

CENTRAL OFFICE AND PABX LEAD-ACID
BATTERIES
GENERAL INFORMATION

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1. GENERAL

1.01 This section provides general information on lead-acid battery cells.

1.02 This section is reissued to update the text and to include information on flame arrestors and procedures for cleaning them. Because of the extensive changes involved, change indicators are omitted. Remove the previous issue of this section from the binder or microfiche file and replace it with this issue.

1.03 GTE AE practices are used by GTE employees for operating and maintaining the equipment GTE AE manufactures and sells. These practices may change or may not be suitable in a specific situation and so are recommended as suggested guidelines only. GTE AE hereby disclaims any responsibility and/or liability for any consequential or inconsequential damages that may result from the use of such practices unless such practices are utilized in conjunction with the operation and maintenance of original equipment manufactured or supplied by GTE AE and covered by its standard warranty. GTE AE acknowledges that the customer's special requirements policy/practices may take precedence over those supplied by GTE AE if conflicts develop during installation and ongoing operation.

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2. PHYSICAL DESCRIPTION

2.01 Lead-acid battery cells are used to supply electrical energy upon demand. During discharge, the electrical energy results from chemical action within the cell.

Plates

2.02 The plates of a storage cell are the electrodes of the cell as well as the conductors by which the current enters and leaves the electrolyte.

2.03 The active material of the negative electrode or plate is made of gray metallic lead in finely divided form, commonly called spongy lead (Pb). The active material of the positive electrode is made of chocolate-brown-colored lead peroxide (PbO₂).

Lead Peroxide

2.04 The term active material does not refer to the frames or grids but to the spongy lead and the lead peroxide.

2.05 Lead peroxide is sometimes called lead dioxide. These materials are not hard enough to be made into plates that are mechanically rugged; therefore, frames or grids of a hard lead-antimony alloy are used. The spongy lead and lead peroxide are pressed into the openings of the grids.

2.06 To obtain large capacity, electrodes or plates must have a large area of active material. This is accomplished by connecting several negative plates in parallel and sandwiching the positive plates between the negative plates. This arrangement requires one more negative plate than positive plate.

2.07 If positive and negative plates touch, the battery will be short-circuited. To prevent this, thin sheets of nonconducting porous material called separators are inserted between the plates.

Separators

2.08 Separators are most often made of rubber but may also be made of wood or glass. The smooth side of the separator is next to the negative plate, and the grooved side is next to the positive plate. This allows the oxygen gas that is formed to escape and the loosened active material to fall to the bottom on the side next to the positive plate. After the separators are placed between the plates, the assembly is called an element, and when immersed in electrolyte, it becomes a cell.

Electrolyte

2.09 An electrolyte conducts electric current; it does this because it dissociates into ions (an ion is an atom or group of atoms that carry an electric charge). When the electric current flows through the electrolyte, the ions circulate through it.

2.10 The electrolyte used in lead-acid cells is composed of water (H₂O) and sulfuric acid (H₂SO₄).

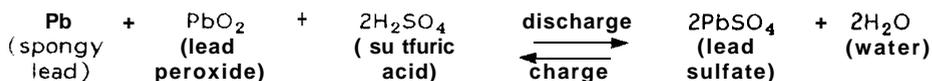
NOTE: All batteries furnished for use in telephone company power rooms are equipped with flame arrestors (see part 9).

3. CHEMICAL REACTION

3.07 Immersion of the battery plates in electrolyte causes a chemical reaction and a difference of potential between the plates.

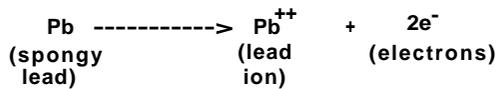
Discharge Cycle

3.02 A description of the chemical reactions in lead-acid cells can best be explained by chemical symbols written in the form of a chemical equation:



3.03 Consider this equation in parts in order to analyze what takes place at the negative and positive plates during the discharge cycle. At the negative plate, the spongy lead (Pb) partially dissolves due to the action of the sulfuric acid (H₂SO₄), and goes into a solution state. Ionization then occurs.

3.04 During ionization, each spongy lead atom loses two electrons and is changed to a lead ion as shown in the following equation

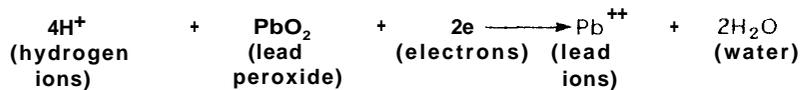


3.05 The negative electrons flow from the negative plate through the external load to the positive plate. The electron flow constitutes the electric current drawn from the cell to the load to do useful work.

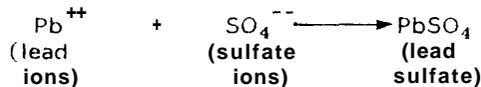
3.06 The lead atom in the PbO₂ molecule of the positive plate is able to absorb the two electrons returning from the external load and thus becomes Pb⁺⁺ as shown:



3.07 Therefore, the action at the positive plate breaks the lead peroxide molecule (PbO₂) into Pb⁺ and O₂. While the previous actions are taking place, the sulfuric acid molecule (H₂SO₄) breaks into H⁺ ions and SO₄⁻⁻ ions. The H⁺ ions from the H₂SO₄ and O, from the PbO₂ are free to unite and form water (H₂O) as shown:



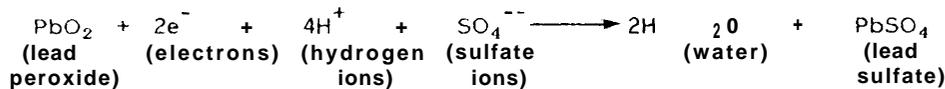
3.08 It can be seen from the above equations that at both the negative and the positive plates there are lead ions (Pb⁺⁺). At both plates, the lead ions (Pb⁺⁺) unite with the sulfate ions (SO₄⁻⁻) to form lead sulfate (PbSO₄) as shown:



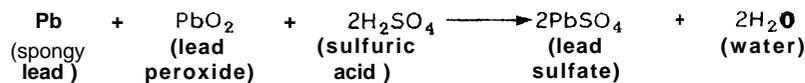
3.09 The chemical reaction at the negative plate, therefore, is the action expressed in paragraphs 3.04 and 3.08. Combining them, we have:



3.10 The reaction at the positive plate is the action expressed in paragraphs 3.07 and 3.08. Consolidating them reveals the following



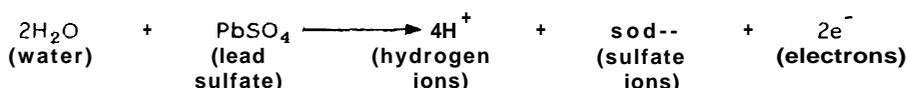
3.17 By adding the actions of the equations in paragraphs 3.09 and 3.10, the following reactions occur at both plates:



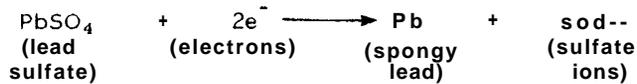
3.12 The equation in paragraph 3.11 is the equation for the discharge cycle of a lead-acid cell. To charge a lead-acid cell, the chemical process just described must be reversed. This is accomplished by introducing a direct steady current in the proper direction. The plus terminal of the cell to be charged should be connected to the plus terminal of the battery charger, and its minus terminal to the minus terminal of the battery charger.

3.13 In this manner, a current is forced into the battery in the opposite direction of the current that the battery would normally supply. The electromotive force of the charging source must be greater than that of the battery.

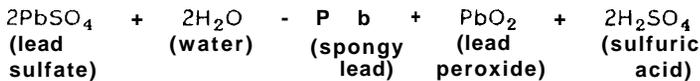
3.14 During charging, at the positive plate, the water (H₂O) and the lead sulfate (PbSO₄) break up to form lead peroxide (PbO₂), hydrogen ions (H⁺), sulfate ions (SO₄⁻⁻) and two negative electrons (2e⁻). This equation is as follows:



3.15 The hydrogen ions and the sulfate ions combine to form sulfuric acid (H₂SO₄). The negative plate gains the two electrons lost by the positive plate. Therefore, at the negative plate, the lead atom of the lead sulfate (PbSO₄) gets back its two electrons and changes back into spongy lead. Consequently, the equation that results is as follows:

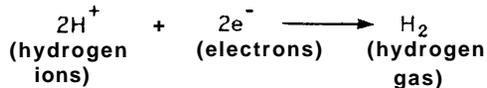


3.16 The combined total reaction at both plates is expressed by adding equations in paragraphs 3.14 and 3.15 together. The result is the following equation :

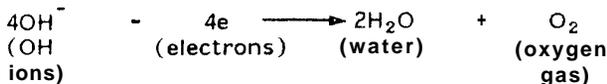


3.17 The equation in paragraph 3.16 is the same as the equation in paragraph 3.02, reading from right to left. In addition to the reactions shown in paragraphs 3.14, 3.15, and 3.16, the passing of a direct current through the cell causes a chemical reaction of the water, which is present in the electrolyte.

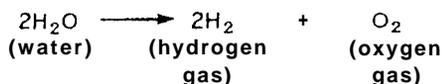
3.18 The water ionizes slightly into H⁺ and OH⁻ ions. The positive (H⁺) ions are attracted to the negative plate where they receive a negative electron and become a hydrogen atom. Each hydrogen (H) atom unites with another hydrogen atom to form a molecule of hydrogen gas (H₂) as shown:



3.19 At the positive plate, the 4OH⁻ ions lose four electrons and break down into water and oxygen molecules. The following equation results:



3.20 The combined result for the action at both plates results in the following equation:



3.21 The above reaction is known as the electrolysis of water. It explains certain effects you may have observed while watching batteries being charged.

3.22 It is possible to determine the polarity of the plates by simply noting the amount of bubbles being formed during charging of the battery. The negative plate will have twice as many hydrogen bubbles compared to oxygen bubbles at the positive plate. This can be seen by the equation in paragraph 3.20.

NOTE: Electrolysis lowers the water level of the cell; therefore, distilled water must be added from time to time.

CAUTION: The oxygen and hydrogen gases emitted from the batteries form a dangerous explosive which ignites in the presence of a spark; therefore, battery charging rooms must be well ventilated and smoking must be prohibited.

4. BATTERY OUTPUT

4.01 The open-circuit voltage of a fully charged lead-acid cell is about 2.05 volts regardless of the size of the cell.

4.02 To form a battery, the cells are connected in series by connector straps made of copper and coated with lead.

4.03 The temperature, discharge rate, specific gravity, and final cell voltage affect the ampere-hour capacity of a battery. For maximum capacity, the battery must be kept fully charged. Battery capacity is a current-time rating and is measured in ampere-hours.

4.04 The discharge rate of a battery is the amount of current (measured in amperes) required to discharge a previously fully charged battery to its Final Cell Voltage (FCV) in a specified period of time. The ampere-hour (Ah) capacity of a battery is the product of the discharge rate in amperes and the discharge time in hours to the FCV. In the telephone industry, the Ah-capacity ratings are standardized on the basis of an 8-hour discharge period to a FCV of 1.75 volts per cell, at which voltage the battery is considered to be fully discharged.

4.05 Thus, a battery capable of delivering 210 amperes of current for 8 hours has a rating of 1,680 ampere-hours. This means the battery can draw 210 amperes of current for 8 hours before the battery reaches its normal minimum (final) cell voltage level of 1.75 volts. Only a small percentage of the cell's rated capacity can be obtained beyond this final cell voltage.

4.06 The same battery also delivers 179 amperes for 10 hours. The ampere-hour rating is based on an 8-hour discharge rate at 77°F and a specific gravity of 1.215. If a battery is discharged at a current higher than its 8-hour rate, its ampere-hour capacity will be much less than its rated ampere-hours; if discharged at a lower rate, it may deliver considerably more than its rated ampere-hours.

4.07 Thus, a battery delivers more ampere-hours at a long, low, or intermittent rate of discharge than at a short, high, or continuous rate. The normal rate of discharge for the battery is determined by the number of hours the battery is expected to be the only source of power.

4.08 Temperature also affects the ampere-hour capacity as indicated in part 7.

4.09 A cell that has become sulfated or has lost some of its active material due to shedding will deliver less current than a good cell. A cell partially discharged will deliver less current for a given period than the fully charged cell since the speed of the chemical reaction depends upon the strength of the electrolyte.

4.10 The strength of acid in the cell varies with the state of charge. If the cell is charged, there is more acid in the electrolyte than when the cell is discharged. When the cell is discharging, the chemical action taking place in the cell breaks down the acid content of the electrolyte. Lead sulfate is formed on the plates. Water is formed in the electrolyte.

4.11 The amount of acid in the electrolyte is an accurate measure of the state of the charge.

4.12 The increase of water in the electrolyte causes the specific gravity of the electrolyte to decrease.

4.13 The specific gravity of the electrolyte in a charged cell is higher than in a discharged cell.

4.14 The standard used for determining specific gravities of liquids is water. One cubic centimeter of water at 4°C weighs 1 gram.

4.15 Comparing the weights of 1 cubic centimeter of sulfuric acid and water indicates that sulfuric acid weighs 0.835 gram more than water. This can be expressed in another way. The ratio (specific gravity) of the weight of 1 cubic centimeter of acid to the weight of 1 cubic centimeter of water is 1.835.

5. MEASURING SPECIFIC GRAVITY

5.01 Two types of hydrometers are used for measuring specific gravity. The float type of hydrometer is used with open cells and is a weighted float with equally marked off divisions on the upper portion.

5.02 The syringe type of hydrometer is used with enclosed cells and is composed of a rubber nozzle, weighted float, glass tube, and rubber bulb. The upper portion of the float is marked off in equal divisions.

5.03 The hydrometer float sinks into the electrolyte far enough to displace a volume of solution equal in weight to the weight of the float. If the solution is heavy, the float will not sink very far into the solution.

5.04 The markings on the upper portion of the hydrometer indicate points of specific gravity within the range of 1.100 to 1.300. The markings indicate 0.001 points of specific gravity.

5.05 The specific gravity of the solution is determined by the depth that the hydrometer float sinks into the solution. The specific gravity of the solution can be read directly from the markings on the float.

Gravity Range

5.06 Each cell has what is called a specific gravity range. The specific gravity of the electrolyte, when the battery is fully charged, depends upon the quantity of the water and the acid (Table 1). The term specific gravity range identifies the difference between the specific gravity of the electrolyte at full charge and complete discharge.

5.07 The specific gravity of electrolyte increases and decreases one point inversely with each 3 degrees of change in the temperature of the electrolyte. A temperature of 77°F is used as a reference point; therefore, all measurements must be corrected to indicate the specific gravity of the electrolyte at 77°F, regardless of the actual electrolyte temperature. Table 2 shows the factors to be used to correct specific gravity measurements to 77°F for electrolyte temperature from 60°F to 90°F.

5.08 For example, if the measured specific gravity of the electrolyte is 1.208 and the temperature of the electrolyte is 71 °F, the correction factor is -0.002 (-0.001 for each 3 degrees below 77 degrees). The cor-

rected specific gravity is then ~~1.026~~ ^{1.206} (1.028 - 0.002). Conversely, if the temperature in the example above were 83°F, the correction factor would be +0.002 (+0.001 for each 3 degrees above 77 degrees). The corrected specific gravity would be 1.210 (1.208 + 0.002).

Thermometers

5.09 Thermometers are used to make temperature corrections for specific gravity readings.

5.10 Two types of thermometers are in general use: the floating type and the nonfloating type. The floating type is used with open cells. The nonfloating type is used with enclosed cells.

5.11 The floating thermometer is marked off in degrees of Fahrenheit and is enclosed in a weighted glass tube that floats upright and partially submerged. Also provided on the thermometer is a scale indicating the correction to be made when measuring specific gravity.

5.12 The nonfloating thermometer is similar to the floating one except that it is arranged to project through the vent hole of the enclosed cell.

5.13 The amount of electrolyte in a cell should be kept between the solution level markings (high and low) because it affects the specific gravity measurements. This is achieved by adding approved water to the cell.

5.14 The electrolyte is lowered by evaporation and electrolysis of the water. The acid, however, does not evaporate and the amount lost during charging is negligible; thus, the specific gravity of the electrolyte is increased. For small cells, a small difference in the amount of electrolyte makes a several-point difference in specific gravity. Specific gravity measurements should be made when the amount of electrolyte is at the maximum.

NOTE: When it is necessary to add water to a cell, use distilled or approved water only. Regular- tap water contains impurities that are harmful to the plates.

6. CHARGING BATTERIES

NOTE: Before charging batteries, check for loose, corroded, or damaged connections. If corrosion is occurring, the connections should be opened and cleaned. Do not, however, interfere with service. In batteries where threaded seal nuts are used, the corrosion may be severe enough (usually around the positive post) that the nuts are cracked. Unless the cells are the type that have cover-supported plates, the seal nuts may be removed. A coating of battery terminal grease M/C 792973 may be applied to prevent further corrosion.

6.01 To charge the cell, an electric current must be forced through it. The direction of the current for charging the battery is applied just opposite to that of the cell during the discharge cycle.

6.02 As charging starts, there is a small immediate increase in the voltage. The voltage increases gradually and more or less uniformly until the charging is completed. It then becomes constant at a value which depends upon charge rate, specific gravity of the electrolyte, the design and the age of the cell, the temperature, etc.

6.03 The charging rate is the current that flows through the cell during charging. The recommended charging rate is specified by the manufacturer of the cell. In general, the charging rate is the current the cell can absorb without causing harmful gassing (see paragraph 6.06).

6.04 The recommended charging rate should not be exceeded particularly toward the end of the charge or when the cell is gassing. There are no harmful effects from charging at a rate less than that recommended by the manufacturer. Usually, a reduced rate is economical and tends toward longer cell life.

6.05 The gas given off by a storage cell is formed by the electrolysis of the water in the electrolyte. When the current flows through the electrolyte, the water is decomposed into twice as much hydrogen as oxygen. Hydrogen is formed at the negative plate and oxygen at the positive plate.

Gassing

6.06 As a cell approaches full charge, most of the active material has been converted to spongy lead and lead peroxide. The remaining material absorbs the hydrogen and oxygen very slowly. The charging current produces more of these gases than can be absorbed; thus, the excess gases are passed off in a process known as gassing.

6.07 Upon completion of a charge, the voltage immediately decreases a small amount. This is a result of the internal resistance of the cell. The voltage then decreases rapidly to about 2.17 volts. Thereafter, it decreases slowly and will remain near 2.17 volts for several minutes while the gas is being dissipated. If the cell is not discharged, the voltage will stay above the open circuit value. After several hours, the voltage will be 2.05 volts.

6.08 A small amount of gassing is beneficial at times, particularly during an equalizing charge. The gassing causes the diffusion of the sulfuric acid during charging. Gassing also assists in loosening and converting sulfate that has formed on the plates into useful material.

6.09 Unnecessary overcharging results in excessive gassing and accelerates the wear on the plates; consequently, the accumulation of sediment is accelerated.

6.10 In storage cells that are regularly charged and discharged, active material is gradually worked loose from the plates. The material settles to the bottom of the cell in the form of sediment. Most of the active material is worked loose from the positive plates.

Mossing

6.77 Accumulation of spongy lead on the top edges of the negative plate is caused by gassing and is known as mossing. This spongy lead is the active material released from the positive plate and circulated about the cell and onto the negative plate by excessive gassing. The lead is changed to negative material during the charging.

6.72 Moss that is deposited onto the active side of the negative plate should not be removed. However, when the moss is deposited in large amounts on the inactive side of the negative plate it indicates that the cell is gassing excessively during charge and should be removed by scraping it to the side of the plate. It should then be allowed to drop into the sediment space.

NOTE: Sediment should not be permitted to pile up high enough to make contact with the bottom of the plates because they will be short circuited. When a cell is not being charged, it will discharge continuously.

Local Action

6.13 Local action or self-discharging takes place continually in a storage cell whether the cell is charging, discharging, or standing on open circuit. Local action increases rapidly with increase of temperature and with increase in the specific gravity of the electrolyte.

6.74 The greater amount of local action occurs in the negative plate. This causes the gradual sulfation of the negative plate. The acid content of the electrolyte is decreased. Local action is indicated by gassing at the negative plate when the cell is standing on open circuit.

Equalizing Charge

6.15 During discharge, lead sulfate is formed on the plates of the cell. If the cell stands completely discharged, continually undercharged, or otherwise neglected, the pores of the plate become filled with sulfate. When this occurs, the active material of the plates becomes hard and dense. The sulfate makes the portion of the plates on which it is deposited inactive. A plate in this condition is referred to as a sulfated plate. Sulfation is more pronounced in the terminal area.

6.76 Sulfated plates reduce the capacity of a cell.

6.77 If the sulfate is not in too large a quantity, it can be converted to active material by an equalizing charge. During this process, the sulfate is decomposed and spongy lead and lead peroxide are formed at the plates.

6.18 An equalizing charge is applied periodically to restore all cells of a battery to a fully charged condition. Whenever a cell shows a deviation of ± 0.05 volt from the average voltage of the other cells of the battery during check charge, an equalizing charge is indicated. In addition, prolonged or frequent battery discharges necessitate an equalizing charge.

6.79 The equalizing charge is applied by the constant voltage method of charging. The charging voltage must not exceed the high-voltage limits of the equipment served by the battery.

6.20 During equalizing charges, the temperature rises considerably. For this type of charge, temperatures up to 110°F have been authorized. It is expected that this temperature will be held for a short time only.

CAUTION: During equalizing of a battery, the charging voltage must not exceed the maximum switching voltage that the system can withstand.

Continuous Float

6.21 When cells are continuously floated, the voltage will not decrease to 2.05 volts unless the cell is defective. The entire charge current is not removed from the cells after an equalizing charge has been completed. The continuous float charge should decrease the voltage below 2.77 volts per cell.

6.22 When the cell is charged by the continuous float method, very little sediment will be deposited. The plates usually wear out before the amount of sediment becomes harmful.

6.23 The continuous float method of charging approximates a true float. True float is a condition where just enough current is forced through the cell to compensate for the internal losses of the cell.

6.24 The continuous float method of charging, from a cell operation standpoint, is the most efficient and satisfactory method of charging. The cells do a minimum amount of work; therefore, the cells have a maximum life span and a maximum reserve capacity.

6.25 Cells charged by the continuous float method stand by as emergency sources of power. They also assist in noise filtering.

Constant-Voltage Charge

6.26 In the constant-voltage method of charging, the voltage is held constant throughout a charge.

Check Charge

6.27 A check charge is given to check the condition of the cells. It should be applied on alternate months.

6.28 The check charge is applied by the constant-voltage method of charging. It is the same as an equalizing charge (refer to paragraph 6.19).

Freshening Charge

6.29 A freshening charge is applied to cells at the time of installation. It is the same as an equalizing charge.

Trickle Charge

6.30 A trickle charge is the type of charge applied when the continuous float method of charging is used. It is used to keep cells fully charged when they are not subject to a load.

7. STRATIFICATION AND TEMPERATURE

Stratification of Electrolyte

7.01 Variation in the specific gravity of the electrolyte with respect to depth is known as stratification. Stratification occurs when the sulfuric acid that is formed during charging settles to the bottom of the cell because it is heavier than water. Temporary stratification may occur as the result of the addition of water to the electrolyte.

7.02 When an equalizing, check, or freshening charge is applied to a cell by the constant-voltage method, stratification will occur. A high initial current is caused to flow through the cells. The high initial current causes a large amount of acid to be formed rapidly. The acid will settle to the bottom of the cell rather than diffuse properly. In the constant-voltage method of charging when the cells approach full charge, the current flow through the cells is low. This does not cause an adequate amount of gassing to properly diffuse the acid.

7.03 When the cells are charged by the continuous float method, stratification is less likely to occur. In this method of charge, there is not high initial current and the formation of acid is very slow.

Temperature of Electrolyte

7.04 The temperature of a cell rises very little during discharge; however, during the time the cell is being charged, the temperature rises considerably.

7.05 The temperature rise during charge is due to the production of heat within the cell. See part 8.

Battery Room Temperature

7.06 The ambient air temperature of lead-acid batteries should be in the range of 60°F to 80°F.

7.07 Prolonged higher temperatures reduce total battery life. However, higher temperatures for a short period will give some additional battery capacity at the time. An application of this could be in an air-conditioned battery room. In the case of a 2- or 3-hour power failure, it is actually desirable that the air-conditioner be inoperative during the power failure if batteries are the only source of power or if engine generator capacity need be conserved.

7.08 When the ambient air temperature is consistently above 90°F due to heat dissipated by chargers or a tropical climate, one of the two following recommendations should be employed:

- (a) Air-conditioning.
- (b) Reduction of specific gravity.

NOTE: If neither recommendation is followed, a 50 percent reduction in battery life can be expected for every 18 degrees above 77°F.

Reduction of Specific Gravity

7.09 Generally, battery manufacturers have recommended the use of a specific gravity maximum of 1.170 when the battery room temperature is 90°F or higher for long periods. This lower gravity will decrease local action and serve to give longer life than the usual specific gravity of 1.215 at 77°F. It is recommended that the battery manufacturer's representative be contacted before reducing specific gravity.

7.10 Battery room temperatures lower than 60°F reduce capacity but will prolong battery life. The main caution is that the temperatures should never be permitted to drop lower than -20°F because freezing of the electrolyte could occur.

8. PRODUCTION OF HEAT

8.01 There are three causes for the production of heat:

- (a) The changing of electrical energy into heat energy.
- (b) The formation of certain compounds,
- (c) The product of charging current and final charge voltage is greater than the sum of the resistance losses and electromechanical energy.

Changing of Electrical Energy Into Heat Energy

8.02 When overcoming the resistance of the cell during charging, heat is produced. This amount of heat can be calculated by squaring the amount of current flowing through the cell and multiplying it by the true ohmic resistance of the cell. This product is then multiplied by a conversion factor. The multiplication by the conversion factor permits the watts to be expressed as calories (unit of heat). For example :

$$\text{Current}^2 \times \text{Resistance} = \text{Watts}$$
$$\text{Watts} \times 14.33 = \text{Calories per minute}$$

8.03 The internal resistance of a cell is comparatively low, and unless an abnormally high charging current is used, the temperature rise during charging is not excessive.

Formation of Certain Compounds

8.04 When certain compounds are formed, heat is evolved. These compounds are formed as the chemical reaction is taking place in the cell during charging. The ionization of the sulfuric acid in the electrolyte, produced during charging, also gives off some heat. These heating effects are small and practically negligible under normal operating conditions.

Heat Difference

8.05 The third cause of heat is much more obscure and more difficult to explain. Toward the end of a charge, a quantity of heat is developed. The product of charging current and final charge voltage is greater than the sum of resistance losses and electromechanical energy. The difference appears in the form of heat. The amount of electromechanical energy involved is that energy involved in the decomposition of the water of the electrolyte.

Heat Theories

8.06 Two theories have been advanced to account for the production of heat. One theory is that ozone is formed at the positive plates as an intermediate reaction. The ozone is immediately converted into oxygen with heat being evolved. The theory is plausible because the odor of ozone is often noted. The other theory involves the formation of atomic hydrogen at the negative plates.

8.07 It has thus far been impossible to establish these theories quantitatively. However, the rapid rise of temperature after gassing begins is a well-known fact.

9. FLAME ARRESTORS

9.01 Each battery cell is equipped with a flame arrestor designed to prevent destruction of the cell due to ignition of hydrogen gases within the cell by an external spark or flame under normal operating conditions.

9.02 Flame arrestors should be cleaned when they become partially clogged from electrolyte spray. To clean the arrestor, perform the following:

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- (a) Fill a 10-gallon bucket with fresh water.
- (b) Immerse the flame arrestor in the water several times.
- (c) Follow each immersion by shaking the arrestor vigorously, or use an air blast to remove the water.
- (d) Following immersion of 15 flame arrestors, dump and refill the bucket with clean water.

NOTE: Do not use any cleaning or neutralizing agents in the cleaning water, because any dry residue may clog the pores of the diffuser material,

TABLE 1. SPECIFIC GRAVITY OF ELECTROLYTE FOR VARIOUS WATER-TO-ACID RATIOS BY VOLUME.

CAUTION: When acid is mixed with water, a large amount of heat evolves; therefore, acid must always be added to the water.

| WHEN MIXING BY VOLUME USING ACID WITH SPECIFIC GRAVITY 1.835 | | SPECIFIC GRAVITY DESIRED AT 77°F | WHEN MIXING BY VOLUME USING ACID WITH SPECIFIC GRAVITY 1.400 | |
|---|------------------------|--|---|------------------------|
| PARTS WATER TO REQUIRED | PARTS ACID REQUIRED | | PARTS WATER TO REQUIRED | PARTS ACID REQUIRED |
| 1.78 | 1 | 1.375 | 0.07 | 1 |
| 1.86 | 1 | 1.365 | 0.11 | 1 |
| 1.94 | 1 | 1.355 | 0.14 | 1 |
| 1.97 | 1 | 1.350 | 0.16 | 1 |
| 2.08 | 1 | 1.340 | 0.20 | 1 |
| 2.17 | 1 | 1.330 | 0.24 | 1 |
| 2.22 | 1 | 1.325 | 0.27 | 1 |
| 2.33 | 1 | 1.315 | 0.31 | 1 |
| 2.42 | 1 | 1.310 | 0.33 | 1 |
| 2.52 | 1 | 1.300 | 0.38 | 1 |
| 2.65 | 1 | 1.290 | 0.43 | 1 |
| 2.70 | 1 | 1.285 | 0.46 | 1 |
| 2.79 | 1 | 1.280 | 0.49 | 1 |
| 2.84 | 1 | 1.275 | 0.53 | 1 |
| 2.92 | 1 | 1.270 | 0.56 | 1 |
| 3.10 | 1 | 1.260 | 0.63 | 1 |
| 3.18 | 1 | 1.255 | 0.67 | 1 |
| 3.26 | 1 | 1.250 | 0.70 | 1 |
| 3.38 | 1 | 1.245 | 0.74 | 1 |
| 3.46 | 1 | 1.240 | 0.78 | 1 |
| 3.67 | 1 | 1.230 | 0.85 | 1 |
| 3.80 | 1 | 1.225 | 0.90 | 1 |
| 3.91 | 1 | 1.220 | 0.96 | 1 |
| 4.03 | 1 | 1.215 | 1.00 | 1 |
| 4.15 | 1 | 1.210 | 1.05 | 1 |
| 4.26 | 1 | 1.205 | 1.11 | 1 |
| 4.43 | 1 | 1.200 | 1.16 | 1 |

NOTE: This table should be used for reference only. The battery manufacturer's representative should be contacted when considering changing the specific gravity of a cell or battery.

TABLE 2. FACTORS USED TO CORRECT SPECIFIC GRAVITY MEASUREMENTS

| ACTUAL TEMPERATURE OF ELECTROLYTE (°F) | CORRECTION FACTOR |
|--|----------------------|
| 90 | +0.004 |
| 89 | +0.004 |
| 88 | +0.003 |
| 87 | +0.003 |
| 86 | +0.003 |
| 85 | +0.002 |
| 84 | +0.002 |
| 83 | +0.002 |
| 82 | +0.001 |
| 81 | +0.001 |
| 80 | +0.001 |
| 79 | ----- |
| 78 | ----- |
| 77 | ----- |
| 76 | ----- |
| 75 | ----- |
| 74 | -0.001 |
| 73 | -0.001 |
| 72 | -0.001 |
| 71 | -0.002 |
| 70 | -0.002 |
| 69 | -0.002 |
| 68 | -0.003 |
| 67 | -0.003 |
| 66 | -0.003 |
| 65 | -0.004 |
| 64 | -0.004 |
| 63 | -0.004 |
| 62 | -0.005 |
| 61 | -0.005 |
| 60 | -0.005 |