TM 10-6140-200-14

TECHNICAL MANUAL

INSTALLATION, USE, MAINTENANCE,
AND REPAIR
OF

INDUSTRIAL MOTIVE POWER STORAGE BATTERIES FOR MATERIALS HANDLING EQUIPMENT

HEADQUARTERS, DEPARTMENT OF THE ARMY

DECEMBER 1977

NOTE

THE FORMAT OF THIS CONTRACTOR PREPARED TECHNICAL MANUAL IS NOT IN ACCORDANCE WITH ESTABLISHED DEPARTMENT OF THE ARMY SPECIFICATIONS, BECAUSE THE ORIGINAL AUTHENTICATED MANUAL (DATED 29 JULY 1954) WAS REVISED BY THE MANUFACTURER. THIS REVISION IS AUTHENTICATED AS AN OFFICIAL DA PUBLICATION AND SUPERSEDES THE 1954 EDITION. THIS SUPPLEMENTAL DATA PROVIDES THE ESSENTIAL INSTRUCTIONS REQUIRED TO PERFORM MAINTENANCE OF LEAD-ACID STORAGE BATTERIES USED TO POWER ELECTRICAL MATERIAL HANDLING EQUIPMENT.

WARNING

REFER TO CHAPTER 4 FOR HEALTH AND SAFETY HAZARDS

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DEPARTMENT OF THE ARMY
WASHINGTON, DC, *20, December 1977*

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*This manual supersedes TM 10-1690A, 29 July 1954, including all changes.

REPORTING OF ERRORS

You can improve this manual by recommending improvements using DA Form 2028 (Recommended Changes to Publications and Blank Forms) or DA Form 2028-2 (Test) located in the back of the manual and mail the form direct to Commander, US Army Tank-Automotive Materiel Readiness Command, ATTN: DRSTA-MSP, Warren, MI 48090. A reply will be furnished direct to you.

CHAPTER 1

INTRODUCTION

Section I. GENERAL

1-1. Scope

This manual contains information concerning the theory, construction, installation, use, maintenance, repair and hazards of lead-acid storage batteries used to power electric industrial trucks, warehouse tractors and cranes.

1-2. Forms, Records and Reports

The following forms will be used by personnel responsible for the receipt, storage, operation, charging and maintenance of lead-acid storage batteries.

a. Report of Improper Shipment: SF Form 363. Report of Improper Shipment must be filled out and forwarded to: United States Army Tank-Automotive Command, Directorate of Product Assurance, Warren, MI 48090.

b. Unsatisfactory Material Report: SF Form 361. Unsatisfactory Material Report must be filled out and forwarded to: United States Army Tank-Automotive Command, Directorate of Product Assurance, Warren, MI 48090, whenever common deficiencies, damages or malfunctions are noted in new batteries.

c. Maintenance Work Request: DA Form 2407. Maintenance Work Request is used to report Equipment Improvement Recommendations (EIR's) in design and maintenance of equipment, safety and efficiency of operation, unsatisfactory design, defects, failures or malfunctions and defects traceable to the absence or inadequacy of spare parts and related equipment. DA Form 2407 should be prepared IAW TM 38-750 and forwarded to: United States Army Tank-Automotive Materiel Readiness Command, ATTN: DRSTA-MVM, Warren, MI 48090.

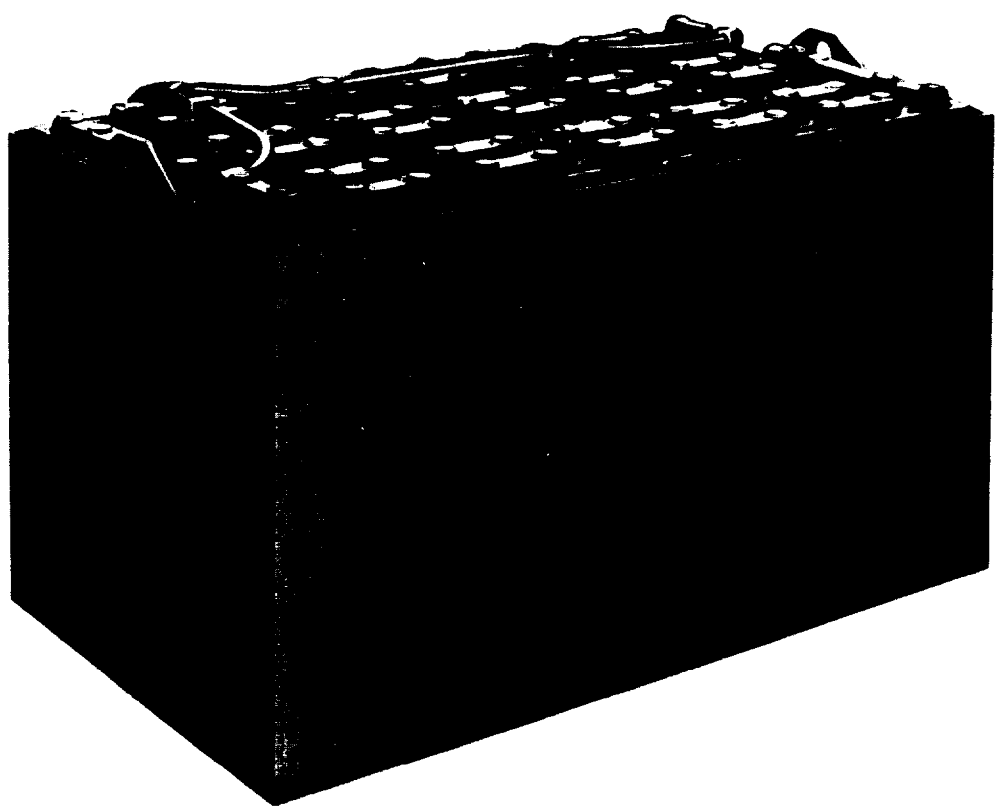

Figure 1-1. Lead-acid storage battery for motive-power service

d. Monthly Storage Battery Record: DA Form 10-161. Monthly Storage Battery Record is to be used to record the services performed on motive power batteries. This record should be prepared and maintained by the using organization and should accompany the battery at all times.

Section II. DEFINITIONS

1-3. Standards

a. Those definitions referenced throughout this manual generally agree with accepted industry standards. For a more complete listing of "Definitions for Lead-Acid Industrial Storage Batteries" see NEMA Standards publication No. IB 1-1971.

b. Copies of NEMA standards may be obtained at nominal cost by writing to: National Electrical Manufacturers Association, Department of Engineering and Safety Regulations, 2101 L Street, N.W. Washington, D.C. 20037.

Section III. DESCRIPTION AND CONSTRUCTION

1-4. Battery

Motive power lead-acid batteries for electric powered industrial trucks, tractors and cranes typically consist of 6, 12, 16 or 18 cells, a steel tray into which the cells are assembled, a battery terminal connector and other components necessary to secure and protect the cells and provide the necessary electrical interconnections. A typical battery is shown in Figure 1-1.

a. Battery Identification and Data. The essential information, necessary for proper care of an industrial motive power battery, appears on the battery either stamped into one of the intercell connectors or on a name plate affixed to the tray. This information usually includes the manufacturers name and model, number of plates per cell, battery capacity, battery voltage, serial number, suggested charging rate and full charge specific gravity of electrolyte.

(1) If vital information is missing, or is no longer legible, such information can be obtained from the manufacturer's manual or by contacting their nearest representative.

(2) Some manufacturers list, as a part of the model or type designation, the rated ampere-hour capacity of a single positive plate, such as "X75." As an alternate means of determining rated battery capacity this number should be multiplied by the total number of positive plates in one cell. To find the number of positive plates in a cell, subtract one from the total number of plates and divide by two. To find the capacity of a battery designated "X75-19," therefore: 19-1=18; 18÷2=9; 9 x 75=675 A.H. battery capacity.

b. Cell Arrangement. The individual cells, which contain the energy generating components of the battery, may be arranged slightly differently for various types of batteries. The typical cell arrangement for 12 volt batteries (6 cells) is a single row of 6 cells; for 24 volts (12 cells) it is either two rows of 6 cells each or three rows of 4 cells each; for 32 volts (16 cells) it is four rows of 4 cells each; and for 36 volts (18 cells) it is three rows of 6 cells each. The cells of all motive power batteries are, however, always connected in series to produce the required voltage. Cell and battery capacity, which is the available ampere-hours or watt-hours, is a function of the total number and size of plates within each cell. Voltage, though, is the same for all cells regardless of size. Each lead-acid cell yields a nominal 2 volts.

c. Connector Arrangement. Connections between cells are made by intercell connectors which may be lead coated copper straps or cast of solid lead. These connections are always welded, in proper sequence, by the application of heat to the terminals of the cells. Total energy from the battery is drawn off by terminal cables which extend beyond the steel tray wall and are in turn permanently joined to the battery terminal connector.

d. Physical Characteristics. Those characteristics which are of general interest and, in effect, constitute "specifications" are shown in Military Standards MS-15367 (Conventional Design) and MS-16974 (Explosion Proof Design Intended For Use In Hazardous Locations).

1-5. Cell

a. This is the basic unit of any battery. A typical cell is shown in Figure 1-2. It is a galvanic cell which produces electrical energy when connected to an electrical load and, after being discharged, may be restored to its original fully charged condition. It has a nominal voltage of 2 volts and consists of an element, from which the energy is derived, and electrolyte, both of which are contained by an impact resistant, molded rubber or plastic jar. The element is prevented from contacting the bottom of the

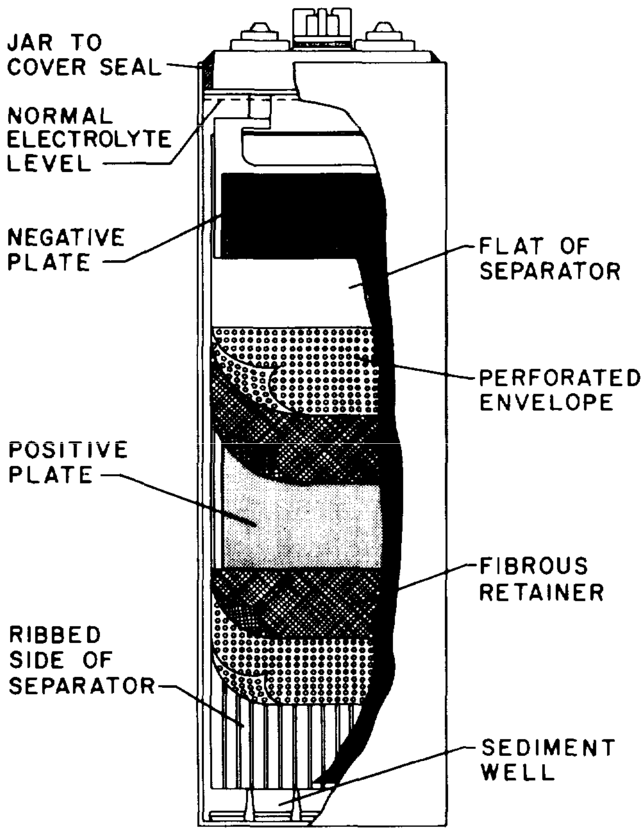

Figure 1-2. Battery cell cutaway view

jar by means of a high impact bridge which consists of a series of support ribs. These ribs provide sediment space below the bottom of the element to accommodate particles of active material, shed by the positive plates during normal operation of the battery.

b. The top of each cell is fitted with a molded rubber or plastic cover sealed to the jar at the edges. A vent or filler cap is located in the center of the cover. This permits the escape of hydrogen and oxygen while the cells are gassing and, when removed, provides an opening through which water may be added to the cell. The positive and negative terminal posts, which are part of the element, fit through openings in the cover. Cells prior to being connected together are so placed that the positive terminal of one cell is adjacent to the negative terminal of the next. This permits a series connection. On some batteries the cell covers are tightened to the terminal posts by seal nuts and gaskets. On others, lead bushings are molded into the covers and welded to the terminal posts. Both methods prevent leakage of acid from the area around the terminal post.

c. Element. The element of the cell consists of one group each of positive and negative plates meshed together. The plates are insulated from each other by separators which are inserted between all plates. A plastic element protector is positioned on top of the separators which prevents mechanical damage to the element and aids in preventing electrical shorts which occur when particles of active material bridge the space between plates. Terminal posts are welded to each group and are used to electrically connect one cell to another. A typical element is shown in Figure 1-3.

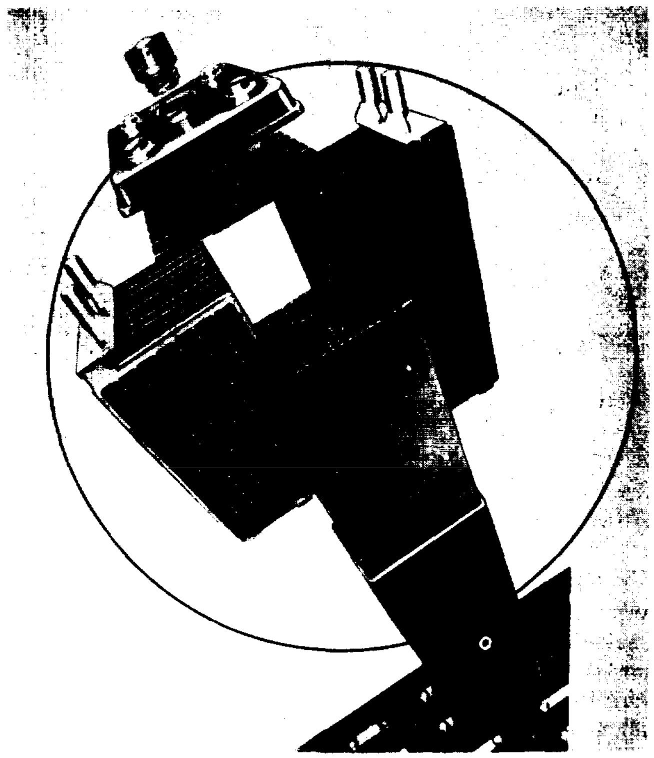

Figure 1-3. Components of a cell

d. Group. This is an assembly of plates of like polarity connected in parallel by welding to a common strap or busbar. A cell must contain one positive and one negative group. The negative group always has one more plate than the positive group. One or more terminal posts are welded to each.

e. Plates. The electrodes or plates are either positive or negative and consist of a cast lead alloy grid and active material. The grid provides support to the active material and becomes the primary electrical conductor. The active materials result from the addition of chemicals to lead oxides which are converted, by electro-chemical processing, to lead dioxide in the positive and sponge lead in the negative. Although negative plates made by all industrial lead-acid battery manufacturers are pasted and essentially similar, the positive plates in common use may be either tubular or pasted type.

(1) *Tubular type.* The grid of the tubular plate consists of a series of cast lead rods connected at the top.

These vertical rods become the conducting cores of a like number of porous, tubular, glass or plastic retainers which contain the active material. Each tube is sealed at the top and bottom after filling to prevent the loss of active material. A typical tubular positive plate is shown in Figure 1-4.

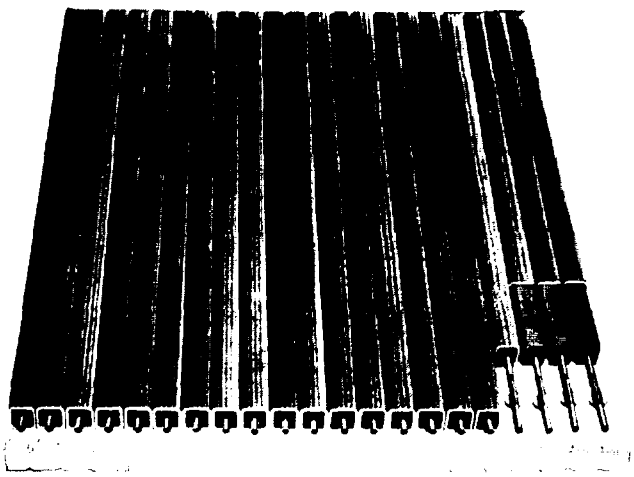

Figure 1-4. Tubular type positive plate

(2) *Pasted type.* The grid of the pasted plate consists of horizontal and vertical or diagonal cast lead conducting members within a rectangular cast frame. A slurry of active material is pasted or squeezed into the voids and the surfaces are then covered by porous glass and plastic retainers to prevent the loss of active material. A typical pasted positive plate is shown in Figure 1-5.

f. Electrolyte. The element within the jar is immersed in an electrolyte, which is a solution of sulfuric acid and "pure" water. This permits the necessary chemical reaction to occur and provides a conducting medium in which the flow of electric current takes place. The electrolyte in a fully charged cell normally has a specific gravity of between 1.275 and 1.395 at 77 degrees F. As a cell discharges, the specific gravity decreases. Measurement of this specific gravity. by means of a hydrometer, indicates the state of charge of a cell. To save time, in determining this state of charge for the battery, a pilot cell or cells may be chosen. This is a selected cell(s) whose condition is assumed to be representative of the condition of the entire battery.

g. Separators. Separators are made from either micro-

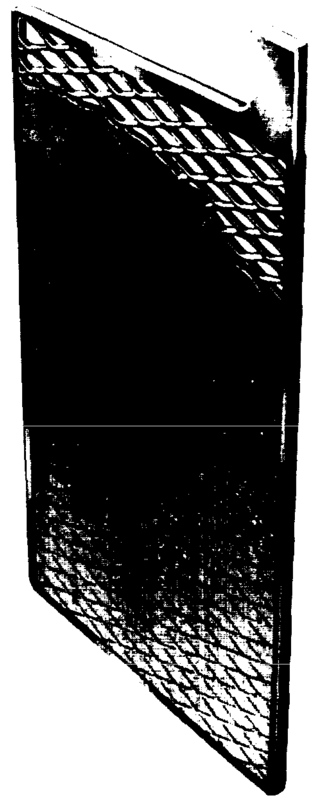

Figure 1-5. Pasted type positive plate

porous rubber or plastic, both of which are resistant to heat and acid. Separators provide mechanical and electrical insulation between positive and negative plates but are porous enough to permit passage of electrolyte. The grooved or ribbed side of the separator is placed toward the positive plate to allow a free flow of electrolyte to the active material. The flat side faces the negative plate to contain the sponge lead.

h. Positive Plate Retainers. Tubular type plate retainers are made from porous glass or plastic which is woven or shaped into the form of a round or square tube. A plate is composed of a number of such tubes which are filled with active material in those areas surrounding the conducting cores of the grid. Pasted type plate retainers are added after pasting, typically by wrapping the plate first with fibrous type glass tape or mats and then by a perforated plastic envelope complete with bottom boot or by other suitable filtering systems. All types of retainers act to prevent the escape of positive active material during normal use. Retainers are not needed on negative plates.

Section IV. PRINCIPLES OF OPERATION

1-6. Fundamentals of Cycling

A cycle is a discharge followed by a charge. During the charge the electrical energy supplied by the charger causes an electrochemical reaction within the battery. This restores the active materials to a fully charged condition.

a. The Fully Charged Cell or Battery. The positive and negative plates, or electrodes, are separated from each other and immersed in electrolyte. In the fully charged condition the active material of the positive plate is lead dioxide and that of the negative plate is sponge lead as indicated in Figure 1-6. The electrolyte is a solution of sulfuric acid and water that normally varies in specific gravity from 1.275 to 1.295. The combination produces a voltage of approximately 2 volts on open circuit. This voltage potential results from the fundamental characteristic of a storage battery which dictates that when two electrodes of dissimilar metals are immersed in suitable electrolyte, and a circuit is closed between the two, electrons begin to flow. A fully charged cell should normally have an on-charge voltage of from 2.45 to 2.70 volts when charging at the finish rate.

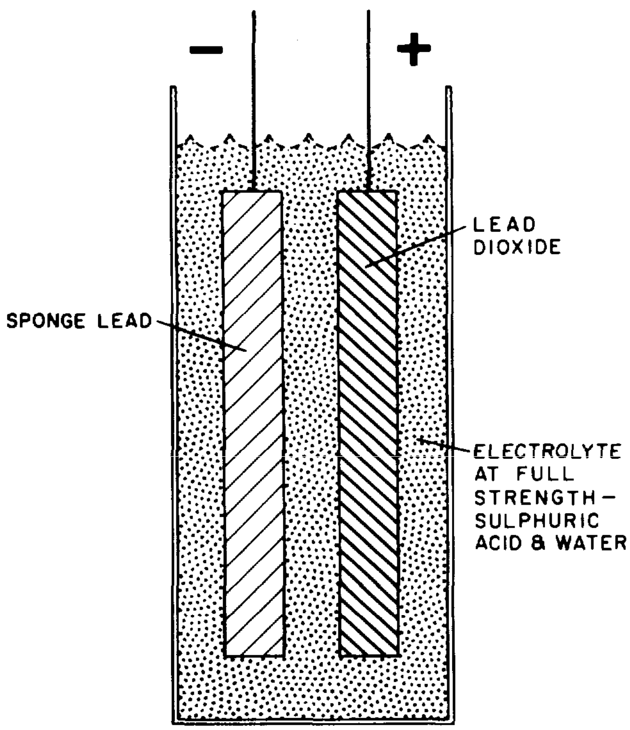

Figure 1-6. Fully charged cell

b. The Discharging Cell or Battery. While a battery is being discharged or used, lead dioxide and sponge lead combine with sulfuric acid to form lead sulfate within both plates as shown in Figure 1-7. This action causes the specific gravity of the electrolyte to decrease. As the discharge progresses, individual cell and battery voltage declines, generally in direct proportion to the rate of discharge.

c. The Discharged Cell or Battery. As the depth of discharge increases more sulphuric acid is removed from the electrolyte so the specific gravity decreases and may drop below 1.100 as it approaches the specific gravity of water. Almost all of the active material of both positive and negative plates is converted to lead sulfate as illustrated by Figure 1-8, and an effective electrochemical reaction is no longer possible. At this point the battery has reached its discharge limit.

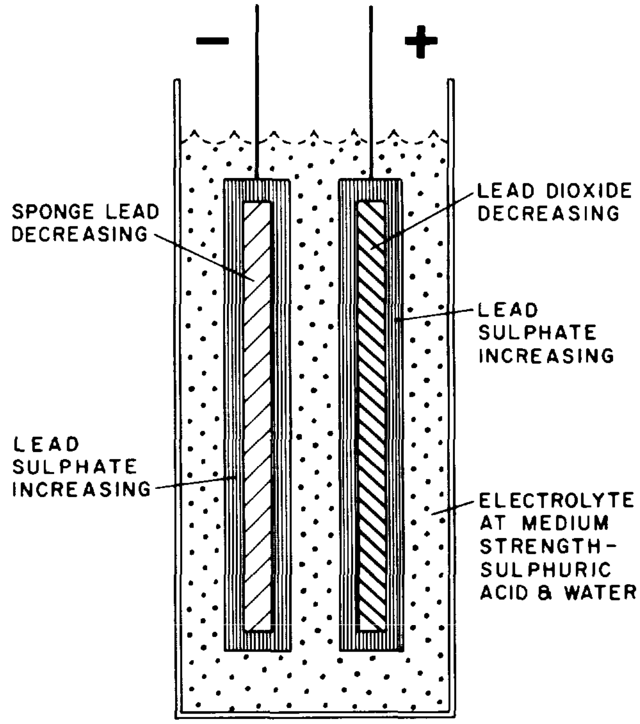

Figure 1-7. Discharging cell

d. The Charging Cell or Battery. The charging action begins when the terminals of the battery are connected to an external source of direct current. The electrochemical reaction is reversed and the positive plates, negative plates, and electrolyte start returning to their original charged condition as indicated by Figure 1-9. Charging causes the battery voltage to rise as active materials are restored. A cell being charged may have a voltage of from 2.12 to 2.70 volts depending upon charging rate and time.

e. General. From the above it can be seen that storage batteries do not actually store electrical energy. Instead, they accept the electrical energy delivered to them during charging and convert it into chemical energy. During discharging, this chemical energy is reconverted into electrical energy to be used as needed.

f. As an operating guide, to obtain the best performance and life from a motive power storage battery, the depth of discharge should not regularly exceed 80% of the battery's rated capacity in ampere-hours. It should be charged after each shift of use or whenever the specific gravity of the electrolyte falls below 1.240. It is very important that proper ventilation be provided during charging to make certain that (1) the hydrogen gas, given off toward the end of the charging process, is dissipated

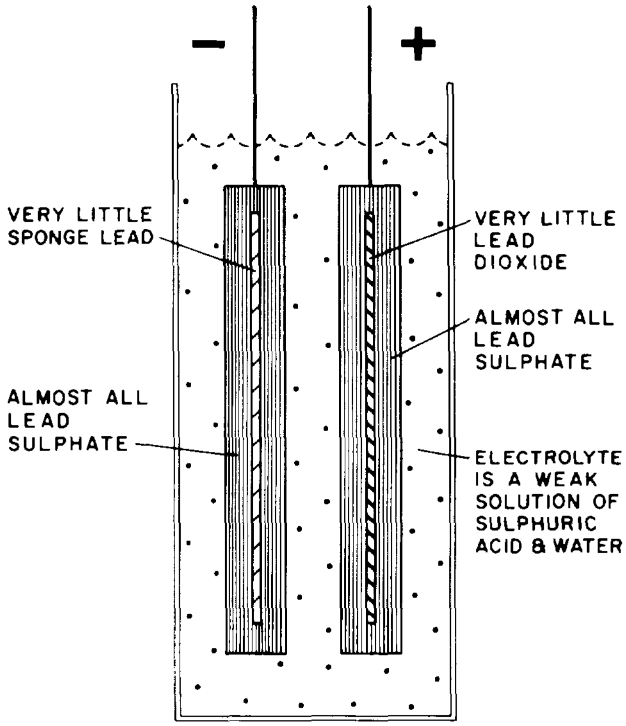

Figure 1-8. Discharged cell

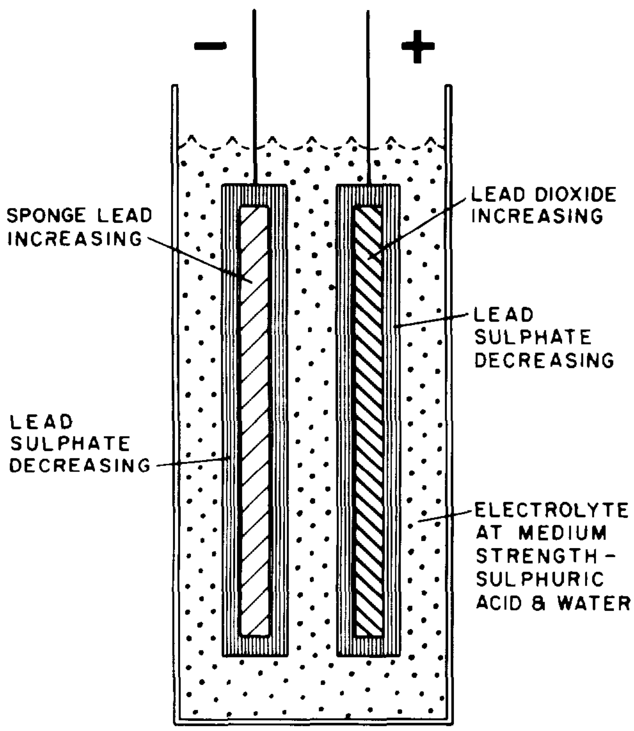

Figure 1-9. Charging cell

(see Chapter 4), and (2) that individual cell electrolyte temperatures, during normal operations, do not exceed 110 degrees F.

1-7. Ampere-Hour Capacity

a. The electrical capability of a storage battery is usually expressed in ampere-hours. The ampere-hour capacity is the number of ampere-hours which can be delivered under specified conditions of temperature, rate of discharge and final voltage. Basically, ampere-hours are determined by multiplying the number of amperes which the battery will deliver by the number of hours during which the current is flowing. Total cell or battery capacity then is determined by the size and number of plates which make up the element. Due to the variety of job requirements batteries are produced with many different sizes of cells.

b. Battery capacities available for each of the commonly used battery sizes, at each of the required voltages, and the utilization of these batteries, by type of equipment, are detailed by Military Standard MS-15367.

1-8. Voltage

With reference specifically to storage batteries, many "voltage" conditions have been recognized. The most important of these are:

a. Open Circuit Voltage. This is the voltage of a cell or battery at the terminals, when no current is flowing. The nominal open circuit voltage of an individual fully charged cell is 2 volts. This is true regardless of cell size. The voltage of an 18 cell lead-acid battery is stated, therefore, as 36 volts.

b. Initial Voltage. The initial voltage of a cell or battery is the closed circuit voltage at the beginning of a discharge. It is usually taken after current has been flowing for a sufficient period of time for the rate of change of the voltage to become practically constant. This usually occurs within a matter of minutes.

c. Average Voltage. The average voltage of the cell or battery is the average value of the voltage during the period of charge or discharge.

d. Final Voltage. The final or cut-off voltage of a cell or battery is the prescribed voltage at which the discharge is considered complete. It is usually chosen so that the useful capacity of the battery is realized without subjecting it to harmful overdischarging. Final voltage will vary with the rate of discharge, cell temperature and the type of service, but for motive power applications it is considered to be 1.70 volts per cell.

e. Voltage conditions b, c, and d above are monitored when conducting test discharges. They are essentially academic as regards normal battery usage in a truck.

1-9. Rated Capacity

The rated capacity of a storage battery is the number of ampere-hours or watt-hours which it is capable of delivering when fully charged and under specified conditions of temperature, rate of discharge, final voltage and specific gravity. United States industry standards for motive power batteries always specify this to be at the 6 hour rate of discharge. The total capacity available from a battery is greatest at low rates of discharge over a long period of time. Discharging at high current rates reduces the total ampere-hours or watt-hours available.

1-10. Sulfation

This occurs when conditions within the cell cause sufficient accumulation of abnormal lead sulfate at both the positive and negative plates to permanently effect the normal chemical reactions. Habitual overdischarging below final voltage, prolonged operation in an undercharged condition and extended stand periods while in a discharged state are major causes of sulfation. A servicing schedule should be followed to provide frequent monitoring and adequate charging. See Chapter 3, Section 1 for methods of restoring a sulfated battery.

1-11. Operating Cycle

An operating cycle of a storage battery is the discharge during use and subsequent charge to restore its initial condition.

1-12. Service Life

The service life of a storage battery is the period during which it provides useful power while being discharged. It is usually expressed as the time period, or number of cycles, which elapses before the ampere-hour capacity falls below 80% of its rated value. To obtain maximum service life it is recommended that a battery be restricted to one full cycle per 24 hour day or fewer than 300 cycles per year. Other factors which most often adversely influence service life are:

a. Abnormally high or low electrolyte temperatures.
b. Frequent overdischarging.
c. Failure to add water regularly.
d. Frequent overcharging.
e. Poor, or high, resistance, connections or contacts.

1-13. Effect of Temperature

The normal operating characteristics of a storage battery are modified by unusually low or high cell temperatures.

a. Low Temperatures. Available battery power is reduced by low temperature because electrolyte viscosity and resistance is increased and diffusion throughout the pores of the active material is retarded. For example, a fully charged battery (1.275 to 1.295 specific gravity at 77 degrees F.), when its electrolyte temperature is about 32 degrees F., will deliver only 75% of the capacity which would be available at normal room temperature. This drops to 40% at 0 degreee F. The electrolyte could freeze if a discharged battery was exposed to very cold temperatures for several hours. See Table 1-1 for freezing points of various electrolyte concentrations.

Table 1-1. Freezing points of various electrolyte concentrations

State of Charge-Approx. (Percent)	Standard Specific Gravity 1.275 to 1.295 Fully Charged	Freezing Point (Degrees Fahrenheit)
100	1.280	-95
75	1.250	-62
50	1.220	-31
25	1.160	+1
10	1.130	+10

b. In addition to the discharge related problems, the charge acceptance of a lead-acid battery is impaired when electrolyte temperatures drop below 60 degrees F. As a result, batteries should always be kept fully charged, especially in cold weather. They should be heated, even during operation or storage, if exposure is severe enough to cause the temperature of the electrolyte to approach 32 degrees F.

c. High Temperatures. Although high temperatures, up to 110 degrees F., do not cause a reduction in available capacity, battery operation is adversely effected. Because most chemical reactions are accelerated at high temperatures, the rate of corrosion of the positive grid is increased and the active material is shed more rapidly. Even electrolyte temperatures above 90 degrees F. will cause some reduction in service life and should be avoided whenever possible. Cell temperatures should never be allowed to exceed 110 degrees F.

d. In the past it was believed that, when batteries were to be used in the tropics, the specific gravity of the electrolyte should be reduced to approximately 1.225. The battery industry no longer recommends such action. Any advantages which can be related to reducing the specific gravity are more than offset by the problems of (1) electrolyte adjustment, (2) identifying such reduction to all battery service personnel so the batteries are properly charged, (3) greater internal resistance, (4) reduced cell capacity and (5) assuring that the higher gravities are again restored if batteries are reshipped to a cold climate where freezing could be a problem.

CHAPTER 2

INSTALLATION, USE AND MAINTENANCE

Section I. PREPARATION FOR USE

2-1. Establishing Requirements

The number of batteries required for service depends primarily upon the number of 8-hour shifts in effect. Normally, for operation on a single shift basis, the minimum number of batteries required will be the same as the number of items of operating equipment and the batteries need not be removed from the truck for charging. For operation on a 2 or 3 shift basis, the minimum number of batteries required will be twice the number of items of operating equipment and it will, therefore, be necessary to exchange discharged batteries for charged batteries at the end of each work shift. Whenever possible, it is recommended that more than the minimum number of batteries be available for multiple shift operation. This will provide at least 8 hours of rest, after charging, as a cooling period. In an emergency any one battery can be used for two 8 hour shifts during a 24 hour period, but if this is repeated regularly it probably will cause high electrolyte temperatures and could seriously effect service life. Therefore, where 3 shift operation is normal, 3 batteries will be required per item of equipment.

2-2. Unpacking Upon Receipt

a. It is important first to examine the exterior of the packing for wet spots on bottom or sides which may indicate leaking jars which could have been broken in shipment. Inspect also for physical damage to battery package which could mean that the battery was effected as well. Report any damage to the superior officer in charge.

b. Make certain that the package is right side up with skid mounts resting firmly on floor.

c. Use a forklift truck or crane of sufficient capacity to remove the packaged battery from the truck or freight car. If a crane is employed be sure the sling is secured against the bottom of the skid and not around the skid mounts.

d. Move the crated battery to the uncrating area and remove packaging, including any wrapping or other protection provided to the battery terminal cable connectors.

e. Inspect battery and report any damage to the superior officer in charge.

f. A properly insulated lifting beam of adequate capacity should be used to lift the battery, by means of an overhead hoist, from the battery skid.

2-3. Handling Batteries

At all times, when lifting batteries, use a device which exerts a vertical pull on the lifting eye or tab. If a chain must be used, it should be in combination with a lifting beam with provision for adjusting lifting hook centers to the exact length of the tray. Any method of lifting which tends to "squeeze" or "stretch" the battery tray may distort it and could damage jars or disturb cell seals. A piece of rubber sheet, or other insulating material, temporarily laid on the battery while lifting, will prevent any possible short circuits from chains or hooks. As an additional precaution against accidental shorting, the lifting beam hooks should be electrically insulated from each other. A typical lifting beam in use is shown in Figure 2-1.

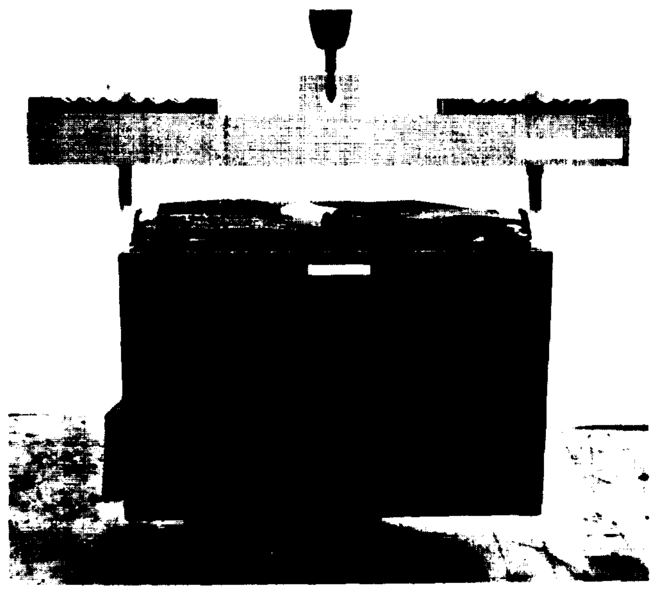

Figure 2-1. Lifting beam and battery

2-4. Preparing Batteries for Use

Batteries are shipped either "charged and dry" or "charged and wet." They vary considerably, of course, in their preparation needs.

a. Charged and Dry Batteries. Charged and dry batteries are shipped with plates which have been charged and dried, dry separators and without electrolyte in the cells. The vent openings of all cells are sealed and must remain so until the battery is being prepared for service. Charged and dry batteries must be properly activated. Prepare these batteries for use as follows:

(1) Remove all vent caps and destroy the sealing device, red tape or other material used to seal the vent cap holes. Make certain that all vent openings will permit free passage of gas.

(2) Fill each cell to the proper level with electrolyte conforming to Federal Specification O-S-801 (Battery Electrolyte Grade) and having a specific gravity 15 points (.015) lower than the designated fully charged specific gravity unless otherwise specified by the manufacturer. For example, if the fully charged specific gravity is to be 1.285 the filling acid should be 1.270. See Table 2-1 for Proportions of Sulfuric Acid and Water. Allow the cells to stand for at least several hours after filling, then adjust electrolyte levels so they are 1/4" to 3/8" below the bottom of the vent well or skirt. Replace the vent caps.

Table 2-1. Proportions of sulfuric acid and water

Specific Gravity Desired	Sulfuric Acid of 1.400 Specific Gravity	
	Parts Water Required	Parts Acid Required
1.375	.075	1
1.365	.11	1
1.355	.14	1
1.350	.16	1
1.340	.20	1
1.330	.24	1
1.325	.27	1
1.315	.31	1
1.310	.33	1
1.300	.38	1
1.290	.43	1
1.285	.46	1
1.280	.49	1
1.275	.53	1
1.270	.56	1
1.260	.63	1
1.255	.67	1
1.250	.70	1
1.245	.74	1
1.240	.78	1
1.230	.85	1
1.225	.905	1
1.220	.96	1
1.215	1.00	1
1.210	1.05	1
1.205	1.11	1
1.200	1.16	1

NOTE

The temperature of the filling electrolyte must not exceed 90 degrees F.

(3) Clean the cell tops if any electrolyte was spilled. Neutralize with soda solution (one pound of baking soda to one gallon of water), rinse with water and dry thoroughly.

(4) Give the battery a freshening charge (see Paragraph 2-10d). Be sure to continue the charge until the specific gravity remains constant for three consecutive hourly readings.

(5) Recheck electrolyte levels after gassing of electrolyte has stopped and take and record specific gravity reading, electrolyte temperature and open circuit voltage of each cell. If irregularities in specific gravity readings exist, they should be adjusted (see Paragraph 3-12). Adjust electrolyte levels so they are 1/8" to 1/4" below vent well skirt.

(6) Each battery manufacturer's instructions will provide additional detail. Follow these instructions to assure compliance with any special requirements.

b. Charged and Wet Batteries. Charged and wet batteries are shipped with cells filled and fully charged. Prepare these batteries for use as follows:

(1) Examine battery to see if electrolyte has been accidentally spilled. If so, clean and neutralize any spillage with a cloth which has been dipped in a soda solution. Rinse with clear water and dry battery thoroughly.

(2) Remove vent caps and check the electrolyte level in each cell. Take and record the specific gravity reading, electrolyte temperature and individual open circuit voltage of each cell. Note any irregularities.

(3) Check to make sure that all cells are properly connected and that terminal connections are tight. If there are irregularities in the electrolyte levels or specific gravity readings or if the battery has been in storage for more than 30 days, it should be given a freshening charge (see Paragraph 2-10d).

(4) Recheck electrolyte levels after charging and after gassing has stopped. Again take and record specific gravity readings and electrolyte temperatures. After the battery has been standing for at least one hour, also take and record the open circuit voltage of each cell. If irregularities in electrolyte specific gravity readings still exist, they should be adjusted as described in Paragraph 3-12.

Section II. CHARGING

2-5. General

a. Economical and dependable performance from a storage battery depends, to a great extent, upon proper charging. Faulty charging causes a decrease in battery service life and dissatisfaction with its performance. The selection of suitable charging equipment and methods is as important as the application of the correct battery. An electric truck installation is completely satisfactory only when the truck, battery and charger operate as a smooth-functioning team. This text on chargers is for general information and guidance only. Because of the complexities and many types of chargers available, it would be virtually impossible to furnish complete operating characteristics for all types. Therefore, if specific data is required on a particular type of charger, contact the nearest manufacturer's representative.

b. When preparing a battery to be charged, make certain that all points of contact between the charger and the battery are clean to assure good conductivity. Also make certain that the positive terminal of the battery is connected to the positive terminal of the charger and, correspondingly, negative of battery to negative of charger.

NOTE

Permanent damage to the battery or charger may result if the battery is connected incorrectly.

2-6. Charging Principles

a. Charging, as applied to a storage battery, is the conversion of electrical energy into chemical energy within the cell or battery. This restores the active materials and is accomplished by maintaining a unidirectional current to the battery in the opposite direction to that during discharge. When a cell or battery is said to be charged it is understood to mean fully charged. The type of battery, service condition, time available for charging and the variation in battery voltages will strongly influence which charging method is best for a particular situation. Normally lead-acid batteries are recharged in 8 hours following a full discharge. However, they can be recharged within other time periods when desirable. A deeply discharged battery will absorb high current rates when the voltage is low. As the charge progresses, the voltage steadily increases until it reaches gassing voltage which is approximately 2.37 volts per cell at 77 degrees F. It is at this point that the battery chargers normally reduce charging rates automatically when the battery reaches gassing voltage and taper to finishing rates which are used to complete the charge. The battery is fully charged when nearly all of the active material has been converted and when the specific gravity of the electrolyte and cell voltage have reached their maximum or constant values (corrected for temperature), as indicated by similar readings over a two or three hour period.

b. Batteries used in motive power applications are cycled. They are either being charged or discharged. In most such circumstances batteries are charged after each shift of use. As a result they are cycled many times during their lifetime. Incorrect charging for only a few cycles will do little harm, but if this should be repeated day after day, the battery's service life will be seriously shortened.

2-7. Charging Rates

a. Proper charging means charging the battery sufficiently without overcharging, overheating or excessive gassing. To accomplish this the charge is usually started at high amperage which is known as the starting rate. Later during the charge this rate of current flow is reduced to what is called the finishing rate. Manufacturers generally suggest that this finishing rate should not exceed 5 amperes per 100 ampere-hours of rated battery capacity. The starting rate may be as much as four to five times higher.

b. Lead-acid batteries should be charged for a sufficient length of time and at a rate which will put back into the battery the same number of ampere-hours removed on discharge plus an approximately 10% additional which is an acceptable, and in fact desirable, overcharge. The specific amount of overcharge depends upon the temperature, age and history of the battery. In general it is more harmful to excessively overcharge an older battery, or one which is operating at high temperature, than a new battery or one operating consistently at room temperature. Any charge rate is permissible which does not produce excessive gassing or cell temperatures greater than 110 degrees F.

2-8. Control of Gassing

a. Gassing is the evolution of gases from one or more of the electrodes during electrolysis. It is a natural phenomenon which takes place when a battery on charge can no longer accept all of the current being applied to it. Gassing is evidenced by bubbling of the electrolyte. The gases liberated are oxygen, evolved at the positive plates, and hydrogen, evolved at the negatives.

b. The point at which significant gassing begins is determined by voltage, but the amount of gas depends upon the portion of the charging current that is not being absorbed by the battery. Normally, noticeable gassing will begin when the voltage exceeds 2.30 volts per cell. At

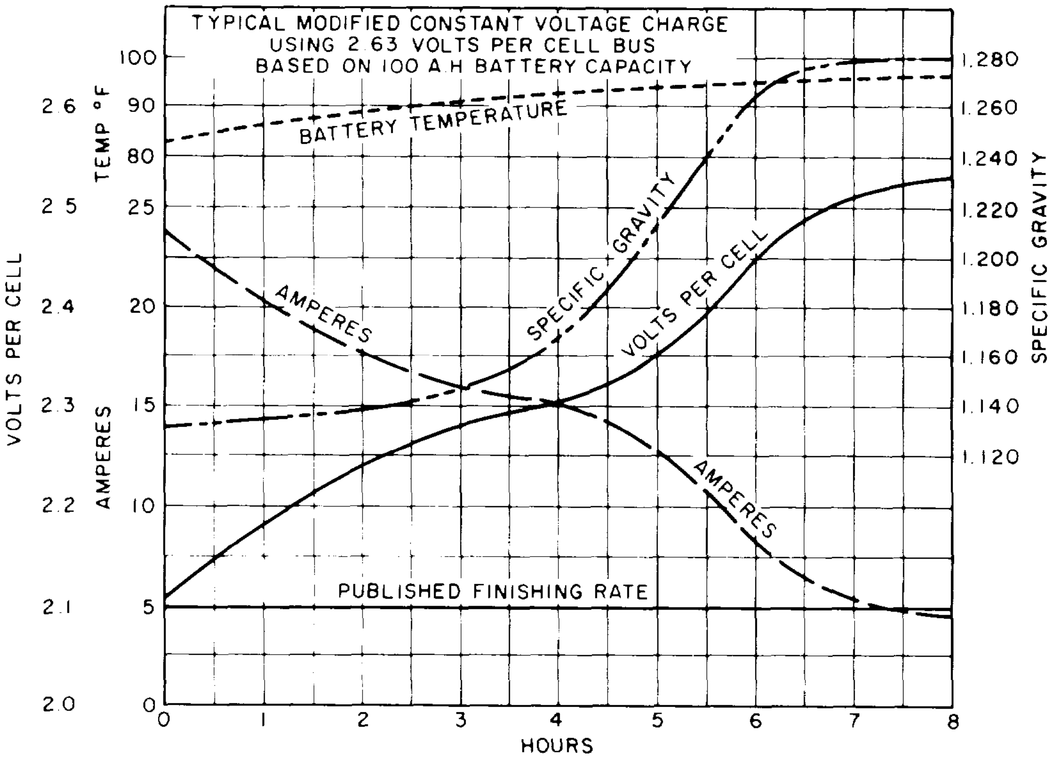

Figure 2-2. Typical modified constant voltage charge

2.40 volts per cell gassing will be normal and at 2.50 it will be rapid. The amperage at which gassing becomes excessive depends primarily upon the state of charge and electrolyte temperatures. As the battery approaches full charge, it is necessary, therefore, to reduce the charging rate to a point at which excessive gassing is prevented. This safe rate is the finishing rate. When proper charging equipment is used the tapering of the charging current to the finishing rate is achieved automatically. Manufacturers instructions will normally prescribe the desired charging rates.

2-9. Charging Methods and Equipment

a. The modern storage battery, used with a properly designed, modern, automatic charger, needs only normal water additions, occasional cleaning, and regular checking of both charger adjustment and battery condition to provide long, dependable service.

b. There are three recommended methods for the normal charging of motive power batteries:

(1) *Modified Constant Voltage (potential) Method.* The modified constant voltage method, in which the tapering of the charging rate is accomplished gradually, requires a source of direct current with a constant bus voltage of approximately 2.63 volts for each cell. This is for an 8 hour charge. Proper series resistance in the output circuit inherently provides the correct starting rate and assures that this will automatically be reduced, as the charge progresses, to the recommended finish rate. The constant voltage source may be either a motor driven generator or rectifier. The characteristics of a typical modified constant voltage charge is illustrated by Figure 2-2.

(2) *Two-Rate Method.* The two-rate method, in which the change from starting rate to finishing rate is accomplished by a sudden drop or step, requires a constant current source, usually a rectifier. The starting rate is allowed to continue until the battery reaches the gassing point of approximately 2.37 volts per cell, corrected to 77 degrees F. When this voltage is reached, a voltage sensitive relay operates to place additional resistance in series with the battery to reduce the charge rate to the recommended finish rate. A timer is then automatically set to control the interval of finishing charge. A typical two-rate charge is shown in Figure 2-3.

(3) *Taper Method.* The taper method can be used with either generator or rectifier type equipment. The charger is designed to provide the correct charge rate during a constantly tapering charge. This is accomplished by coordinating the rising battery voltage with the design characteristics of the charger. The shape of the current taper curve will vary with different types of equipment but the result is essentially the same. Solid state chargers are available which deliver as much current as the battery

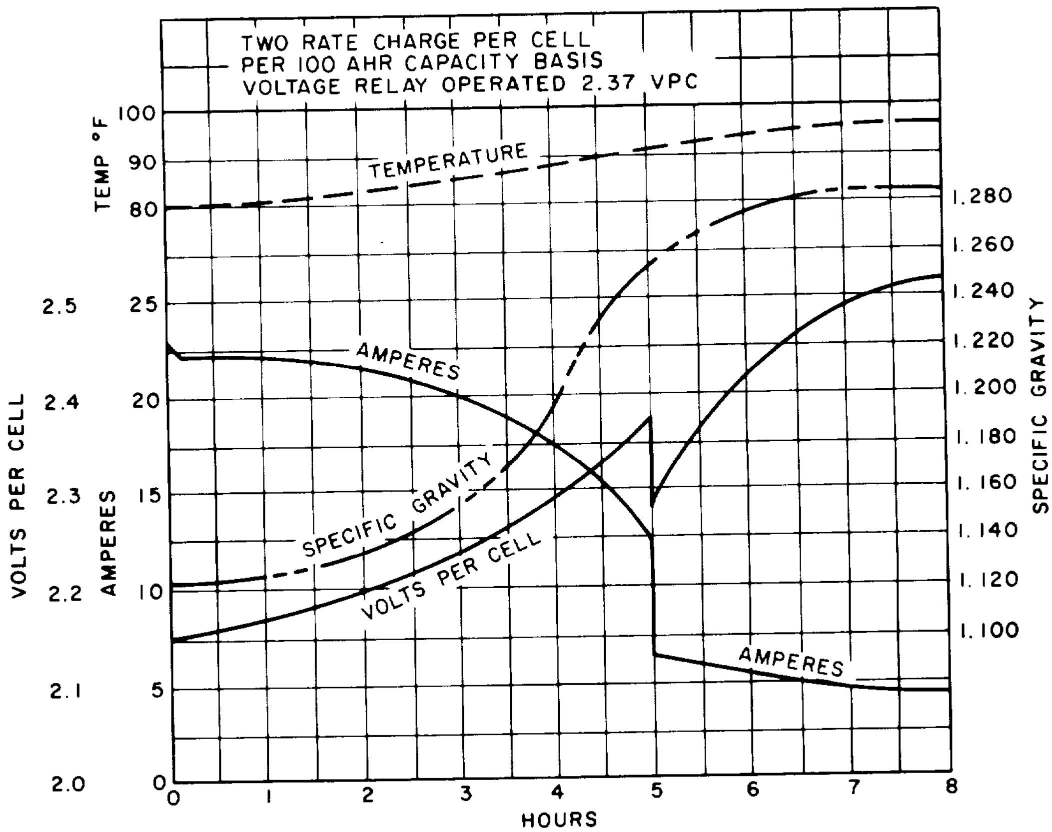

Figure 2-3. Two rate charge

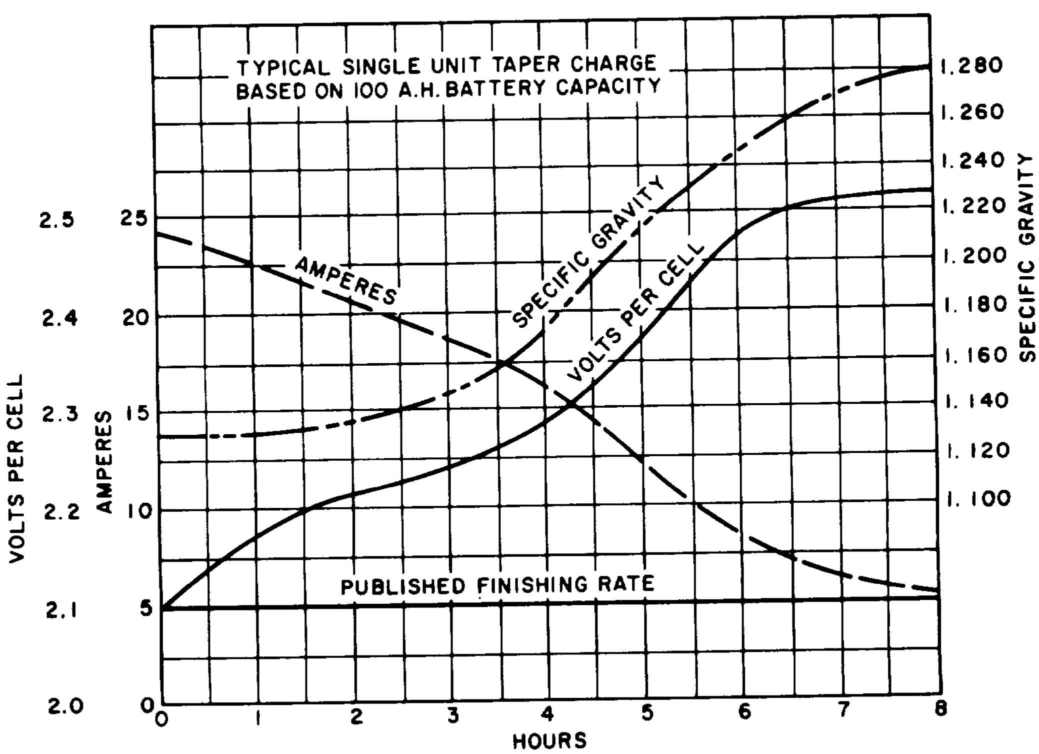

Figure 2-4. Typical single unit taper charge

can accept, up to maximum charger output, and then taper the input sharply, when cells begin to gas, to keep finish rates low. These chargers do not require adjustment. A typical taper charge is illustrated by Figure 2-4.

2-10. Types of Charge

a. Normal charge. The three generally recommended types of normal or routine charges, following a deep discharge, are: (1) modified constant voltage charge, (2) two-rate charge, and (3) taper charge. Since these methods are described in Paragraph 2-9, "Charging Methods and Equipment," no further definition of normal charges will be included here.

b. Boost Charge (Quick Charge). A boost charge of a storage battery is a partial charge, usually at a high rate for a short period. Such a charge is given in an emergency when it is believed that the ampere-hour capacity of the battery may be less than normal and insufficient to complete a planned period of work. A boost charge may also be used when it is not possible to give a battery one of the recommended types of normal charge.

c. Equalizing Charge. An equalizing charge of a storage battery is a prolonged charge, usually at the finishing rate or less, to correct any inequalities of voltage or specific gravity which may have developed between cells during service. It consists of following a normal charge with an extended charge of 3 to 4 hours at a rate no higher than the finishing rate. In motive power applications, a battery should receive an equalizing charge only when differences in individual cell voltages or specific gravities indicate the need. Frequent and unnecessary equalizing charges cause excessive overcharge which can result in significant loss of battery life. Generally, equalizing charges will not be required if a battery is healthy and is cycled almost daily. On the other hand, if a battery is cycled no more than twice a week, a monthly equalizing charge will normally keep it in proper condition.

d. Freshening Charge. A freshening charge of a storage battery is a charge given to batteries in storage or during inactive periods to replace losses due to self-discharge and to assure that every cell is periodically brought to a fully charged state.

2-11. Charging Precautions

a. When connecting the battery to the charger always connect positive (+) to positive and negative (-) to negative terminals.

b. Always recharge the battery as soon as possible after discharging.

c. Keep vent caps tightly in place while the battery is being charged except when servicing the cell or when taking specific gravity or temperature readings.

d. Make sure that battery and charger voltages and ampere-hour ratings match when preparing to charge batteries.

e. Make certain that charging area is well ventilated.

f. Prohibit smoking and open flames in charging area.

g. Tools or other metal objects should never be allowed to contact intercell connectors.

h. Observe safety and health practices defined in Chapter 4, Section II. It is especially important, while preparing for charging, to take the following precautions:

(1) Wear protective gear provided.

(2) Use proper mechanical equipment to move or lift batteries.

(3) Provide acceptable fire extinguishing equipment.

(4) Know the location of the nearest source of fresh water for emergency use.

Section III. ROUTINE MAINTENANCE

2-12. General

The modern industrial battery is designed and built to give an average of 1500 cycles of charge and discharge during its life, depending upon the application and the operating environment. The exact length of the service life will depend, to a great extent, upon the care the battery receives. The following maintenance procedures, carried out at the proper time, will do much to prolong the life of the battery and provide efficient, satisfactory service.

2-13. Charger Adjustment

Make sure that the charger adjustment, for control of charging rates and cut-off are correct. This will assure that the batteries are properly charged with no excessive over-charge. Batteries that are overcharged regularly will need water more often, and cell temperatures usually will be higher than normal. If either condition is evident, adjust the charge rate downward, in those chargers which have provision for adjustment, so it is between a normal finish rate and one-half normal finish rate. Also check the adjustment of the ampere-hour meter and temperature-voltage relay, if either are used, as well as the timer switch.

2-14. Cleaning a Battery

a. Inspect the battery at least once each month to make certain terminal connections are tight. Remove dirt or electrolyte accumulation from the tops of the cells. Wash with clean water and dry. Using a solution of baking soda and water (one pound of baking soda to one gallon of water) neutralize any acid which may be collected at cell or battery terminals to keep them free from corrosion.

b. Use the solution until all fizzing stops. Work the solution under the connectors with a clean paint brush. To remove all traces of soda solution and loose dirt, rinse the battery down with clear water from a low pressure hose. Whenever the battery top is being cleaned or rinsed, vent caps must be tightly in place.

2-15. Adding Water

a. A certain amount of water loss in cells is normal and it should be replaced with "pure" tap water or distilled water. In some geographical areas tap water may contain chemicals or other impurities harmful to batteries. The NEMA recommendation for battery replacement water lists the following maximum allowable impurities (parts per million) :

Total solids	350 PPM
Chlorides as C1	25 PPM
Nitrates as NO_3	10 PPM
Iron as Fe	4 PPM

NOTE

Most industrial truck battery manufacturers provide water analysis service. A minimum sample of one quart is required.

b. Check the height of the electrolyte at least weekly and, if water is needed, add just enough to bring the electrolyte to proper level. Do not overfill. Never fill cells to above the bottom of the vent well or skirt. To avoid overfilling, it is best to add water at the end of a charge.

c. Water should be added often enough to prevent the electrolyte level from dropping below the perforated separator protector. Ideally a watering schedule should be established. This would assure adequate watering while taking into consideration those factors which control water consumption, such as (1) frequency of charging, (2) water storage capacity of the specific cell type and (3) age and condition of the battery.

2-16. Taking Hydrometer Reading

a. Squeeze the syringe bulb and then slowly release it, drawing into the cylinder or barrel just enough electrolyte to permit the hydrometer float to ride free. The float stem must not touch the side of the cylinder nor the top of the syringe. If the float stem touches the upper area of the syringe, too much electrolyte has been drawn up; if the float still rests on the bottom, too little electrolyte has been drawn up.

b. Read the hydrometer float scale with eye at same level as electrolyte (See Figure 2-5). The reading should be taken at the surface of the liquid disregarding any slight curvature. This reading will be the specific gravity of the electrolyte uncorrected for temperature. See Table 2-2 for correction factors.

c. Return all electrolyte to cell.

2-17. Record Keeping

Facilities with more than just a few batteries will find that records of battery cycles, maintenance and repair are indispensable for an effective battery maintenance program. In addition to those monthly records referenced in Paragraph 1-2d, which require the posting of data each time a battery is charged, the following procedure will be helpful:

a. Establish a battery identification system giving each battery a code number. A multiple-digit system is suggested such as 1201, 1202, etc., for all 12 volt 375

Figure 2-5. Taking specific gravity reading

Table 2-2. Specific gravity temperature correction chart

Electrolyte Temperature (Degrees Fahrenheit)	Point Correction
110	+11
107	+10
104	+ 9
101	+ 8
98	+ 7
95	+ 6
92	+ 5
89	+ 4
86	+ 3
83	+ 2
80	+ 1
77	No Correction
74	- 1
71	- 2
68	- 3
68	- 4
65	- 5
59	- 6
56	- 7
53	- 8
50	- 9
47	-10
44	-11
41	-12
38	-13
35	-14
32	-15

ampere-hour batteries, and 3601, 3602, etc., for all 36 volt 750 ampere-hour batteries etc.

b. Record specific gravity of the pilot cell or cells before and after each charge. Pilot cells should be selected from those nearest the center of the battery and identified by differently colored vent caps. They should be representative of the balance of the cells in the battery.

c. Record the number of cycles on a cumulative basis plus maintenance and repair information. Note any irregularities. The use of a "Battery Cycle and Maintenance Record" form such as shown in Figure 2-6 is recommended. If variations in specific gravity readings exceed 20 points (.020) and on-charge voltage, after an equalizing charge, varies by more than .15 volts, contact the manufacturer's service representative.

d. When the battery is new, and on at least an annual basis thereafter, read and record the specific gravity and open circuit voltage for all cells of the battery.

Battery Cycle and Maintenance Record	**Identification** Type ______ Amp. Hr. Capacity ______ Serial No. ______ Date in Service ______ Voltage ______ Date out Service ______	**Battery Number**

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY TOTAL	ACCUM. DATE

Battery Repair and Capacity Tests

Date	Repair or Comments	%Capacity Delivered	Labor Hrs.	Parts Cost	Total Cost

Figure 2-6. Battery cycle and maintenance record card

CHAPTER 3

FIELD SERVICING AND REPAIR

Section I. TROUBLESHOOTING

3-1. General

a. In addition to the required routine maintenance described in Chapter 2, Section III, storage batteries may, at some time during their service life, require more extensive or unusual care. Such care should be given as soon as it has been determined that a problem exists or that trouble may be developing. As a result, this section deals with the means of identifying existing or impending problems and offers possible solutions.

b. Troubleshooting Chart, which is Table 3-1, defines the most common problems which could occur during a battery's lifetime. If the suggested operational remedies are ineffective, it may be assumed that there is an internal problem and it will be necessary to disassemble the cell or cells to inspect the elements and sediment well. If the cause of the problem can only be corrected by completely rebuilding cells or the battery, this should be reported to the designated person in authority.

3-2. Restoring a Sulfated Battery

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

b. If the sulfation has not progressed too far, it may be possible to restore the battery to a serviceable condition by using the following special procedures:

(1) Thoroughly clean the battery (See Paragraph 2-14).

(2) Bring the electrolyte level up to a point which is just visible over the separator protector by adding approved water.

(3) Put the battery on charge at the prescribed finishing rate until the rated ampere-hour capacity has been returned to the battery. Record the voltage and specific gravity readings. Correct the specific gravity readings for temperature by using Table 2-1. If the temperature at any time during these procedures exceeds 110 degrees F., stop the charge and allow the battery to cool to 90 degrees F. or below before continuing. Charge the battery until the specific gravity shows no change during a 3 hour period while taking hourly readings. With automatic charging equipment, the battery may have to be placed on equalizing charge two or three times. If a battery is badly sulfated, the specific gravity may rise only 30 to 40 points (.030 to .040) during the first charge.

(4) Place the battery into service and discharge it to a fully discharged condition.

(5) Charge the battery again until the specific gravity shows no change during a 3 hour period.

(6) Repeat the cycling process until the specific gravity rises to within 30 points of a normal fully charged battery, then place the battery back in routine service. Even though specific gravities may be lower than normal they should not vary much from cell to cell. If they do, problems other than sulfation may be present. If the spread between the highest and the lowest gravity reading is 50 points or more, refer to the Troubleshooting Chart, Table 3-1, for help in identifying the problem. If the battery still has not responded to treatment, it should be replaced.

3-3. Correcting Excessive Self-Discharge

a. While a storage battery is in a charged state, a local electrochemical reaction takes place within the cells which causes very gradual discharging. This is known as self-discharge. A small amount is quite normal in motive power batteries where grids are made from antimonial lead. The rate of self-discharge is temperature related, however, and increases significantly as temperatures rise. Table 3-2 shows the relationship between temperature and loss of specific gravity. The normal rate at 77 degrees F. to 80 degrees F. causes a loss in specific gravity of about one point (.001) per day. This becomes of concern only when a wet battery is to be stored for weeks at a time. It can be ignored as a factor in normal battery operation.

b. It is possible, however, particularly during the latter stages of a battery's life, for the rate of discharge to become much greater and even limit the battery's duty cycle. Excessive selfdischarge may be caused by defective separators or plates which have become shorted at the edges. Edge shorting is usually caused by loss of positive active material which can fill the sediment well or build up on the top or sides of the plates and eventually bridge the space between the positives and negatives. If a shorted condition seems likely, the element should be pulled for examination and the defective separator replaced, shorts

Table 3-1. Storage battery troubleshooting chart

Symptoms	Possible Cause	Possible Remedy
Battery overheats during charge	1. Malfunctioning Charging Equipment	1. Replace or repair defective charger parts (timer, voltage sensitive relay, control board, etc.)
	2. Charging equipment out of adjustment.	2. Adjust start and/or finish charging rates.
	3. Defective or weak cell(s).	3. Replace or repair problem cell(s).
	4. Battery worn out and beyond economical repair.	4. Replace battery.
	5. High resistance connection within battery.	5. Check for hot wires, cells, intercell connectors, charging plugs, etc. Repair or replace defective component.
	6. Low electrolyte level.	6. Water battery to proper level at end of charge.
	7. Battery charged in the vehicle with battery compartment closed or the tray cover closed.	7. Open the compartment during charge or charge the battery out of the truck with the tray cover opened.
	8. Battery over 110 degrees F. when placed on charge.	8. Allow battery to cool below 90 degrees F. before charging. Use cooling fans to speed process.
Battery overheats during discharge	1. See causes 3 through 8 above.	1. See remedies 3 through 8 above.
	2. Worn out bearings, brakes dragging or other vehicle problem causing high current draws.	2. Repair or replace defective lift truck parts.
	3. Overdischarge of battery.	3. a. Requires drivers to return battery for recharge when vehicle begins to slow down. b. Put more batteries into service.
Battery not completing full work shift.	1. Battery not fully charged before placed into operation.	1. See that battery has reached full charge specific gravity before placing into operation.
	2. Weak, leaking or defective cell(s) in battery	2. Repair or replace cell(s) or battery.
	3. Grounds or shorts in the battery.	3. Remove grounds or shorts.
	4. Battery worn out and beyond economical repair.	4. Replace battery with equal or higher capacity battery.
	5. Battery too small for job.	5. a. Replace battery with one having higher capacity. b. Purchase extra batteries (with higher capacity if possible) and change them more frequently.
	6. Electrical or mechanical problem in vehicle.	6. Troubleshoot vehicle and repair.

Table 3-1. Storage battery troubleshooting chart - Continued

Symptoms	Possible Cause	Possible Remedy
Low electrolyte	1. Cracked or broken jar(s).	1. Replace jar(s) and adjust gravity.
	2. Cell missed when watered.	2. More careful attention when watering.
	3. Defective or weak cell(s).	3. Repair or replace cell(s).
	4. Frequent overcharge.	4. See items 1 and 2 in "Battery Over-heats During Charge."
	5. Battery not regularly watered.	5. Water battery regularly.
Unequal cell voltages	1. Grounds in battery.	1. Clean battery.
	2. There is a "tap" off the battery for auxiliary equipment (radio, light, etc.)	2. a. Use dropping resistor instead of tap. b. Equalize battery regularly.
	3. Battery sluggish due to lack of work.	3. a. Give battery a deep discharge and equalizing charge. b. Equalize the battery periodically.
	4. Leaking cell or cover.	4. Replace jar or cover and adjust gravity.
	5. Defective or weak cell(s).	5. Repair or replace defective cell(s).
	6. Battery worn out and beyond economical repair.	6. Replace the battery.
	7. Acid loss in a few cells by tipping battery over.	7. Adjust specific gravity.
	8. Frequent overwatering causing electrolyte loss due to flooding.	8. Fill to proper level and adjust specific gravity.

Table 3-2. Temperature effect on battery self-discharge

Temperature (Degrees Fahrenheit)	Loss of Specific Gravity Per Day
120	.004
100	.003
80	.001
50	.0005

cleared or cells replaced. Usually, if the sediment well is full, salvage is impractical.

3-4. Test Discharge

a. A capacity test is sometimes desirable to determine a battery's actual discharge capability as compared to its 6 hour rated capacity.

This can be a significant diagnostic tool when equipment does not operate as expected and it can help determine when the battery should be replaced. When a battery consistently delivers less than 80% of its rated ampere-hour capacity, either some cells are sub-standard or it has reached the end of its useful life and should be replaced.

b. A test discharge is performed by discharging a fully charged battery at a fixed rate under carefully controlled test conditions. If a battery is to be capacity tested, it is recommended that the test conditions, methods and procedures specified in NEMA Standards Publication No. IB2-1974 entitled "Determination of Capacity of Lead-Acid Industrial Storage Batteries for Motive Power Service" be used.

c. A copy of this Standard may be obtained from National Electrical Manufacturers Association, Department of Engineering and Safety Regulations, 2101 L Street, N.W. Washington, D.C. 20037.

Section II. REPAIRING BATTERIES

3-5. General

a. Storage batteries which have been damaged or which contain defective cells may, if the rebuilding cost and time are justified, be restored to a serviceable condition.

b. It is important to check a battery thoroughly if it has been involved in an accident or if it is believed to be defective. A neglected battery will continue to deteriorate even when not in use. Usually rebuilding is justified if the majority of cells are in good condition.

c. This section explains how to remove cells from a battery and how to repair them if they are to be salvaged. Some special tools and parts will be required depending upon the work to be done. Reference will be made to the use of such special devices but they will not be further identified in this manual. Although there is much similarity of tools and battery parts among the various battery manufacturers, the differences that exist are critical. For this reason you must, when replacing or repairing cells, refer to the applicable battery manufacturers listing of special tools, accessories and replacement parts. These will be referenced in the General Services Administration, Federal Supply Catalog, FSC Group 61, part 11, Class 6140-Batteries-Heavy Duty, Electric Storage. Each manufacturer identifies all tools, accessories and replacement parts by an appropriate part number. Use this number when making reference to them.

d. The General Services Federal Supply Catalogs can be requisitioned from: General Services Administration, Centralized Mailing Lists Services, Building 41, Denver Federal Center, Denver, CO 80225.

3-6. Purging of Gas

Before starting any repairs, remove all vent caps from cells to be repaired as well as from all surrounding cells. The space above the electrolyte must be cleared of hydrogen gas before proceeding with repairs. This can be accomplished by introducing a low volume air stream (volume and force equal to that produced by fanning each cell with a stiff piece of cardboard or other suitable nonconducting material) into each cell for at least 30 seconds. Be very careful when using air so that the electrolyte is not splashed out of the cell. Do not blow breath into cells. Wear protective face shield or goggles, rubber gloves and apron. After cells have been purged, cover all vent openings with several layers of water dampened cloth before starting repairs.

3-7. Removing Intercell Connectors

Each battery manufacturer offers special intercell connector drills designed to cut the bond between the cell post and the connector while permitting the post to remain for rebuilding later. (See Figure 3-1). The drills come in different sizes. When using them be careful to cut only as deeply as necessary, usually 1/4” to 3/8”. Make certain vent plugs are in place. During drilling try to center on the cover bushing and make sure any lead curl produced does not short across other connectors. After drilling, the intercell connectors can be lifted off with a pair of pliers.

Figure 3-1. Drilling cell connector

3-8. Removing a Complete Cell

a. After removing connectors as described in Paragraph 3-7, isolate the cell from adjacent cells. This may require cutting of compound or removal of spacers. Use a long spatula or similar tool to free the cell from top to bottom When the jar walls are free the cell can be lifted from the battery tray. All cells are heavy so a suitable lifting device, such as an electric hoist, is recommended. Threaded post clamps or cell pullers are available which can be burned or clamped to the posts, as shown in Figure 3-2, and used to pull the cell. Use a non-conducting bar between the loops of the post clamps and hook the hoist to this bar.

b. After removing the cell, neutralize any acid in the tray with a soda solution and clean up the residue.

c. When a cell or element is being pulled, it is advisable to have on hand both a replacement jar and a cover in

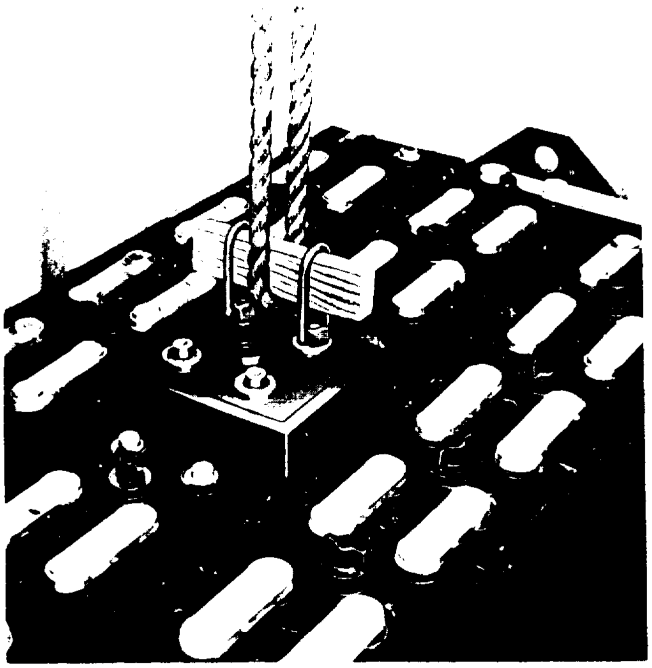

Figure 3-2. Removing a complete cell from battery

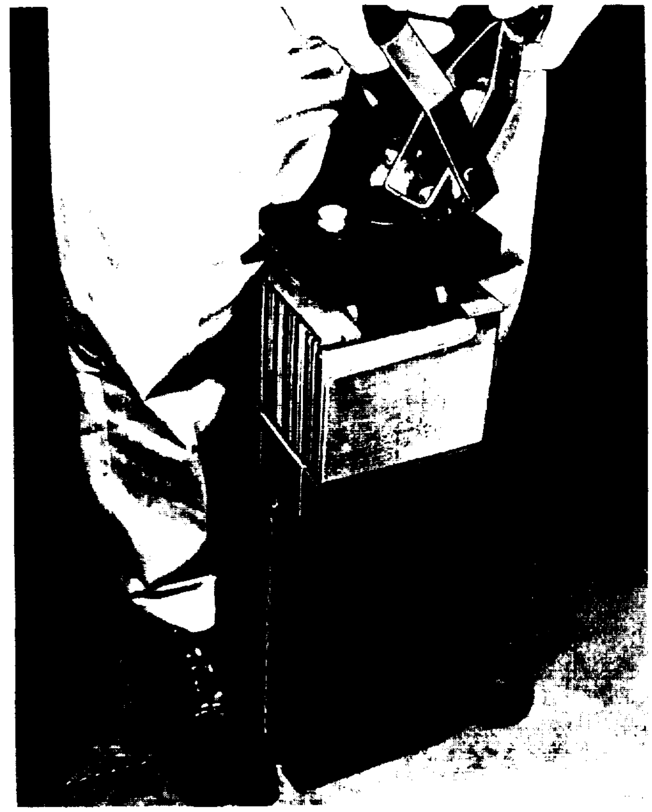

Figure 3-3. Removing element from cell

the event that either of the original parts are damaged in the process.

d. If a wet and charged cell has been pulled and allowed to stand unsupported, the jar walls may bulge permitting the electrolyte level to drop. Do not attempt to adjust electrolyte levels until cells have been reinstalled in the battery.

3-9. Removing an Element

a. If the jar is known to be serviceable, it may not be necessary to remove the complete cell. Usually only the element, complete with cell cover, has to be pulled. This can only be done, however, on those batteries containing a compound type cover to jar seal. On these, after removing connectors, draw a warm putty knife through the sealing compound close to the inside jar wall. Use a threaded post clamp or cell puller and hoist to raise the element, with cover in place, first to drain position, and then up and out of the jar.

b. When pulling an clement from a cell which has been removed from a battery, use jar hold-down clamps as shown in Figure 3-3.

c. Some batteries are furnished with permanent seals between the cover and jar. With these, if a defect occurs, the complete cell must be pulled and cover to jar seal cut or sawed to permit removal of the element. In doing so, both jar and cover must be replaced and resealed in accordance with the particular battery manufacturer's instructions.

d. When removing an element, lift it halfway out of the jar and hold it at this position until most of the electrolyte has drained off. Then raise the element to clear the top of the jar. Do not, unless absolutely necessary, expose an element to air longer than five minutes. Oxygen in the air combines with the active material in the negative plates causing them to oxidize and heat. If the exposure persists, negatives will discharge. While the element is out of the jar, check the sediment well in the bottom of the jar. If it is full of shed material, the cell probably will have to be replaced.

e. Plate and separator edges may be inspected while the element is suspended above the jar. A more thorough inspection of separators, plate insulation, grids and active materials may be indicated. If so, lay the clement on its side on a clean, non-metallic surface. The plates should be at right angles to the table surface so the element can be fanned slightly to permit the removal of separators.

f. When reinstalling separators make certain that the flat side of the separator is against the negative plate and the ribbed side is facing the positive. They should be pushed up until they are flush with the bottom of the element and they should project equally on each side of the plates.

g. Before installing an element in a previously used jar, wash out any sediment which may have accumulated in the bottom of the jar and clean all compound from around the inside of the top edge.

h. Clamp the element, if necessary, when reinstalling it in the jar. Make certain that the element is entering the jar properly and that the plates are at right angles to the plate support ribs in the bottom. When installing an element with a cell cover attached, use a putty knife to guide the lip of the cover past the top edges of the jar.

3-10. Replacing Cell in Battery

a. Cells from which the elements were pulled, or which had damaged jars replaced, should be given an equalizing charge and acid should be adjusted immediately following repair before they are returned to service. (See Paragraphs 2-10c and 3-12).

b. Before lowering a cell into a battery tray, be sure that it is correctly positioned relative to adjoining cells to which it is to be connected. Cells must be connected in series with the positive side of one cell connected to the negative side of the adjacent cell.

c. When the problem has been corrected and the cell is back in place in the battery tray, the cover must be resealed to the jar. With the exception of those cells which contain a permanent jar to cover seal, a special asphalt type sealing compound is used for this purpose. Heat the compound until it melts, but do not let the temperature get above 435 degrees F. Pack any large openings between cover lip and jar wall with cold compound and then pour the hot compound into the sealing groove in two steps. First pour the groove half full and soft flame with a torch to improve the adhesion; then fill the groove and flame again. Allow compound to cool and trim excess.

d. After sealing, pressure test cells for 10 seconds at a maximum of 1.5 P.S.I. and reinstall intercell connectors by welding or "burning" them to the terminal posts. A small hot flame is recommended such as is available from a standard commercial burning torch using natural gas and oxygen or propane and oxygen. Carbon burning outfits are also acceptable. These are available from the battery suppliers. (See General Services Administration's Federal Supply Catalog as referenced in Paragraph 3-5).

CAUTION

Always be sure the cells are purged of gas, as explained in Paragraph 3-6, before using an open flame or burning arc on top of the battery.

3-11. Replacing a Cell Cover

The specific methods used to seal cell covers to both the jar and the terminal posts vary with the manufacturer and the system used. The techniques used to replace a cover will be dictated by these different sealing methods:

a. Sealing Compound and Lead Bushing Design. This is probably the most commonly used system where an asphalt type compound is applied to seal the cover to both rubber and plastic jars. Lead bushings, molded into the cover as inserts, are welded or "burned" to the terminal posts to prevent electrolyte leakage around the posts. When replacing a cover of this type first cut the compound using a warm putty knife. Cut the full depth of the cover adjacent to the jar wall from corner to corner on each of the four sides. Since reuse of covers, which have been removed from the element, is not recommended, use a post trimmer to cut off the post extensions above the cover. Break the lead bond between post and lead insert by driving the cover down approximately 1/32". The lead insert mold placed over the post and tapped with a hammer serves this purpose. Remove the cover by inserting a hook through the vent opening and lifting it off. Remove all sealing compound adhering to jar wall and neutralize these surfaces and upper portion of all terminal posts using a cloth moistened with a soda solution. Thoroughly dry all of the neutralized surfaces. Install the new cover, complete cover to jar seal and reburn cell connectors as described in Paragraph 3-10.

b. Sealing Compound and Seal Nut Design. This also has been a frequently used system. The jar to cover seal is the same asphalt type sealing compound as used in the system described in Paragraph 3-11a above. The seal between the cover and the terminal post is accomplished by means of threaded seal nuts over the posts which tighten against compression type soft rubber post gaskets. When replacing a cover of this type cut the compound as described in Paragraph 3-11a. Assuming that the connectors have been drilled off, unscrew all seal nuts, using a seal nut wrench, and remove the soft rubber post gasket. Lift the cover from cell with a hook inserted into the vent opening. Clean and neutralize the jar walls and terminal posts as described above in Paragraph 3-11a. Wipe the surfaces of the new cover with a clean cloth and place into position. Clean the seal nut grooves by removing any old no-ox-id grease. Replace rubber gaskets and seal nuts. Tighten seal nuts with special wrench to prevent them from loosening. Renew the no-ox-id grease by melting it and pouring into the grooves at the top of the seal nut. Reseal cover to jar and reinstall intercell connectors as described in Paragraph 3-10.

c. Epoxy Seal and Seal Nut Design. This is one of the newer systems which employs an epoxy or permanent, hard seal between cover and jar. The cover to the post seal is identical to that described in Paragraph 3-11b above. To disassemble a cell of this design requires that the jar be cut and that both jar and cover be replaced. When reassembling with a new jar and cover it is very important to adhere to the following procedure to obtain an effective seal:

(1) Use epoxy only on rubber jars and covers.

(2) Thoroughly clean cover and jar sealing areas first with xylol (xylene), then with isopropyl alcohol using a separate cleaning cloth for each.

(3) Caulk bottom of seal groove with glass cord. Tamp corners in. Make overlap small. Do not use warm compound with epoxy.

(4) Use special epoxy sealant as recommended by the battery manufacturer. Follow instructions provided. This is available in kit form.

(5) Apply epoxy in two pours. Second pour within two hours after first pour. Fill to top of jar. Do not overfill.

(6) Pressure test seal after three hours or more from time of pouring. Pressure test to 1.5 P.S.I. for 10 seconds.

d. Heat Bonded Plastic Cover to Jar Seal and Lead Bushing Design. This is the newest of the sealing systems used with motive power batteries. To disassemble a cell of this design also requires that the jar be cut and both jar and cover be replaced. The seal between jar and cover is, in effect, a plastic weld. It can only be used with jars and covers made from the identical plastic molding material.

e. Since special techniques must be used when resealing these covers, the battery manufacturer recommends that these cover to jar seals not be attempted in the field. Manufacturers instructions request that such repairs be made in their service stations only.

3-12. Adjusting Specific Gravity of Electrolyte

a. Fully charged cells usually operate at a specific gravity between 1.275 and 1.295. Normally it should never be necessary to adjust the gravity, but upsets, jar breakage, additions of too much water and careless use of hydrometer can result in electrolyte loss and possible reductions of battery capacity. Lost electrolyte must be replaced but only after it has been determined that charging will not restore the gravity to normal when at the recommended level.

b. Therefore a cell or battery must first be given an equalizing charge as described in Paragraph 2-10c. Never make a gravity adjustment on a cell which does not gas vigorously while on charge.

c. If, after the equalizing charge, the specific gravity of any cell, corrected for temperature, is lower than normal, it should be adjusted in the following manner:

(1) Put battery back on charge at the finish rate until cells are actively gassing to provide proper mixing.

(2) Remove electrolyte from the low reading cells until level reaches the separator protector.

(3) Slowly add 1.400 specific gravity sulfuric acid to the cell while it is still gassing.

(4) Wait 15 to 20 minutes for the added acid to become thoroughly mixed and then read the specific gravity. If it is still low, repeat the process until gravity is normal. As a guide, every 1/4" of electrolyte that has been removed and replaced by 1.400 acid will cause the specific gravity to rise 4 to 5 points (.004 to .005).

d. If the corrected specific gravity of any cell is higher than normal, proceed as follows:

(1) While the battery is gassing on charge, withdraw from the cell a small amount of electrolyte and replace with approved water.

(2) Repeat, if necessary, at 20 to 30 minute intervals until the desired reading is obtained. Every 1/4" of electrolyte, which is replaced by water, will cause the specific gravity of the cell electrolyte to drop 4 to 5 points (.004 to .005).

WARNING

Never add acid with a specific gravity higher than 1.400. Stronger acid could permanently damage the cell. When mixing or cutting acid, always add the acid to the water. NEVER pour water into acid. A violent reaction could result which might cause personal injury. When working with acid always use a face shield or goggles, rubber gloves and an acid resistant apron.

CHAPTER 4

HEALTH AND SAFETY

Section I. BATTERY HAZARDS

4-1. General

A lead-acid battery can be a very useful, safe source of electrical power. While installing, using, maintaining or repairing a motive power battery, opportunities exist, however, for exposure to potentially dangerous situations. This section identifies those hazards which could result from improper handling or use.

4-2. Hazards

a. **A SULFURIC ACID** solution is used as the electrolyte in lead-acid batteries and has a concentration of approximately 37% by weight of sulfuric acid in water. In this diluted state it is not as hazardous as strong or concentrated sulfuric acid, but it acts as an oxidizing agent and can burn the skin or eyes and destroy clothing made of many common materials such as cotton or rayon.

b. **AN EXPLOSIVE MIXTURE** of hydrogen and oxygen is produced in a lead-acid battery while it is being charged. The gases can combine explosively if a spark or flame is present to ignite them. Because hydrogen is so light, it normally rises and diffuses into the air before it can concentrate in an explosive mixture. If it accumulates into gas pockets, as can occur within a cell, it might explode if ignited.

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

d. **THE WEIGHT** of these heavy batteries can easily cause painful strains or crushed hands or feet if improperly lifted or handled. Batteries can be damaged if dropped. The average motive power battery weighs more than one ton, so proper equipment must be provided when changing or handling batteries.

e. **BURNS** can result from contact with molten lead or hot compound while repairing a battery. Lead can splash when intercell connectors are being reburned and hot compound can be spilled when resealing covers to jars. The protective gear provided, if worn, will prevent such burns.

Section II. SAFETY PROCEDURES

4-3. Federal Standards

a. In 1970, Congress passed the Occupational Safety and Health Act (OSHA). This act established the minimal acceptable standards for safe and healthful working conditions. The safety procedures suggested in this manual have been compiled from standards developed over the years by professional and technical organizations and by battery manufacturers and users. Experience has shown them to be the most effective safety standards. In all cases they exceed the minimum standards of OSHA for personal safety and include procedures for safeguarding equipment as well.

b. The safety procedures have been grouped by functional area of most logical application or need. The applicable military safety procedures must also be followed.

4-4. Safety Procedures While Handling Batteries

a. Lift batteries with mechanical equipment only, such as an overhead hoist, crane or lift truck. A properly insulated lifting beam, of adequate capacity, should always be used with overhead lifting equipment. Do not use chains attached to a hoist at a single central point forming a triangle. This procedure is unsafe and could damage the steel tray.

b. Always wear safety shoes, safety glasses, and a hard hat made of a non-conducting material.

c. Tools, chains and other metallic objects will be kept away from the top of uncovered batteries to prevent possible short circuits.

d. Battery operated equipment should be properly positioned with switch off, brake set, and battery unplugged when changing batteries or charging them while in the equipment.

e. Personnel who work around batteries should not wear jewelry made from a conductive material. Metal items can short circuit a battery and could cause severe burns.

f. Only trained and authorized personnel should be permitted to change or charge batteries.

g. Reinstalled batteries should be properly positioned and secured in the truck, tractor or crane. Before installing a new or different battery, check both the truck or tractor nameplate and battery service weight to make sure that the proper weight battery is being used. A battery of the wrong weight can change the center of gravity and cause equipment to upset. (See Figure 4-1).

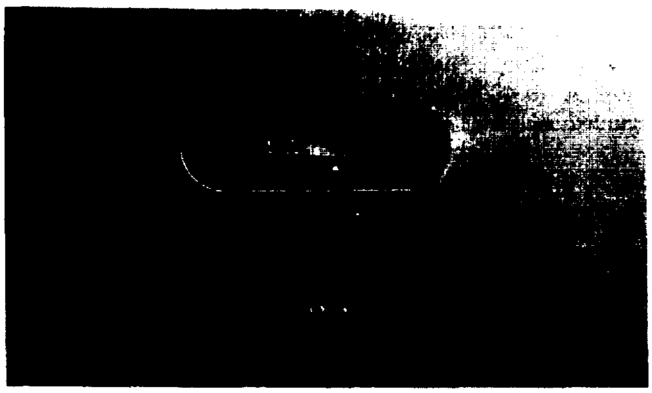

Figure 4-1. Weight designation on battery

4-5. Safety Procedures While Charging Batteries

a. Specific areas should be designated for charging batteries. These areas should be equipped with overhead hoists, conveyors or cranes for handling batteries.

b. Charging areas should be adequately ventilated. The actual amount of ventilation will depend upon such factors as number and size of batteries being charged at the same time, room size, ceiling height and air-tightness of the building. Hydrogen concentrations above 4% can be explosive.

c. Smoking, open flames, and sparks should all be prohibited in the charging area. Post placards “Hydrogen”, “Flammable Gas”, “No Smoking” and “No Open Flames”.

d. Facilities should be provided for flushing and neutralizing spilled electrolyte, for fire protection, including hand operated fire extinguishers, and for protecting charging equipment from damage by trucks, tractors or cranes.

e. Fresh water should always be available in case electrolyte is splashed on skin, clothing or into eyes. The kinds of equipment available for eye-wash and acid neutralization vary widely but either an eye-wash fountain or deluge shower and chemical burn station (squeeze bottle containing a buffering solution for relief of acid burns) should be located in the immediate work area. These should be clearly identified and readily accessible.

f. Before connecting a battery to, or disconnecting it from, a charger, the charger should be turned off. Live leads can cause arcing and pitting of battery connector contact surfaces.

g. Make sure that all electrical connections are tight and mechanically sound to prevent any arcing or loss of power.

h. Wear a face shield or goggles, rubber gloves, apron and boots when checking, filling, charging or repairing batteries during periods of possible exposure to acid or electrolyte.

i. When batteries are charged on racks, the racks should be insulated to prevent any possibility of shorting.

j. When charging an enclosed or covered battery, always keep the battery tray cover, or compartment cover, open during the charging period. This will help to keep the battery cool and disperse the gases.

k. Keep vent caps in place at all times except while servicing or repairing cells. This minimizes the loss of electrolyte and prevents foreign matter from entering the cells.

l. Shut off and disconnect both input and output connections to the charger before repairing charging equip ment.

4-6. Safety Procedures While Handling Acids

a. The splashing of acid into the eyes is the most dangerous condition which can be encountered while handling sulfuric acid or electrolyte. If this should happen, the eyes should immediately be gently flooded with clean, fresh, running water for at least 15 minutes followed as quickly as possible with a physicians examination. If the person is wearing contact lenses they should be removed before rinsing the eyes.

WARNING

Do not use a buffering or neutralizing agent in the eyes without medical approval.

b. Acid or electrolyte splashed onto the skin should be washed off under running water. Battery electrolyte will usually only cause irritation of the skin; but if a bum develops, it should be treated medically.

c. When electrolyte is splashed on clothing, use a weak solution of bicarbonate of soda, as soon as possible, to neutralize the acid.

d. A carboy tilter or safety siphon should be provided for handling acid from a carboy container. Use the protective box when moving a carboy. Store acid in a cool place out of the direct rays of the sun. Use only glass, lead or acid resistant plastic containers when storing acid or electrolyte.

e. When mixing acid, to prepare electrolyte, always pour the acid slowly into the water and stir constantly to mix well. Never pour water into acid. Never use sulfuric acid solutions which are over 1.400 specific gravity.

f. Apply a neutralizing solution, such as bicarbonate of soda and water, when acid is spilled on floor and clean up promptly. A mixture of one pound of soda to one gallon of water is recommended.

4-7. Safety Procedures While Servicing or Repairing Batteries

a. Disconnect the battery from the truck, tractor or crane when servicing or repairing either the battery or the equipment. Also make certain the battery is disconnected from the charger before handling or repairing the battery.

b. Before repairing a battery, remove all of the vent caps and blow out each cell with a low pressure air hose to remove any residual gas. Use only a gentle stream of air to avoid splashing electrolyte.

c. Open or "break" the circuit before repairing damaged or dirty terminal plugs or receptacles connected to a battery, by removing and insulating one terminal lead at a time.

d. When melting sealing compound, in preparation for resealing cells, be careful not to puncture the top section of unmelted compound with a screw driver or other pointed object. A build-up of pressure from the melted compound in the bottom could cause liquid compound to squirt and inflict a severe burn. Do not allow compound to ignite by overheating. Compound becomes workable at 400 to 425 degrees F.

e. Check batteries frequently for acid leakage or signs of corrosion.

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

g. When taking specific gravity readings, use a face shield or goggles and read the hydrometer with eye at about the same level as the electrolyte. (See Figure 2-5). Return all electrolyte to the cell.

CHAPTER 5

STORAGE AND SHIPMENT

5-1. General

Guidelines are provided for those occasions when batteries must be stored, in either a wet or dry state, and for possible reshipment to other areas.

5-2. Storage Methods

a. Charged and Wet Batteries. Lead acid batteries may be stored in a charged and wet (filled with electrolyte) condition when necessary for periods of up to several months. During such periods they should be stored in a clean, cool, dry and well ventilated location away from radiators, hot air ducts or other sources of heat, and protected from exposure to direct sunlight. Before being stored, the battery should be fully charged and the electrolyte should be brought to the proper level. Any leads should be disconnected or insulated to prevent accidental discharge. The top of the battery must be protected from dust, foreign matter and moisture. Do not attempt to dismantle the battery.

b. If the average storage temperature is 80 degrees F. or higher, the specific gravity of the electrolyte should be checked at least monthly. If below 80 degrees F., check gravities at least every two months. Whenever the specific gravity, corrected to 80 degrees F., falls to 1.240 or below, the battery should be given a freshening charge as described in Paragraph 2-10d. A freshening charge is also recommended just before returning a battery to service.

c. Charged and Dry Batteries. New batteries are often supplied charged and dry (without electrolyte). Batteries in this condition can remain in storage, unattended, for a period of at least two years. They should be stored in a cool, dry place with vent caps tightly closed. Average temperatures should not exceed 80 degrees F. Batteries should not be stored near radiators, hot air ducts, or other sources of heat, and should be protected from exposure to direct sunlight. The top of the battery should be protected from dust, foreign matter and moisture. Charged and dry batteries when removed from storage should be activated as described in Paragraph 2-4a.

5-3. Shipment

a. Charged and Wet Batteries. Depots or using organizations may make shipments of motive power batteries in a charged and wet condition if intended for use within a period of 90 days. The battery service weight is usually stamped into the steel tray near one of the lifting holes. (See Figure 4-1). Obtain the cubage either by computing it from battery dimensions shown on Military Standard MS-15367 or from dimensions obtained by measuring the actual battery. Detailed battery information may also be obtained from manufacturers catalog.

b. Before crating a wet battery for shipment it should be given a freshening charge as described in Paragraph 2-10d. A tag should be attached to both the battery and the crate showing the date of the last charge and the specific gravity of the electrolyte at the completion of the charge. Make certain that the battery is properly protected when crated. The receiving organization should be alerted also to the need for a freshening charge before the battery is put into service.

c. Charged and Dry Batteries. Depots will normally make domestic and export shipments of new batteries which usually will be in a charged and dry condition. Batteries, and the accompanying electrolyte in separate carboys, which are intended for export shipment must be packaged in accordance with approved methods.

NOTE

Whenever batteries are shipped by common carrier, ICC regulations will, of course, apply.

By Order of the Secretary of the Army:

BERNARD W. ROGERS
General, United States Army
Chief of Staff

Official:

J. C. PENNINGTON
Brigadier General, United States Army
The Adjutant General

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512		191		Fig. 191, item 3 has the wrong NSN. Supply rejects orders for this item. The NSN shown here is not listed in the AMDF or the MERL. Please give us the correct NSN and P/N.

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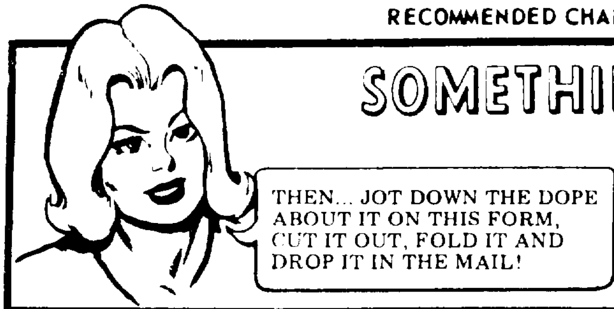

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