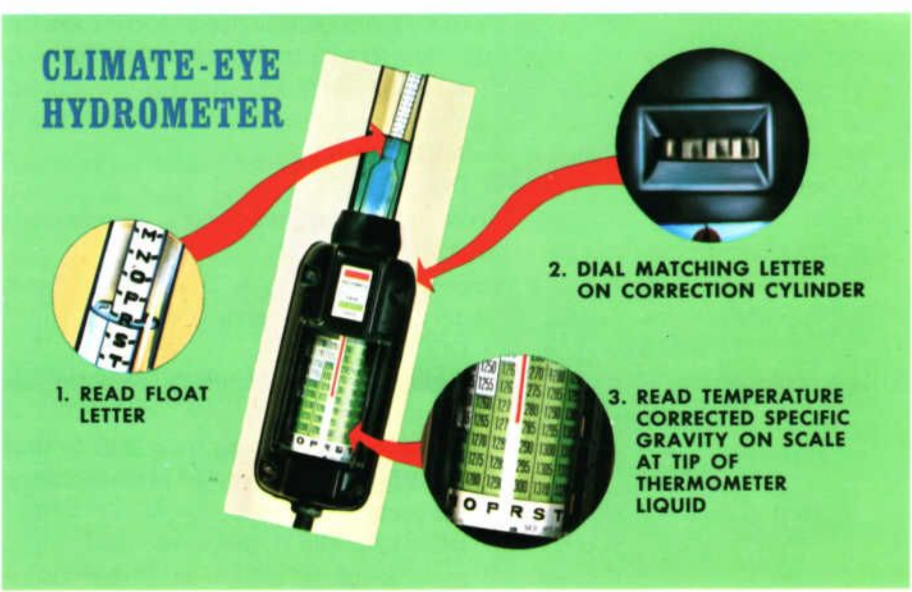
The condition and size of cables is important. The high current requirements of the starting system demand a minimum of voltage loss through the cables. To guard against difficulty in this respect . . .

1. Cable clamps should be inspected for:
   a. Excessive corrosion deposits
   b. Acid erosion of clamp or bolt and nut
   c. Loose clamp to battery post connections
2. The size of the cable used should be noted and compared to manufacturer's recommendations.
   a. A number 4 gauge is recommended for 12-volt applications.
   b. A number 0 or a number 1 gauge is recommended for 6-volt applications.
   c. Special applications may require heavier gauge cables than those recommended.
   d. Any separated wire strands will require that the remaining strands carry the same current load as a new cable.
   e. Periodic cleaning helps lengthen service life.



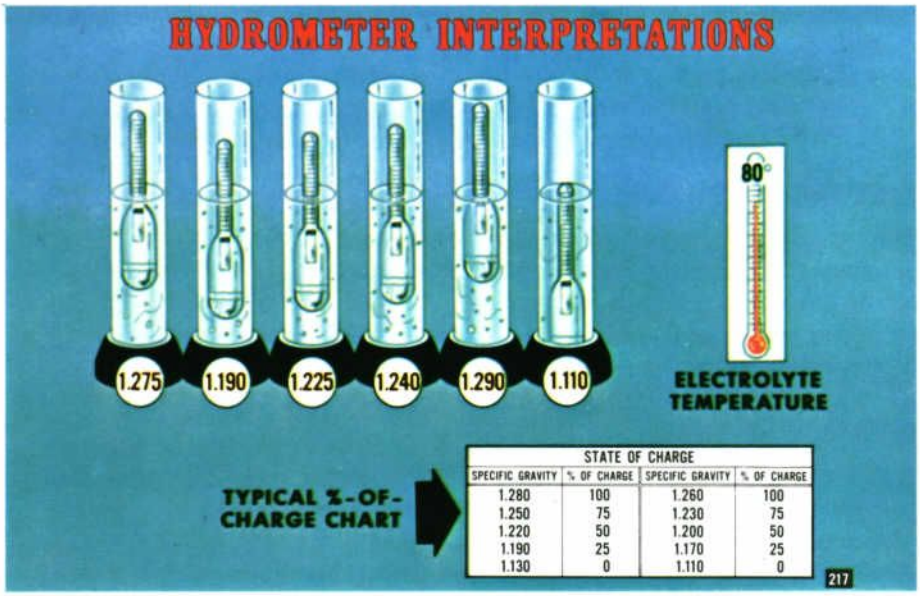
Hydrometer Tests

The basic equipment needed to perform a hydrometer test is a syringe-type hydrometer and a dairy-type, mercury-in-glass thermometer which has a scale reading up to 125° F. and a pick-up tube immersion requirement of not more than 1-inch. The float in the basic design of hydrometer covers an approximate specific gravity range from 1.100 to 1.300 gravity points. (This point rating is based on the relative weight of equal volumes of water and electrolyte—water, for the equivalent volumn of electrolyte, having a rating of 1.000 gravity point.)



The majority of hydrometers now on the market combine the basic hydrometer and thermometer. The Autolite Climate-Eye unit used in our Battery Service and Testing Clinic is one of these combination hydrometers. To further simplify the obtaining of a temperature corrected reading, however, the float is letter-coded instead of designating the gravity points. This letter code is then dialed with a thumb wheel on the back of the hydrometer and a corrected reading may be observed directly through an unbreakable, lucite, magnifying lens. This reading is superimposed on a colored background which tells at a glance whether the state of charge of the battery is good or fair . . . or whether recharging is necessary. Read the column directly to the right of the thermometer tip.

For more background information about electrolyte and its significance as a media for testing batteries, refer to "Electrolyte and Specific Gravity" in the "Theory" portion of this manual.



STATE OF CHARGE			
SPECIFIC GRAVITY	% OF CHARGE	SPECIFIC GRAVITY	% OF CHARGE
1.280	100	1.260	100
1.250	75	1.230	75
1.220	50	1.200	50
1.190	25	1.170	25
1.130	0	1.110	0

TEST PROCEDURE

The procedure and service tips which follow apply to a hydrometer test made with a Climate-Eye Hydrometer. Refer to the illustration which shows the barrel, float, thermometer, reading scale, and thumb wheel for orientation to the instrument. (If another type of hydrometer is used, it will be necessary to handle the temperature correction step in accord with provisions the device incorporates for this necessary alteration of the basic float reading.)

1. Raise hood and put fender cover in place.
2. Remove all vent plugs.
   a. Visually check vent openings.
   b. If a plugged vent is suspected, blow out with compressed air.
3. Make sure the electrolyte level is high enough to withdraw proper amount of acid into hydrometer barrel.
   a. Take no readings immediately after adding water.
   b. Water must be thoroughly mixed with underlying electrolyte, *by charging,* before hydrometer readings are reliable.
4. Insert hydrometer pick-up tube into cell with bulb squeezed tightly by thumb pressure.
5. Slowly release thumb pressure until bulb is fully expanded and float is suspended freely in the barrel.
   a. Always hold barrel level to prevent float from binding or sticking to sides.
      (1) Wash barrel and float assembly periodically with soap and water.
      (2) While disassembled, inspect float assembly for leaks.
   b. Float assembly should *not* touch top or bottom stoppers of barrel.
6. Raise hydrometer or lower eye level to read float scale *at the electrolyte level.*
   (Hydrometer floats are calibrated at 80° F.)
7. Note the letter on the float scale which is intersected by the upper surface of the electrolyte in the hydrometer barrel.
8. Using the thumb wheel on the back side of the hydrometer, dial the matching letter on the correction cylinder. (The red thermometer column will be adjacent to the letter you have just dialed.)
9. Record the specific gravity reading which aligns with the tip (bottom) of the thermometer column.
10. Repeat this procedure (Steps 3 through 9) for each cell in the battery.

TEST CONCLUSIONS

1. If all cells are even at 1.215 or above, the state of charge is probably good.
   WHAT TO DO . . .
   To confirm that the state of charge is satisfactory, make a capacity test; and, if okay, check the voltage limiter setting and the balance of the electrical system for short circuits or excessive voltage losses.
   (CAPACITY TEST PROCEDURES ARE COVERED UNDER "VARIABLE LOAD TESTER" IN THIS SECTION OF THE MANUAL.)
2. If all cells are even, but less than 1.215, the state of charge is doubtful.
   WHAT TO DO . . .
   Recharge according to manufacturer's recommendations and retest.
3. If the difference between cells is less than 50 points (.050), the battery is probably serviceable.
   WHAT TO DO . . .
   Recharge according to manufacturer's recommendations and retest.
4. If the specific gravity between any two cells is more than 50 points (.050), the battery is not satisfactory for service and is probably defective.
   WHAT TO DO . . .
   Recommend replacement to avoid unexpected failure.

Each manufacturer recommends a high rate charge schedule for the batteries in his product line.
Autolite recommends the following:

Specific Gravity Reading	Charge Rate Amperes	Battery Capacity – Amp. Hours			
		45	55	70	80
		High Rate Charging Time			
1.125* to 1.150	35	65 min.	80 min.	100 min.	115 min.
1.150 to 1.175	35	50 min.	65 min.	80 min.	95 min.
1.175 to 1.200	35	40 min.	50 min.	60 min.	70 min.
1.200 to 1.225	35	30 min.	35 min.	45 min.	50 min.
Above to 1.225	5	NOTE: Charge at low rate only until specific gravity reaches 1.250 at 80° F.			

*If specific gravity is below 1.125, use indicated high rate, then follow with low rate of charge (5 amperes) until specific gravity reaches 1.250 at 80° F.

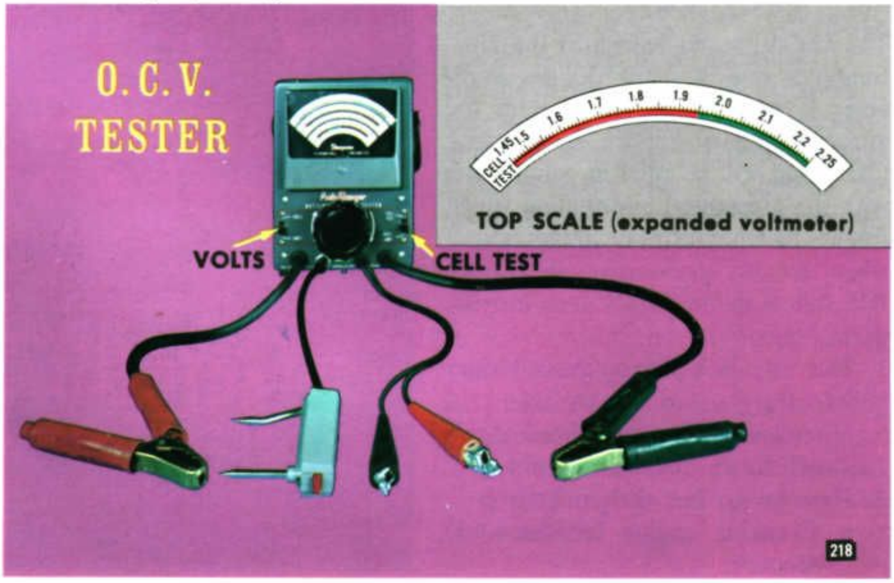
REVIEW

The figure entitled "Hydrometer Interpretations" is provided as a general review illustration. It points out graphically the various positions a float will assume in the hydrometer at various specific gravity conditions. As the thermometer indicates, the gravity ratings called out and float-positions shown are representative of conditions at the standard electrolyte temperature of 80° F.

The state of charge table illustrates typical ranges of specific gravity readings for a cell in various percentages of charge. This percentage value is based on a cell's contribution to the cranking effort of an engine at 80° F. Full-charge (100%) specific gravity is charted for 1.260 and 1.280 electrolyte–both being widely used mixtures. Amperage draw to start an engine is sufficiently high to make the percent-of-charge and temperature a very important relationship. For example, a fully-charged battery at 80° F is only 40% efficient at 0° F. This means that 2½ times as much power is needed to crank an engine at 0° F. as is needed to do the same job at 80° F.

Open Circuit Voltage Tests

An open circuit voltage tester (O.C.V.) is capable of measuring the state of charge of a battery cell as a voltage value. In this respect, it might be considered to be an electric hydrometer. It is the instrument used throughout the industry to conduct what is known as a "light load test".



Essentially, the light load test uses 1.95 volts as an index point and 0.05 volt as the variation limit. From this basis, we determine the following:

1. *Whether a battery is satisfactorily charged.* (All cells above 1.95 volts and within 0.05 volt between the lowest and highest reading.)
2. *Whether it is discharged.* (Cells above and below 1.95 volts but within 0.05 volt between the lowest and highest reading. If all cells read below 1.95 volts, the battery is too

low to test without first boost-charging it.)

3. *Whether it is defective.* (If any one or more cells read 1.95 volts or more and the spread betwen the lowest and highest reading exceeds 0.05 volt.)

In its capacity as an "electric hydrometer", the cell readings obtained with an O.C.V. tester may be converted to specific gravity as shown in the adjacent chart. The voltmeter is extremely sensitive and must be read carefully to obtain accurate readings.

VOLTAGE TO SPECIFIC GRAVITY COMPARISON CHART

Open Circuit Voltage Reading	Corresponding Specific Gravity	Open Circuit Voltage Reading	Corresponding Specific Gravity
1.95	1.100	2.05	1.200
1.96	1.110	2.06	1.210
1.97	1.120	2.07	1.220
1.98	1.130	2.08	1.230
1.99	1.140	2.09	1.240
2.00	1.150	2.10	1.250
2.01	1.160	2.11	1.260
2.02	1.170	2.12	1.270
2.03	1.180	2.13	1.280
2.04	1.190	2.14	1.290
		2.15	1.300

Briefly, the chart at the top of the next column indicates that each incremental increase of 0.01 volt, corresponds to a 10 point specific gravity increase.

An O.C.V. tester, as a preliminary state of charge indicator has an advantage over a hydrometer in that the person making the tests will not be exposed to the acid in the electrolyte solution. It also has some comparative disadvantages.

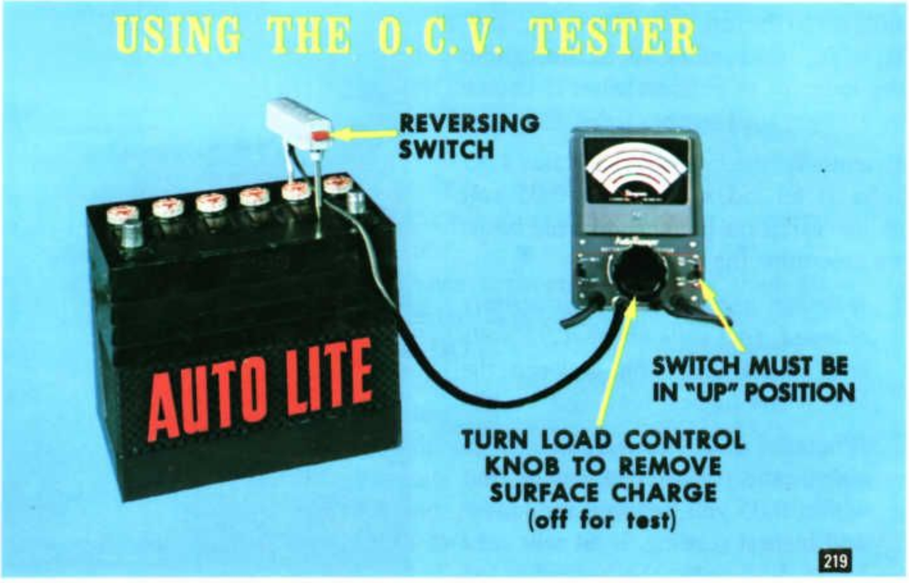
1. It cannot be used on the one-piece design of battery cover.
2. Cannot be read accurately on batteries which have just come off charge.
   a. Surface charge must be removed from plates before testing.
   b. Light load (headlights) is maintained while readings are taken.
   c. Testers that incorporate a carbon pile load may be adjusted to approximately 10-amperes for bench testing.

TEST PROCEDURE

The O.C.V. tester shown in the illustration is one of many designs available. It was selected for use in the Autolite Battery Service and Testing Clinic and will be used in conjunction with the procedural information which follows. If other instrumentation is used when actually performing an O.C.V. test, follow the manufacturer's instructions.

1. Insert the jack plug on the cell tester into the jack in the variable load tester and flip the right hand toggle switch to the "cell-test" position.
2. Remove surface charge by:
   a. Cranking engine for three (3) seconds.
      (1) Remove coil to distributor high tension lead on conventional ignition systems to prevent engine starting.
      (2) Ground coil to distributor high tension lead with jumper wire on transistor ignition systems to prevent engine starting.
   b. Turning on low-beam headlights for one (1) minute prior to testing and leaving them on while performing tests.
   c. Letting stand for a minimum of eight (8) hours.
3. Determine battery polarity and position of cell connector straps:
   a. Large posts (11/16″ on top) are positive.
   b. Small posts (5/8″ on top) are negative.
   c. Red markings are positive posts.

With the instrument in the illustration, a reversing switch is built into the handle. Depressing this switch eliminates the necessity for rotating the tester between terminal connectors to observe proper polarity relationships. If the



needle in the variable load unit deflects to the left, depressing the red button will correct the condition.

4. Prod each cell separately and record the readings obtained.
   a. The resultant holes from the prodding operation should be resealed by thumb pressure or by smoothing with a heated metallic object.
   b. Never bring open flames close to the battery.
   c. Do not allow tester prods to span two (2) cells at once, as this may damage the tester.

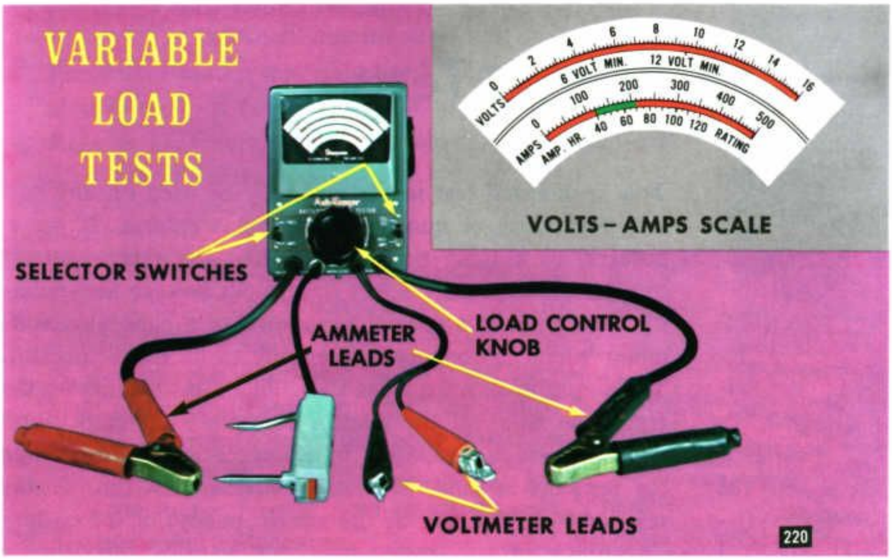
TEST CONCLUSIONS

1. If all cells are even at 1.95 volts or more, battery is satisfactory for service and will accept a full charge.
   WHAT TO DO . . .
   Make a capacity test*; and, if okay, check voltage limiter setting and balance of electrical system for short circuits or excessive voltage losses. Correct any malfunction noted; then, bring the battery up to a state of full-charge with service charging equipment or with enough vehicle operation to accomplish a state of full-charge.
   *SEE "Variable Load Tests" in this section of the Manual.
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, the battery is good, but requires charging.
   WHAT TO DO . . .
   Recharge according to manufacturer's recommendations and re-test. Again, remove surface charge before re-testing.
3. If any cell reads 1.95 volts or more, and there is a difference of 0.05 volt between the highest and lowest cell, the battery is defective.
   WHAT TO DO . . .
   Replace with an Autolite battery that meets or exceeds application requirements.
4. If all cells read less than 1.95 volts, battery is too low to test accurately.
   WHAT TO DO . . .
   Boost-charge and re-test according to the following charging rates:
   a. 12-volt passenger and light truck batteries @ 1000 ampere minutes (20 minutes x 50 amperes).
   b. All other 6- or 12-volt batteries @ 1800 ampere minutes (30 minutes x 60 amperes).

Variable Load Tests

The purpose of a variable load test is to determine whether or not a battery is capable of meeting the specified demands of the starting motor. The demand conditions are duplicated with the test instrument.

(It is important to note that a variable load test is also referred to as a CAPACITY TEST or HIGH RATE DISCHARGE TEST.)



In the test instrument shown in the illustration, the ammeter scale reads straight amperes (0-500 amps.) and ampere-hours (⅓ times amps.) in the upper and lower segments respectively. The voltmeter scale highlights the acceptable minimum voltages under load of 4.8 for a 6-volt battery and 9.6 for a 12-volt battery.

Among the safety precautions to be observed when using a variable load tester, the following are of particular importance:

1. The load limit should not be maintained for more than 15 seconds.
2. The battery should not be load tested if the electrolyte temperature is below 60° F.
3. The battery should not be load tested if the specific gravity of the electrolyte is below 1.225. (The tropical mixture, where 1.225 is a full-charge gravity reading is an exception.)

In the absence of test equipment, cranking the engine for 15 seconds, and then, checking the terminal voltage while cranking with a voltmeter for conformity to the specified minimums is a suggested substitute.

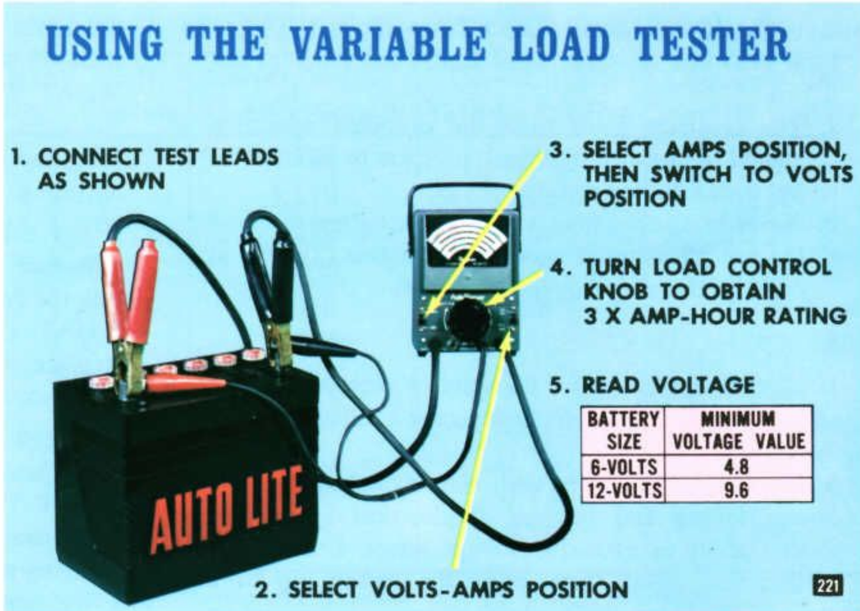
TEST PROCEDURE

1. Raise hood and put fender cover in place.
2. Add water, if necessary, to bring electrolyte to proper level.
3. Check to make sure that the load control knob is "off" or all the way to the left.

4. Connect tester leads to the battery posts.
   a. Positive to positive and negative to negative.
   b. Large leads are for the ammeter and small leads for the voltmeter.

   CAUTION

   Variable load test equipment of the type we are describing is designed to read amperage across the battery terminals. DO NOT ATTEMPT TO USE OTHER THAN A HEAVY DUTY AMMETER FOR THIS KIND OF TEST INSTALLATION. THE HIGH CURRENT INVOLVED WILL BURN-UP AN UNDER-CAPACITY TESTER.



5. Set test selector switch to volts-amps position and volts-amps selector switch to amps position.
6. Turn load control knob to the right until the meter corresponds to the specified ampere-hour rating of the battery.

   NOTE 1—If specified rating is not available, use a 60 ampere-hour rate for 12-volt batteries or a 100 ampere-hour rate for 6-volt batteries.

   NOTE 2—Do not exceed 15 seconds for tests.
7. Set volts-amps selector switch to volts position and read voltmeter.

TEST CONCLUSIONS

1. If the terminal voltage is 9.6 volts or more for a 12-volt battery, or 4.8 volts or more for a 6-volt battery, the battery has a good output capacity and will accept a normal charge.
2. If battery construction will allow, the voltage of each cell may be measured separately while subjected to the same load as was previously discussed.
   a. If cell voltage is below 1.5 volts or—
   b. If there is a variation of .15 volts or more between cells, the battery should be placed on a charger and subjected to a 3-minute charge test.
3. If the terminal voltage is below 9.6 volts for a 12-volt battery or 4.8 volts for a 6-volt battery, the battery should not be condemned until it has been placed on a charger, subjected to a 3-minute charge test, recharged, and re-tested for capacity.

The procedure for performing a 3-minute charge test is covered in this section of the Manual under "Discharged Battery Test". A battery charger with an adjustable charging rate and an ammeter that reads 40 amps and 75 amps is best suited for this particular test.

Specialized Instrument Tests

New test instruments—many with multi-purpose designs—are being made available to service technicians to help them diagnose battery problems quickly and accurately. The device we shall describe below is one of these new instruments.

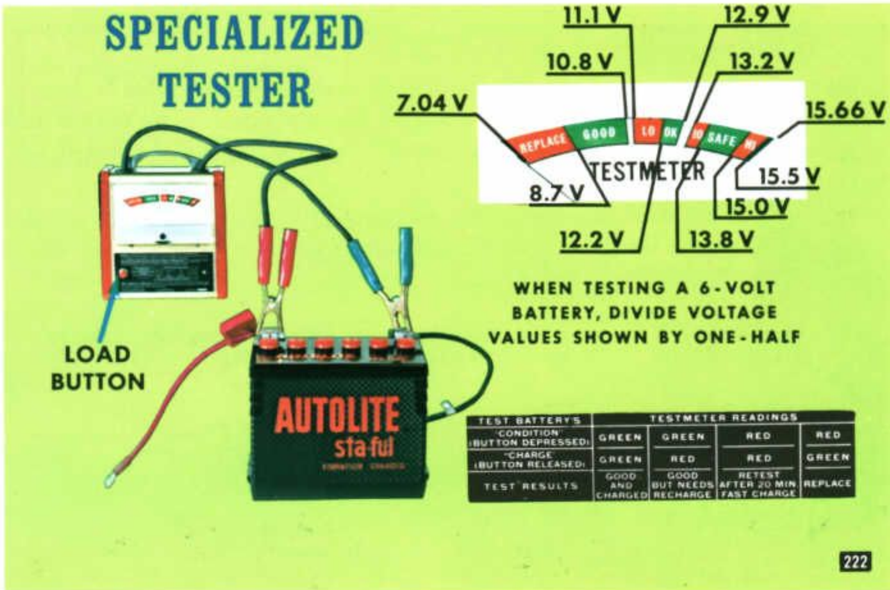
NOTE: THIS EQUIPMENT IS NOT A PRODUCT OF THE FORD MOTOR COMPANY, AND IS NOT MERCHANDISED BY THE COMPANY OR ITS DIVISIONS. ACCORDINGLY, WE EXPRESS OUR APPRECIATION TO CHRISTIE ELECTRIC CORPORATION FOR THE PERMISSION THEY HAVE GIVEN TO USE THEIR T-3 TESTER AS A TRAINING AID IN OUR FIELD SERVICE TRAINING PROGRAMS.

PRINCIPLES OF OPERATION

This specialized test instrument may be used on any battery regardless of construction design features. It incorporates no moving parts, other than the relay contacts used to automatically select the proper voltage and polarity. The tester is a special adaptation of a calibrated voltmeter which is connected internally to a "fixed" resistor. The descriptive word "fixed" could be misleading as the resistance value of the resistor changes with temperature variation. Heat dissipation is accomplished by imbedding the resistors in sand. The actual current flow through the resistor is determined by the size (capacity) of the battery —accuracy of this tester has been verified by Autolite Engineering.

Batteries of 70 ampere-hour capacity were accurately tested and it is believed that the same high degree of accuracy could be expected on a battery with an 80 ampere-hour rating.

The basic principle of operation, therefore, lies in voltage stabilization. Whenever the button is depressed, it must be held until the needle remains stationary. In other words, a voltage reading is taken whenever the amperage potential of the battery and its related heat characteristics match the designed resistance (heat absorption characteristics) of the instrument. No reading is attempted until the imbedded resistors have reached their heat saturation point.



MULTI-PURPOSE TESTER

This test device is advertised as having many applications . . .

- Determining battery's condition and state of charge
- Testing battery cables
- Testing electrical systems for shorts and leaks
- All other voltmeter applications such as checking the voltage drops in the starting and charging system circuits.

In this Manual, we shall cover the first three of the applications listed.

TEST PROCEDURE FOR BATTERY'S CONDITION AND CHARGE

1. Raise hood and put fender cover in place.
2. Connect positive tester lead to battery positive post and negative tester lead to battery negative post.
   a. Twist tester clips to insure good contact.
   b. Make sure vehicle's lights and electrical accessories are "off".
      (1) Any reading indicates proper hook-up.
      (2) If no reading, fast charge battery for 20 minutes before attempting any tests.
3. Press load button and hold until tester needle remains stationary—then read "battery's condition".
4. Release load button and read "battery's charge" only after needle remains stationary.

TEST CONCLUSIONS

1. The chart in the illustration above shows the combinations of conditions which the test meter will indicate and the conclusions to be drawn.
2. A slow charge is required to bring a battery to a full state of charge. Thus, the "recharge" called for in the second column of the chart permits a 20-minute fast charge for testing.
3. Any "chattering" sound indicates a discharged battery or poor cable connections.
4. Remember to hold load button as long as necessary.

ELECTRICAL SYSTEMS SHORTS AND LEAKAGE TEST

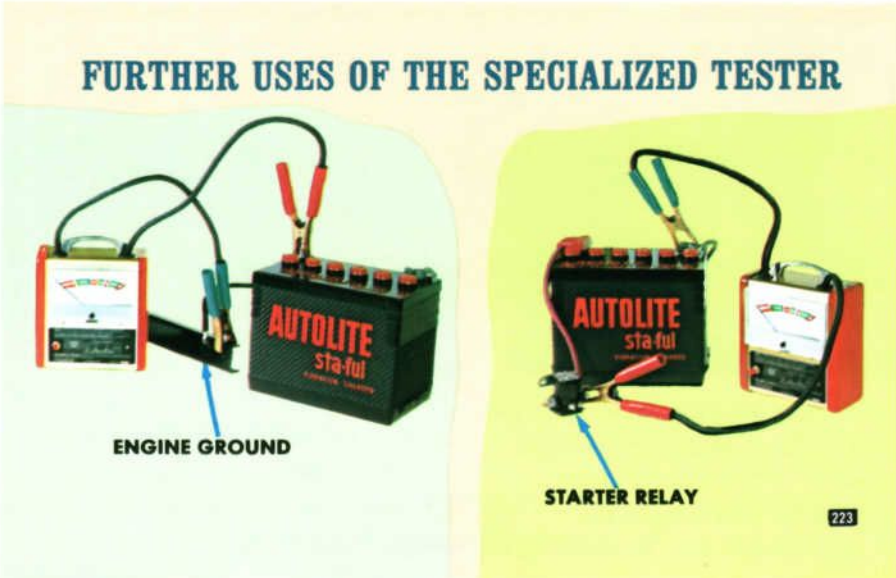
The following test is based on voltmeter function. From the illustration in the upper right corner, note the voltage values. Any reading obtained in this test will show at approximately 12-volts.

TEST PROCEDURE

1. Remove ground cable from battery post.
2. Connect negative tester lead to negative battery post and positive tester lead to engine ground.

NOTE

The above instructions apply to negative grounded systems. Reverse leads for positive grounded system.



TEST CONCLUSIONS

Any reading indicates a constant drain on the battery. Recheck to insure that all switches are off and momentarily touch negative cable back to negative battery post to rewind electric clock. The clock momentarily rewinds at approximately 3-minute intervals. It will not rewind through the test instrument with the negative cable disconnected.

BATTERY CABLES TEST PROCEDURE

NOTE 1

Perform only if battery is in good condition and fully charged.

NOTE 2

All lights and electrical accessories must be off.

1. Check negative cable first.
   a. Connect positive tester lead to positive battery post.
   b. Connect negative tester lead to engine ground.
2. Press load button and read "battery's condition".
3. Check positive cable last.
   a. Connect negative tester lead to negative battery post.
   b. Connect positive tester lead to battery side of starter relay.
4. Press load button and read "battery's condition".

TEST CONCLUSIONS

1. The following readings are the same for both the negative and positive cables:
   a. Green area–cable good.
   b. Red area–Clean cable connections and retest. Replace cable, if required.
2. Reverse connections in procedural steps 1 (a & b) and 3 (a & b), for positive grounded systems.

Discharged Battery Test

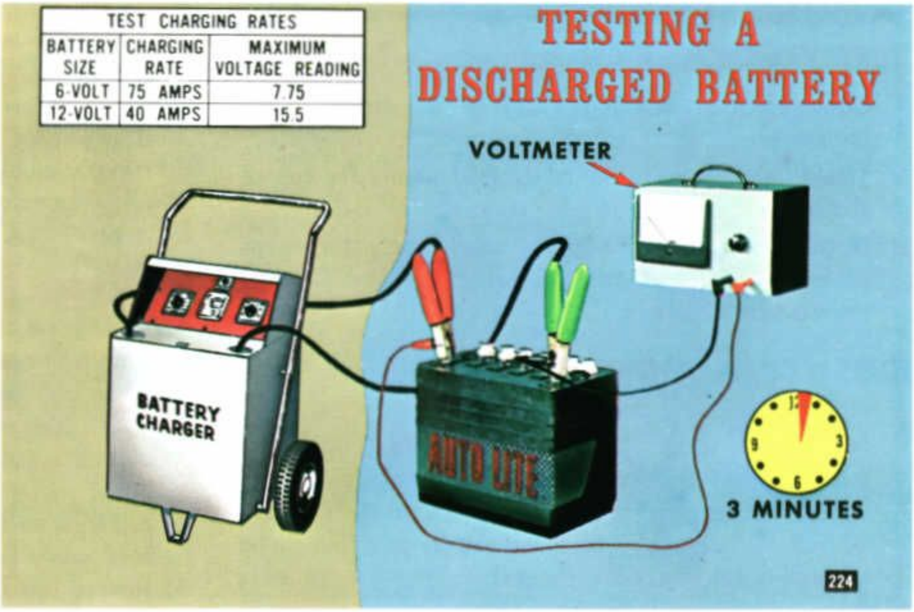
In preceding text materials, we have covered variable load (capacity) tests, and, in these materials, recommended that a 3-minute charge acceptance test be conducted on a battery which fails to measure-up to voltage specifications. Here, we are deviating from the rule of "never testing a discharged battery" . . . but we are doing it for a purpose. Knowing that a battery is discharged, we are next interested in knowing whether it has sulfated to the point where it will not accept a charge. Charging dislodges the lead sulfate on the plates, returning the sulphate portion of the compound back into the electrolyte solution to form sulphuric acid. It is this action which is to be introduced for a 3-minute period to show whether the battery will successfully respond to further charging and ultimately reach a fully-charged condition.

TYPES OF CHARGERS

There are two types of chargers in common service use–one is a constant potential charger . . . the other is a constant current or slow charger. (The illustration employs the former type.) The "Useful Information" section of this manual describes the principles of these types of chargers in detail.

TEST PROCEDURE

1. Check battery polarity and connect charger leads positive to positive and negative to negative.
2. Charge battery for three minutes at the following suggested rates.
   a. 12-volt battery—40 amperes
   b. 6-volt battery—75 amperes
3. At the end of 3 minutes, with the charger still operating, connect a voltmeter across:
   a. Each individual cell (if applicable).
   b. Battery terminals (especially with one-piece cover design).
4. Record voltage readings.



TEST CONCLUSIONS

1. Battery is satisfactory and may be safely charged if reading is:
   a. Less than 15.5 volts on 12-volt battery.
   b. Less than 7.75 volts on 6-volt battery.
   WHAT TO DO . . .
   Charge according to manufacturer's recommended rates and place back in service.
2. Battery plates are probably sulfated if reading is:
   a. More than 15.5 volts on 12-volt battery.
   b. More than 7.75 volts on 6-volt battery.
   WHAT TO DO . . .
   Place battery on slow-charger at the rate of one ampere per positive plate per cell for time period needed to bring battery to a full state of charge.
3. Battery is probably defective if a reading of 0.1 volt or more between cells is obtained.
   WHAT TO DO . . .
   Replace battery.
4. In some instances, the reading will be right on the "borderline".
   WHAT TO DO . . .
   Place battery on recommended slow charge and re-test.

Basic Instrumentation Tests

The basic voltmeter is perhaps the most versatile single purpose instrument available to a service technician. In fact, the voltmeter is a component of the many combination and specialized testers available on the market.

In their specialized applications, specific readings are frequently replaced with color bands or other visual markings which aid in quickly determining the acceptability of the item being checked. This type of dial marking sacrifices the all-around application of the unit for instant recognition media. It is important to remember that a voltmeter is installed in parallel with all or any portion of a circuit to be tested. The readings obtained with this instrument reflect an electrical pressure difference between the two check points used. Low readings mean low resistance and high readings mean high resistance.

VOLTMETER TESTS:

- External leakage test.
- Circuit resistance tests.
- Constant current drain test.
- Starter ground circuit test.

When making these tests, observe polarity very carefully.

EXTERNAL LEAKAGE TEST PROCEDURE

1. Connect either voltmeter lead to its corresponding battery post.
2. "Rake" the opposite voltmeter lead across the top of the battery.
3. Note voltage reading (do not touch connector straps or battery terminal with voltmeter lead that is being moved across battery.)

TEST CONCLUSIONS

1. Any indication on the voltmeter would show excessive leakage.
2. Dirt and acid accumulations allow loss of current by:
   a. Self-discharge from one battery post to the other.
   b. Self-discharge from insulated battery post to metallic hold-down, which is grounded.
3. Remedy by neutralizing the acid deposits.
4. Corrosive deposits are more noticeable at the positive post.

REMEMBER . . . Current leakage and corrosion rate is greater on 12-volt batteries than on 6-volt because the voltage is twice as great. This also points out the need for preventive maintenance service on a periodic basis.

WHAT TO DO . . .
Wash battery with a solution of:
a. Baking soda and water, or
b. Household ammonia and water.
c. Rinse with clear water.

CONSTANT CURRENT DRAIN TEST

NOTE:
Either a test ammeter or a test voltmeter may be used for this test. Many service technicians prefer the voltmeter in as much as it will indicate full battery voltage, no matter how slight the leakage may be.

REMEMBER . . . That the following two factors may lead to an incorrect diagnosis:
1. Blown fuses
2. Electric clock rewind

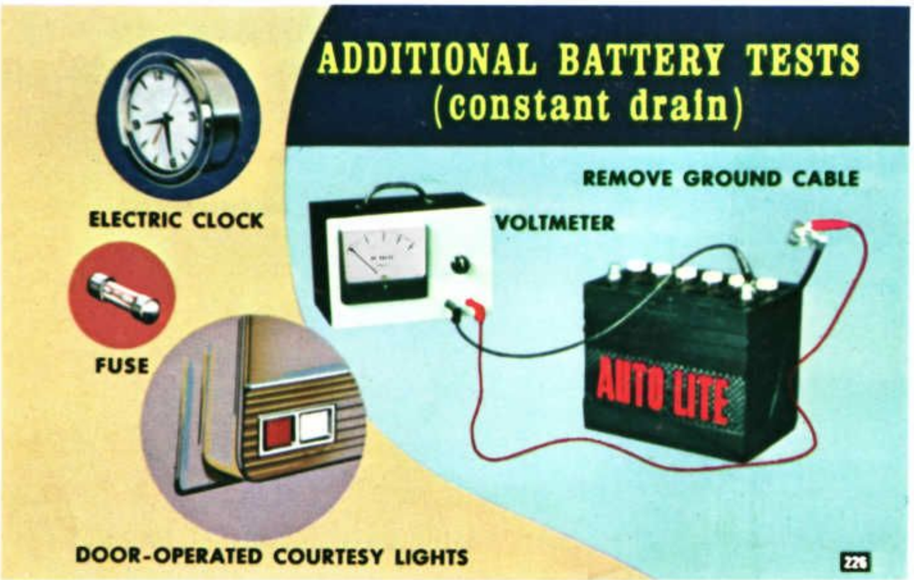
If you encounter trouble in obtaining a reading, check these two items.

TEST PROCEDURE

1. Raise hood and put fender cover in place.
2. Remove negative cable from battery post.
3. Clean corrosive deposits from both cable and post.
4. Insert test instrument *in series* between the disconnected negative battery cable and negative battery post.
   a. Negative tester lead to negative battery post.
   b. Positive tester lead to negative battery cable.
5. Record test instrument reading.

TEST CONCLUSIONS

1. Any reading on the test instrument indicates that a constant current is being drained from the battery. This will probably be reflected as a battery in a constant low state of charge.
2. Familiarization with automotive electrical circuits will be a tremendous aid in pinpointing the trouble to a specific circuit: e.g., if an ammeter is used in the above tests, then:
   a. An 8-amp. reading would probably indicate trouble in the headlight circuit.
   b. A reading of less than 2-amps. would probably eliminate the vehicle radio and headlights as possible trouble spots.
3. Most test ammeters are not sensitive enough to differentiate tenths of amperes. It may be more practical to make use of the voltmeter in place of the ammeter.



NOTE:
Do not overlook the possibility of switches being accidentally left "on". A complete recheck should be made of:
1. Ignition switch
2. Lighting switches (door operated dome and courtesy lamps)
3. Trunk switch (mercury operated). Etc.

For testing purposes, the electric clock is included on the illustration to emphasize that it may be rewound by temporarily touching the negative battery cable to the negative battery post without disconnecting any instrument leads.

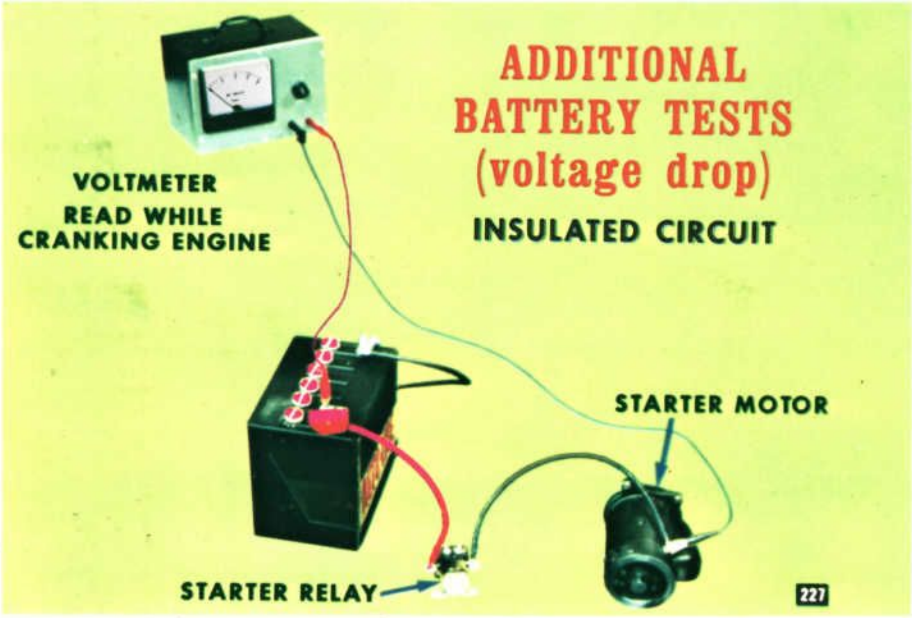
CIRCUIT RESISTANCE TESTS (VOLTAGE DROP)

When checking resistance in all-or any portion of a circuit, consideration should be given to the following:

1. That current must be flowing in the circuit.
2. That the circuit is being checked for *excessive* resistance. If an excess is encountered, deduction, based on background, must be employed to pinpoint the *cause*. High resistance in a total circuit should be traced to the component of that circuit which incorporates the cause; and then, a detailed check should be made of the component for necessary repair if it is a serviceable item.
3. Among the major causes of high resistance, we include loose connections, dirt, corrosion, damaged conductors and defects in assemblies in a circuit which do not allow them to perform up to specifications.

In this manual, we are limiting our coverage to the battery and its cables. The cause of excessive resistance may extend beyond these points. For example, the battery may be failing because of excessive resistance in the starter circuit. With this condition prevailing, charging the battery will be no more than a temporary fix. Thus, as an objective we suggest that competent service is aimed at eliminating the *cause* of trouble–not just restoring, repairing, or replacing parts without regard to cause. If a battery and its cables prove to be physically sound and in themselves free of excessive resistance–recurring battery problems must be attributed to a cause located beyond the battery terminals. Make it a point to find this cause.

Now, let us consider the procedures for checking for resistance in the battery cables.



TEST PROCEDURE FOR INSULATED CABLE AND STARTER RELAY CONTACTS

1. Connect positive voltmeter lead *to insulated battery* post and negative voltmeter lead to *field terminal* of starting motor as shown above.
2. Crank engine and observe voltmeter.
3. Record the reading obtained and compare to manufacturer's specifications.

TEST CONCLUSIONS

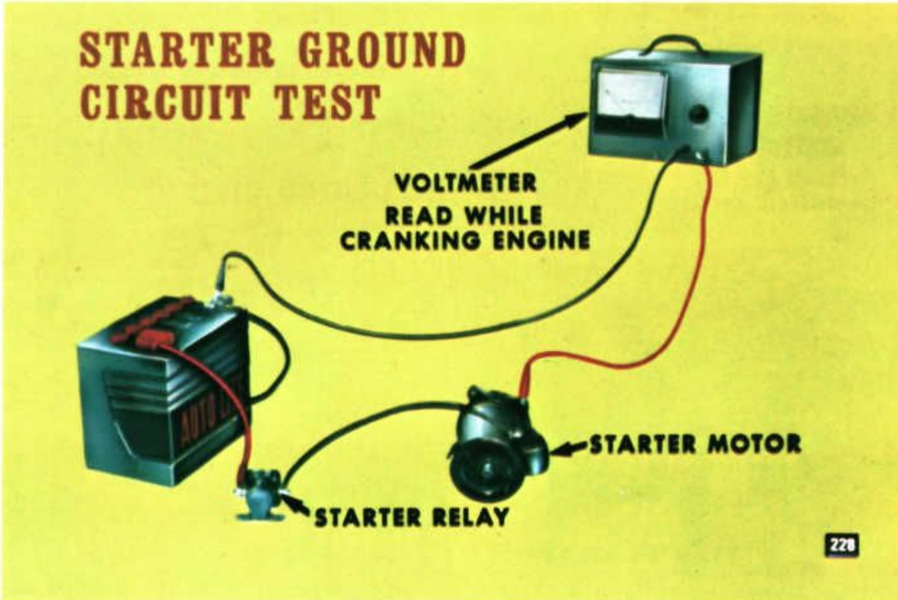
1. Each manufacturer publishes recommended specifications and these should be followed whenever possible. A general "rule of thumb", however, is to allow no more than 0.2 volt for any one portion of the circuit being tested. In the above test, we are concerned with resistance of the:
   a. Insulated battery cable (one-or two-piece).
   b. Heavy contact points of the starter relay.
   c. Cable connections.
   d. Soldered terminals.
2. If voltage drop exceeds specified voltage, move negative voltmeter lead to:
   a. *Starter terminal of starter relay* and repeat test. A lesser reading shows resistance to be in the cable or its connections between the starter relay and starter motor. Clean or replace cable, as required.
   b. *Battery terminal of starter relay*. A lesser reading now shows excessive resistance to be across the relay contacts. Replace starter relay (difficult to clean as cover is sealed).
   c. *Cable connection of insulated battery post*. (Leave positive tester lead hooked directly to positive post.) Any reading at this point would necessarily have to be in the cable connection.

TEST PROCEDURE FOR STARTER GROUND CIRCUIT TEST

1. Connect positive voltmeter lead to frame of starter motor as shown in the illustration on the following page.
2. Connect negative voltmeter lead to negative battery post.
3. Crank engine and observe voltage readings.

TEST CONCLUSIONS

1. An ideal reading would be zero (0) volts.
2. Remember that the vehicle frame is considered a large return "wire" on automotive applications.
3. There should be no more than 0.2 volt in the total grounded side of the circuit.



4. Voltage readings in excess of 0.2 volt may be traced or "pinpointed" by moving the positive voltmeter lead along the circuit toward the negative battery post and measuring voltage loss across each portion of the circuit while cranking the engine.
5. Clean connections and retest, replace ground cable, as required.

Make a Record of Your Findings

Now . . . to complete our test procedure coverage . . . we strongly emphasize a systematic approach to battery diagnosis and testing. Many technicians find that a check list is an aid in this respect.

The "Service Technician's Battery Test Sheet" which follows is a suggested format for a check list. No attempt has been made to "customize" the form. It covers all of the tests and instrumentation which are described in this manual. Accordingly, segments may be selected to tailor the test sheet to the varying needs of technicians.

SERVICE TECHNICIAN'S BATTERY TEST SHEET

BATTERY AND VEHICLE IDENTIFICATION

APPLICATION	IDENTIFICATION	SERVICE DATA
VEHICLE MAKE ________	BATTERY MAKE ________	ACTIVATION DATE ________
VEHICLE MODEL ______ YEAR ______	ORIGINAL EQUIP. YES ☐ NO ☐	DESIGN LIFE (WARRANTED):
CHARGING SYSTEM GEN. ☐ ALT. ☐	BATTERY NUMBER ________	3 MOS. ☐ 6 MOS. ☐
RATED OUTPUT ______ AMPS AT ______ R.P.M.	CATALOG REPLACEMENT NUMBER ________	12 MOS. ☐ 18 MOS. ☐
		24 MOS. ☐ 36 MOS. ☐

VISUAL INSPECTION

ITEM TO BE CHECKED	SERVICE NEEDED	ITEM TO BE CHECKED	SERVICE NEEDED
CONDITION OF CASE:		CONDITION AND SIZE OF CABLES:	
SIGNS OF ABUSE	☐	TIGHTNESS OF CABLE CLAMPS	☐
CRACKS OR BULGES	☐	INDICATIONS OF EROSION AND CORROSION	☐
PROPER FIT IN MOUNTING TRAY	☐	CONDITION OF INSULATION	☐
CONDITION OF COVER(S):		SIZE OF CABLE	☐
SIGNS OF ABUSE	☐	CONDITION OF ELECTROLYTE:	☐
CRACKS OR DISTORTION	☐	DISCOLORATION	☐
INDICATIONS OF LEAKAGE	☐	OFFENSIVE ODOR	☐
VENT PLUGS NOT CLOGGED	☐	LEVEL	☐

SERVICE TECHNICIAN'S BATTERY TEST SHEET - Cont.

HYDROMETER TESTS

TEST ITEM	CELL NUMBER						EVALUATION
	1	2	3	4	5	6	• IF ALL READINGS ARE EVEN AT 1.215 OR ABOVE – BATTERY IS O.K.*
SPECIFIC GRAVITY READING							• IF ALL READINGS ARE EVEN BUT LESS THAN 1.215 RECHARGE AND RETEST.
ELECTROLYTE TEMPERATURE							• IF THE HIGH-LOW VARIATION BETWEEN CELLS IS LESS THAN 50 POINTS – RECHARGE AND RETEST.
CORRECTED GRAVITY READING							
GRAVITY RANGE	HIGHEST			LOWEST			• IF THE HIGH-LOW VARIATION BETWEEN CELLS EXCEEDS 50 POINTS – REPLACE BATTERY.

(*BRING BATTERY UP TO FULL-CHARGE CONDITION)

OPEN CIRCUIT VOLTAGE TESTS

TEST ITEM	CELL NUMBER					
	1	2	3	4	5	6
EXPANDED SCALE VOLTAGE READING						
VOLTAGE RANGE	HIGHEST			LOWEST		

EVALUATION

- IF ALL READINGS ARE EVEN AT 1.95 VOLTS OR MORE – BATTERY IS OK.*
- IF READINGS ARE ABOVE AND BELOW 1.95 VOLTS, BUT DO NOT EXCEED .05 VOLT HIGH-LOW VARIATION, RECHARGE AND RETEST.
- IF ANY CELL READS 1.95 VOLTS OR MORE BUT THE HIGH-LOW VARIATION EXCEEDS .05 VOLT – REPLACE BATTERY.
- IF ALL CELLS READ LESS THAN 1.95 VOLTS, RECHARGE AND RETEST.

VOLTAGE TO SPECIFIC GRAVITY CONVERSION

CONVERSION FACTOR . . . 0.01 VOLT = .010 GRAVITY POINT

TYPICAL EQUIVALENTS

VOLTS	SP. GR.	VOLTS	SP. GR.
1.95	1.100	2.05	1.200
1.97	1.120	2.07	1.220
1.99	1.140	2.11	1.260
2.01	1.160	2.13	1.280
2.03	1.180	2.15	1.300

(*BRING BATTERY UP TO FULL-CHARGE CONDITION)

VARIABLE LOAD TESTS

1. SPECIFIC GRAVITY__________. DO NOT LOAD TEST IF SPECIFIC GRAVITY INDICATES THAT BATTERY IS LESS THAN 3/4 FULL CHARGE. (1.180 FOR TROPICAL CLIMATES AND 1.225 FOR ALL OTHERS.)
2. TERMINAL VOLTAGE READING___________. MINIMUM VOLTAGE IS 9.6 FOR 12-VOLT BATTERY OR 4.6 FOR 6-VOLT BATTERY UNDER SPECIFIED TEST LOAD.
3. READING AFTER 3-MINUTE CHARGE TEST _______________. (USE THIS TEST WHEN TERMINAL VOLTAGE IS BELOW MINIMUMS SPECIFIED FOR LOAD TEST.)

DISCHARGED BATTERY TESTS

1. VOLTAGE REQUIRED TO ATTAIN ______ AMPS. IS _______VOLTS.

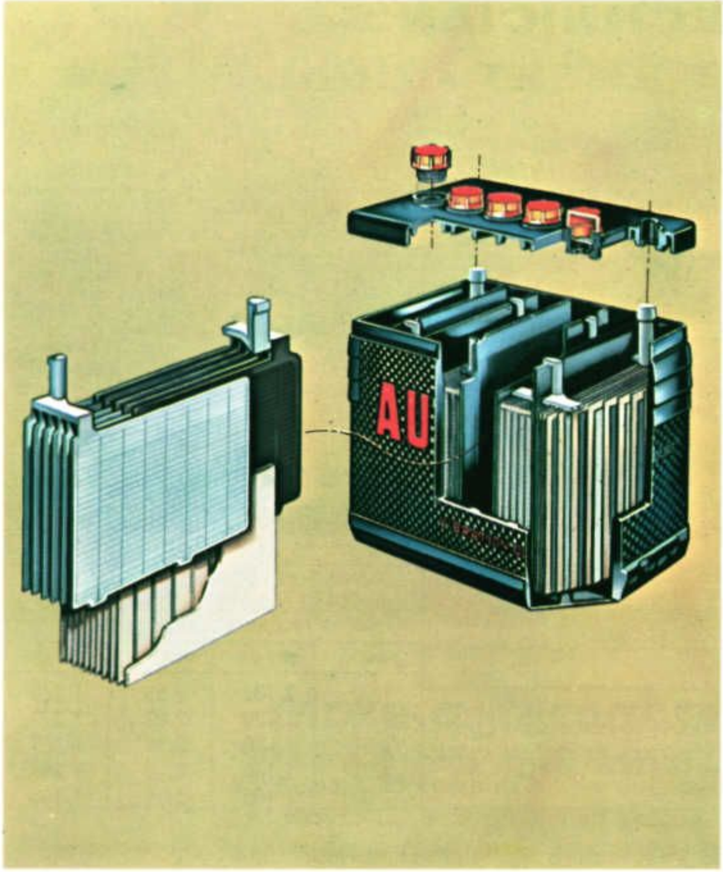
BATTERY SIZE	3-MINUTE CHARGE RATE (AMPS.)	MAXIMUM VOLTAGE	EVALUATION: BELOW MAXIMUM VOLTAGE	EVALUATION: ABOVE MAXIMUM VOLTAGE
12-VOLTS	40	15.5	BATTERY OK. BRING UP TO FULL CHARGE	BATTERY SULFATED SLOW CHARGE AT 1 AMP./POSITIVE PLATE/CELL
6-VOLTS	75	7.75		

2. INDIVIDUAL CELL READINGS, IF OBTAINABLE, ARE:

TEST ITEM	CELL NUMBER						EVALUATION
	1	2	3	4	5	6	
VOLTAGE							VARIATION OF 0.1 VOLT OR MORE BETWEEN CELLS – REPLACE BATTERY.
VOLTAGE RANGE	HIGHEST			LOWEST			(RECHARGE & RETEST BORDERLINE CASES.)

ADDITIONAL BATTERY TESTS

1. EXTERNAL LEAKAGE ______________________(ANY READING INDICATES LEAKAGE.)
2. CURRENT DRAIN ______________________(ANY READING INDICATES DRAIN.)
3. VOLTAGE DROP (CIRCUIT RESISTANCE):
   - INSULATED BATTERY POST TO STARTING MOTOR FIELD TERMINAL. . . . . ________(0.5 V. MAXIMUM)
   - INSULATED BATTERY CABLE . . . . ________(0.1 V. MAXIMUM)
   - STARTER RELAY TERMINALS (BATTERY & STARTING MOTOR) . . . . ________(0.2 V. MAXIMUM)
   - CABLE CONNECTIONS (CLAMP TO POST) . . . . ________(0.1 V. MAXIMUM)
   - STARTER GROUND CIRCUIT. . . . . ________(0.1 V. MAXIMUM)



5
Theory

The information covered under "Principles of Operation" is included for those who wish to supplement their technical understanding of battery operation with that portion of electrical theory which relates chemistry and electricity. Although we encourage you to read this material, it is not necessarily mandatory background information without which your ability to properly service a battery would be impaired.

No attempt is made to fully cover the highly technical aspects of ionization or changes in atomic structure. An effort has been made, however, to handle the applicable portions of these subjects in a manner which will minimize the need for additional background on the part of the reader.

PRINCIPLES OF OPERATION

PURPOSE OF A BATTERY

The automotive storage battery is an electro-chemical device that converts electricity into chemical energy. This chemical energy is stored in the battery until it is connected to an external circuit. At that time, the chemical energy is converted back into electrical energy and current flows through the circuit. The amount of current the battery can supply is limited by the CAPACITY of the battery, which in turn, is dependent upon the amount of chemicals that is used in making the battery.

The three main functions of the storage battery are to:

1. Provide current for starting the engine.
   a. To the starting motor.
   b. To the ignition system.
2. Provide current to supplement the vehicle's electrical load requirements whenever they exceed the charging system's supply.
3. Act as a voltage stabilizer in the charging system—this function is accomplished by a change in counter voltage—often called C.E.M.F. (Counter Electromotive Force).

It is beyond the scope of this manual to go into detail regarding charging system operation. If you would like specific information on charging systems, you may wish to attend an Autolite clinic on that subject.

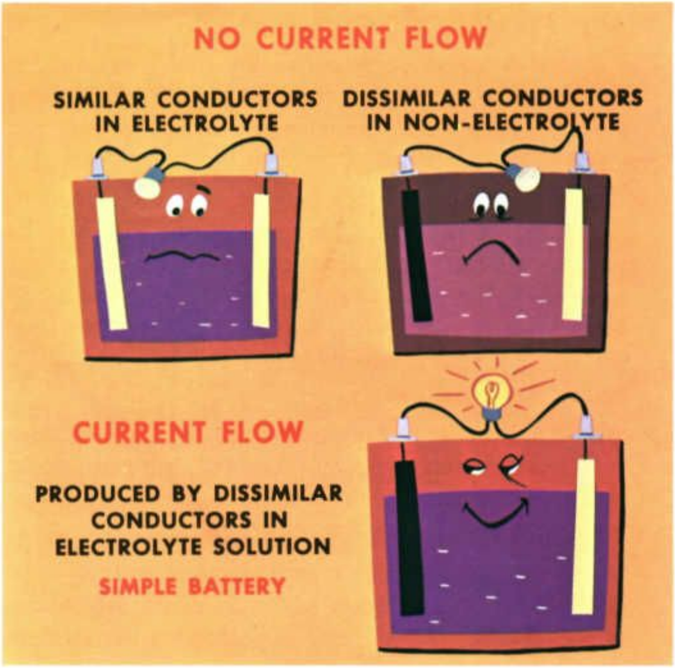
HOW PURPOSE IS ACCOMPLISHED

The three functions mentioned under "PURPOSE OF THE BATTERY", are accomplished by the design and construction of the battery, as well as the method in which it is connected into the electrical system.

Generally speaking, the action of the lead-acid type storage battery is determined by the selected ingredients (chemicals) that go into its make-up. Those chemicals are:

1. Lead peroxide (dioxide)—a paste.
2. Sulfuric acid—a liquid.
3. Water—a liquid.
4. Lead—a solid.

These chemicals are brought together in a manner that will cause them to react chemically to produce a current flow. Whenever the plates are assembled, they are given an initial "forming" charge by passing a direct current through them while being immersed in a diluted solution of sulfuric acid. In the case of the dry-charged battery the plates are then removed from the diluted electrolyte solution, rinsed with clear water, and dried without exposing the negative plates to air or oxygen (dried in a vacuum, superheated steam, carbon dioxide, etc.). The positive plates and separators are also dried so that the plates are free of moisture. They then remain in this dry condition until activated by addition of the proper strength electrolyte when the battery is placed in service.



Electrical energy is produced by a chemical reaction between two dissimilar conductors and an electrolyte. The availability and amount of electrical energy that can be produced by the battery is limited by the active area and weight of the materials in the plates and by the quantity of sulfuric acid in the electrolyte. Whenever all the active materials have reacted, the battery is *discharged.*

The most valuable characteristic of the lead-acid type storage battery is its chemical reversibility. Whenever the chemicals of the battery have been "used up" by the discharge process, the potential energy may be restored by charging the battery; that is, by passing an electrical current through it in a direction opposite to the direction of discharge. The battery's active materials are restored to an almost "new" state.

VEHICLE REQUIREMENTS

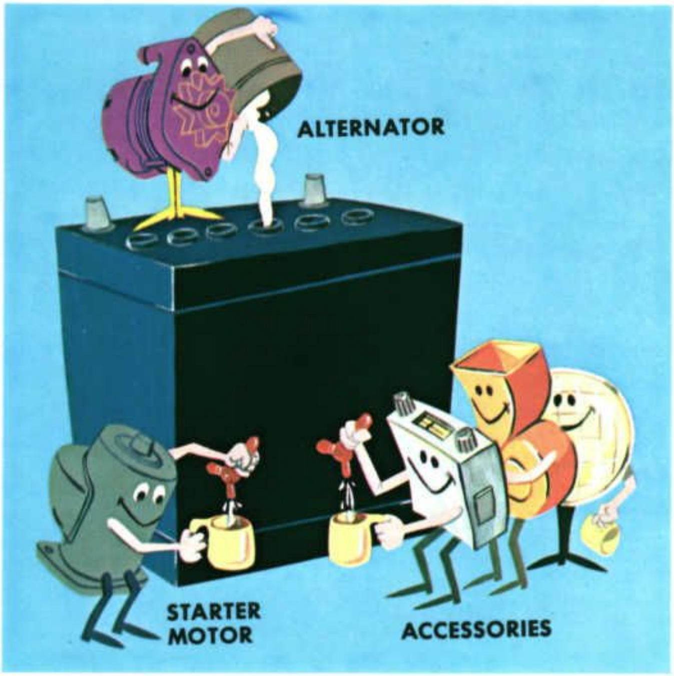
Now that you have been exposed to the basic preliminaries, let's consider some more of the actual detail as to how a battery accomplishes its three-fold purpose. As we mentioned in "PURPOSE OF THE BATTERY", the first responsibility of the battery is to *supply current to start the engine.* As you know, each vehicle that leaves the factory is equipped with many options or variations of electrical accessories. As a service technician, you must familarize yourself with each vehicle that you are called upon to service. Theoretically, each make and model of automobile could require a different size battery. Let's take a closer look at what we must know in order to select a battery to fit the needs of a particular vehicle:

1. We must know what total current demands will be made on the battery.
2. We must know what actually determines the current capacity of the battery.
   a. The number of plates, their size and thickness, and the amount of acid content of the electrolyte determines the battery's capacity. The open circuit voltage, regardless of the size of the cell remains the same–slightly over 2-volts. If we compare a 9 plate (per cell) battery to a 15 plate battery, they would both have the same open circuit voltage; however, the 15 plate battery would have greater capacity and higher voltage on discharge.
   b. The adjacent chart is provided to give you an idea of the current demands made on the battery of a typical 12-volt vehicle.

TYPICAL CURRENT LOAD OF MODERN CARS (in Amperes)

Switch	Accessory Switch Load	Max. Vehicle Operating Load
Parking	4 to 8	–
Low-Beam Headlamp	8 to 14	–
High Beam (4) Headlamp	12 to 18	18
Heater	6 to 7	–
Windshield Wiper	2 to 3	3
Air Conditioner	10 to 15	15
Radio	0.4 to 1.8	1.8
Ignition – Standard	3	–
Ignition – Transistorized	8 to 12	12
Alternator Field	3 to 5	5
Total	–	54.8

Summer Starting 100 – 400 Amperes*
Winter Starting 225 – 500 Amperes*
*Values vary with engine size, engine temperature and oil viscosity.



The second function or responsibility that is required of the battery is to supplement the vehicle load requirements *whenever* they *exceed* the *charging system's ability to* deliver.

1. The drain on the battery may be very high when the engine is not running. Charging systems with high capacities will carry the electrical load when the engine is running, but too small a battery may be discharged by lights and radio when parked. Cold weather starting is made more difficult before the charging system can recharge the battery.
2. Always follow manufacturer's recommendations when replacing a battery or select one with a higher electrical capacity if any additional current-consuming devices have been installed on the vehicle.

The third phase of the battery's function–*to act as a voltage stabilizer in the charging system* is most easily understood if we think of generator/alternator and battery as two opposing forces. Current always tends to flow from the greater toward the lesser force. In order to keep both the generator/alternator and battery from harming each other, we rely on a regulating device. We shall make no attempt to explain the operation or function of the regulator, other than to briefly state the overall purpose of each individual unit within the regulator:

1. Cut-out relay–an automatic switch that connects and disconnects the generator/alternator to the battery on demand.
2. Current Limiter–protects the generator from producing too much current (not used on most alternators).
3. Voltage Limiter–protects the battery and balance of electrical system from excessive voltages.

Whenever the generator/alternator or battery tends to stray outside its designed limitations, the regulator steps in and guides them back to the proper path.

Temperature and *rate of charge* are the two factors which limit the battery's ability to develop a counter-voltage (resistance–or the other opposing force). Keep in mind that the terminal voltage of a battery being *discharged* will DECREASE with:

a. An INCREASED rate of discharge.
b. A DECREASING state of charge.
c. A DECREASE in temperature.

To illustrate the above, think of observing a voltmeter that is connected across the battery terminals while trying to crank a cold engine at approximately 0°F.; then imagine the different reading you would get when its 80°F. outside.

While the battery is being charged, however, a different set of circumstances prevail. Here is where we see a drastic change in counter-electromotive force (C.E.M.F.) or in plain words, the resistance to charge that the battery develops.

The terminal voltage INCREASES on a battery being charged with:

a. An INCREASE in charging rate.
b. An INCREASE in state of charge.
c. A DECREASE in temperature.

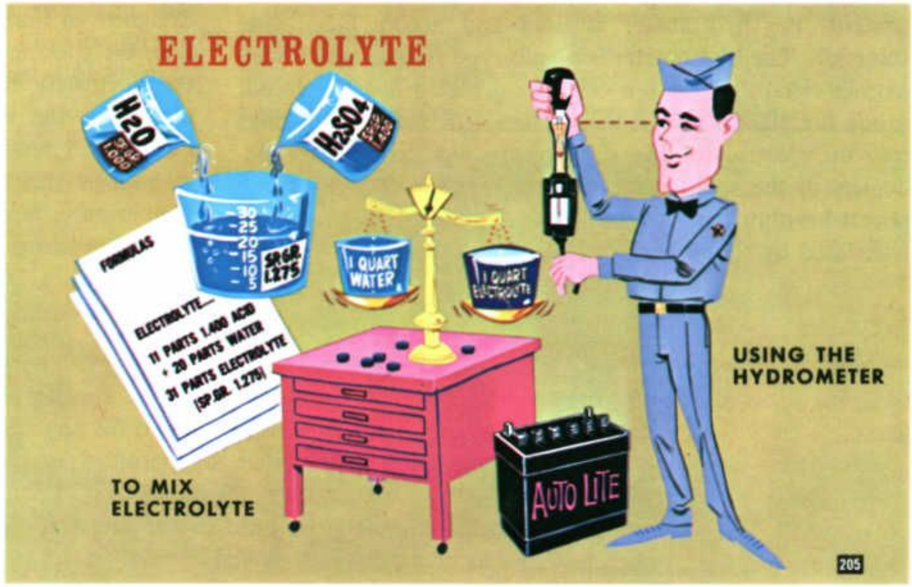
To further illustrate the above statements, we would suggest that you recall OHM'S Law–"It takes *ONE VOLT* to push *ONE AMP* through *ONE OHM* of resistance". If the voltmeter across the battery terminals is observed under the above conditions, we can see that if resistance remains the same, voltage would increase when the charging rate (amperes) goes up. In the next instance, (item b above), the state of charge (internal resistance of the battery) goes up, therefore, voltage has to go up to maintain the same rate of current flow. In the last instance (item c above), a decrease in temperature slows down chemical reactions within the battery and increases resistance to current flow because the electrolyte cannot penetrate the plates as quickly. Again, an increase in resistance means a proportionate increase in voltage to maintain the same rate of current flow.

In summary, we ask you to remember that an automotive storage battery has many jobs to do and will do them properly if we give consideration to selection, limitations, and load demands that it will be subjected to when placed into a vehicle.

Electrolyte and Specific Gravity

ELECTROLYTE

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 is also the carrier for the electric current as it passes through the separators to the plates. The framework of the grids then becomes the conductors which carry 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 releases 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 nothing more than a unit 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. Water has arbitrarily 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–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 of many 12-volt batteries used on today's vehicles. This simply means that the electrolyte is 1.26 times as heavy as the water.

The specific gravity varies with TEMPERATURE and 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. (See "TEMPERATURE CORRECTION" on page 32).

WATER

The most satisfactory water to mix with sulfuric acid in the making of electrolyte is distilled water. There have been many ruined batteries with the use of impure water. Results have been somewhat less than satisfactory when the mineral content is found to be excessive. Specifically, the use of swamp water, rain water that has been collected in metal containers, or water of a known high mineral content should never be used in a battery. Naturally, there are exceptions, but generally speaking, any water that is safe to drink is safe to use in a battery. Always avoid the use of metallic containers. A small amount of impure water that is added to a battery will not ruin it immediately. Continued use of such water, however, will concentrate the foreign particles as only pure water leaves when gassing occurs.

If the occasion should arise whereby you are required to mix acid and water, *always* pour the *acid into the water* while stirring slowly and never attempt to pour water into the acid. A dangerous "spattering" will result, not unlike a steel ball bouncing up from a cement floor. This is caused by the extreme heat that is generated whenever a strong acid is united with water. It's a good idea to have common household baking soda within easy reach in case acid is accidentally splashed on skin or clothes. If acid is splashed into eyes, wash it out with plenty of *clean water only*. Then, if discomfort continues, seek medical aid.

MEASURING SPECIFIC GRAVITY

Since it would be highly impractical to draw out quantities of electrolyte and weigh it to determine the sulfuric acid content, the hydrometer is used and accomplishes the same job. 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 service technician 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 designed so that when the float rides *high* in the electrolyte, the specific gravity is *high.* If the float sinks *low* into the electrolyte, the specific gravity is low. (For details pertaining to the use of the hydrometer, see TEST PROCEDURES section). Most hydrometers used today have a built-in thermometer to compensate for 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). The reason for this temperature compensation is because of the fact that acid volume will rise when heated and contract when cooled. When heated, the electrolyte will not be as 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.

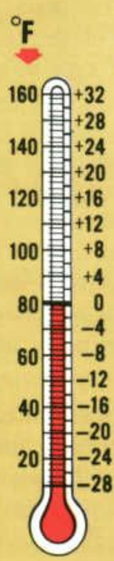
Regardless of the reference temperature (60°F. or 80°F.) used as a standard, the correction factor of .004 gravity points is used for each 10°F. change in temperature. *Four points* of gravity are added to the indicated reading for each 10°F. increment above 80°F. and four points are subtracted for each 10°F. increment below 80°F. Vehicle batteries are required to function properly in sub-zero weather, as well as in the heat extremes to which it is exposed under the hood. The following sample is offered for clarification.

EXAMPLE 1

Hydrometer Reading 1.260
Electrolyte Temp. 20°F.

20° is (6 × 10) Six Increments of 10° From The Standard Base of 80°F.

Correction Factor–	**.004**
	(×) 6
	.024
Corrected Reading–	**1.260**
	(–) .024
	1.236



EXAMPLE 2

Hydrometer Reading 1.235
Electrolyte Temp. 110 °F.

110° is (3 × 10) Three Increments of 10° From The Standard Base of 80°F.

Correction Factor–	**.004**
	(×) 3
	.012
Corrected Reading–	**1.235**
	(+) .012
	1.247

Attention is called to three instances whereby a reading could be misleading to the servicing dealer. 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

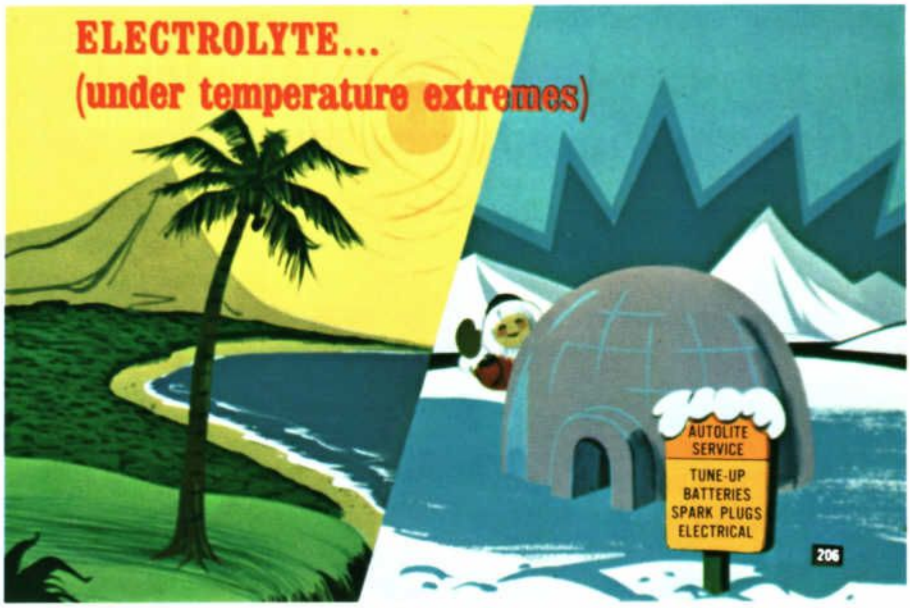
Most batteries used in temperate climates are placed in service with a nominal specific gravity of 1.260 for one-piece cover designs and 1.270 for all other designs. These batteries are designed to function at maximum efficiency under these conditions. The electrolyte used in batteries that are prepared for tropical or arctic conditions 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 the temperature is never cold enough to freeze water. This milder strength of acid is considered less harmful to the plates and separators.

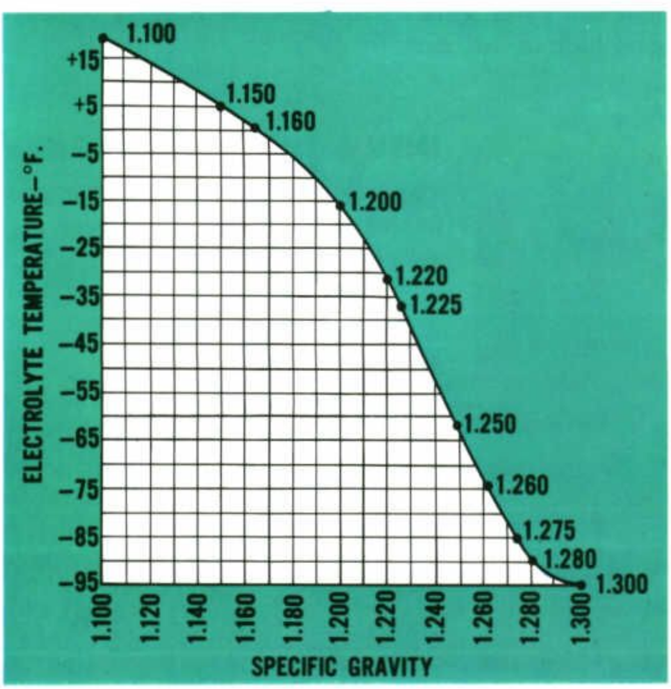
The adjacent chart is provided to show you the approximate state of charge of a battery whose specific gravity has been prepared for use under tropical conditions.
Remember that batteries can be fully charged and still have different values of specific gravity. Gravity ranges also depend on battery construction and ratio of electrolyte volume to active material.

STATE OF CHARGE	SPECIFIC GRAVITY
Fully-Charged	1.225
75% Charged	1.180
50% Charged	1.135
25% Charged	1.090
Discharged	1.045



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 0°F. it is only about 40% effective.

Sub-freezing climates necessitate 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 a service technician 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 ¾ charge. A longer service life can be expected if the battery is not subjected to deep-cycling effects or allowed to approach freezing conditions.

For your convenience, a chart showing the approximate freezing point of electrolyte is provided.

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.

(As explained previously with the hydrometer–For specific information, refer to "Test Procedure" section of this manual)

State of charge is the term used to identify the battery's internal condition in relation to a fully-charged unit. It is usually expressed as a percentage of a fully-charged battery. The specifications for "full-charge" usually fall between 1.260 and 1.300 specific gravity. The adjacent chart 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

Current Flow in the Internal and External Circuits

The internal circuit is defined as that which is physically located within the battery itself–from the negative terminal to the positive terminal.

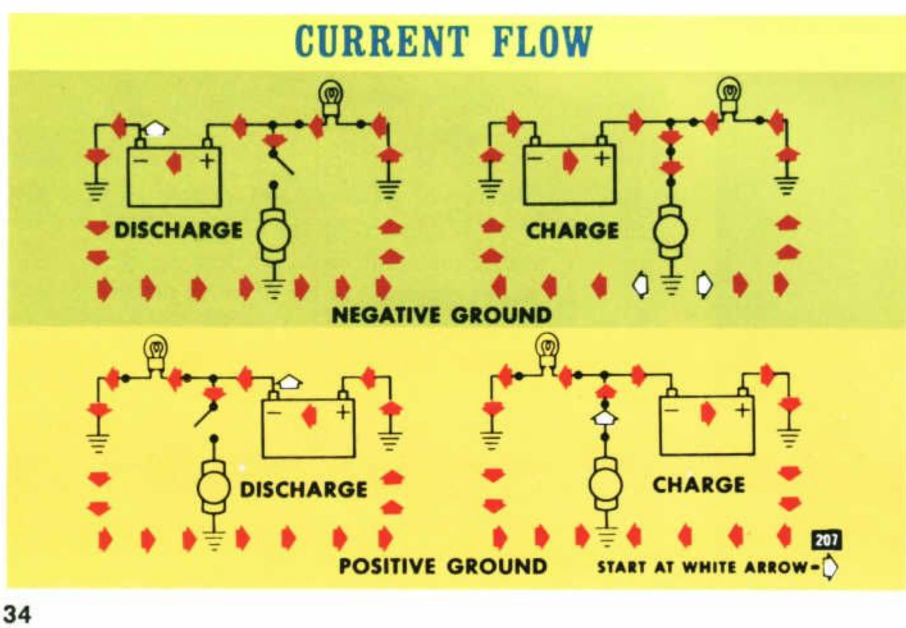
The external circuit consists of the entire electrical system of the vehicle, excluding the battery itself and particularly the charging system.

For many years two conflicting theories have been in existence with regard to the direction of current flow in a D.C. circuit. Specifically, they are the CURRENT FLOW theory and the ELECTRON theory. The older theory of current flow was based on the concept of current traveling from positive to negative in the external circuit. In recent years, however, the electron theory–that electrons flow from negative to positive–has received widespread acceptance. It is now an established scientific fact that electron flow is synomonous with current flow and the direction is actually from *negative* to *positive*.

Along with the two concepts, of course, comes the confusion of one textbook advocating one theory and another which teaches the exact opposite. Most shop service manuals show the direction of current flow from the insulated post of the battery to the component loads and back to the grounded post by way of the frame and other metallic components.

Take a good long look at the illustration at the bottom of the page. Note the white arrow and trace the current flow from that arrow through the circuit and, finally, back to that same arrow. Trace each of the four (4) circuits shown on the illustration. This is a simplified schematic which shows direction of current flow according to the ELECTRON theory. Many previous publications have made it a policy to recognize the electron theory–then explain that it is easier to follow electrical circuits by going the opposite direction.

Take particular notice of the arrows which indicate direction of current flow on the illustration. Begin on the DISCHARGE cycle, with the battery negative terminal to ground, to load, and back to battery. By following the electron theory of negative to positive current flow on the CHARGE cycle, begin with the negative terminal of the charging device, through ground, to the negative battery terminal (thus, sending a current in a direction which is opposite to that of discharge), and return to the charging device by way of the insulated wiring. It is helpful to remember a basic rule of electricity which states–"Current will never leave its source unless it has a complete path back to that same source".



INSIDE THE BATTERY

The four basic ingredients of the automotive lead-acid storage battery are:

1. PbO_2–Lead Peroxide
2. Pb–Sponge Lead
3. H_2SO_4–Sulfuric Acid
4. H_2O–Water

A current flow is caused whenever there is a chemical reaction between the two dissimilar metals of the plates and the sulfuric acid in the electrolyte. As mentioned previously, electrolyte is made up of a mixture of approximately 40% sulfuric acid (1.835 specific gravity) and 60% water (1.000 specific gravity).

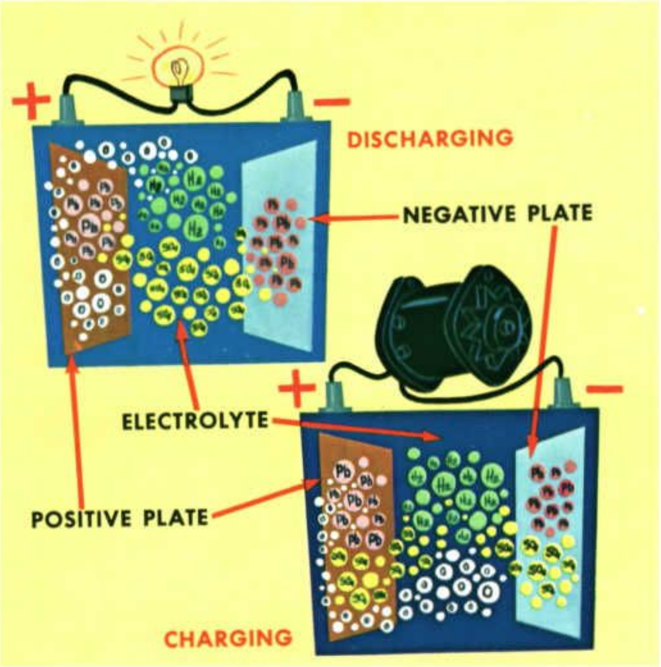
DISCHARGE CYCLE

When the battery is connected to an external circuit, current begins to flow from the battery. This is known as the discharge cycle. The lead peroxide (PbO_2) in the positive plate is a compound of lead (Pb) and Oxygen O_2). Sulfuric acid is a compound of hydrogen (H_2) and the sulfate radical (SO_4). Oxygen in the active material of the positive plate combines with hydrogen from the sulfuric acid to form water (H_2O). At the same time, lead in the active material of the positive plate combines with the sulfate radical, forming lead sulfate ($PbSO_4$).

A very similar reaction is happening at the negative plate at the same time the electrolyte is reacting with the positive plate. Lead (Pb) of the negative active material combines with the sulfate radical to form lead sulfate ($PbSO_4$).

Thus, we can see that the active portion of the electrolyte is absorbed by both the positive and negative plates. As the discharge is continued, both plates tend to become more alike or less dissimilar (this accounts for the loss in voltage, since potential depends on the difference between the two materials plus the amount of acid concentration of the electrolyte), while the active material of the electrolyte causes a reduction in its specific gravity. This reduction in specific gravity of electrolyte provides an accurate and convenient method for determining the battery's state of charge.

The chemical reversibility OR the battery's ability to accept a charge (thus restoring it to an almost new condition) is its most valuable asset.



CHARGE CYCLE

The chemical reactions that take place within the battery during charge are basically the reverse of those that occur during discharge. The accumulated lead sulfate on the plates is driven off the plate–back into the electrolyte solution by the action of the charging device.

The lead sulfate of both plates is split up into its original form of lead (Pb) and sulfate (SO_4), while water is forced to split into hydrogen (H_2) and oxygen (O). As the sulfate leaves the plates, it combines with the hydrogen and is restored to sulfuric acid (H_2SO_4). While this process is going on, the oxygen combines chemically with the lead of the positive plate to form lead peroxide (PbO_2). The specific gravity of the electrolyte increases during charge because of the fact that sulfuric acid is formed and water is used up (given up in gaseous form). Do not overlook the important role that water plays in the chemistry of a lead-acid storage battery.

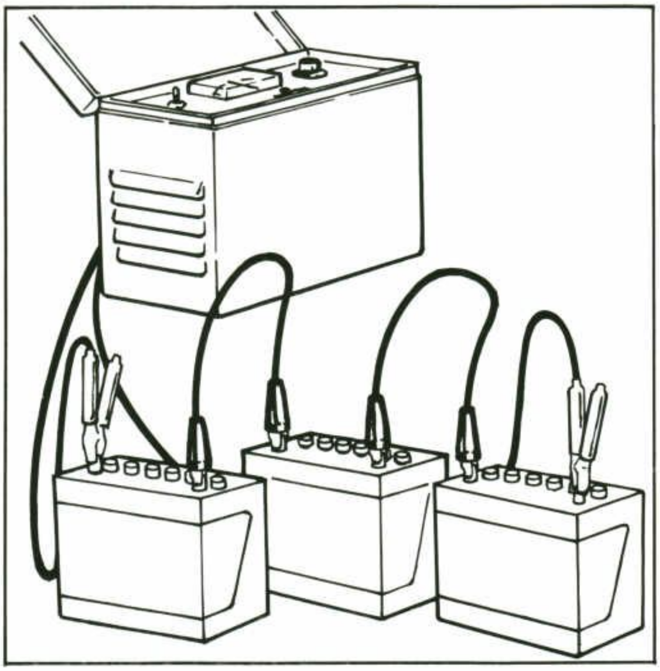
6 Useful Information

The industry recognizes a variety of charging methods, each of which has a specific purpose. They include the following:

- CONSTANT-CURRENT SLOW-CHARGING
- HIGH-RATE FAST-CHARGING
- CONSTANT-POTENTIAL CHARGING
- TRICKLE CHARGING
- BOOST CHARGING
- QUICK BOOST CHARGING

CONSTANT-CURRENT SLOW-CHARGING

Slow charging is the only method which will fully charge a battery. Slow charging should be at the rate of 1 ampere for each positive plate in one cell for a sufficient length of time to fully charge the battery. The battery is fully charged when the cells are all gassing freely and the specific gravity ceases to rise for three successive readings taken at hourly intervals. Do not stop charging short of the



fully charged state, even if it requires charging for 24 hours or more. A battery which is badly sulfated will require more charging time than a normal battery. If overnight charging is necessary, it is suggested that the rate be reduced to one-half the daytime charge rate.

To effect a slow charge, connect the positive lead from the charger to the positive terminal of the battery and connect the negative lead to the negative terminal. If several batteries are being charged in series, they should be connected from the positive terminal of one to the negative terminal of another so that when the row of batteries is connected there will be a positive and a negative battery terminal free for connecting the positive and negative charger leads respectively.

Watch the temperature of electrolyte carefully. If the 125° F maximum is reached and charging is still required, reduce the rate to avoid expansion of the electrolyte to the point where it runs over.

The average time to charge a battery is 12-16 hours. Extreme sulfation, as indicated previously, can extend this time interval considerably.

Unless electrolyte has been lost through spilling or leaking, it should not be necessary to add acid to a battery during its life. Remember to make the temperature correction for hydrometer readings.

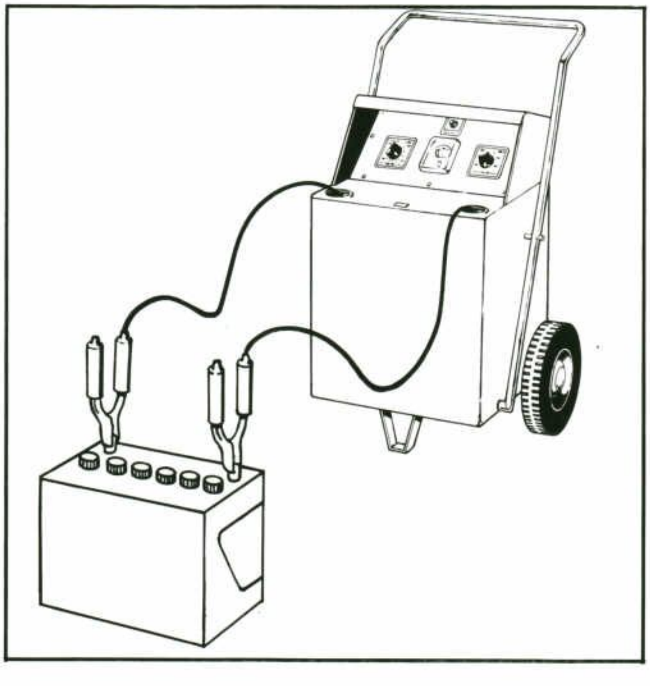
HIGH-RATE FAST-CHARGING

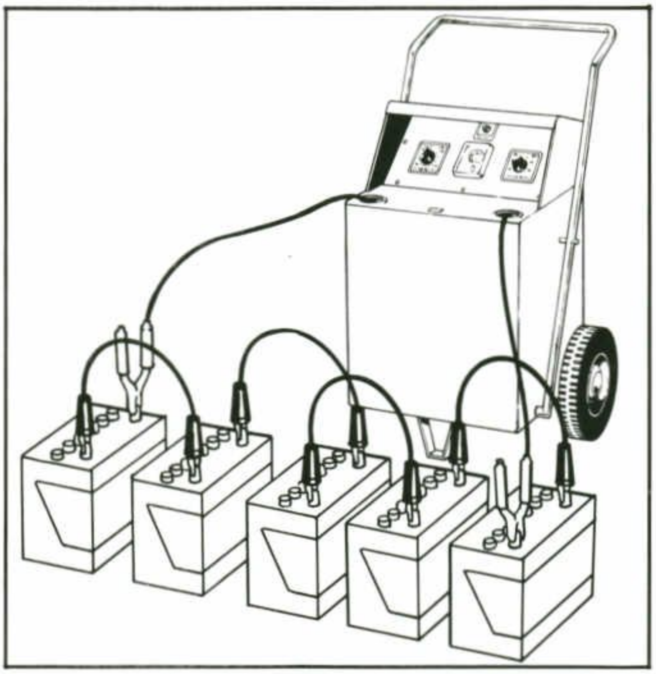
A high rate charger has the ability to quickly "boost" a battery without removing it from the car. A high rate charger may also be used to quickly "boost" a battery while in the process of bench charging. A high rate charge must always be followed by slow charging for a length of time necessary to bring the battery to full charge. Follow the instructions provided by the maker of the high rate charger being used, limiting the charge rate to 75 amperes on a 6-volt battery and 40 amperes on a 12-volt battery. Be sure the electrolyte temperature of any one cell does not exceed 125° F. and does not cause excessive loss of electrolyte. See the Specific Gravity-Fast Charge time table for recommended maximum fast charge time for batteries in various stages of discharge.

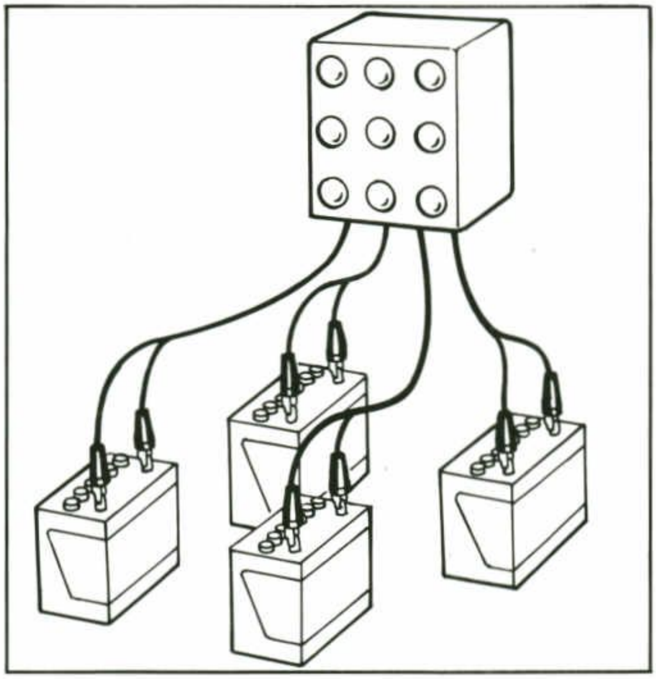
High-rate Chargers cannot be expected to fully charge batteries within an hour, but they do charge the battery sufficiently well so that it can continue to give service commensurate with its condition and state of charge. These machines supplement the constant rate type of slow charger which is still a necessary piece of equipment where the accurate diagnosis of battery troubles must be made or where dry-charged batteries are made wet and held in stock.

Specific Gravity	Fast Charge
1.150 or less	* 1 hour
1.150 to 1.175	*¾ hour
1.175 to 1.200	*½ hour
1.200 to 1.225	*¼ hour
Above 1.255	*Slow Charge Only

*FOLLOW WITH SLOW CHARGE RATE OF 1 AMPERE PER POSITIVE PLATE PER CELL.







MULTIPLE HOOK-UP

A battery may be charged at any rate which does not cause the electrolyte temperature of any cell to exceed 125°F. and does not cause excessive loss of the electrolyte. This rule does not apply to badly-sulfated batteries. Such batteries should be charged at specified low rates.

More than one battery, either all 12-volt or all 6-volt, can be charged on high-rate fast chargers. When this is done, connect the batteries in parallel; that is, connect the positive to positive, and negative to negative.

The high-rate chargers can inflict irreparable damage on a battery if the safeguards provided by the manufacturer are ignored or circumvented by the operator. Operating instructions on high-rate chargers, as issued by each manufacturer, should be carefully followed.

CONSTANT POTENTIAL CHARGING

Constant-potential chargers start the charge off at a high rate, and as the battery voltage builds up, the charge rate tapers off to a lower value depending on the design of the charger and on the condition, age, and temperature of the battery. A battery in good condition is not harmed by this type of charging. A badly-sulfated battery, however, may not come up to full-charge in a normal way on this type of charger. Temperature must be watched carefully with this method of charging as it may rise very rapidly.

TRICKLE CHARGING

Trickle chargers are effectively used for keeping display batteries freshly charged and ready for sale. Avoid continuous overcharge for long periods of time.

Whenever such chargers which have an output of less than one ampere are used, it is very important that they be used in strict accordance with directions, since continuous overcharging for an indefinite time, even though at a very low rate, can be very destructive to the grids of the positive plates, causing them to disintegrate. Many who operate such chargers turn them off at night to avoid overcharging.

BOOST CHARGING

Boost charging is recomended in conjunction with O.C.V. testing when all cells read less than 1.95 volts. To perform this charging operation, install the charger leads observing battery terminal polarity. Apply the amount of charge according to whichever of the following is applicable:

- 12-VOLT BATTERIES–1000 AMPERE MINUTES (50 AMPS. X 20 MIN., OR EQUIVALENT.)
- 6-VOLT BATTERIES–1800 AMPERE MINUTES (60 AMPS. X 30 MIN., OR EQUIVALENT.) ALL OTHER BATTERIES USE THE 6-VOLT RATE FOR BOOST CHARGING.

QUICK BOOST CHARGING

The intent of quick boost charging is to introduce enough available voltage into the battery to enable it to perform its functions until the vehicle charging system can bring it to a state of full charge. Most battery charging equipment manufacturers recommend 10 minutes at 15 amperes for a regular 12-volt unit and 10 minutes at 30 amperes for a 6-volt or 12-volt heavy-duty unit.

Activation of Dry-Charged Batteries

A dry-charge battery when packaged for dealer 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 separators, permits expansion of electrolyte as battery is boost charged.
2. When the manufacturer recommends filling gravities of 1.250 or higher, boost charge 12-volt batteries at 30-40 amps. (6-volt batteries at 60-70 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 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 filling 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 car. Turn lights on and be sure ammeter shows discharge. For cars not having ammeters, check manufacturer's manual for proper polarity. Request customer to return in one week for battery check. After battery has been in service, add only approved water. DO NOT ADD ACID.

Following these instructions will assure proper activation and satisfied customers, regardless of temperature and conditions of storage.

Battery Capacity Ratings

1. ACTIVATION TEST (For dry-charged batteries–determines initial high rate discharge capability.)
2. CURRENT ACCEPTANCE TESTS (Ability to accept a charge.)
3. 20-HOUR RATING IN AMPERE-HOURS (Electrical reserve or reserve capacity.)
4. COLD RATING AT ZERO DEGREES (Cranking ability at low temperature.)
5. 20-MINUTE RATING IN AMPERES (Cranking ability at warm temperature.)
6. LIFE TESTS (Simulated laboratory duplication of vehicle conditions.)
7. OVERCHARGE LIFE TESTS (Tests positive plate grid alloy and grid design.)
8. LIFE CYCLE TEST (Evaluation of internal battery components.)
9. 25-AMPERE RATE (Ability to carry electrical load when charging system is not operating.)

Take a look at the many ways in which a battery is rated for performance. The list above will give you an idea of how many rating tests are used or have been used in the past.

Since service specifications are primarily based on the ampere-hour rating, we will examine the method for determining ampere-hour capacity more closely.

CAPACITY RATINGS

1. The capacity of a battery is the amount of electrical energy that a fully charged unit is capable of delivering. The size and number of plates per cell, the number of cells per battery, and the strength and volume of electrolyte are the determining factors.
2. Capacity is expressed as a rating based on one or more of the following tests:
   a. Ampere-Hour Capacity
      This test indicates the amount of active material in the plates and the lasting power of the battery under light load. It is performed by discharging the battery for 20-hours at a rate equal to 1/20 of the manufacturer's specified ampere-hour rating. (Electrolyte temperature, during this test, should be controlled at 80°F., ±5°F.)

A 12-volt battery, for example, rated at 80 ampere-hours by the manufacturer would be discharged at 1/20 of 80 amperes or 4 amperes for 20 hours. The average voltage per cell at the end of the test should be not less than 1.75 volts.

This test may also be referred to as the 20-hour rate. It represents the amount of current a battery will deliver for 20 hours before the cell voltage drops below 1.75 volts. A battery which delivers 4-amperes for 20-hours would be rated as an 80-ampere-hour battery (4 amps x 20 hours).

b. Zero Test
This test is conducted to determine the cranking ability of the battery at low temperatures (0°F). In performing the test, a load of 300 or 150 amperes is applied for the length of time required to reduce available cell voltage to 1-volt. Manufacturer's specifications stipulate the load and number of minutes which apply to various size and types of batteries in their product lines.

c. 5-Second Voltage Test
This is another cold test made with an electrolyte temperature of 0°F. Again, depending upon manufacturer's specifications, a 300 or 150 ampere load is applied. In this test, a 5-second discharge period is a controlling factor. Acceptability of the battery is determined by comparing test results with specifications.

The purpose of the test is to find out whether available ignition voltage is present when the battery is being subjected to a heavy load at cold temperature.

Each of these tests are primarily designed as laboratory evaluations. However, knowing what they are and what they indicate is useful background information.

POWER RATINGS IN WATT-HOURS

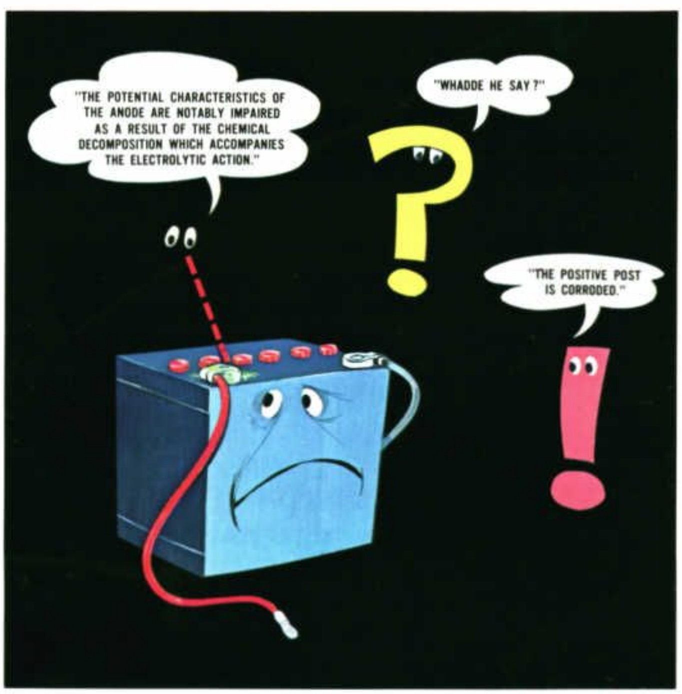
A comparison of ampere-hour capacities between 6-volt and 12-volt batteries can often be misleading. For example, a 15-plate, 6-volt battery has a 105 ampere-hour rating, while a 15-plate, 12-volt battery has a 90 ampere-hour capacity. At first glance, the impression is that there would be more power available from the 6-volt battery.

Power is a product of amperes times voltage (ampere x volts=watts). A basis for comparing battery power-ratings presents a clearer picture if we take the ampere-hour rating and multiply it by the battery voltage. (Ampere-hours x volts =watt-hours.). Now it can be seen that the 6-volt battery would give a power rating of 630 watt-hours (6-volts x 105 ampere-hours) while the 12-volt battery would be rated at 1080 watt-hours. (12-volts x 90 ampere-hours).

Ampere-hour ratings have a useful application in determining the appropriate slow charging rate for a given battery. Some battery 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 batteries with thin, short, or narrow plates. Instead, they recommend a charging rate of 7 percent of the published ampere-hour rating (to the nearest ampere).

Terminology

The meanings of words are often misleading when used in varying situations. An attempt has been made in the following list to simplify words that are commonly used when dealing with automotive storage batteries.



ACTIVE MATERIAL–The material of which the plates are made. Peroxide of lead (brown in color) and sponge or metallic lead (gray in color)–positive and negative plates, respectively–upon which the sulphuric acid acts.

AMPERE (AMP.)–The unit of measurement to determine the flow of electrons in a circuit. Measures current flow.

AMPERE-HOUR–The unit of measurement for determining battery capacity, obtained by multiplying the current flow in amperes by the time, in hours that the current flows.

AMMETER–An instrument for measuring electron flow in amperes.

ANODE–Equivalent to the positive terminal of a battery.

BATTERY–A group of 2 or more cells connected together to produce an electric current. It converts chemical energy into electrical energy. With reference to an automobile, any number of complete electrical cells assembled in one housing or battery case.

CATHODE–Equivalent to the negative pole or electrode of a battery.

CELL–In a flashlight "battery", a dry cell; in a storage battery, a compartment for containing positive and negative plates which, with electrolyte, generates electricity.

CHARGE (RECHARGE)–To restore the active materials in a battery by passing a direct current through it in an opposite direction to that of discharge.

CIRCUIT–The complete path provided for current flow. This complete path is called a closed circuit and when its continuity is broken, an open circuit.

CIRCUIT (SERIES)–A circuit which provides only *one path* for the current to flow. In a storage battery, the connection of negative-to-positive and positive-to-negative.

CIRCUIT (PARALLEL)–A circuit which provides more than one path for current to flow. An arrangement whereby all positive poles, terminals, etc., are connected to a conductor and all negative poles, terminals, etc., are connected to another conductor. This arrangement provides full electrical potential (voltage) to all portions of the circuit.

CONDUCTOR–A wire or other metallic object capable of transmitting electricity.

CONNECTOR–A device used to link the components of an electrical circuit together.

CURRENT–The movement of electricity comparable to the flow of a stream of water. Sometimes used to identify the rate of such movement. The movement of free electrons along a conductor.

CURRENT (ALTERNATING)–A periodic conduction current that reverses its direction at regular intervals.

CURRENT (DIRECT)–An electrical current flowing in one direction only.

COUNTER ELECTROMOTIVE FORCE (CEMF)–The total of two opposing voltages within the battery to a charging current; the internal resistance (voltage drop) and the chemical voltage.

CYCLE–A series of events that occur over and over in a given sequence. In a battery, the process of constant discharging and charging.

DRAW (AMPERAGE)–The quantity of current used to operate an electrical device.

DROP (VOLTAGE)–The net difference in electrical pressure when measured across a resistance.

ELECTRICITY–The movement of electrons from one body of matter to another.

ELECTRODE–Either terminal of an electric source; especially either conductor by which the current enters and leaves an electrolyte.

ELECTROLYTE–A substance in which the conduction of electricity is accompanied by chemical decomposition. In a battery, a mixture of sulphuric acid and water.

ELECTROMOTIVE FORCE That which moves or tends to move electricity. Caused by a difference in electrical potential.

ELEMENT–In a battery, one set of positive and negative plates complete with separators in assembled form.

ELECTRON–The negatively charged particles of an atom which revolve around the nucleus.

ELECTRON THEORY–States that all matter is made up of atoms which contain electrons, some of which are free to move from one atom to another.

ENERGY–The capacity for doing work–with a source of either chemical reaction, electrical action, or mechanical action.

FREE ELECTRON–An electron in the outer orbit of an atom, not strongly attracted to the nucleus; it can easily be forced out of its orbit.

GRID–A lead-antimony framework which supports the active material of a battery plate and conducts current.

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

HYDROMETER–A float-type instrument for determining specific gravities; such as the density of battery electrolyte.

IONIZATION–When a molecule of gas loses electrons due to electrical excitation. To render or become conducting, supposedly by the formation of ions.

JAR–In a battery, the rubber or composition container for a cell.

LEAD-ACID BATTERY–A common battery in which the secondary cells are composed of lead, lead peroxide, and a solution of sulfuric acid.

LIVE–Electrical parts attached to the insulated part of an electrical system: often called the "hot lead".

NEGATIVE–Designating or pertaining to a kind of electrical potential. The negative plate of an electrolytic cell–the point from which an electrical current flows.

OHM–The practical unit for measuring electrical resistance.

OHMMETER–A test device used to measure electrical resistance.

POLARITY–The quality or condition in a body which has opposite properties or directions; having poles, as in an electric cell, a magnet, or a magnetic field.

POSITIVE–Designating or pertaining to a kind of electrical potential–tending to lose electrons and thus become positive; opposite of negative.

POTENTIAL–A latent or unreleased electrical energy.

PRIMARY–An electric cell which cannot be recharged, e.g., a flashlight "battery". Also in a transformer, the winding which is attached to the source of current.

RESISTANCE–The opposition offered by a substance or body to the free flow of an electric current.

RHEOSTAT–A resistor for regulating a current by means of a variable resistance.

SECONDARY CELL–One of the cells in a battery. It can be recharged by passing a current through it in a direction opposite to that of discharge.

SHORT CIRCUIT–Often used to describe an intentional grounding of a circuit. More accurately, a path created when an insulation breakdown occurs.

SPECIFIC GRAVITY–The ratio of the weight of any volume of a substance to the weight of an equal volume of some substance taken as a standard; usually water for solids and liquids and air or hydrogen for gases.

TERMINAL–A device attached to the end of a wire or cable or to an apparatus for convenience in making electrical connections.

VOLT–A practical unit for measuring current pressure in a circuit; that force, when steadily applied to a conductor with a resistance of one ohm will produce a current flow of one ampere.

VOLTMETER–An instrument for measuring the differences of potential between different points of an electrical circuit.

WATT–The unit for measuring electrical energy or "work". One watt is the product of one ampere multiplied by one volt.

WATT-HOUR–The unit of electrical energy obtained by multiplying the ampere-hour output by the average voltage during discharge. (Watt-hours equals (=) volts X amperes X hours.)

Suggested Battery Servicing Tools and Test Equipment

BATTERY SERVICING TOOLS


Cable Puller


Terminal Nut Wrench (9/16")

Battery Plier


Battery terminal spreader


Scraper


Post and Terminal Cleaning Brush

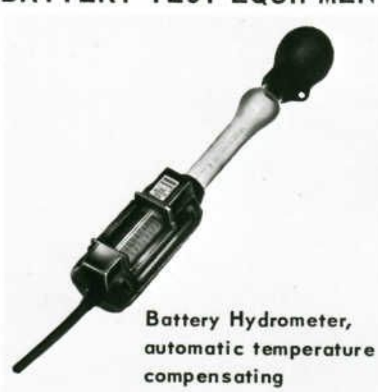

Filler, Syringe Type


Filler, Self-leveling


Wire Brush

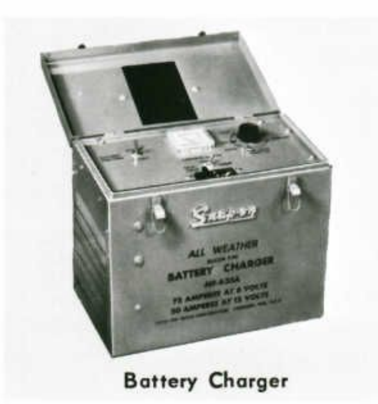

Booster Cable Set

BATTERY TEST EQUIPMENT


Battery Hydrometer, automatic temperature compensating

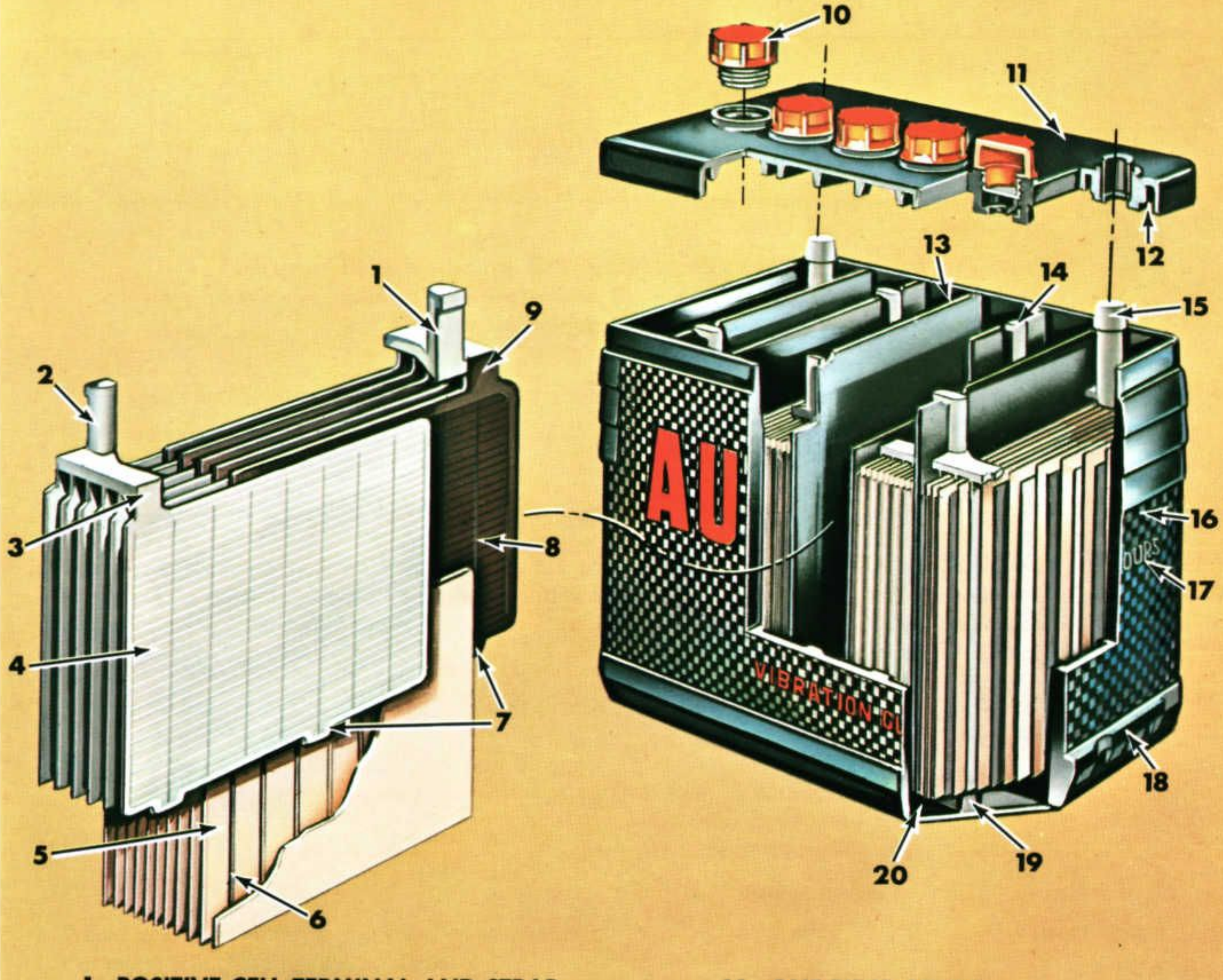

Cell Tester


Battery-Starter Tester


Battery Charger


Christie Tester (T-3)

BATTERY CONSTRUCTION DETAILS



1. POSITIVE CELL TERMINAL AND STRAP
2. NEGATIVE CELL TERMINAL AND STRAP
3. NEGATIVE TERMINAL LUG
4. NEGATIVE PLATE (GRID AND SPONGE LEAD)
5. SEPARATOR
6. SEPARATOR RIB
7. PLATE FEET
8. POSITIVE PLATE (GRID & LEAD DIOXIDE)
9. POSITIVE TERMINAL LUG
10. VENT PLUG
11. ONE-PIECE COVER
12. EPOXY RESIN SEALING LIP
13. CELL PARTITION
14. OVER-PARTITION CONNECTOR
15. TERMINAL POST
16. CONTAINER
17. AMPERE-HOUR RATING
18. MOUNTING LEDGE
19. ELEMENT REST
20. SEDIMENT SPACE

Battery Service and Testing Procedures Questionnaire

____
(Name of Student—Please Print)

____
(Address of Student)

____
(Employer's Name)

____
(Employer's Address)

______________	______________	______________
(Date)	(Location of Clinic)	(Name of Instructor)

Directions: Each of the ten (10) questions which follow have four (4) possible answers. You are to select the *one* answer that is *most* correct by placing an "X" in the appropriate ☐ provided.

1. The positive battery plate is brown in color and is made up of:

   ☐ Lead sulfate ☐ Lead acid
   ☐ Lead antimony ☐ Lead dioxide

2. The active materials of both battery plates are converted into a different chemical compound during the discharge cycle. This compound is called:

   ☐ Lead oxide ☐ Lead acid
   ☐ Lead sulfur ☐ Lead sulfate

3. For every ten (.010) points variation of specific gravity, the individual cell voltage will vary:

   ☐ 0.100 volt ☐ 0.001 volt
   ☐ 0.010 volt ☐ 0.005 volt

4. When charging batteries by the "constant-current" method, a safe charging rate would be:

   ☐ 1 amp per positive plate per cell ☐ 1 amp per negative plate per cell
   ☐ 1 volt per positive plate per cell ☐ 1 volt per negative plate per cell

5. When charging batteries by the "constant-potential" method, a safe charging rate would be one which does not allow the electrolyte temperature to exceed:

   ☐ 110°F. ☐ 125°F.
   ☐ 300°F. ☐ 80°F.

6. The variable-load (high-rate discharge) test is not valid on any battery whose specific gravity is less than:

   ☐ 1.240 ☐ 1.175
   ☐ 1.225 ☐ 1.125

7. To place a load on a battery for the variable load (high rate discharge) test, turn the carbon-pile load control to three (3) times the ampere-hour rating of the battery or operate the vehicle:

   ☐ headlights ☐ generator/alternator
   ☐ starter relay ☐ starter motor

8. If a battery consistently uses more than one to two ounces of water per cell per 1,000 miles of driving, check the setting of the:

   ☐ voltage limiter ☐ neutral voltage
   ☐ field relay ☐ current limiter

9. The freezing point of an electrolyte whose specific gravity is 1.260 at 80°F. would be:

   ☐ −32°F. ☐ −75°F.
   ☐ +32°F. ☐ −92°F.

10. If a hydrometer reads 1.220 specific gravity and the thermometer registers 110°F., the corrected specific gravity reading would be:

    ☐ 1.208 ☐ 1.242
    ☐ 1.196 ☐ 1.232

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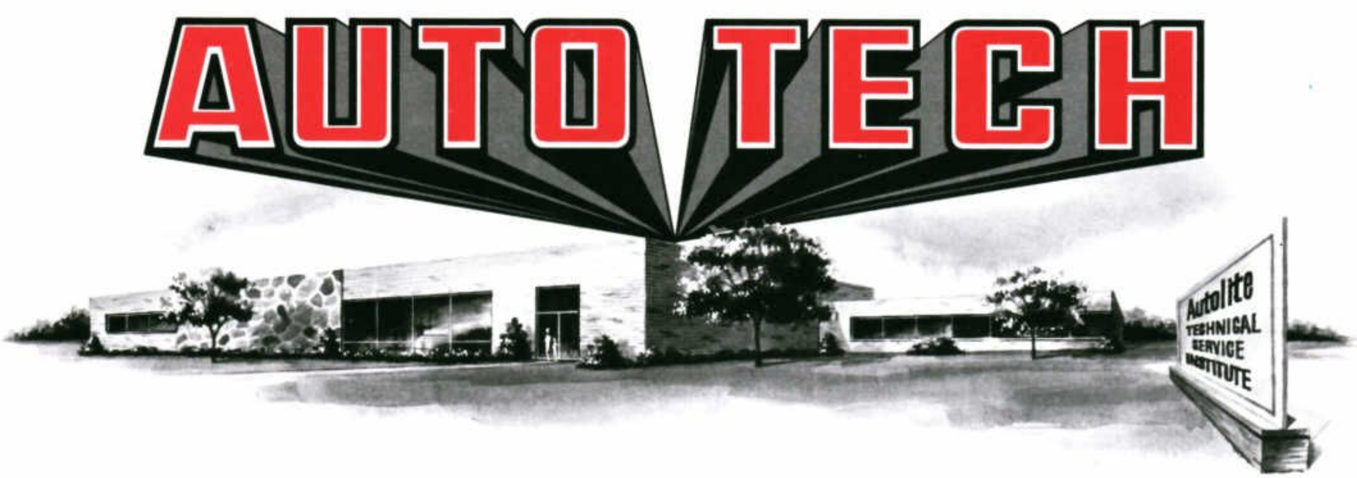

for further details, turn the page

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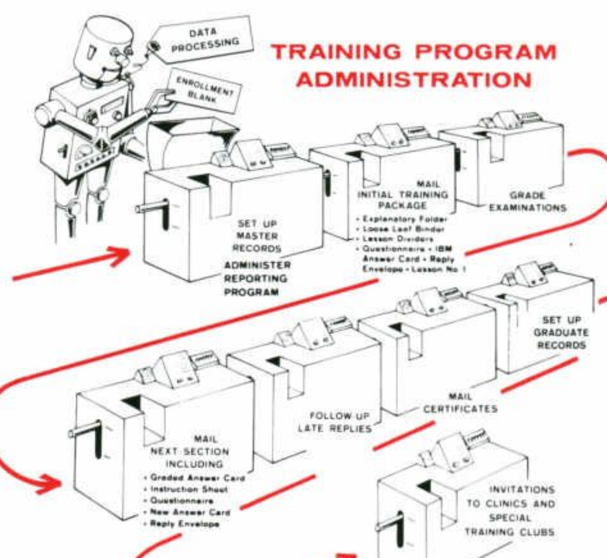
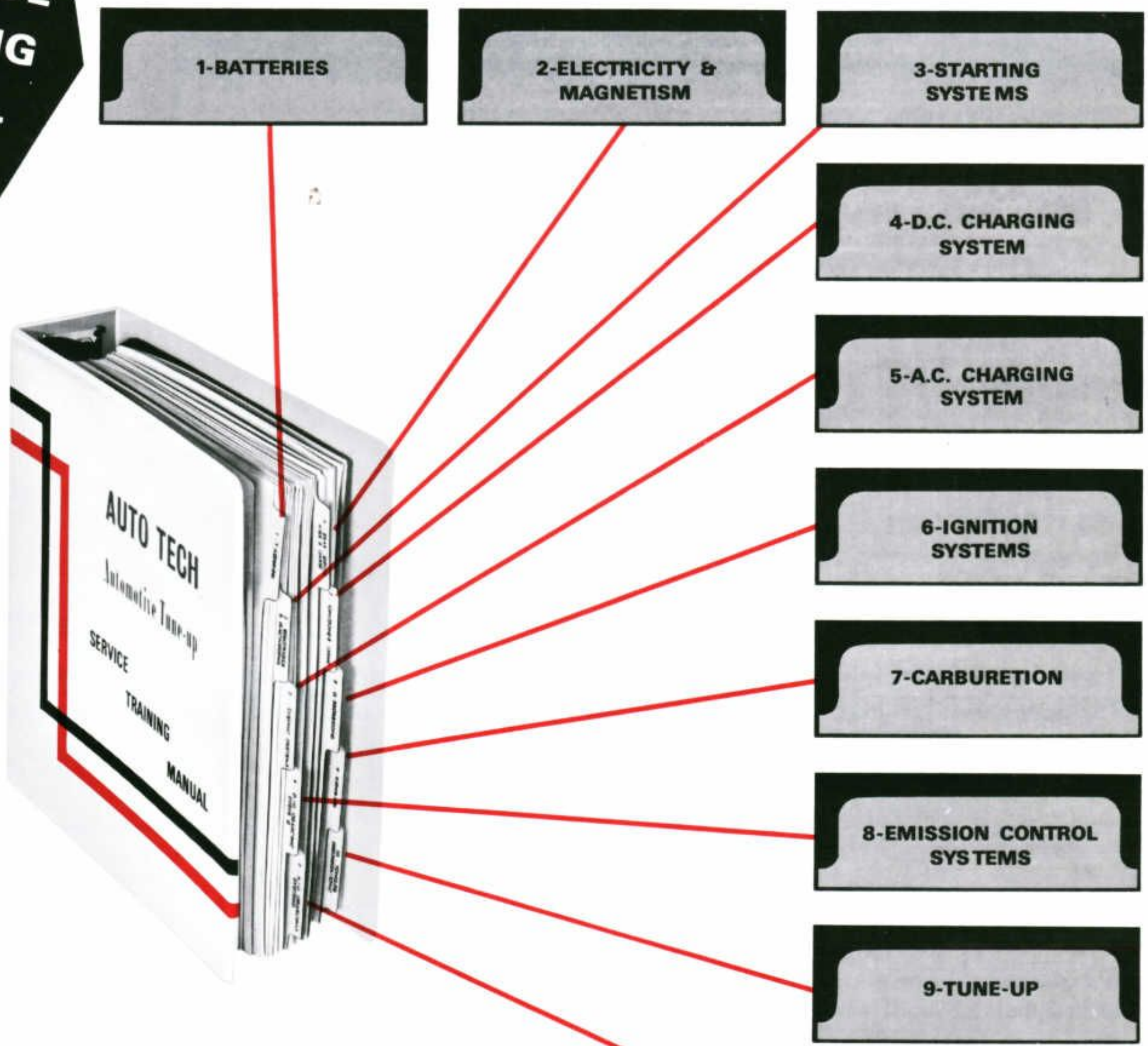


WHAT DOES AUTO TECH PROVIDE?

A UNIQUE TRAINING MANUAL



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PLEASE PRINT OR TYPE

ENROLLEE

Name

Home Address

City State Zip Code

Social Security Number Job Description

Enrollee's Signature

TEAR HERE

EMPLOYED BY

Company Name

Address

City State Zip Code

Type of Business

Employer's Signature (optional)

NOTE: All materials will be sent to home addresses unless otherwise indicated below.

Address

City State Zip Code

Important: Be sure to enclose check with this form in the amount of $20 payable to Autolite Technical Service Institute. (Michigan Enrollees must add 4% sales tax)

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