Chapter 3

ALKALINE BATTERIES

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LIST OF ILLUSTRATIONS

Introduction

1. An alkaline battery differs from a lead-acid battery in that it uses an alkaline instead of an acid electrolyte and different electrode materials. The fundamental principle of this type of battery is the oxidation and reduction of metals or their oxides in an aqueous solution of potassium hydroxide (caustic potash). The electrolyte does not combine with, nor does it dissolve, the metals or their oxides. The construction of a typical alkaline cell is shown in fig. 1.

2. Sintered-plate alkaline batteries differ considerably from conventional alkaline batteries both in construction and in operating characteristics. Information on such batteries will be found in Chap. 7 of this section.

DESCRIPTION

Plates

3. The active material in the positive plate is nickel hydroxide mixed with graphite; this hydroxide after plate formation becomes nickel sequioxide. The active material in the negative plate is a mixture of cadmium

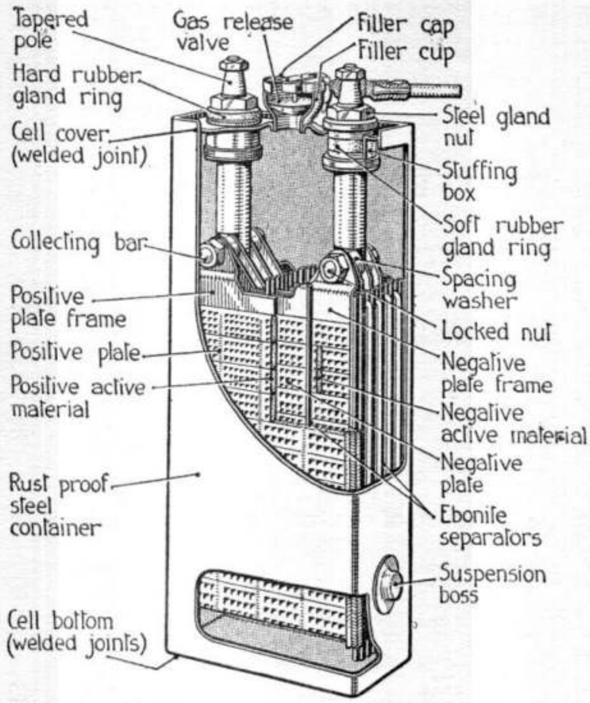

Fig. 1. Construction of typical alkaline cell

oxide and iron oxide, the former predominating. The iron oxide is included to increase conductivity. With present manufacturing methods the active materials are formed into briquettes under very high pressure and are then fed into a closing machine between two finely perforated steel strips. The machine rolls the edges of the two strips to form a flat tube filled with active material, which is then cut into sections of the required length and mounted in a welded steel frame to form the complete plate. The plate is then put under pressure and the active material is forced into close contact with the supporting grid. During this process the grooves for the ebonite separators are impressed.

Containers

4. The containers are made of welded sheet metal, plated on the outside to prevent rusting. As the electrolyte has no reaction with steel, there is no internal corrosion. Batteries may consist of a number of single cells or a number

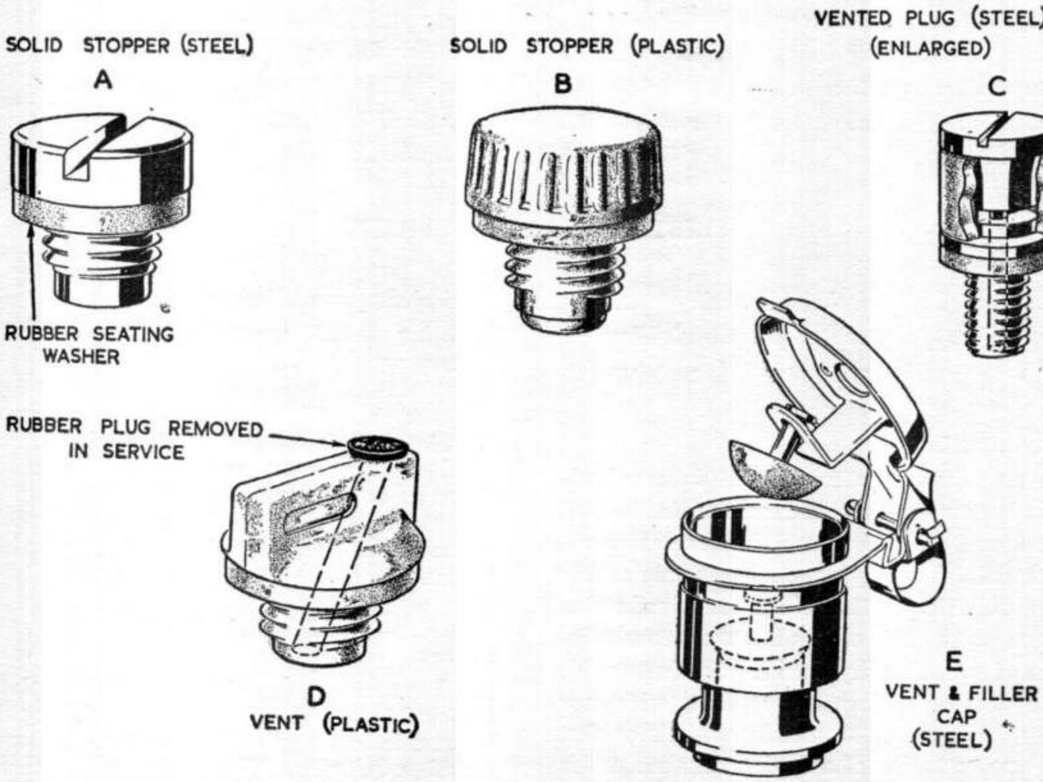

Fig. 2. Typical stoppers, vented plugs and filler caps

of welded pairs of cells, mounted in crates of teak, oak, or birch. The cells are suspended from the sides of the crates on rubber or ebonite insulators which fit over steel bosses welded to the container sides.

Vent plugs

5. Batteries have the cells fitted with various types of stoppers or vented plugs, typical examples of which are illustrated in fig. 2. Solid stoppers may be either of steel (A) or plastic (B), with a rubber seating washer. For airborne use, a vented plug (C) may be used, with a rubber ring over the vent acting as a release device. Another type (D) has a vent which is sealed by a rubber plug when not in use. Certain M.T. batteries are provided with a vent and spring-loaded filler cap (E); this incorporates the type of gas relief valve shown in fig. 1, which allows the escape of gases given off during charging, but prevents entry of air which causes deterioration of the electrolyte.

Electrolyte

6. Caustic potash is supplied in solid form in airtight containers and the complete contents of each container, once opened, must be dissolved in distilled water. The specific gravity of electrolyte for initial filling is normally 1·180, and 1·190 for subsequent renewal of electrolyte. Certain special batteries, however, may require electrolyte of a higher S.G., in which case the manufacturer's instructions should be followed.

Chemical reaction

7. During discharge the nickel sesquioxide in the positive plates is reduced to nickel monoxide and the cadmium and iron in the negative plates are oxidised. These changes are reversed during charge. No apparent chemical change occurs in the electrolyte during charge or discharge and, in consequence, its specific gravity remains unaltered and gives no indication of the state of charge.

Voltage

8. The voltage of a fully charged cell on open circuit is approximately 1·35, although it may be 1·5 volts or even higher immediately after charge, depending on the charging current.

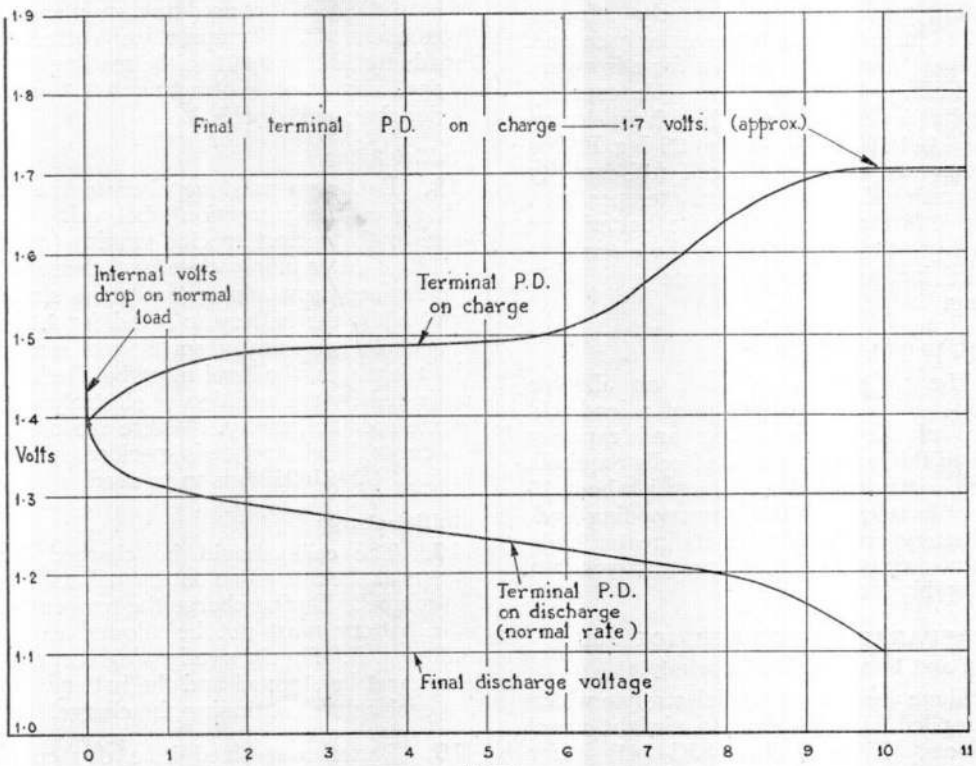

Fig. 3. Typical charge and discharge curves

Charge-discharge characteristics

9. Curves showing the voltage of a typical cell during charge and discharge are given in fig. 3. It will be seen that the voltage rises very gradually during the first two-thirds of the charge, but more rapidly towards the end of the charge, after which the rise in voltage is small. Since there are no direct indications of the state of charge, the charge must be continued until the voltage has reached a maximum and remained substantially constant for at least 1½ hours.

10. During normal discharge the voltage falls quickly at first, and then very gradually during the greater part of the discharge. The discharge must not be continued after the voltage has fallen below 1·0 volt per cell on light load.

Capacity

11. The capacity of a battery is usually stated in amperes at the 10-hour rate, and the current output at this rate may be regarded as the normal discharge current.

Effect of temperature

12. The capacity of alkaline batteries is affected by temperature. At temperatures above 120 deg. F. (50 deg. C.) the active materials may become adversely affected, and this temperature must never be exceeded. At temperatures below normal there is a very rapid falling off both of available capacity and voltage. Freezing, which with an electrolyte of S.G. 1·190 takes place at 25 deg. F., has no permanent effect on the cell, full capacity being restored with normal temperature. Where it is required to operate batteries at low temperatures, the S.G. of the electrolyte may be increased proportionately to avoid freezing.

Weight, volume, and life

13. The weight and size of an alkaline battery are greater than that of a lead-acid battery of the same voltage and capacity owing to the larger number of cells required, and the aircraft alkaline battery is about 10 per cent heavier than the corresponding lead-acid battery, in addition to its greater bulk. Its robust construction, however, gives it a considerably longer life.

PREPARATION FOR SERVICE USE

Mixing and breaking down electrolyte

14. There are two types of electrolyte which are supplied in solid form in airtight metal containers. Type A (Ref. 33C/541) is for general use, and Type B (Ref. 33C/220), which contains a small percentage of lithium hydroxide, is for use in electric truck batteries. The whole contents of a container should be completely dissolved in distilled water to give a solution of specific gravity 1·300 at 60 deg. F., in which form it should be stored, securely stoppered, if not required for immediate use.

15. Mixing must be done in glass, glazed earthenware, or plain iron vessels. ON NO ACCOUNT ARE GALVANIZED IRON, ALUMINIUM, OR VESSELS WITH SOLDERED JOINTS TO BE USED. When filling batteries or mixing electrolyte, protective clothing and goggles must be worn (*para.* 44) and a first aid outfit as outlined in para. 43 should be at hand. When mixing, stir the solution continuously with a clean glass rod or wooden stick. Scum may be removed with a strip of clean sheet iron.

16. If the solution is required for immediate use it should be diluted with distilled water to the specific gravity stated on the battery makers' instruction label.

Temperature correction

17. The S.G. of the electrolyte decreases with a rise in temperature and increases with a fall in temperature, and is to be corrected to 60 deg. F. A hydrometer, Type B (Ref. 5J/1650) is to be used for specific gravity measurements. Temperature correction is made by adding 0·001 to the reading for each 4 deg. above, or subtracting 0·001 for each 4 deg. below 60 deg. F.

Initial filling

18. Each cell must be filled to the height shown on the instruction label, using electrolyte of the correct specific gravity (normally 1·180). After filling, close gas release valves, or replace vent plugs (not solid stoppers), and allow the battery to stand for 12 hours. To make good any absorption of electrolyte by the plates, the level must be checked and adjusted by the addition of electrolyte of the same specific gravity. Where the use of oil to cover the electrolyte is specified, oil OM–16 (Ref. 34D/9100599) is to be used.

Initial charge

19. The cells should be charged for 12 hours at the rate given on the makers' instruction label. During charge the temperature of the battery must not be allowed to exceed 120 deg. F. Should overheating occur, charging must be stopped and the battery allowed to cool before continuing the charge.

20. Batteries received in a dry condition will require additional charging in order to overcome sluggishness. They should be partially discharged and then re-charged as follows:—

(1) Discharge at normal charging rate for half battery capacity (A 75 ampere hour battery normally charged at 15 amp. for 7 hours, will be discharged at 15 amp. for $\frac{75}{2 \times 15} = 2\frac{1}{2}$ hrs).

(2) Recharge at the normal rate.

21. The specific gravity of the electrolyte remains constant during charge and discharge and gassing commences early in the charge period; these factors do not, therefore, give any indication of the stage of charge. An alkaline battery is considered fully charged when the voltage, measured with the charging current flowing, has remained constant at approximately 1·7 volts per cell for at least 1½ hours.

22. On completion of charge, switch off the current, remove the battery, and allow it to stand for 12 hours. Gently tilt the battery from side to side to free the trapped gases, then check and adjust the level of the electrolyte. Wipe the battery dry, tighten the vent plugs, and smear all exposed metal parts with protective PX-7 (Ref. 34B/9100487).

WARNING

Solid stoppers must not be inserted and tightened until 24 hours after charging is completed.

GENERAL CHARGING PROCEDURE

Cleanliness

23. Before charging, examine all batteries for external damage, corrosion and incrustation. Corrosion products and incrustation can be removed with a stiff bristle brush and boric acid solution, afterwards washing thoroughly with water. During cleaning, securely plug the vent holes to prevent any acid solution or water entering the cells. Finally, wipe the cell dry and smear lightly with protective PX-7.

24. In order to prevent inter-cell leakage, batteries must be kept clean and dry. Water must not be spilt between the cells when topping up. Remove the cells from the crates periodically and clean thoroughly. Grease the cells and the interior of the crates to prevent corrosion.

Topping up

25. In order to obtain the full rated capacity from a battery, the electrolyte must be maintained at the correct level. Losses due to evaporation should be restored by the addition of distilled water only. Topping up may be required daily in tropical climates. If electrolyte is known to have been spilt, restore the level by adding electrolyte of the same specific gravity as that specified for the battery (normally 1·190). To obtain a true level, wait until gassing has ceased and the trapped gasses have been freed by tilting the battery from side to side.

Routine charging

26. Batteries to be charged at the same charging rate should be connected in series, their number depending upon the voltage available in the charging circuit. In determining the number, a voltage of 1·75 must be allowed for each cell, e.g., two 12-volt batteries of 10 cells each would require a charging voltage of 35. Each bank must have a separate charging circuit, and two or more banks must never be connected in parallel in the same circuit. Each charging circuit must have its own ammeter, variable resistance and other control apparatus connected in series with it. A charging board may have several such circuits, each terminating in a pair of terminals, but only one bank of batteries may be connected to each circuit.

27. Where space permits, batteries should be placed in a single line with the supply leads connected at opposite ends; where this is not possible, they should be arranged in a double row connected in zig-zag fashion. A space of at least ½ in. must be allowed between adjacent batteries.

28. All supply leads and connecting cables must be well insulated, of ample cross-sectional area, and as short as possible. All leads and cables must be fitted with lugs, cable end; free ends of wire must never be used. The connecting cables between the batteries should be fitted first, followed by the supply leads. One pair of ends of the latter must first be connected to the charging board terminals, after which the remaining pair should be connected to the bank of batteries. To avoid risk of explosion ensure that all terminals are firmly tightened down.

29. It is important to obtain the correct polarity when connecting up. If any doubt exists, a battery, or the charging terminals, may be tested with a moving coil voltmeter, or by one of the following methods:—

(1) Dip the ends of two wires connected to the terminals into a vessel containing tap water. Bubbles will be given off most rapidly from the wire connected to the negative terminal.

(2) Press the ends of the two wires against a piece of damp blue-print paper. The negative wire will leave a white spot.

30. All vent plugs must be unscrewed, lifted, but left in the filling holes, before charging is commenced. They must not be re-screwed until charging is completed; solid stoppers must not be inserted and tightened until 24 hours after charging is completed. Spring filler caps are to be kept closed.

31. Charging is commenced by placing the rheostat in the position of maximum resistance (i.e., minimum current), closing the switches and adjusting the current by means of the rheostat to the appropriate value. The correct charging current is usually specified by the makers; if no instructions are available, the charging rate can be taken as—

$$\frac{\text{Ampere hour capacity}}{8} \times \frac{3}{2} \text{ amperes.}$$

Batteries should not be undercharged, for persistent undercharging reduces the capacity.

32. The period for a complete re-charge is normally about 7 to 8 hours. An alkaline battery can be given a full charge at any time without damage, irrespective of its state of charge at the commencement. If some batteries reach the fully charged condition (*para.* 21) before the others, switch off the charging current and disconnect the fully charged batteries. Re-connect the remaining batteries, switch on and re-adjust the charging current.

33. The temperature of cells on charge must not be allowed to exceed 120 deg. F. (50 deg. C.). In temperate climates it is unlikely that this figure will be exceeded, but in tropical climates special precautions must be taken to prevent over-heating. The temperature in the charging room must be kept as low as possible, and, if necessary, charging should be carried out at night. If the temperature exceeds 120 deg. F., charging must be stopped and the battery allowed to cool down before continuing the charge.

34. When charging is completed, switch off, disconnect the supply leads first from the batteries and then from the charging board terminals. The batteries should then be disconnected from one another, removed, allowed to stand for 12 hours, and the procedure in para. 22 followed.

Boost charge

35. If due care is taken with regard to temperature rise, a generous charge at a high charging rate will not injure an alkaline battery, but will tend to reduce sluggishness in the active materials. If facilities are available, a boost charge should be given once every three months. Up to 5 times the normal charging current may be employed, and the duration of charge will be—

$$\frac{\text{Normal time of charge} \times \text{Normal rate of charge}}{\text{Boost rate of charge}}$$

It will be seen that a 52 ampere hour battery, normally charged at 10·5 amp. for 7 hours, can be charged at 50 amp. for 1·5 hours, or at 30 amp. for 2·5 hours.

36. Charging boards may be adapted for boost charging as shown in fig. 4. Where ammeters are fitted in the individual circuits, the current in the boost circuit will be the sum of the ammeter readings, but where there is only one ammeter the current will be three times that shown.

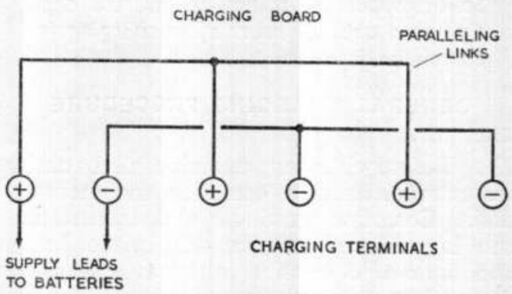

Fig. 4. Charging board connections for boost charging

RENEWAL OF ELECTROLYTE

37. The specific gravity of the electrolyte may fall gradually due to contamination by the carbon dioxide in the atmosphere. The electrolyte should therefore be renewed every two years, or whenever the specific gravity falls 0·03 below the nominal value. The procedure is as follows:—

(1) Discharge the battery until the voltage on light load falls to 0·8 volt per cell.

(2) Remove the cells from the crate, and empty out half the electrolyte.

(3) Shake each cell to loosen the sediment, and empty completely.

(4) Refill each cell with fresh electrolyte, shake thoroughly to remove all sediment, and empty.

(5) *Immediately* refill with fresh electrolyte of the correct S.G.

(6) Clean, dry and grease the cells and also the interior of the crate, and remount in the crate.

(7) Recharge at the normal rate for 12 hours, and carry out the procedure given in para. 22.

TESTING

38. No leakage test is likely to be required as leakage is rare, owing to the robust construction of the cell, but a leaking container can be repaired by welding.

39. There is little loss of capacity when the cell is standing on open circuit and no short load test is required when issuing a re-charged battery.

Insulation Test

40. Before a battery is issued from the charging room, it should be tested for insulation resistance between the battery terminals and the metal case, using a 250-volt insulation resistance tester; the minimum permissible reading is 0·5 megohm.

◀ **Note . . .**
This test is not applicable to such batteries as Ref. No. 5J9101802, 5J/9101806, 5J/9101807 *or* 5J/9101808, *which, although they may have rubber jackets, do not have any outer container other than the cell casing. Batteries of this type with rubber jackets, and those with plastic containers such as Ref. No.* 5J/3340, *may be tested for insulation resistance by placing the battery on a metal plate, and testing between the plate and the battery terminals.* ▶

Capacity test

41. Once every year all batteries are to be tested for capacity in a similar manner to lead-acid batteries (*Chap.* 2). This is to be done as follows:—

(1) Fully charge the battery.

(2) Discharge at the normal rate until the voltage per cell on light load falls to 1·0 volt, maintaining the correct discharge current by periodically adjusting the resistance. The capacity = Rate of discharge (amp.) × Hours of discharge.

(3) If the efficiency is less than 70 per cent of the rated capacity, renew the electrolyte, recharge for 12 hours and re-test for capacity. If the capacity is below 60 per cent, discharge, re-charge for 12 hours, and then repeat capacity test. Batteries whose capacity is less than 50 per cent are unserviceable.

Immediately the test is concluded, a battery, if serviceable, must be re-charged.

STORAGE AND TRANSPORT OF FILLED BATTERIES

42. Full instructions for the storage and transport of filled batteries will be found in A.P.830, Vol. 2, Leaflet F2.

ACID CONTAMINATION

43. Acid will ruin alkaline batteries. It is therefore very necessary to ensure that hydrometers, syringes, distilled water containers, tins of temporary protective, etc., used for these batteries are never used for any other purpose.

SAFETY PRECAUTIONS

Protective clothing

44. When handling batteries or alkali, aprons and rubber gloves should be worn; in addition, goggles must be worn at all times when handling or dealing with alkali. After use, these articles must be rinsed free of alkali and dried thoroughly. To avoid cracking or perishing they should be stored in a cool place, the aprons being hung with as few folds as possible.

Naked lights

45. The gases given off during battery charging are highly inflammable; therefore naked lights are not to be brought into charging rooms, or at any time used to examine a battery.

Spilt alkali

46. When electrolyte has been spilt on the floor or benches, it should be soaked up with sawdust, which should be removed and buried. The surface should then be washed with water until all signs of alkali are removed.

First aid

47. Instructions on first aid for chemical burns are given in Poster 174.


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