

SECTION 6, CHAPTER 6

BATTERIES

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Introduction

1. The battery is an indispensable part of the electrical equipment of an electrical servicing and starting trolley. It consists of a number of secondary cells in which an E.M.F. is developed between plates of dissimilar metals which are partly immersed in a chemical solution (electrolyte); current flows when an external circuit is connected to the plates until the chemical energy of the cell is exhausted. The chemical energy can then be restored by passing current through the cell in the reverse direction to that of the discharge current. This "charging" current is continued until the electrolyte and plates have been restored to their original condition, when the cell is again capable of supplying current with its terminal voltage at the original level. The action of a secondary cell is therefore reversible, and its life consists of a relatively large number of cycles of charge and discharge.

Voltage

2. The voltage of a secondary cell depends on the materials of which the plates are composed, nature of the electrolyte, and the state of charge. During discharge the voltage of the cell gradually falls, and a minimum permissible voltage is specified for

each type; the efficiency of the cell may be seriously impaired if discharge is continued below this point.

Discharge Rate

3. The time taken to discharge a fully charged cell until it reaches its minimum permissible voltage is called the discharge rate. Service battery tests are based on the 10-hour rate, when the discharge is equal to:—

$$\frac{\text{NOMINAL CAPACITY}}{10} \text{ Amperes}$$

Capacity

4. The quantity of electricity that can be taken from a fully charged cell before its voltage falls to the permissible minimum is termed the capacity of the cell. The capacity of a battery is that quantity which can be taken from a fully charged battery before the voltage of any one cell falls to the minimum permissible voltage. Capacity is measured in ampere-hours and is the product of discharge current (in amperes) and time of discharge (in hours).

5. **Rated or Nominal Capacity.** The rated or nominal capacity of a battery or cell is the capacity of a new and fully charged battery (A.L. 12, Oct. 62)

when discharged continuously at the 10-hour rate. For example, a new battery rated at 25 ampere-hours should be able to sustain a discharge current of 2.5 amperes continuously for 10 hours before the voltage of any cell falls to the permissible minimum voltage, the cell voltages being measured on load.

capacity 6-volt batteries may be easier to accommodate than one 12-volt battery of similar capacity. In this case the two batteries are connected in series as shown in Fig. 1 to give 12 volts; the capacity of the pair is the same as that of a single battery. Again, for a 24-volt system, two 12-volt

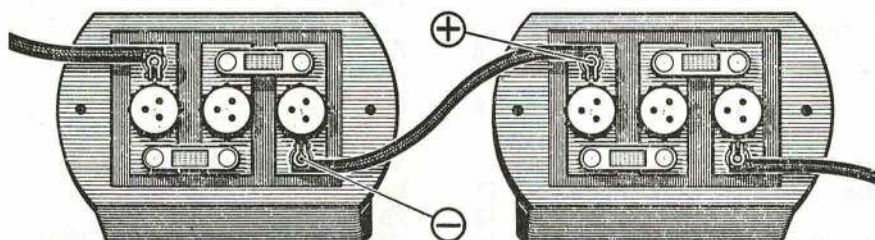


Fig. 1. SERIES CONNECTED.

6. Effective Capacity. The actual capacity of a battery is affected by age and condition, and by the discharge rate at which it is worked. For example, the capacity of a new battery at the 5-hour rate is approximately 75 per cent. of the nominal (10-hour rate) capacity, while at the one-hour rate the actual capacity is reduced to approximately 60 per cent. of the nominal. Decreased discharge rate or intermittent working, on the other hand, tends to increase the effective capacity.

Useful Life

7. Batteries deteriorate when in use, and the capacity falls until the capacity/weight ratio becomes uneconomic. The number of cycles of charge and discharge completed before this state is reached is called the "useful life" of the battery, and this is affected by the treatment the battery receives in service.

Grouping

8. A battery consists of two or more cells connected in series (i.e. the positive of one cell connected to the negative of the next), or in parallel. A battery composed of cells in series gives increased voltage, but has the same capacity as a single cell, while cells (or batteries) in parallel give increased capacity with the voltage of a single cell (or battery).

9. Series Connection. Although many installations use a single 6-volt or 12-volt battery, according to the voltage of the electrical installation, there are cases where multiple batteries are employed. Two large

batteries are connected in series to give this voltage.

10. Parallel Connection. Another form of battery arrangement which is occasionally used has two 6-volt or two 12-volt batteries connected in parallel as shown in Fig. 2.; i.e. the positive terminals of both batteries are connected together and to the positive of the installation; likewise the negative terminals. This grouping gives the voltage of a single battery but the capacity is the sum of the individual battery capacities.

Note.—Grouping should be restricted to cells or batteries of the same capacity.

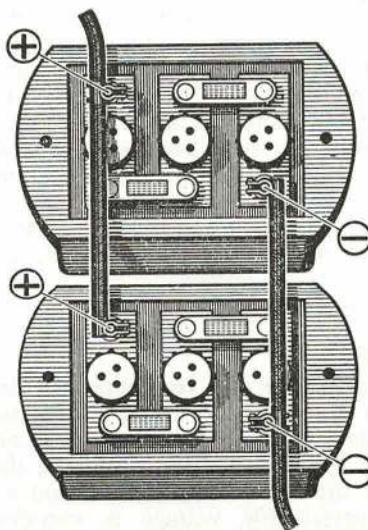


Fig. 2. PARALLEL CONNECTED.

LEAD/ACID BATTERIES

Introduction

11. The majority of batteries used on electrical servicing and starting trolleys are of the lead/acid type, although other types may be employed on special duties which demand certain outstanding qualities. Lead/acid batteries are available in various voltages and capacities, the nominal voltage being based on an estimated 2 volts per cell. Their construction varies according to the use for which they are intended.

Principle

12. A lead/acid cell consists essentially of two plates, one of lead peroxide, the other of pure lead in a spongy form, almost completely immersed in an electrolyte of dilute sulphuric acid. A difference of potential of approximately 2.2 volts exists between the exposed portions of the plates, the lead peroxide plate being at the higher potential.

13. When a conductor is connected between the exposed portions of the plates, a current flows in the external circuit from the lead peroxide (positive) plate to the pure lead (negative) plate, and then through the electrolyte. The passage of current through the plates and the electrolyte sets up a chemical action in the cell, resulting in the formation of lead sulphate on the surface of both plates and the formation of additional water in the electrolyte. As the plates become increasingly coated with lead sulphate and the electrolyte is progressively weakened, the voltage gradually decreases. In practice, the discharge should be discontinued before the voltage of the cell has fallen to 1.8 volts on load.

14. The chemical action of the cell is reversible, i.e., the plates can be cleared of lead sulphate and the strength of the electrolyte restored by passing current through the electrolyte from the positive to the negative plate. This is done by applying a direct current supply, which has a voltage slightly higher than that of the cell, to the cell terminals. Provided the cell has not been discharged to a point well below the minimum permissible voltage and left in that condition for an appreciable period, this charging action will, if continued for the requisite period, restore the chemical energy which was expended during the discharge period. The

cell is then available again as a source of electrical energy.

Note.—The secondary cell or battery does NOT store electricity. It converts electrical energy into chemical energy during the charging process, retaining it in the chemical form until an external circuit is connected to the terminals.

Cell Construction

15. **Plates.** These usually consist of lead grids into which the active material, in paste form, is pressed. Each cell contains several positive and negative plates, interleaved alternately to permit both sides of each plate (except the end plates) to be effective. This arrangement permits maximum capacity for a given size of cell. In practice, it is found that positive plates tend to become distorted when chemical action is restricted to one side; the plates are, therefore, arranged so that, using an extra negative plate, the outside plates are both negative. All plates of the same polarity are attached to a lug (Fig. 3) which forms both a mechanical support and an electrical connection to the terminal. They are further supported by ribs on the inside of the container, and they are raised clear of the bottom of the cell to avoid shorting between the plates by sediment, etc.

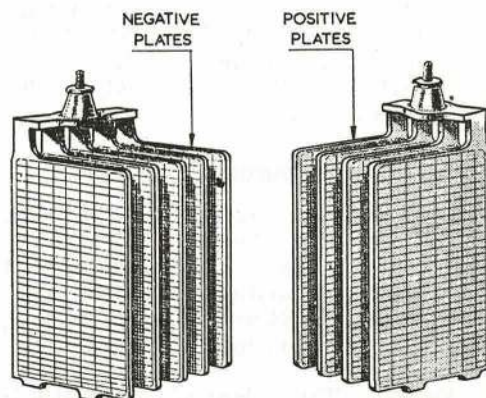


Fig. 3. PLATE ASSEMBLIES OF LEAD/ACID CELL.

16. **Separators.** These are used to prevent contact between positive and negative plates, and are designed to permit free circulation of electrolyte. They are made of chemically treated Port Orford cedar wood, rubber, or highly microporous plastic materials.

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17. Containers. The containers used for portable batteries are made of black moulded insulating material which is impervious to the action of dilute sulphuric acid. The internal ribbing which supports the plates also tends to strengthen the container. Containers for stationary batteries may be of glass, or of teak with lead lining.

18. Vent Plugs. Each cell is fitted with a vent plug to permit the escape of gas generated by chemical action.

19. Electrolyte. Only pure sulphuric acid diluted with distilled water is to be used as an electrolyte, and it must be of the correct specific gravity as indicated on the maker's instruction label attached to all new batteries. Refined battery acid, diluted to specific gravity 1.270, 1.285 or 1.350, is supplied from stores, ready for use; undiluted acid (S.G. 1.840) is also obtainable but this must be prepared by diluting to the required specific gravity.

Note.—Specific gravity of a liquid is the ratio of the weight of a given volume of the liquid to the weight of a similar volume of water at the same temperature. For example, one cubic centimetre of water at a temperature of 4 deg. C. weighs one gramme; one cubic centimetre of an electrolyte at the same temperature weighs 1.200 grammes. The ratio, i.e., the specific gravity of the electrolyte, is 1.200:1.000; this is simply written as S.G. 1.200.

State of Charge During Discharge

20. It is possible to assess the state of charge of a cell during the discharge half-cycle by two indications, viz., voltage on load and specific gravity of electrolyte. The two indications should always be considered together, as a single indication may be misleading.

21. Voltage. The voltage of a cell which is being discharged from the fully charged state (2.2 volts) falls rapidly at first to about 2.1 volts, then slowly and steadily to about 1.95 volts. From this point the fall becomes more rapid, until it reaches the minimum permissible figure of 1.8 volts. The voltage on load is, therefore, a fairly reliable, but not infallible, guide to the state of charge of the cell.

22. Specific Gravity. The specific gravity of the electrolyte decreases steadily during the discharge half-cycle. A minimum figure for specific gravity is given on the maker's instruction label; by comparing the known specific gravity with the maximum and minimum values, it is possible to assess the state of charge fairly accurately.

23. Indications of a Fully Discharged Cell. A cell should be considered as fully discharged when either:—

- (a) The voltage on load falls below 1.8 volts.
- (b) The specific gravity falls to the minimum value.

Indications of Fully Charged Cell

24. Voltage. The voltage of a cell on charge rises rapidly at the commencement of the charge. This is followed by a slow but steady rise until the cell approaches the fully charged state, when the voltage rises rapidly to maximum value. This maximum voltage may vary with different specifications for electrolyte, but under normal conditions it should reach, and maintain for at least one hour, a value of 2.7 volts. The charge should never be considered as complete until the voltage has been steady for this period.

25. Specific Gravity. The specific gravity of the cell during the early stages of the charge remains approximately constant, then rises steadily to a maximum. This maximum should be maintained for at least one hour before ending the charge.

26. Gassing. The chemical action in the cell during the charging process releases hydrogen and oxygen, the bulk of these gases being absorbed into the electrolyte. On completion of the charge the electrolyte can no longer absorb the gases which have been released from the plates, and they rise to the surface in the form of a constant stream of bubbles. Free gassing is, therefore, a third sign of the completion of the charge.

Note.—The charge must not be considered complete until all three indications have been obtained.

Faults

27. The modern lead/acid battery is capable of good service over a long period, if it is given fair treatment and correct servicing,

but neglect, ill treatment, and incorrect servicing cause certain faults which curtail the useful life of the battery to a serious extent. The commonest of these faults are sulphation and internal short circuits.

28. Sulphation. A sulphated cell is one in which the lead sulphate formed during discharge is incompletely removed from the plates during charging, leading to loss of capacity, etc. The fault is caused by persistent undercharging, persistent discharge to too low a voltage, and by leaving the battery in a discharged state. It is indicated by a low specific gravity of the electrolyte at the end of the charge and, if neglected, by the formation of a white deposit on the plates. Slight sulphation can be cured, but if it has reached the white deposit stage, it is always difficult, and often impossible, to cure it.

29. Internal Short Circuits. A cell whose plates are short circuited will show little or no voltage across the terminals, nor will it gas when on charge. Causes and treatment are as follows:—

(a) **Sediment.** This is due to paste being dislodged from the plates, and occurs to some extent with normal usage. It is, however, accelerated by persistent overcharging. The sediment can be removed by washing out the cell with weak acid, refilling with electrolyte of the correct specific gravity, and recharging.

(b) **Split Separators.** This is another result of overcharging; it may also be caused by excessive charge or discharge currents which tend to buckle the plates and so crush the separators. Repairs can be carried out only at a properly equipped Repair Depot.

(c) **Permeation of Separators by Lead Hydrate.** This fault occurs when batteries are left in an over-discharged condition. No local treatment is possible, as the separators must be renewed completely.

ALKALINE BATTERIES

Introduction

30. Lead/acid batteries require a considerable amount of careful servicing to maintain them in good condition; they are adversely affected by high charging rates, and they suffer from sulphation, etc., if allowed to

stand in a partially discharged condition for considerable periods. Where a battery is required to withstand such conditions it is sometimes possible to make use of another form of secondary cell, viz., the alkaline cell. This particular form of secondary cell, although extremely sturdy, resistant to trouble and capable of long and strenuous service, suffers from certain disadvantages which make it unsuitable for many purposes; these disadvantages are dealt with at a later stage in this chapter.

Principle

31. The type of alkaline cell used in the Service employs nickel oxide for the positive plates, cadmium and iron oxide for the negative plates and a solution of potassium hydroxide in water as the electrolyte. On charge the positive plates become a higher oxide of nickel (nickel sesqui-oxide), while

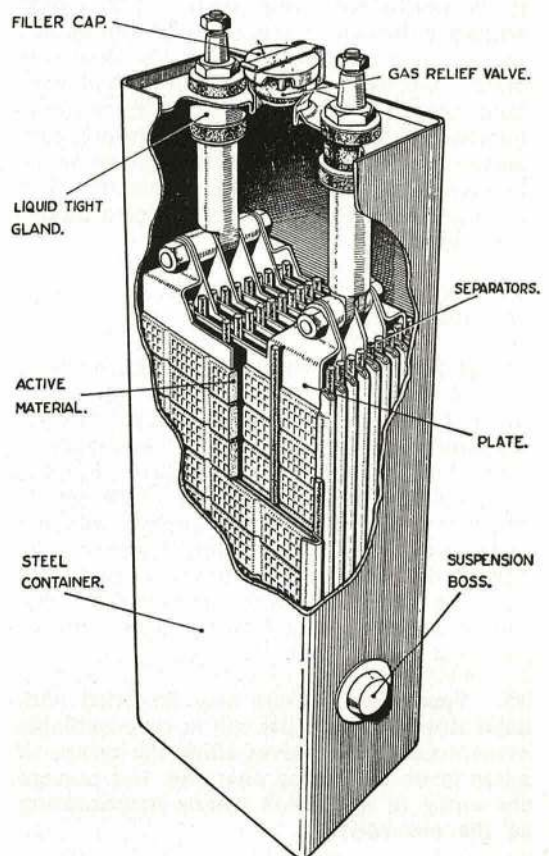


Fig. 4. ALKALINE CELL.

(A.L. 12, Oct. 62)

the negative plates become de-oxidized to a certain extent. On discharge the reverse action occurs, the negative plates becoming oxidized. It should be noted that, unlike the lead/acid cell, no chemical change occurs in the electrolyte, the specific gravity of which remains virtually constant throughout the charge/discharge cycle except for variations due to temperature. The normal voltage in the fully charged state, off charge, is 1.3 volts.

Construction

32. Plates. The active material in the positive plates is nickel hydroxide mixed with graphite, while that in the negative plates is a mixture of cadmium oxide and iron oxide, the former predominating (the iron oxide is added to increase conductivity). The active materials are compressed into briquettes under very high pressure and are then fed into a closing machine between two finely perforated steel strips. The closed strips are then cut to length and mounted in a welded steel frame to form the complete plate. Grooves are provided in each plate to hold the separators in position. The required number of plates of each polarity are connected to a common bar carrying one of the two terminals. The terminal posts are taken through the cell cover by means of a liquid-tight gland.

33. Separators. Ebonite rods are used as separators.

34. Containers. The containers are made of welded sheet steel, plated on the outside to prevent rusting. As the electrolyte has no reaction with steel, there is no internal corrosion. Alternatively, welded stainless steel containers may be used. One set of plates is usually in electrical contact with the steel case; cells should not, therefore, be placed on metal-topped benches, and care must be taken to avoid dropping metallic objects such as spanners, etc., on the cells, as this will cause short circuiting.

35. Vent Plugs. Cells may be fitted with solid stoppers, gas relief valves, or unspillable vents. Gas relief valves allow the escape of gases given off during charging, but prevent the entry of air which causes deterioration of the electrolyte.

36. Electrolyte. Potassium hydroxide (caustic potash) is supplied in solid form in air-

tight welded containers. There are two types of electrolyte supplied; Type A for aircraft (Type N) batteries, and Type B for other batteries (M.T., etc.). The electrolyte is dissolved in distilled water to the specific gravity shown on the instruction label for the particular battery.

37. Battery Assembly. An alkaline battery consists of a number of single cells (or a number of welded pairs of cells) mounted in a crate of teak, oak or birch. The cells are suspended from the sides of the crate on rubber or ebonite insulators which fit over steel bosses welded to the container sides. In some cases the cells are insulated from each other by separators of flexible insulation material, but the usual practice is to locate the cells firmly by a pair of insulated bosses on each of two sides leaving a good air gap between adjacent cells.

Voltage Variation

38. The voltage of an alkaline cell which is placed on charge will, after an initial quick rise, increase very gradually for the first two-thirds, of the charge. After this the rise becomes more rapid, and eventually levels off at approximately 1.7 volts. On discontinuing the charge when the fully charged state has been reached, the open circuit voltage may be 1.5 volts or even higher, depending upon the rate of charge, but it will fall to about 1.35 volts as the cell cools and gassing ceases. During discharge at the 10-hour rate from the fully charged state, the voltage falls rapidly to about 1.25 volts, then declines slowly and steadily until the fully discharged state is reached.

Indications of State of Charge

39. The specific gravity of the electrolyte of an alkaline cell does not vary during the charge/discharge cycle; it is, therefore, no guide to the state of charge. Gassing commences almost as soon as the cell is put on charge and continues for a considerable time after the charge has ceased; there is no gassing during discharge. The prevalence of gassing is consequently of no use when assessing the state of charge. The voltage alone varies with the state of charge, and is the only reliable guide.

40. Indication of Discharged Cell. For normal purposes an alkaline cell is considered to be fully discharged when the voltage on load falls to 1.1 volts.

41. Indication of Fully Charged Cell.

(a) **On Charge.** A cell is considered to be fully charged when the voltage, with the correct charging current flowing, has remained constant at approximately 1.7 volts for at least $1\frac{1}{2}$ hours. This period is a minimum, and can safely be extended.

(b) **On Open Circuit.** After gassing has ceased, the cell voltage should be about 1.3 volts.

Faults

42. Alkaline cells are relatively trouble-free, owing to the robust construction of plates and containers and the nature of the materials used. The most common fault is loss of capacity; this is caused in most cases by undercharging or by allowing the cell to stand idle (not necessarily in a discharged state). The full capacity is obtained when the electrolyte is able to penetrate to the whole of the active material, and this is impossible if the material has been allowed to settle down into a solidly caked mass. The remedy is simple; a full charge at two or three times the normal rate will loosen the materials and restore the capacity of the cell. There is no danger of the heavy current causing the plates to "shed" their active materials, since the latter are contained in steel pockets. Provided the temperature of the cell is kept within reasonable limits, high charging rates, overcharging, or high discharge rates will not cause damage.

43. The specific gravity of the electrolyte falls gradually as a result of contamination by the atmosphere; the potassium hydroxide solution reacts with the carbon dioxide in the atmosphere, producing potassium carbonate and weakening the strength of the solution. The electrolyte must, therefore, be changed periodically (at least every two years),

and whenever its specific gravity falls 0.030 below the normal value as laid down on the instruction label.

Comparison of Alkaline With Lead/Acid Batteries

44. The advantages of alkaline as compared with lead/acid batteries are:—

- (a) Longer life.
- (b) More robust construction.
- (c) Higher permissible charging rate, and insensitivity to overcharging.
- (d) Ability to stand for long periods in partially discharged state without deterioration.
- (e) Ability to retain charge for much longer periods.
- (f) Higher permissible working temperature.
- (g) Over-discharge, in terms of amperes or ampere-hours, has no permanent adverse effect.

45. Their disadvantages are:—

- (a) Lower individual cell voltage, requiring more cells per battery for a given voltage.
- (b) Greater range of voltage during charge and discharge cycle.
- (c) Higher internal resistance than comparable lead/acid batteries.
- (d) Loss of capacity at low temperature.
- (e) Increased weight for a battery of given voltage and capacity.
- (f) Containers are alive, and require effective insulation.
- (g) Need for sealing to prevent deterioration of electrolyte by carbon dioxide in the air.
- (h) Greater initial cost.

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