



WS No. 19 Mark III

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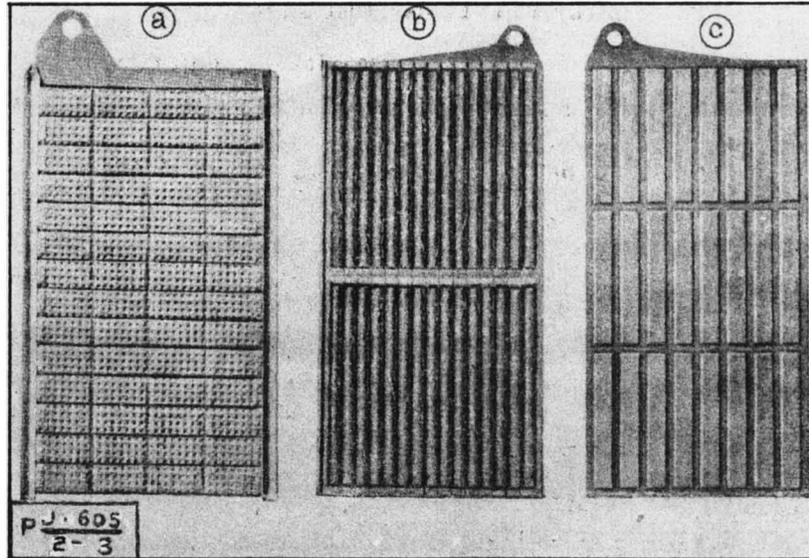


Fig. 3 - (a) NIFE positive or negative plate
(b) Edison positive plate
(c) Edison negative plate

cells. The strength of the solution does not vary during either discharge or charge, and this point will be mentioned again later when dealing with the chemical reactions occurring in the cells. The electrolyte has no action on iron or steel so that there is no possibility of internal corrosion.

Assembly

5. In making up batteries the cells are mounted in wooden crates which are usually made from a hard wood, such as teak, oak or birch. The cells are suspended from the sides of the crates on ebonite insulators which fit over steel bosses welded on to the container sides, and the cells are connected together by means of special plated copper connectors which generally have conical sockets to ensure effective electrical contact (see Fig. 4). Stationary batteries are sometimes erected on stands, and the usual practice is to place the crates of cells on these, and, since the cells are insulated in their own crates, it is not necessary to provide stand insulators as in lead battery practice. Small batteries, as used on motor cycles, are usually provided with an outer casing of moulded insulating material.

6. It will be seen that steel is used throughout in the construction of the cell; this is of great advantage and permits of greater accuracy in manufacture than would otherwise be possible. The mechanical strength, durability and robustness are much in advance of that which can be obtained even in the best designs of lead cells - vibrations and shocks cannot dislodge the active material with the result that there is a total absence of sludge and deposit - the steel plates cannot twist, buckle, break off or grow. The nickel cadmium type cells do not suffer appreciable damage from isolated cases of overcharging or overdischarging, but persistent overcharging or overdischarging will lead to loss in capacity of the cell. (If overcharging is carried out at grossly excessive rates it is then possible to cause damage to the active material of the plates from overheating). The nickel iron cell, on the other hand, can withstand persistent overcharging and discharging without

appreciable harm being done. (Here again grossly excessive charge rates can produce harm from overheating the active material of the plates).

Active material

7. In both types the active material in the positive plates is essentially the same, and consists of nickel hydroxide, the action that takes place on discharge

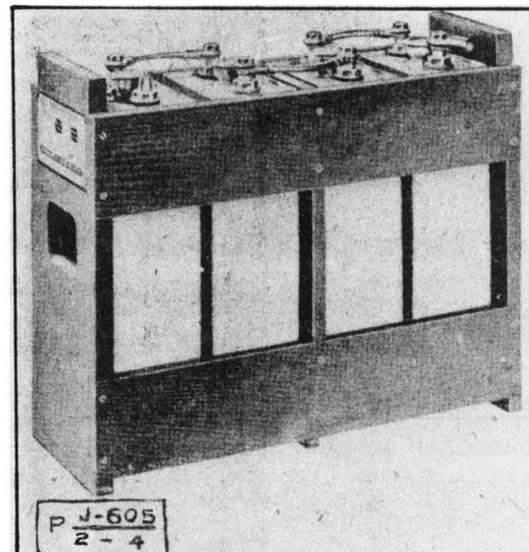


Fig. 4 - General view of nickel-iron battery

being a reduction from a higher form of nickel hydroxide to a lower form, and vice versa on charge. In the nickel-iron cell the active material in the negative plate is metallic iron which is oxidized on discharge to iron oxide (or hydroxide) and

vice versa on charge, while in the nickel-cadmium cell the iron is replaced with cadmium. Various methods are used to overcome the high electrical resistance of the actual active materials used in the alkaline cell.

8. In one example the nickel hydroxide is mixed with flakes of pure nickel, $\frac{1}{16}$ in. square and 0.00004 in. thick, the object being to have alternate layers of nickel hydroxide and flake nickel. Another method is that of mixing the nickel hydroxide intimately with a specially prepared flake graphite which is chemically inert.

9. With the nickel-iron cell the high resistance of the iron

oxide formed on discharge is overcome by mixing the materials intimately with about 6 per cent of yellow mercuric oxide.

10. The resistance of cadmium oxide in the nickel-cadmium cell, however, is very much lower and it is unnecessary to add any, special conducting material. There is, however, a tendency for the cadmium oxide to cake and lose porosity and, in order to overcome this, the cadmium is mixed intimately with a small quantity of iron, the mixture retaining all the advantages of the cadmium and having none of the disadvantages of the iron.

CHARGE AND DISCHARGE

Voltage

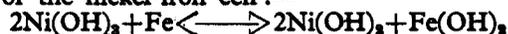
11. The theoretical discharge voltage of the cadmium negative plate is roughly 0.03V lower than that of the iron negative plate. This is, however, more than counter-balanced by the lower resistance of the cadmium plate, and the resulting voltage on discharge, except in the very early stage, is actually slightly higher, this being particularly noticeable at higher discharge rates.

12. The charging voltage of cadmium oxide is very much lower than that of iron oxide and this is one of the more important advantages of the cadmium plate. The voltage required for the conversion of cadmium oxide to cadmium (with a nickel hydroxide positive plate) is from 1.35 to 1.50V, while that for converting iron oxide to iron is 1.55 to 1.80V, these figures assuming approximately normal charging rates (see Fig. 6).

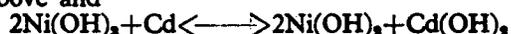
Chemical action

13. The chemical reactions occurring in alkaline cells are extremely involved, and it is very difficult to give anything really conclusive, as various oxides of nickel, iron and cadmium appear to be formed almost simultaneously in different degrees of hydration, but for a very rough approximation the following equations may be considered:—

For the nickel-iron cell:—



For the nickel-cadmium cell, a combination of the above and



14. The electrolyte appears to take no active part in the reactions of the cell, and to function merely as a conductor. Apart from considerations of temperature rise and alteration in gravity due to electrolysis on charge, the quantity of electrolyte can thus be reduced to a minimum and the plates placed very closely together.

15. It will also be seen that, although oxygen plays a part in the reaction, being transferred from one plate to another, no free oxygen is liberated on discharge, and therefore as no gases are evolved it would appear that a cell could be made absolutely unspillable by fitting solid stoppers. The iron present in a fully charged nickel-iron cell, however, is not completely stable and tends to become oxidized slowly when standing idle; this is accompanied by the evolution of hydrogen and by a self-discharge of the cell. The cadmium negative, on the other hand, is completely stable and has, in addition, a stabilizing effect on the small quantity of iron, with the result that in the nickel-cadmium cell there is no gassing, either on discharge or when standing idle, and no self-discharge. A

nickel-cadmium cell can, therefore, be made completely unspillable by fitting solid stoppers. A short period, however, should elapse after the completion of charge before inserting the solid stoppers in order to allow the gases generated during charge to escape completely.

16. The charging voltage of a pure nickel-cadmium cell is from 1.35 to 1.50V compared with 1.55 to 1.80V for a nickel-iron cell, and the open-circuit voltage of both types is between 1.25 and 1.40V, depending on the state of charge. It will be interesting to consider what this means. The voltage necessary for the evolution of a gas by electrolysis is of the order of 1.45V, which is appreciably below the charging voltage required for a nickel-iron cell. The iron oxide in the nickel-iron cell cannot be reduced unless a definite degree of polarization is reached and, at low current densities, therefore, the current is wasted in the evolution of gas. As the charging rate is increased the voltage rises until the charging voltage of iron oxide is reached, and above this rate part of the current is usefully employed and part is still wasted in generating gas. Consequently the ampere-hour efficiency is lower and it is not possible to charge nickel-iron cells at very low rates or to operate them satisfactorily as "floating" batteries.

17. The cadmium-iron negative plate, however, can be charged at very low rates as the charging voltage of cadmium oxide is slightly below the voltage at which gas is evolved. This means then, that a nickel-cadmium cell can be charged at very low rates and, since the difference in voltage on passing from charge to discharge is quite small, it can be operated quite successfully as a "floating" battery.

Internal resistance

18. The internal resistance of the nickel-cadmium cell is considerably lower than that of the nickel-iron and is of such a value as to allow the cell to deal very effectively with the heavy peak discharges, such as those which may be required under engine starting conditions.

19. The results of some tests at high discharge rates on nickel-cadmium cells are shown in Fig. 5, and these also illustrate very clearly the high percentage capacity which is available at these rates.

20. A comparison of the charge and discharge curves of the two types of cell is given in Fig. 6. On charge at normal rate the voltage of the nickel-iron rises rapidly from 1.55 to 1.68V and is then followed by a slight drop. It then rises again gradually until near the end of charge, subsequently rising more steeply to a steady value of about 1.82V.

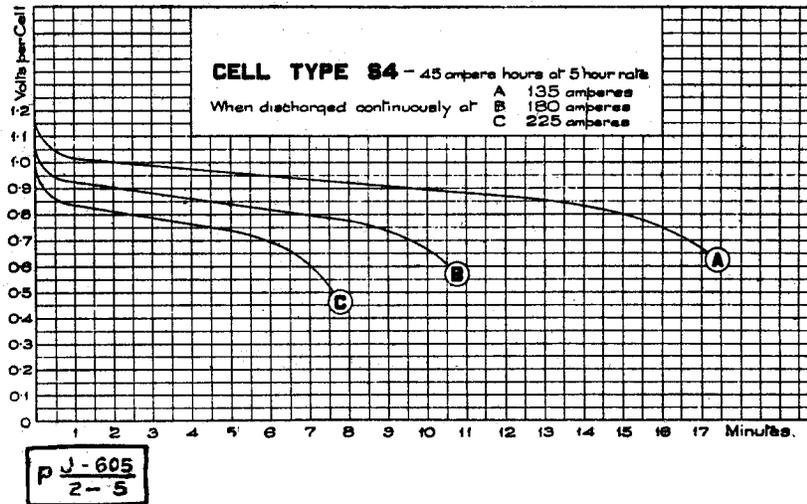


Fig. 5 - Voltage characteristics of NIFE low-resistance nickel-cadmium cell

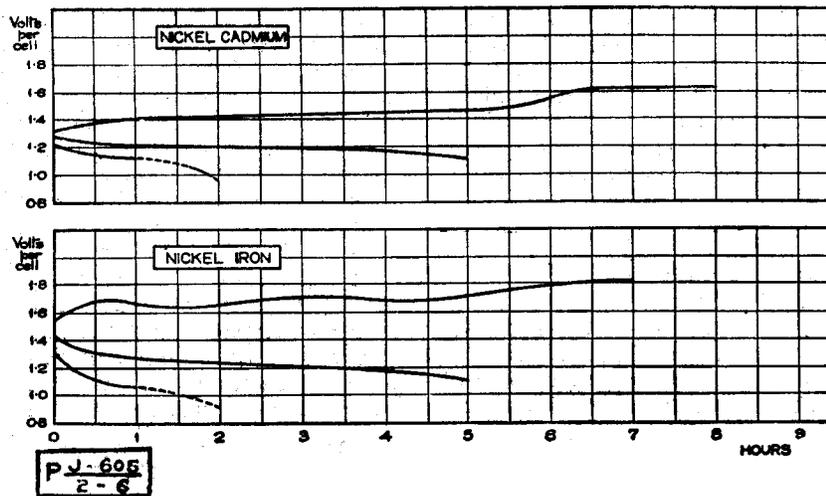


Fig. 6 - Charge and discharge curves of nickel-cadmium and nickel-iron cells

21. On the other hand, with the nickel-cadmium cell, the voltage at the start of the charge is about 1.35V and this rises slowly but steadily until towards the end of the charge, when there is a steep rise to about 1.63V, at which value it remains practically constant. The lower voltage at the beginning is due to the cadmium portion of the active material, while the higher voltage at the end is due to the iron. The final voltage does not go so high as the nickel-iron cell due to the much lower resistance of the cadmium-iron mixture.

22. The discharge curves also show how the lower internal resistance of the nickel-cadmium cell gives a very level voltage characteristic, which increases the ability of the cell to give heavy discharge currents without abnormal voltage drop.

Effect of temperature

23. Both types of cell are affected in a similar manner by temperature, but not to the same extent. Normal temperature is usually taken at 59°F (15°C) and the capacity and voltage on discharge increase as they are operated above normal. Beyond 122°F (50°C), however, the capacity obtainable falls off although

the voltage continues to rise. At temperatures above 122°F (50°C) the active materials may become adversely affected. At temperatures below normal there is a rapid falling off in both capacity and voltage of the nickel-iron cell. The nickel-cadmium cell, on the other hand, is not so seriously affected, as is shown in Table 1.

Percentage capacity available at normal rate of discharge

	59°F (15°C)	41°F (5°C)	23°F (-5°C)	5°F (-15°C)
Nickel-iron	100	79	52.5	15.8
Nickel-cadmium	100	96.5	92	74.4

Table 1 - Percentage capacities (nickel-iron and nickel-cadmium) at temperatures from 15°C. to -15°C.

24. Freezing of the electrolyte has no permanent effect on either the nickel-iron or nickel-cadmium cell, and results only in an inertness which is removed when the temperature is raised again.

Encl. 12 to 57/Maint./1490(M.E.8(c))

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