CHAPTER 14

STORAGE BATTERIES

Section I--CONSIDERATIONS

14-1. Battery usage.

Storage batteries are used in exterior facility electrical distribution systems to provide a power supply to devices whose control response will be damaged by an electrical system power outage. This chapter describes station batteries as they are generally called, as opposed to uninterruptible power system batteries or automotive type batteries. A storage battery is composed of one or more rechargeable electrochemical type cells. Systems are designed for full-float operation, with a battery charger to maintain the battery in a charged condition. Batteries used for control of substation and power equipment are required to provide low currents for long periods and high currents for short periods. A battery's reserve capacity requirements are based on a duty cycle (usually an 8-hour operating time period) when all continuous and momentary loads must be supplied by the battery with no recharging available from the battery charger.

14-2. Battery types.

The two electrochemical types in general use for station batteries are lead-acid and nickel-cadmium. Construction types include vented (flooded) and valve-regulated (sealed) units. For specific information on a particular type, refer to the manufacturer's instructions. There are five basic components to a battery cell: the container, the positive plate (electrode), the separator or retainer, the negative plate (electrode), and the electrolyte.

a. Lead-acid units. Lead acid batteries have an acidic electrolyte solution of sulfuric acid (H_2SO_4). The active materials used are lead dioxide (PbO_2) for the positive plate, and sponge lead (Pb) for the negative plate. The active materials for both the positive and negative plates are incorporated in a plate structure composed of lead or a lead alloy. The NEC defines their nominal battery voltage at 2.0 volts per cell.

b. Nickel-cadmium units. Nickel cadmium batteries use an alkaline electrolyte (potassium hydroxide). The active materials used are nickel hydroxide for the positive plate and cadmium hydroxide for the negative plate. The NEC defines their nominal battery voltage at 1.2 volts per cell.

c. Vented batteries. Vented (flooded) cells are constructed with the liquid electrolyte completely covering (flooding) the closely spaced plates, so that there is a large volume of free electrolyte. The electrolyte maintains uniform contact with the plates. Vented units are characterized by a removable vent cap which allows the electrolyte to be checked and adjusted as needed. Overcharge will produce gases which vent through the cell, requiring regular water replacement. Vent caps must be accessible, so batteries are larger than valve-regulated types and are provided with flame arresters. Gassing requires ventilation to avoid explosive possibilities and possible corrosive damage to battery terminals.

d. Valve-regulated batteries. Valve-regulated cells are sealed, with the exception of a valve that opens periodically to relieve excessive internal pressure. To limit water consumption, cells are designed to provide recombination of charge gases by passing oxygen evolved from the positive plate over the negative plate, where the recombination reaction occurs. The valve regulates the internal pressure to optimize recombination efficiency (hence the term valve-regulated). The valve opens when the cell's internal pressure exceeds a set limit and once the pressure is relieved the valve closes and reseals. No cell check of an electrolyte level nor the specific gravity of each cell is required. These batteries are not maintenance-free as some 10 or more maintenance checks are still necessary. Outgassing of these batteries is low at normal charge rates, but it can occur when there is a battery or battery charger failure. Cells can pose a hazard if enclosed so as to inhibit cooling air, or installed so as to place them in the heat flow of electronics which may occupy the same enclosure.

14-3. Battery safety.

Safety precautions cannot be ignored, since every station battery installation presents hazards. The importance of using safety equipment, such as rubber gloves, goggles, aprons, and of having an eyewash water bottle present, cannot be overemphasized. The three major hazards are from the electrolyte in the battery, the gases emitted by the battery, and the potential electrical short circuit capability available from the battery's stored energy. Most persons trained to work in an electrical environment are aware that batteries are dangerous, but need to be warned and advised again as to the extent of the hazards posed by all station battery systems, regardless of size or type.

a. Warnings. All batteries contain an electrolyte which may be liquid and is corrosive. Lead-acid batteries contain diluted sulfuric acid and nickel-cadmium batteries contain potassium hydroxide. Direct contact with the electrolyte should be avoided as contact may result in severe chemical burns. Accidental contact must be removed immediately by washing and flushing with baking soda (bicarbonate of soda). This solution is beneficial in neutralizing either alkaline or acid electrolyte. Extreme care must be taken in the use of hydrometers or syringes to avoid accidentally squirting electrolyte at or on anyone.

(1) *Warning notice.* It is recommended that a warning notice be posed near the battery installation as shown in table 14-1. Use the first parenthesis as applicable to the electrolyte type. Fill in the fault current amperes.

(2) *Warning sign.* It is recommended that a warning sign be posted in advance of the installed table 14-1 warning notice. Figure 14-1 is a warning sign used by a manufacturer who provides small sealed, low-gassing type batteries. Note that this warning sign indicates *DANGER* even for what is represented as a small sealed-battery system. Particular attention must be given to the prevention of sparks or flames near batteries. The hydrogen gas produced by charging batteries is flammable in an atmosphere where the gas content exceeds 4 percent hydrogen gas. If the mixture contains more than 8 percent hydrogen, it can explode.

b. Electrolyte hazard. Battery rooms are required by OSHA to provide emergency-use quick-drenching facilities for the eyes and body within 25 feet of the work area. Permanent emergency eyewash and showers are recommended. Portable emergency eyewash and showers must be brought into the maintenance area if permanent facilities are not provided. Squeeze bottles can substitute for eyewash fountains, and canisters that resemble fire extinguishers can be fitted to provide an eyewash or a quick drench. Periodic inspection and maintenance of these devices are mandatory. Be sure to change the water as recommended to eliminate possible bacteria. Squeeze bottles are date coded and should be replaced before the expiration date. Exercise canister units periodically to prevent clogging of the head. Ensure that a good flow of water is available when it's really needed.

c. Explosive gas hazard. The NEC requires removal of possible explosive gas buildup, since all battery types can outgas. Check that gas accumulation is limited to less than 2 percent of the total volume of the battery room or enclosure. For flooded lead-acid batteries, the maximum hydrogen evolution rate is 0.000269 cubic feet (7618 cubic millimeters) per minute per charging ampere per cell at 77 degrees F (25 degrees C), one atmosphere. The maximum rate occurs when a fully charged battery has maximum current forced into it.

d. Electrical hazard. Most batteries are operated ungrounded, so touching a live part will not result in a shock. The real hazard exists when an accidental ground is already present and a person touches a live part. In this case, the person completes the circuit to ground and current will flow through the person. While personnel may recognize that this

Table 14-l. Battery room warning notice

Batteries contain (sulfuric acid) (potassium hydroxide solution). If the electrolyte is splashed on eyes, flush with clear water and consult a physician. If the electrolyte contacts the skin, flush with clear water. Storage batteries are high current sources. Accidental short circuits can cause severe arcing, equipment damage, battery explosion, and personal injury. This installation can deliver a fault current of 1,000 amperes. Do not use uninsulated tools or touch uninsulated wires or terminals. Remove conductive watches/rings/bracelets, and wear both eye protection and protective clothing when working on batteries. Keep batteries upright. Use tools with insulated handles. Do not smoke or permit naked flames near the battery. Do not wear clothes which can create static electricity. Switch off circuits before connecting or disconnecting the battery to avoid sparks. Be sure connections are tight before switching on. Two people should perform battery maintenance inspections, with only one person working on any battery at the same time.

Figure 14-1. Battery warning sign

hazard exists, they may not be concerned because nominal cell voltages are only 1.2 to 2 volts per cell. Another hazard occurs when there is an accidental connection between positive and negative points, which can cause arc or a possible battery explosion.

(1) *Possible effects.* Batteries in station systems often contain individual cells connected in series (to form a string), and may reach voltages as high as 250 volts. Consider the amount of short-circuit current batteries can deliver because of their low internal resistance. Batteries can deliver massive short-circuit currents, measured in the thousands of amperes. Such current can almost instantly make a wristwatch, screwdriver, or any other conductive path red hot or vaporize the metal. The short-circuit capability of any battery can be obtained from the manufacturer and it is recommended that it be posted as a part of the battery room warning notice (see table 14-14).

(2) *Accidental grounds.* It is not uncommon to find that a ground exists on a battery. This can occur when the electrolyte on top of a cell tracks across the cover, down the plastic jar, and contacts a metallic part of the rack. The electrolyte, being conductive, establishes a ground path.

(3) *Normal safety procedures.* When working around batteries, all normal safety procedures should be followed, including the use of protective equipment. Caution must be exercised in placing meters on top of batteries. Under certain conditions, meters with enclosures partially made of metal can cause a short circuit and sparks. Metal objects should never be placed on top of batteries, and metal tools used on batteries should be insulated to prevent accidental short circuits. Generally, a ground detector is provided as part of the dc system, most often in the battery charger. Be certain to check the ground detector before starting work. If an unintentional ground exists, it should be cleared before work begins.

(4) *Two-person teams.* Always have two persons assigned to perform battery maintenance inspections. One person takes the readings and the other records them. They should not work on different parts of the battery at one time because they could become two points, completing a circuit to ground.

14-4. General battery maintenance procedures.

Always follow the battery manufacturer's maintenance procedures and check warranty requirements. Battery temperature examples given are not justification for ignoring the temperature requirements given in this chapter for battery rooms or areas. Manufacturers will normally provide assistance in developing a maintenance program for batteries which they supply. All manufacturers have maintenance instructions for their cells and some will conduct maintenance seminars or presentations. This important source of information should not be overlooked. Also become familiar with procedures for maintenance, testing, and replacement of storage batteries, as described in ANSI/IEEE 450 and ANSI/IEEE 1106 for lead-acid and nickel-cadmium types, respectively.

a. Maintenance program. The maintenance program selected should address the specific needs of the battery installed and should be both consistent and regular. Recommended maintenance intervals should never be longer than those required by the manufacturer to satisfy warranty requirements. In addition, critical load requirements may dictate more frequent maintenance based upon the importance of the installation and the impact of a battery failure on the load it serves. Proper maintenance will ensure optimum battery life, assuming the battery has been properly sized and installed. When allocating time to battery maintenance, ensure that it is sufficient for the tasks to be performed. Small inaccuracies that can occur when personnel are rushed can result in useless data, and overlooking of other obvious problems. Wherever practicable, tests should be carried out in a manner that accomplishes one or more objectives at the same time. For example, a capacity test also can be used to check for high connection resistance.

b. Battery specifics. A maintenance program must address the specific battery installed. Although the tests and frequency of maintenance may be the same, there are subtle differences between batteries. For example, the nominal float voltage will vary between lead-antimony and lead-calcium cells. In addition, the total float (terminal) voltage will be different when the total number of cells provided varies (as for nickel-cadmium units) even though the nominal voltage per cell may be the same. For instance, a nominal 24-volt lead-acid battery system can be made up from 12 to 14 cells of the same type. Another consideration is that the float voltage used will vary with the nominal specific gravity of the cell.

(1) *Battery system replacement.* When a battery is replaced, the new battery often continues to be maintained in the same manner as the old one. However, the new battery may be of a different alloy or nominal specific gravity, or may contain a different number of cells. Maintenance personnel may not recognize the differences, which can lead to irreversible damage.

(2) *Battery condition.* Battery condition can be assessed based upon comparisons of current and

past data. Data collected during maintenance must always be corrected to the standard temperature reference, so that meaningful data comparisons can be made. Maintenance forms used to record data should be straightforward and must include provisions for making all corrections to standard values.

(3) *Inspection requirements.* Maintenance of a battery begins at the time of installation. The test data recorded at the installation acceptance test form the base set of values for the battery to which all later test data must be referenced. Storage batteries should be completely checked monthly (see section VI). Where experience indicates that scheduled inspections are insufficient to ensure battery reliability, the frequency of inspection should be increased as necessary. In cold weather conditions, more frequent inspection of batteries may be necessary. Routine inspection should include the checking and recording of all pertinent information, such as voltage, specific gravity, level of electrolyte, charging rate, internal and ambient temperatures, ventilation, and cleanliness.

c. Understanding requirements. In the following sections, general information on basic battery maintenance is presented for flooded lead-cell batteries. Flooded lead-acid batteries are discussed, since these are most often encountered. Valve-regulated lead-acid batteries and nickel-cadmium batteries are discussed in separate sections to the extent that their maintenance differs from that of flooded lead-acid cells. Periodic maintenance tasks are summarized in a following section.

Section II-FLOODED LEAD-ACID BATTERY MAINTENANCE

14-5. Visual inspections of batteries.

Visual inspections will indicate when cleaning is necessary and afford the opportunity to check cells for damage or evidence of improper charging or other mishandling. A flashlight or other localized unsparking light source is essential for inspecting cell components and connections and for checking for evidence of excessive gassing, mossing, sediment, and low electrolyte levels. Check that there is no battery vibration. Under abnormal operating conditions, hydration and frozen electrolytes can occur and if not recognized could cause irreparable damage.

a. Cell *and connection inspections.* The jars, plates, and connections should be closely inspected on each cell.

(1) *Jars.* Jars, covers, and cover-to-jar and cover-to-post seals should be checked for cracks or other structural damage. Failure of any seal will cause the electrolyte to seep out. A light source can be directed through clear jars to locate cracks or structural damage to the jar, cover, and seals. Such defects should be noted and the manufacturer should be consulted for remedial action.

(2) *Plates.* Unwrapped plates in a clear jar should be examined, as they show the battery's condition. The color of the positive plate of the lead-acid cell will vary from light- to deep-chocolate brown. The darker the color the most likely the battery has been overcharged. The negative plate will be gray in color, with a tendency to darken with age. Check and note any buckling, warping, scaling, swelling, or cracking of plates. Sulphation may be detected by shining a light source on the plates, which will reflect light from any sulphate crystals on the plate edges. If sulphation is visible, inspect the connections between the plates, straps (that is, the bus bar connecting plates to the post), and posts for obvious abnormalities. In areas of high seismic activity, connections sometimes fail if seismic acceptance testing was not properly performed.

(3) *Battery terminals.* Battery terminals may be inspected using a current/resistance (IR) probe. A connection carrying current with resistance will heat up. Retorquing cell connections without justification will lead to failure. If connection is loose or has high resistance (heating) it must be disassembled, cleaned and reassembled, including torquing. If the nut does not turn on the bolt freely, the bolt and nut must be replaced. A connection carrying current without heating does not need to be retorqued. A connection which is heating needs to be cleaned.

(4) *Other checks.* Check for electrolyte spillage, evidence of corrosion, and vent cap damage, and correct any problems. Examine cables connecting the battery to the battery charger and those cables used as intercell or intertier connectors, to ensure there is no strain on the cell posts, and to check that terminal posts and connections are clean.

b. Excessive gassing. Although some gassing on recharge is normal, excessive gassing can indicate overcharging, and should always be noted. A lead-acid battery begins to gas when the cell voltage reaches approximately 2.30 volts. Outgassing, when a cell is on open circuit or on float charge, may be an indication of high local action and undercharging. The gas coming from the negative plate is not generated, but is squeezed out of the expanding active plate material by the sulphate formed as the cell discharges. Most local action takes place at the negative plates, and the positive plates may remain well charged. As uniformly discharged positive and negative plates will not have a large drop in specific-gravity; a specific-gravity check may not detect this action. Cells which do not gas during charge may indicate problems such as undercharge, short circuits in the cell, or impurities in the electrolyte.

c. Mossing. Mossing of lead-acid cells is caused by overcharging, or charging at excessively high rates. The manufacturer may provide moss shield protection on the top of the plates for some cell constructions. Mossing results from the accumulation of a sponge-like material on top of the negative plates or straps. The material is shed predominantly from the positive plates and is carried off by gassing. If deposited on the positive plates, gassing simply washes it off again, but the material will adhere if deposited on the negative plates. Over time, the negative plates build up a sufficient deposit to bridge and make contact with positive plates, causing partial shorts. If mossing is found during an inspection, expect to find excessive sediment as well.

d. Sediment. Observing quantity and color of sediment in clear lead-acid battery jars also indicates the battery's condition.

(1) *Excessive sediment.* Excessive sediment usually indicates overcharge or charge at excessively high rates. The sediment from a well maintained cell may look like a layer of dust on the bottom of the jar. The sediment from a poorly maintained cell may completely fill the space provided under the plates and resemble hills. Partial short circuits will occur when the sediment hills reach the plate bottoms.

(2) *Color of sediment.* Dark or chocolate brown sediment hills beneath the positive plates indicates continuous overcharge. Gray sediment in hills beneath the negative plates indicates continuous undercharge. Excessive but somewhat mixed sediment hills, showing both positive and negative materials, indicate the battery has probably undergone random periods of undercharge and overcharge. Where excessive sediment is noted, examine cells for mossing.

e. Battery racks. Battery racks should be checked during visual inspections. Included are checks for structural integrity, corrosion, and proper grounding.

(1) *Corrosion.* The jars normally rest on corrosion-resistant supports or plastic jar-supporting channels installed on the rack structure. Check these and all items composing the rack for corrosion.

(2) *Seismic.* If the battery rack is a seismic type for installations requiring earthquake protection, additional checks of the rails and spacers must be made. Seismic racks use rails and spacers to prevent movement of cells during an earthquake, and the spacers function to prevent adjacent cells from knocking together. The side rails are covered by a corrosion-resistant cover (such as a plastic channel) where they touch the jars. Check to ensure that all side rails, end rails, and spacers are in place, and that bolts are properly torqued. Portions of the rack seismic equipment may occasionally be disassembled to allow maintenance to be performed on the battery or for cell replacement. The ability of the rack to protect the battery during an earthquake will be impaired if rack reassembly is not properly tightened.

(3) *Grounding.* Check that ground connections are correct, tight, and uncorroded.

f. Damaging actions to be noted. Low electrolyte levels, vibration, hydration, or frozen electrolyte can often damage batteries beyond repairability and such batteries should be noted for prompt replacement.

g. Low electrolyte levels. Water should be added to cells when inspection reveals electrolyte levels below the high level line. The manufacturer should be consulted immediately about cells where the electrolyte level is below the plate tops. Water should not be added to these cells until the manufacturer has agreed that this is the proper action or has inspected the cells and recommended filling. Electrolyte levels below the plate tops can cause permanent cell damage, and the cell may need to be replaced. A record of the amount of water added to each cell should be kept and checked with the battery manufacturer's normal cell water consumption requirement. Lead-antimony batteries normally experience an increase in water consumption with age. Water consumption in excess of the manufacturer's requirement is an indication of overcharging. A cell that has been recently moved or transported should not have water added until it has been placed back on charge for the period of time recommended by the manufacturer. If the plates were exposed while moving cells, consult the manufacturer for recommended action. Vibration during movement will tend to free hydrogen bubbles attached to the plates. The loss of these bubbles will cause a decrease in the electrolye level. Once the cell is installed, the bubbles will reappear, and the electrolyte level will increase. Never add acid (or alkali) to a cell, nor any additive which claims to rejuvenate cells.

(1) *Vibration.* Check the surface of the electrolyte for indication of any battery vibration. Battery life will be reduced in proportion to the length of time and action of any severe systematic vibration. Excess sediment, when there is no apparent reason for that sediment (the battery has not experienced overcharging or undercharging), can indicate recur-

rent vibration. Where signs indicate vibration, reexamine the battery supporting/restraining system and eliminate this source of damaging activity.

(2) *Hydration*. Overdischarge of a lead-acid battery without immediate recharge can cause hydration. This can happen if the battery charger is shut down or if a lead-acid battery is kept in storage for an extended period without recharging. The cell must be replaced if irreversible damage is indicated, for example, by a whitish "bathtub ring" visible approximately halfway up a clear jar. The lead and lead compounds in the cell dissolve in the water released during overdischarge and form lead hydrate, which is deposited on the separators. Thousands of short circuits between the positive and negative plates will occur when the battery is recharged after hydration. Hydration can also occur when a dry-charged battery is mistakenly filled with water instead of the electrolyte solution.

(3) *Frozen electrolyte.* Freezing of operating batteries is unlikely if care is taken when water is added. When water is added to a battery in freezing temperature, the battery must be charged to mix the water with the electrolyte, or the water will remain on top and freeze. Nominal 1.200 specific-gravity lead-acid electrolyte starts forming slush at approximately minus 20 degrees F (minus 29 degrees C). But, during discharge, a lead-acid cell's specific gravity decreases, and there is a resultant increase in the temperature at which slush could form. Freezing would begin at 16 degrees F (minus 8 degrees C), if the battery's specific gravity decreased to 1.100. Irreparable damage occurs when ice crystals form within the battery, even though damage may not be visible. In essence, the frozen electrolyte will cause the active materials to expand and lose contact with the grid. The frozen electrolyte can also cause structural damage to the jar.

14-6. Measurements of battery condition.

Simultaneous measurements of specific gravity, voltage, and temperature can identify the condition of the cell. Measurements and tests are often performed on individual cells, referred to as pilot cells, instead of on the entire battery.

a. Pilot cells for voltage and specific gravity measurements. One or more pilot cells may be chosen to reduce the time necessary to perform inspections and tests, while still affording some degree of confidence in the battery's condition. The selection is arbitrary, but one cell per rack section should be chosen, so that all levels are represented. Sometimes the pilot cells are selected after a quarterly check of all of the cells' voltages and specific gravities have been made. Criteria for selection include cells with the lowest specific gravity, lowest voltage, highest specific gravity, highest voltage, or combinations of both. Pilot cells should be rotated periodically, usually on a monthly basis. One reason for this is to limit electrolyte loss. Whenever a cell's specific gravity is read, some small amount of electrolyte will remain in the hydrometer. For a frequently read pilot cell, this loss of electrolyte, although very small, could ultimately affect the cell over a long period of time.

h. Temperature readings. Electrolyte temperatures should be read and be recorded any time specific-gravity or voltage readings are taken. The specific gravity of the electrolyte varies with temperature. In order to compensate for this effect, the temperature needs to be recorded at the same time that the hydrometer is read.

(1) *Differential temperature.* Differential electrolyte temperatures, greater than 5 degrees F (2.75 degrees C), between cells can be a problem. This problem normally occurs when one portion of a battery is located near a localized heat source, such as a sunny window or when a battery rack with more than two steps or tiers is used. A battery temperature differential will cause some cells to be overcharged and some cells to be undercharged.

(2) *Ambient temperature.* Ambient temperature of the battery area should be read and recorded periodically, even where the room or area is environmentally conditioned. Battery performance is based upon the cell electrolyte temperature, which can differ from the room ambient temperature. Optimum battery performance is obtained when electrolyte temperature is maintained at 77 degrees F (25 degrees C).

(3) *Recording temperature.* Some hydrometers have a thermometer and table showing the temperature correction that should be applied to the reading. If the hydrometer being used does not have a thermometer, a battery thermometer should be placed into the cell and the electrolyte temperature recorded.

(4) *Temperature correction.* Comparisons are made for readings corrected to 77 degrees F (25 degrees C). The temperature correction for lead-acid batteries requires adding one point (.00l) to the hydrometer reading for every 3 degrees F (1.67 degrees C) above 77 degrees F (25 degrees C) and subtracting one point for every 3 degrees F (1.67 degrees C) below 77 degrees F (25 degrees C).

c. Specific-gravity readings. Specific gravity is a good indication of state-of-charge of lead-acid cells. Corrections for electrolyte temperature and level must be applied to adjust the specific-gravity readings to a standard reference temperature. Level corrections can vary for each cell type and should be obtained from the manufacturer. Note that specific-gravity readings, taken within 72 hours of the termination of an equalizing charge or a water addition, will not be correct. These specific-gravity readings are inaccurate because the added water has not been properly mixed with the existing electrolyte solution and stratification occurs.

(1) *Differences in specific gravity.* Lead-antimony or lead-calcium battery electrolytes do not always have the same nominal specific gravities, even if the plate alloy is the same. Maintenance personnel should not install a replacement cell which requires a specific-gravity electrolyte different from the existing cells. In similar cells with different specific gravities, the higher specific gravity cells will have higher float voltage requirements, provide increased local action, and consume more water. Some application considerations may also cause a manufacturer to vary the nominal 1.200 specific gravity for stationary cells. High or low ambient temperatures influence specific-gravity requirements. A higher specific gravity electrolyte is provided when ambient temperatures are extremely low. This increases cell performance and serves to lower the freezing point of the electrolyte. Similarly, with high ambient temperatures, normally above 90 degrees F (32 degrees C), a lower specific-gravity electrolyte is provided to reduce losses and maintain expected life.

(2) *Comparisons.* The measured specific gravity should be corrected to the reference temperature and compared to previous data. Readings should be uniform, with a minimum different between the high and low readings. Where specific gravities vary considerably over the battery, they are termed "ragged" and corrective action is required, as covered in ANSI/IEEE 450 and ANSE/IEEE 1106.

(3) *Method of measurement.* With all cells connected in series, the specific gravity reading of one cell, known as a pilot cell, indicates the state of discharge or charge of the whole battery. When a reading is being taken, the nozzle of the hydrometer syringe is inserted into the cell, and just enough electrolyte is drawn from the cell to float the hydrometer freely without touching at the top or bottom. Read the specific gravity on the float, making sure to obtain this reading at the bottom of the meniscus (the bottom of the liquid-surface curvature). For correct readings be sure to hold the hydrometer in a true vertical position to avoid the float's touching the cylinder walls. After testing, the electrolyte should ways be returned to the cell. Cell readings can be inaccurate if taken sooner than 72 hours after equalizing or water corrections.

d. Voltage readings. The open-circuit voltage of a lead-acid cell is a direct function of specific gravity and can be approximated by equation 14-1. This relationship holds for cells that are truly open-circuited (that is, there is no current flowing through the cell). The battery should have a well-mixed electrolyte and been off charge for more than 16 hours. A voltage below that expected by equation 14-l indicates there may be a problem.

$$\text{Open-circuit voltage} = \text{Specific gravity} + 0.84 \qquad \text{(eq. 14-1)}$$

e. Connection resistance. A connection resistance check is very important but is often neglected, even though it can be conducted with the battery in service. The instruments normally used are the same as those used to measure a power circuit-breaker's contact resistance. A moderate to high current is passed through the connection under test and the voltage drop is measured and converted at the meter output to microhms. These measurements are difficult to perform, especially when the cells have multiple posts per cell and multiple intercell connectors per post. In these cases, multiple measurements per cell must be made or there will be significant errors in the measurement. The test, performed at the initial installation, should be repeated periodically and the results compared. High connection resistance, if not detected, can cause severe damage, especially in a stationary cell required to discharge at a high current rate for a period of time. High connection resistance can actually melt battery posts.

14-7. Battery maintenance specifics.

The battery installations must be kept clean. Measurements which determine the need for water or electrolyte additions are required. Pilot cell comparisons are necessary. Battery charging and water quality help in providing the optimum operation and life for battery installations.

a. Cleaning. Keep batteries; connections, and battery racks clean at all times.

(1) *Battery cells.* Jars or covers should be wiped with a clean lint-free cloth or wiper moistened with clean water. The cloth should be moistened with a suitable neutralizing agent to clean any electrolyte spilled on the cover or jar. Remove moisture with a clean dry cloth or wiper, once cleaning is finished. Never use solvents, detergents, oils, waxes, polishes, or ammonia to clean the jars, as this may cause permanent damage to the jar. For lead-acid batteries; use tin acid-neutralizing agent consisting of a soda solution. The soda solution should consist of one pound (454 grams) of bicarbonate of soda to one gallon (3.785 liters) of water. Other neutralizing agents may damage the jar. The solution must not get into the cells.

(2) *Battery connections.* Terminal posts and connections should be wiped with a clean lint-free

cloth or wiper moistened with a suitable neutralizing agent. Cleaning charged batteries can present a safety hazard if heavy corrosion is present. Corroded connections should be unbolted and cleaned. Connector bolts should be tightened as required to ensure a good connection. Suitable means to continue service should be arranged for batteries which must remain in service. This may mean jumpering out cells being worked on and jumpering in other cells, to maintain system voltage requirements. Normally, lowering of voltage, jumpered out by removal of some cells, will not degrade the ability of the battery to supply the system, if the number jumpered out is in accordance with the systems manufacturer's recommendations. Follow the manufacturer's directions when cleaning heavily corroded posts and connectors. Do not clean the surfaces so rigorously that the plating is removed. A plastic bristle brush can be used. Once the connection is clean, a thin coating of an approved corrosion inhibitor (such as No-Ox-Id) should be applied. Never use anti-corrosion sprays in aerosol containers. Observe the manufacturer's recommended torque values when remaking the connection.

(3) *Battery vent caps.* Vent plugs must be in place with their gas escape holes open. Flame arrestor vent caps should be cleaned periodically by thoroughly rinsing in clean, clear water. No solvents or detergents should be used.

(4) *Battery racks.* Clean any corrosion found and recoat the battery rack with a chemical-resistant coating, in accordance with the manufacturer's instructions. Replace cracked or broken corrosion-resistant rack covers. Consult the manufacturer if replacement spacers are required. Spacers are usually of foam plastic as they must be corrosion-resistant and nonswelling. Swelling of spacers can damage the battery jars. Recheck and retorque all rack bolts and anchoring bolts, steel plates, and welds. Note and correct any deficiencies in accordance with the manufacturer's recommendations/drawings.

b. Trouble indication comparisons. If two successive monthly readings for a particular cell are low in either voltage or specific gravity, a check should be made to see that this cell gasses properly while on charge. If it does, no action needs to be taken unless the reading goes still lower the next month. A lower reading indicates an insufficient charge, a short circuit, or impure electrolyte. The trouble should be corrected promptly. The manufacturer should be consulted if necessary. The full-charge specific gravity decreases as a battery cell ages. Although no definite value can be given, this decrease should not be more than a few points per year and can usually be overlooked if the trend is regular.

c. Proper charging. The proper charging of a battery is as important as any other maintenance consideration, since a battery cannot function without a charger to provide its original and replacement energy.

d. Water quality. Use of distilled or deionized water is recommended to eliminate the possible addition of foreign contaminants, which will reduce cell life and performance. The battery manufacturer will provide information on the maximum allowable impurities in water used for maintaining electrolyte levels if it is desired to test whether a local water system provides the desired water quality. Approved battery water should be stored in chemically inert, nonmetallic containers.

(1) *Additives.* Nothing but approved battery water should be added to storage batteries. Never add acid, electrolyte, any special powders, solutions, or jellies. Special powders, solutions, or jellies may be injurious; and have a corrosive or rotting action on the battery plates, reducing the voltage and capacity of the cells. The use of such additives will void the battery manufacturer's warranty.

(2) *Impurities.* Impurities in the electrolyte, beyond the manufacturer's maximum levels will cause irregular cell operation and should be removed as soon as discovered. If removal is delayed and foreign matter becomes dissolved, the battery should be replaced immediately. It may be possible to replace the electrolyte, but only if the manufacturer recommends a procedure to correct the specific condition which has occurred.

14-8. Testing of batteries.

Do not overtest. Frequent testing will shorten the service life. ANSI/IEEE 450 and ANSI/IEEE 1106 require a performance test within the first 2 years of service (a constant current capacity test, which discharges a battery to a designated terminal voltage, to detect any change in the capacity determined by the initial acceptance test). Subsequent performance tests are recommended at 5-year intervals, until the battery shows signs of degradation or has reached 85 percent of the service life expected. Degradation of lead-acid batteries is indicated when battery capacity drops more than 10 percent below its capacity on a previous performance test or is less than 90 percent of the manufacturer's rating. Perform tests in accordance with ANSI/IEEE 450 requirements.

a. Capacity tests. The only true indication of battery condition and capacity is a discharge test. Stationary cells designed for float operation should have no more than two deep discharges per year. The duration of these tests, test setup, personnel needed, and other requirements make frequent testing impractical. Another consideration is that the battery is not available to serve its load during a capacity test, requiring a system protective shutdown or provision of a redundant/replacement battery. For these reasons, voltage and specific gravity tests are used to periodically monitor the battery condition. Recognize that these readings indicate state-of-charge, but do not indicate the capacity of the battery.

(1) Use of *capacity tests.* The results of the capacity test can be used to determine the need for a replacement battery. Battery test sets are currently available from a number of manufacturers, or the user can fabricate a load bank (sometimes actual loads can be used). Three types of battery capacity tests are described in the standards: acceptance, performance, and service tests. Of these, the last two are required for normal maintenance testing.

(2) *Comparison of results.* It is important to compare the results to prior test data to establish a trend. Battery capacity may be less than 100 percent of nameplate rating during the first few years of operation, unless 100 percent capacity at delivery was required by the purchase specification. The capacity of a new battery (normally 90 to 95 percent of nameplate) will rise to its rated value after several charge-discharge cycles or after several years of float operation.

b. Test equipment. Test equipment used in battery maintenance is described in table 14-2. Special equipment may be available or may be rented, dependent upon the site's maintenance capabilities. Normal test equipment and safety equipment should already be available as a part of the electrical maintenance equipment. The use of safety equipment to protect personnel is mandatory; it should be available to maintenance personnel at all times. Periodically, recalibrate all devices as necessary. A number of new instruments are available which can continuously monitor a battery. These are often provided for systems serving very critical loads. One final caution is that instruments inserted into electrolyte should not be used for different battery types. For example, a hydrometer used on a lead-antimony battery should never be used on a lead-calcium or a nickel-cadmium battery. This cross use of equipment will cause cell contamination.

Table 14-2. Suggested test accessory list for battery maintenance

Item	Disposition
Battery capacity test set.	Special
Battery conductance tester	Special
Battery lifter.	Special
Metering of dc (located on the battery charger).	Normal
Hydrometer set.	Normal
Microhmmeter.	Normal
Portable infrared temperature measuring device	Normal
Terminal protective grease.	Normal
Thermometer set	Normal
Torque wrench	Normal
Chemical-resistant gloves.	Safety
Goggles and face shield.	Safety
Protective aprons or suits and shoes.	Safety
Rubber matting	Safety

Section III-FLOODED LEAD-ACID BATTERY CHARGING

14-9. Battery charging precautions.

Batteries are normally connected to their permanent charging equipment, but there may be occasions where testing or charging of new batteries requires connection to a test-shop charging device.

a. All charging. The following precautions will always be taken:

(1) Use tools with insulated handles.

(2) Prohibit smoking and open flames, and keep possible arcing devices removed from the immediate vicinity of the battery.

(3) Ensure that the load test leads are connected with suficient cable length to prevent accidental arcing in the vicinity of the battery.

(4) Ensure that all connections to load test equipment include short-circuit protection.

(5) Ensure that battery area ventilation is operable.

(6) Ensure unobstructed egress from the battery area.

(7) Avoid the wearing of metallic objects such as jewelry.

(8) Neutralize static buildup just before working on batteries by making contact with the nearest effectively grounded surface.

(9) Remove vent plugs from cells only to take readings or add water.

(10) Ensure that there are no unintentional grounds.

b. Test-shop charging. Use only direct-current equipment having the proper voltage. Connect the positive terminal of the charging circuit to the positive terminal of the battery and the negative terminal to the negative terminal.

14-10. Battery charging considerations.

The most desirable situation is for the battery to be operating fully charged. The approximate state of battery charge can be determined by the amount of charging current going into the battery if the connected- load is constant. Initially, the charging current, read at the charging ammeter, is a combination of the load current plus the charging current. The charging current will decrease and eventually stabilize when the battery is fully charged. If the connected load is variable, the battery voltage needs to be monitored. If the voltage across the pilot cell is stable for 6 consecutive hours, the battery is 100 percent charged. A constant current level for 3 consecutive hours indicates a charge of 95 to 98 percent.

a. Initial charge. Initial charge for placing a new battery in service is covered in section VIII.

b. Recharge. Following a discharge, all batteries should be recharged as soon as possible. To do this as quickly as possible, the battery charger output voltage is raised to the highest value that the connected system will permit.

14-11. Normal floating battery charge.

The floating (trickle) charge method is commonly used for returning the full charge on station batteries permanently connected to battery chargers. The floating charge rate is the sum of the low current (trickle rate) required to counteract internal battery losses, plus the average current requirements for the rest of the circuit. The required floating current is provided automatically, when the proper voltage is supplied to the battery.

a. Float action. The float-voltage point should just overcome the battery's trickle rate and cause the least amount of corrosion and gassing. Ambient temperature differences will affect the charging ability of the selected float-voltage level. The recommended float voltages range from 2.25 to 2.28 volts per cell. Select any volts-per-cell value within this range that is equal to the average volts per cell'in a series string. The excess energy of too high a float voltage results in loss of water, cell gassing, accelerated corrosion, and shorter cell life. To eliminate such actions, on daily or frequent discharges, the charge is stopped slightly short of a fully-charged condition. However, permissible cell manufacturing tolerances and ambient temperature influences will cause individual cell-charge variations.

b. Recharge requirements on loss of ac input. Providing the precise amount of charge on each and every cell for each and every recharge (caused by loss of ac input to the battery charger) is impractical for a continuously-floating battery operation. An overlong interval would be required to restore full charge on a deeply discharged battery if the battery charger remained at the low float voltage rate. To shorten the recharge period, a higher voltage charging rate is usually provided, either automatically or manually, This recharge is known as an equalizing charge.

c. Float voltages. Float voltages are directly related to cell type and plate alloy, as well as to the specific gravity of the cell. The higher the specific gravity, the higher the minimum float voltage must be. This ensures that sufficient charging current is available to overcome the increased local action. Too high a float voltage will result in overcharging and reduce battery life. A slightly higher float voltage is sometimes selected for maintenance purposes to reduce or even eliminate the need for periodic equalizing charges required because of nonuniform cell voltages.

14-12. Equalizing battery charge.

An equalizing charge is an extended charge to a measured end point on a storage battery cell to ensure complete restoration of the active materials in plates of the cell. Equalizing charges are provided after a battery discharge or for periodic maintenance. Equalizing voltages are selected by the battery chargers equalizing timer, as covered in section VII. Equalizing charges may need to be given a monthly check.

a. After discharge equalizing. An equalizing charge is required after any battery discharge. Although it is called an equalizing charge, it is basically a recharge, at about a 10 percent higher voltage, than the float voltage to restore the discharged battery to a fully charged state within a reasonable length of time.

b. Periodic equalizing. Lead-acid battery individual cell voltages will begin to drift apart, even if the battery is not discharged. A manually set charging rate will be necessary to "equalize" the voltage irregularities. Nonuniformity of cells can result from a low float voltage due to improper adjustment of the battery charger, a panel voltmeter that is reading an incorrect output voltage, or variations in cell temperatures greater than 5 degrees F (2.75 degrees C).

(1) *Provision.* Equalizing voltages should be given if the float voltage of the pilot cell is less than 2.20 volts per cell or more than 0.04 volts per cell below the average of the battery. Equalizing voltage is required if the individual pilot cell voltages show an increase in spread since the previous readings, or if the periodic check of all cell voltages reveals a difference of 0.04 volts between any cell and the average cell voltage.

(2) *Action. An* equalizing charge is made at a rate not higher than the normal charging rate of the battery. It is continued until all the cells gas freely and any low cells are fully charged. Low cells are usually found in the warmest section of the battery. They normally have the lowest voltage while on

charge, or a lower specific gravity between equalizing charges when compared with adjacent cells.

c. Charging voltage. Battery voltage should be increased for a definite period of time as shown in table 14-3. The highest voltage that circuit and equipment limitations will permit should be used. A continuous charge is preferable, but intermittent charging may be necessary to conform to working schedules. In any case, the charge must be continued until all cells gas freely. Raising the voltage, particularly to the higher values of table 14-3, should be done gradually to avoid excessive currents. After completing the equalizing charge, the charging voltage should be reduced slowly to below the floating value and the ammeter should be watched to avoid reversal of the current to the charging source. After a few minutes, the voltage should be increased to the floating value. Do not wait for the battery voltage and current to stabilize at precharge values.

d. Charging current. Actual battery charging current depends on temperature, battery age, and recent use of the battery. Therefore, specific charging current values cannot be given. As a general guide, at its optimum operating temperature, current flowing to a fully charged battery, that has been under constant voltage of 2.15 volts per cell for approximately 1 hour or more, should be between 0.25 and 1.0 percent of the 8-hour rate of the battery At a higher temperature, or when there has been a recent discharge, an increase in current is required. At lower temperatures, if the battery has been subject to a higher voltage, a lower current will be observed which may flow temporarily in the discharge direction. If the trickle rate is consistently less than 0.25 percent or more than 1.0 percent of the 8-hour rate of the battery, the meter should be checked. A permanently connected ammeter in the battery circuit is impracticable, because any high discharge currents would pass through the meter in a reverse direction.

Table 14-3. Equalizing charge

Battery voltage per cell (volts)	Battery voltage for 60 cells (volts)	Length of monthly Charge (hours)
2.42	145	3 to 8
2.39	143	4 to 12
2.36	142	6to 16
2.33	140	8 to 24
2.30	138	11 to 34

Section IV-VALVE-REGULATED LEAD-ACID CELL BATTERIES

14-13. Valve-regulated cell differences.

Valve-regulated sealed lead-acid cells are not installed in transparent jars like traditional cells. Plates are not visible, and the electrolyte is not accessible.

a. *Maintenance.* These batteries are neither sealed nor maintenance-free. The cell cannot be considered sealed as a pressure relief valve is provided to open when the cell's internal pressure exceeds a set limit. Once the pressure is relieved the valve closes and reseals. Cell which do not reseal but leak may require replacement. For this type of construction there is no need to check the electrolyte level nor the specific gravity of each cell. Other battery maintenance requirements are still necessary, such as visual inspection, cleanliness, cell voltage resistance, charging, capacity testing, and others previously covered. Outgassing of these batteries is low at normal charge rates, but it can occur when there is a battery or a battery charger failure. Do not fully enclose cells in any manner which inhibits cooling air, and do not place them in the heat flow of electronics which may occupy the same enclosure. For safety reasons these batteries require the necessary air changes covered earlier.

b. Types. There are two types of cells commercially available: the absorbed (or starved) electrolyte cell and the gelled electrolyte cell. Both operate to enhance a recombination of hydrogen and oxygen back to water. Properly charged, there is a minimal loss of evolved hydrogen and oxygen; therefore, no water needs to be replaced during the battery's expected life. Charging above the manufacturer's recommended rating will result in venting hydrogen and oxygen from the cell and, if prolonged, will cause premature failure. Gelled electrolyte cells are normally operated in a vertical orientation; however, some manufacturers can-produce a cell which can be operated horizontally.

14-14. Charging of valve-regulated cells.

Charging of valve-regulated sealed lead-acid cells is similar to charging of flooded cells, but the charging voltage must be monitored more closely. Normally, the cells operate on float charge without the need for a periodic equalizing charge. Recharge times are relatively short when recharges are required. Temperature compensation of the float voltage is more critical than ‘for flooded cells, and a temperature-compensated battery charger should be utilized.

14-15. Temperature compensation for valve-regulated cells.

Failure to temperature-compensate the float voltage can cause premature cell failure. The recommended float voltage is 2.25 volts per cell at 77 degrees F (25 degrees C). The float voltage may need to be increased to 2.33 volts per cell if the ambient temperature is 55 degrees F (13 degrees C); and may need to be decreased to 2.18 volts per cell if the ambient temperature is 95 degrees F (35 degrees C). Consult manufacturers' catalogs for specific values for their cells. Ripple content of the battery charger output must also be considered Ripple voltage limits are specified by some battery manufacturers on their cell data sheets. Excess ripple may reduce the expected life of the battery, particularly when the battery has a low internal resistance.

Section V-NICKEL-CADMIUM CELL BATTERIES

14-16. Description of nickel-cadmium batteries.

The nickel-cadmium technology results in more expensive batteries but these batteries are resistant to mechanical and electrical abuse; will operate well over a wide temperature range; and can tolerate frequent shallow or deep discharging.

a. Construction. Nickel-cadmium (NiCad) batteries may be flooded cell type; valve-regulated cell type, or sealed cells.

(1) *Flooded cells.* These units utilize plates made of nickel-oxide for the positive electrode and cadmium for the negative electrode. The electrolyte is an alkaline solution of potassium hydroxide which does not take part in the cell reaction. Accordingly, its specific gravity does not change during charge or discharge, and the electrolyte retains its ability to transfer ions irrespective of the charge level. The majority of cells used in station battery applications are of the vented type. During discharge, vented-type cells can produce hydrogen gas and oxygen gas in a potentially explosive mixture which must be adequately exhausted. Since the gas is free from corrosive vapors, a dedicated battery room is not required, although it is still recommended.

(2) *Value-regulated cells.* These are similar in construction to the vented types, except that their design allows evolved gases to combine and thereby reduces water losses.

(3) *Sealed cells.* Because of their limited capacity, sealed cells without valve-regulation are normally used only for backup of electronic devices.

14-17. Requirements for nickel-cadmium batteries.

In general, all of the procedures and tests described for flooded lead-acid cell batteries are valid for nickel-cadmium batteries, except for specific gravity. The nickel-cadmium electrolyte is a solution of potassium hydroxide in water with a specific gravity between 1.180 and 1.200, depending upon the manufacturer. The electrolyte does not enter into the reaction of the nickel-cadmium cell. Therefore specific gravity is not an indication of state-of-charge and specific-gravity readings are not part of normal routine maintenance. If readings are taken, the temperature correction for the electrolyte is the same as for lead-acid batteries. The electrolyte in a nickel-cadmium cell with a specific gravity of 1.190 will start to freeze (slush) at approximately minus 10 degrees F (minus 23 degrees C). Occasionally, grayish-white deposits of potassium carbonate may be seen on the cell tops. These deposits form because the electrolye entrained in the escaping gas reacts with the carbon dioxide in the air. Although not corrosive, this deposit is a conductor when damp and needs to be removed from the battery.

a. Parameters. The maintenance procedures for flooded lead-acid cell batteries, discussed previously, also apply to nickel-cadmium cell batteries if the parameters are changed to those appropriate for alkaline cells. Float voltages for nickel-cadmium cells are significantly different from those for lead-acid cells. For the same battery terminal voltage, the number of cells will be greater, because a lead-acid battery is a nominal 2-volts per cell while a nickel-cadmium battery is a nominal 1.2-volts per cell. Degradation of nickel-cadmium batteries or excessive capacity loss is indicated when the battery capacity has dropped more than 1.5 percent of rated capacity per year from its previous performance test capacity. Thereafter, annual performance tests must be provided in accordance with ANSI/IEEE 1106 requirements.

b. Temperature. Nickel-cadmium batteries are less affected by temperature than lead-acid batteries. They can sustain high temperatures more easily, because the chemistry in the active materials is relatively stable. For example, at 90 degrees F (32 degrees C) the normal life of a nickel-cadmium cell is reduced by about 20 percent, compared with a reduction of about 50 percent for a lead-acid cell. With a normal electrolyte, the battery will operate at temperatures as low as minus 30 to 40 degrees C. With a higher specific gravity electrolyte, it will operate at even lower temperatures. The available capacity is reduced at low temperatures, but at minus 40 degrees C a nickel cadmium battery can still deliver 60 percent or more of its rated capacity.

c. Memory effect. Nickel-cadmium cells charged at very low rates are subject to a condition known as a "memory effect." Repeated shallow cycling, to approximately the same depth of discharge, leads to continual low-rate charging and results in a loss of surface area in the negative active material, due to the growth of large crystals. This increase in the cell's resistance produces a grater voltage drop. The result is a reduction in the effective reserve time of the system. The memory effect can be erased by providing a complete discharge followed by a full charge with constant current. This breaks up the crystalline growth on the plates. The conditions of station operation will rarely lead to this type of cycling, but users should be aware of the cause and the cure.

d. Electrolyte level. Vented type units will need to have the electrolyte level checked, even though a specific gravity reading may not be required.

(1) *Electrolyte level.* Caution must be taken when handling the electrolyte. The electrolyte level in all cells should be checked monthly. The maximum level of the electrolyte is halfway between the tops of the plates and the inside of the cell covers. (Do not include vent heights.) The level can be checked visually if the cell containers are transparent. If not, the level may be determined by inserting an electrolyte-level test tube (plastic or glass) through the vent until it rests on top of the plates. Then place a finger tightly over the exposed end, and withdraw the tube for inspection. The electrolyte must always be returned to the cell from which it was withdrawn. When the electrolyte level is low, distilled water should be added to restore the electrolyte to the proper level, but the cell should not be overfilled. If the cells are overfilled, the electrolyte will be forced out of vents during charging and will saturate trays. This causes electrolysis between the cells, corrosion of the cell containers, and troublesome grounds in the electrical circuit. Overfilling the cells will also dilute the electrolyte to such an extent that the battery's specific gravity will be reduced and cell plates will be damaged.

(2) *Electrolyte renewal.* When electrolyte is clear and colorless, it is in good condition. Electrolyte that has become contaminated with small quantities of carbon dioxide from the air will form potassium carbonate and will appear cloudy. If the solution becomes colored or cloudy, it is evident that the electrolyte is contaminated with impurities and should be changed. It may also become necessary to change the electrolyte due to overcharging or overflow, which cause the specific gravity to fall outside the manufacturer's specified range. If the specific gravity is low, continued operation will result in a rapid reduction in the life of the battery. Therefore, when the specific gravity falls below 1.170, the electrolyte should be changed. Follow the manufacturer's instruction when renewing the electrolyte. The battery warranty may not permit renewal without the manufacturer's permission.

e. Charging. Specific gravity or cell voltage readings generally cannot be used to determine the state of charge of a nickel-cadmium battery. To ensure that the battery is fully charged, it should be given a booster charge once a month, after any heavy or intermittent discharges, or after the battery charger has been out of service. Maintenance personnel should maintain a record of the monthly booster charges. The accuracy of the charger voltmeter should be checked against a recently calibrated voltmeter at least once a year. A summary of charging requirements for nickel-cadmium batteries is given in table 14-4.

f. Precautions. In addition to the precautions given for lead-acid cell batteries, prohibit the use of acid-contaminated tools and equipment, such as hydrometers and thermometers used for lead-acid cell maintenance.

Table 144. Charging of nickel-cadmium batteries

Charge	Requirements
Initial charge	1. The first charge of batteries that are delivered discharged should be carried out at constant current. 2. When the battery charger's maximum voltage setting is too low to supply constant current charging, divide the battery system into two parts to be charged individually. 3. Follow the manufacturer's instructions for setting the charging rates.
Float charge	1. Float charge voltage should be maintained at 1.43 volts to 1.45 volts per cell to avoid gassing. 2. Maintain constant voltage charging to prevent the battery from discharging at a depressed voltage level. 3. To prevent excessive water consumption, avoid charging the battery at higher values than recommended.
Booster charge	1. The booster charge should be 1.65 volts per cell. 2. A fully discharged battery in good condition can be fully charged in 4 hours. 3. If the float charge has maintained the battery in a fully charged condition during the month, the monthly booster charge will be minimal. 4. The booster charge should be continued until the charging current has leveled off for two consecutive readings one-half hour apart. 5. When applying a booster charge, it is important to watch the electrolyte temperature in the cells. If the temperature reaches 100 degrees F (43 degrees C), the charging rate should be reduced at once.

Section VI-CHECKS AND TROUBLESHOOTING

14-l 8. Inspections of batteries.

Inspections should be made under normal conditions and performed on a regularly scheduled basis. All inspections should be made under normal float conditions. Specific gravity readings are not meaningful during charge or following the addition of water. Readings should be taken in accordance with the manufacturer's instructions. Refer to the appendices of ANSI/IEEE 450 and ANSI/IEEE 1106 for more information.

a. Monthly. Provide recorded checks of the following data:

(1) Check float voltage measured at the battery terminal.

(2) Observe general appearance and cleanliness of the battery, the battery rack, and battery area.

(3) Check battery charger output current and voltage

(4) Check electrolyte levels.

(5) Check for cracks in cells or leakage of electrolyte.

(6) Check for any evidence of corrosion at terminals, connectors, or racks.

(7) Check ambient temperature and condition of ventilation equipment.

(8) Check the pilot-cell (if used) voltage, specific gravity of flooded lead-acid pilot cells, electrolyte temperature of flooded pilot cells, and terminal temperature of valve-regulated cells.

b. Quarterly. In addition to the monthly items, provide recorded checks of the following data:

(1) Check all cell voltages, specific gravities of all flooded lead-acid cells, and all terminal temperatures of valve-regulated batteries.

(2) Check total battery terminal voltage.

(3) Check 10 percent of intercell connection resistances chosen at random.

(4) Clean and provide corrosion protection of cells, terminals, and racks, and add water, as necessary, to adjust electrolyte levels.

(5) Provide an equalizing charge if cells are unbalanced.

(6) Analyze records and report any recommendations.

c. Annually. In addition to the quarterly items, provide recorded checks of the following data.

(1) Provide a detailed visual inspection of each cell.

(2) Check all bolt connections in accordance with ANSI/IEEE 450 or ANSI/IEEE 1106 to see if retorquing is required. Retorque to the manufacturer's specifications if required.

(3) Check intercell, intertier, and battery terminal connection resistances.

(4) Check integrity of the battery racks.

d. Special inspections. A special inspection should be made whenever a battery experiences an abnormal condition (such as a severe discharge or overcharge) to ensure that the battery has not been damaged. This inspection should include all the quarterly tests.

14-19. Troubleshooting batteries.

When battery system performance is questionable, all the service checks required under annual inspections will need to be made. Generally, any cell which demonstrates conditions beyond the manufacturer's recommended limits should be replaced. The system should be rechecked to ensure all suspect cells have been removed. Where widespread premature battery failures are encountered, the battery manufacturer's service department should be contacted for further instructions. Cell polarity reversal, failure to hold charge, and inability to maintain an acceptable specific gravity are conditions which mandate further investigation. When low or high float voltages, temperature variations, visual observation of deterioration or swelling, and low open-circuit voltages, all exceed the manufacturer's parameters, the cells are probably damaged beyond repair.

Section VII-BATTERY CHARGING EQUIPMENT

14-20. Battery charging requirement.

A battery cannot function without a device which maintains its properly charged condition. A well-designed battery charger should provide the correct balance between overcharging and undercharging so as not to damage a battery. Additionally, a battery charger may have features to limit or alarm when the battery discharges to the point where the cells approach exhaustion, or where the voltage falls below a useful level (usually about 80 percent of the battery's rated capacity). Overcharging, if done frequently, results in increased water use. Overdischarging tends to raise the temperature, which may cause permanent damage.

a. Current flow. Batteries are connected to the battery charger so that the two voltages oppose each other, positive of battery to positive of battery charger and negative to negative. Battery current is the result of the voltage differences between the battery and the battery charger which flows through the battery's extremely low opposing resistance. The voltage of the battery which rises during charging starts to limit current flow. Battery chargers are designed to limit charging currents to values that keep the charging equipment within a reasonable size and cost. Battery chargers must also maintain a sufficiently high current throughout charging, so that at least 95 percent of the complete storage capacity is replaced within an acceptable time period. This recharge time is usually not more than 8 hours for station service.

b. Charging equipment. Batteries must be charged by direct-current. The available sources are an ac-to-dc rectifier and an ac-to-dc motor-generator set. The use of motor-generator sets to supply station batteries is an unusual practice now because the function is so reliably and economically handled by rectifier type battery chargers. If motor-generator sets are used, maintenance should be in accordance with the manufacturer's instructions.

14-21. Rectifier type battery chargers.

There are several types of rectifiers used for battery charging. All operate on the same principle permitting current to pass freely in one direction, while permitting little, if any, current to flow in the reverse direction. Refer to manufacturer's instructions for details of each type.

a. Silicon-controlled rectifier (SCR) type. This type uses silicon diodes to provide the rectification of ac voltage input to dc voltage output. Units may include transistor-controlled magnetic amplifiers. If not filtered, units can cause electromagnetic interference (EMI) and radio frequency interference (RFI). A properly filtered unit will eliminate this problem. However, the filter capacitor may take several minutes to discharge, even after isolation of the battery charger from the ac input and the battery. This feature should be noted by a warning label on the battery charger.

b. Controlled ferro-resonant type. This is an improved version of the simple ferro-resonant type, which was the first static battery charger developed, and which used a constant voltage transformer and selenium stacks. The simple ferro-resonant type was quieter and much easier to use than a motor-generator, but had serious control shortcomings. The controlled ferro-resonant type includes a control winding, a triac, and a control circuit to overcome these problems. It is very important for personnel to distinguish between "simple" ferro-resonant units and "controlled" ferro-resonant units to be sure that the dual-rate (float/equalize) requirement for battery charging is acceptable.

14-22. Accessories for battery chargers.

Dependent upon the specific unit, battery chargers will be provided with various accessories. The maintenance of these devices should be as recommended by the manufacturer. Included in the category of accessories are meters, equalizing control, indicating lamps, dc voltage level alarm, ground detection alarm, and electrolyte level alarm. Meters and indicating lamps should be connected to the load side of the circuit breakers on the circuit being monitored. Connections on the line side can give a false indication of power availability.

a. Equalizing control. Equalizing control should include a manual switch for transferring the lower-rate float charge to the higher-rate equalize charge. Optional accessories include equalizing timers and automatically-controlled equalizing timing for adjustable interval settings.

(b) Input and output. Input and output circuits are always provided with protection. Fuses are standard accessories. Circuit breakers are optional, but are a preferred means of isolating the battery charger for maintenance.

14-23. Maintenance of battery chargers.

Battery chargers are designed to require a minimum of maintenance. There are no rotating parts, except in the optional timer, and all components normally have an indefinite life and no aging effects. However, it is possible for a diode or rectifying stack to fail at long intervals, either by open-circuiting or short-circuiting. Failed items should be replaced in accordance with the manufacturer's instructions. Battery chargers should be kept clean, dry, and checked periodically to make sure all connections are tight. If necessary, dry air may be used to blow dust out of the interior. In the event of any irregular operation, examine and tighten, if necessary, all internal and external connections and check circuits for continuity. If the difficulty cannot be remedied, contact the manufacturer.

a. Checking. Regardless of the quality of the battery charger, its operation should be checked, at the same time as its battery is inspected, to ensure that it is functioning properly. Any radical trouble will be indicated by overheated components on either the battery charger or the battery installation, by blown fuses, or by failure to complete the charge. In such cases the trouble must be located and remedied. Certain adjustments may gradually "drift" from their normal position and require correction. At each monthly inspection provide recorded checks on the following data:

(1) Check the voltage of battery chargers in floating operation.

(2) Check the current output and/or voltage of battery chargers in cycle operation, during normal use.

(3) Check the operating temperature of equipment, (by touch)

(4) Check the operating voltage of voltage-sensitive relays.

(5) Check the operation of timers.

(6) Check that all meters are at zero calibration.

b. Potential testing. Whenever checking circuits or components, do not test with a megohmeter of any potential higher than the voltage of the equipment which is being tested. Any higher voltage may break down rectifying elements or insulation not designed to withstand it.

c. Slope characteristic. Every battery charger has a relationship between the output voltage and the output current throughout its complete range. For any given voltage, the battery charger will always deliver a given current and vice versa. This slope characteristic is inherent in the battery charger and is not affected by the size or type of battery. It simply responds to the counter-voltage of the battery.

(1) *Battery charger suitability.* The battery charger, if properly designed, will have a slope characteristic compatible with the battery it is charging.

2. *Checking of the battery charger slope.* In the event of any apparent improper operation, the battery charger slope characteristics should be checked. If actual readings of voltage and current fall on or reasonably near the slope line, the battery charger is not at fault and the trouble is elsewhere.

Section VIII-PLACING A NEW BATTERY IN SERVICE

14-24. Placing lead-acid batteries in service.

Most lead-acid batteries are manufactured as wet-charged units. However, vented (flooded) batteries can be ordered as dry-charged units, when it is desirable to store them for a considerable period before they are put in use.

a. Wet-charged batteries. Wet-charged lead-acid batteries contain fully-charged elements and are filled with electrolyte at the time of manufacture. A wet-charged battery will not maintain its charged condition during storage, and must be recharged periodically even if not used. Upon receipt of a battery, it is recommended that it be given an initial charge for a period of from 3 to 6 hours. Charge until there is no rise in the specific gravity. Use the finishing rate as indicated in the specific battery instructions or on the battery nameplate. Cell temperature during charge should not exceed 110 degrees F (43 degrees C). Should the temperature become excessive, the charging rate should be decreased.

b. Dry-charged batteries. A dry-charged battery contains fully-charged elements, but it contains no electrolyte until it is activated for service. It leaves the manufacturer in a dry state. Once activated, it is essentially the same as a wet-charged battery. At the time of manufacture, the battery elements are charged by a direct current being passed through the plates while they are immersed in an electrolyte of dilute sulfuric acid. The fully-charged plates are then removed from the electrolyte, washed in water, and completely dried. The battery is then assembled. A dry-charged battery retains its state of full charge as long as moisture is not allowed to enter the cells.

(1) *Filling.* Most manufacturers furnish a packaged electrolyte and instructions for placing the battery in service to ensure that the proper electrolyte is used and that the battery is properly charged. The furnished electrolyte will probably have a specific gravity about 10 points lower than the nominal full charge specific gravity of the battery.

(2) *Freshening charge.* It is a good practice to slow charge a freshly-activated battery. This ensures a fully-charged battery. Always charge a newly-activated battery for at least an hour. Once it has been properly prepared and installed, a dry-charged battery will have the capacity, characteristics, and the life of a similar wet-charged battery.

14-25. Placing nickel-cadmium batteries in service.

Batteries will generally be supplied “filled and discharged”, but “filled and partially charged” units can be provided. Either type should be capable of being stored for up to one year without a recharge. Vented (flooded) units can also be provided as “discharged and empty” and can be stored indefinitely. All vented batteries must be firmly fitted with vent plugs during transit. Check plugs periodically to ensure integrity of the seals. Charging during storage, charging prior to putting in service, and filling empty cells should be done in accordance with the manufacturer’s instructions and using the manufacturer’s electrolyte.

14-26. Connections for batteries.

Clean all points of electrical contact to be certain of good conductivity through terminal connections. If connections are copper, apply a coat of petroleum jelly (such as Vaseline) to prevent corrosion.

Section IX-PUTTING A BATTERY IN STORAGE

14-27. Battery storage procedure.

If a battery is to be temporarily taken out of service, charge it until all the cells gas; add water to vented type batteries during the charge, so that the gassing provides complete mixing to ensure against freezing. Add enough water to raise the level of the electrolyte to the full line marked on the jar, or as recommended by the manufacturer. After the charge is completed, remove all fuses to prevent use of the battery during its storage period. Make sure that all vent plugs are in place. To put the battery in service again, give it a freshening charge in accordance with the manufacturer's instructions.

14-28. Periodic check of a stored battery.

At certain periods, each stored battery should be reconnected; water should be added to vented type batteries; and the batteries should be charged. For lead-acid batteries, this should be done every 2 months in climates averaging 70 to 80 degrees F (21 to 27 degrees C); every 6 months when the average temperature is on the order of 40 degrees F (5 degrees C); and every 3 or 4 months for temperatures in between. Nickel-cadmium batteries may be stored for longer periods.

Section X-REPLACEMENT AND DISPOSAL

14-29. Replacement of a battery.

Generally, if a battery's capacity is less than 80 percent of the rated capacity, the recommended action (by industry consensus) is replacement. The urgency of the replacement will depend upon the available capacity margin, and the sizing criteria compared to normal load requirements. Whenever replacement is dictated, the maximum delay should be no more than 12 months.

a. Other replacement criteria. Significant differences in the capacities of individual cells, cell polarity reversal, failure to hold charge, and inability to maintain an acceptable specific gravity are conditions which require further investigation. Replacement of individual cells may be required in order to maintain capacity.

b. Cell replacement. Replacement cells must be compatible with the remaining battery cells and should be discharge tested before installation. As a battery installation approaches the end of its service life, it is not recommended that individual cells be replaced.

14-30. Disposal of batteries.

Unless tested and proven otherwise, batteries, because of their electrolytes, are classified as hazardous waste. Recycling is the most cost-effective and trouble-free method of disposal, and therefore is the preferred disposal method when batteries are removed from service. The Resource Conservation and Recovery Act (RCRA) governs the requirements for management and control of all wastes, hazardous or nonhazardous, and applies to the disposal of batteries. RCRA states that spent batteries must be sent to a battery manufacturer for recycling or regeneration. Other recyclers are not acceptable. Some manufacturers will accept old batteries for recycling and regeneration. Although manufacturers generally accept lead-acid batteries more willingly than nickel-cadmium batteries, a fee may be charged for regeneration. Actual disposal must meet both RCRA and local facility requirements.