



Which battery to use?

The advent of microcircuits leading to miniaturisation of equipment and to decreased power demands has resulted in a resurgence of battery operated devices. Advances in technology have led to some remarkable developments in batteries today. But there you have a problem. Which battery to use?

MANY PEOPLE have a tendency to replace conventional 'dry' cells with the rechargeable nickel-cadmium type simply to avoid replacement costs, but this practice may not be cost effective and can even lead to reduced equipment performance and greater cost. In order to make some form of meaningful comparison between types, it was necessary to select one common size of cell and look at the performance under similar load conditions. Also, because the performance of carbon-zinc cells is more dependent on usage than alkaline or NiCad cells, a definite statement as to which is best cannot readily be made.

The purpose of this article is to try to present a guide to the selection of cell type best suited for an application, bearing in mind equipment performance, duty cycle, current demand, weight and cost. The information presented here has been obtained from the data sheets

of many manufacturers and should not be regarded as typical of any particular make. Because of the variation in performance of carbon-zinc cells with differing loads, the presentation has been optimised to give a reasonable overall guide to performance without being too optimistic.

Cells tested

The basic cells compared are the nickel-cadmium rechargeable type, the ordinary carbon-zinc dry cell, both normal and heavy duty (leclanche type) and the manganese dioxide-alkaline type. The size of the cells selected for comparison are the 'AA' or UM-3, SAA designation R6. In the case of the NiCad this is a 450 mA hour capacity cell. The load characteristic selected was a current drain of 30 mA for four hours per day. This is typical of much portable

equipment such as walkie-talkies, portable radios, calculators, etc. This was also the load which was easiest to compare on a range of data for various cells.

Result of comparisons

Generally, the comparison here shows alkaline cells to have a performance about twice that of ordinary carbon-zinc cells, however they can be many times better, depending on usage. Alkaline cells have higher efficiency when used for continuous or heavy load (high current) applications where the conventional carbon-zinc cell is less effective. The rechargeable NiCad is good for heavy current applications, provided the correct supply voltage can be achieved. Unfortunately, carbon-zinc and alkaline cells are not directly interchangeable with NiCad cells due to ▶

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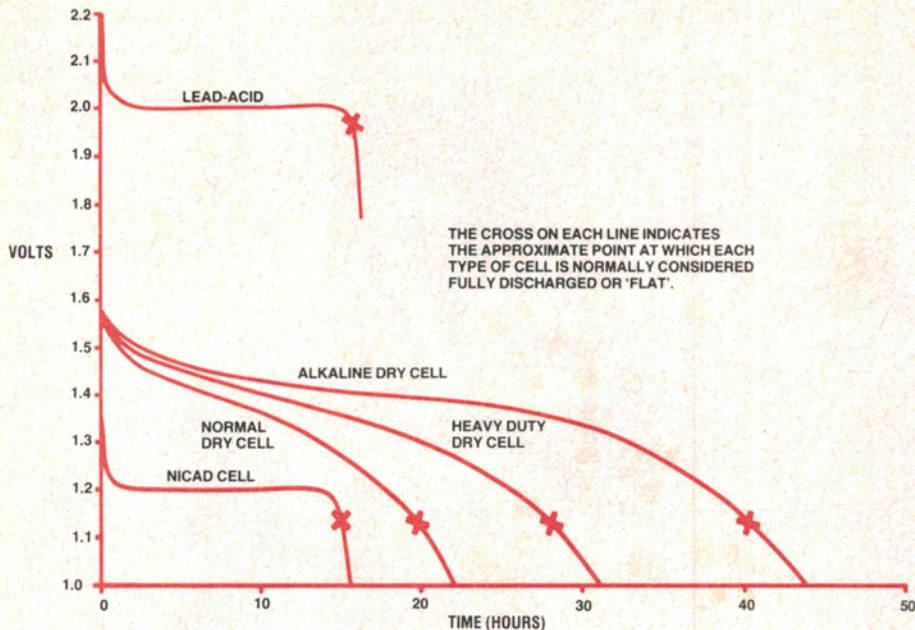


Figure 1. The discharge performance of various cells. The discharge characteristics of a lead-acid cell are shown for comparison. Note that terminal voltage cannot be used to indicate the state of charge of NiCad cells.

differing terminal voltages. This is caused by the different types of materials and construction used for these cells. The result is that while carbon-zinc and alkaline cells have a terminal voltage of 1.5 V, the NiCad cell has a voltage of only 1.2 V.

Figure 1 shows the performance of the various cells and that of a similar capacity lead-acid cell for comparison. It is important to note that the terminal voltage cannot be used to indicate the state of charge of the NiCad cell but can be used as an approximate indicator for 'dry' cells. NiCad cells are about 25% to 30% heavier than 'dry' cells and because more of them may be required for the same voltage, this could mean a substantial weight penalty in portable equipment.

Batteries at work

The place where these various cells must work is in the equipment, and this is where many factors become important. The points to be considered are: *duty cycle* — is the load to be continuous or intermittent high current, or is it to be low current, continuous or intermittent? *Operating environment* — will the power be required at extremes of temperature? What is the design voltage of the equipment and can sufficient cells be accommodated to provide this? *Replacement or recharging* — in a particular situation one option may be preferable to the other, and which option is cost effective? *Operational life* — how long will the selected cell operate before recharge or replacement is necessary? *Shelf or storage life* — how good is a particular cell after a period of no use?

Duty cycle

This will have a major effect on the performance of a cell in any situation. Conventional carbon-zinc cells perform best at a relatively light load when operated intermittently. This allows a degree of recovery between periods of use. The service life of alkaline cells is relatively constant regardless of whether use is continuous or intermittent. This type of cell then shows its advantage mainly when continuous use is required. It can have a service life of three to ten times that of carbon-zinc cells in ideal circumstances.

Another advantage of the alkaline cell is its ability to supply considerably higher currents than the carbon-zinc type. In fact, the current available from alkaline cells can approach that from NiCad rechargeable cells in some circumstances. For high current loads, intermittent or continuous, the NiCad cell may be preferred, either because other cell types cannot supply the required current or because discharge is so rapid that continual replacement would be necessary. Substitution of carbon-zinc or alkaline cells with NiCads should only be undertaken after consideration of all the factors involved, including operating environment, equipment voltage requirements and storage life.

Operating environment

Carbon-zinc cells deteriorate quickly at temperatures above about 50°C and become rapidly unable to deliver useful current below -18°C. Alkaline cells

show better operating characteristics at extremes of temperature. Although it is difficult to determine the upper temperature limit of these cells, it is considerably better than carbon-zinc cells. Alkaline cells perform reasonably well down to temperatures of -40°C.

NiCad rechargeable cells have an operating temperature range of about -20°C to +45°C but should not be exposed to temperatures below 0°C while charging. Generally, their operating temperatures are about the same as for carbon-zinc cells. There may be some temperature rise in NiCad cells during charging or heavy discharge, and this factor should be considered if these cells are used as a replacement for 'dry' cells in sensitive or critical equipment.

Design voltage of equipment

This is an important factor when consideration is being given to replacing carbon-zinc or alkaline cells with rechargeable NiCad types or replacing NiCads with 'dry' cells. In equipment such as portable transceivers, satisfactory operation depends greatly on the available supply voltage. Some of this equipment is designed to operate from NiCad cells while other is intended to use 'dry' cells. Most such equipment has a specified operating range of voltages and attempted use outside of this range will result in severely degraded performance, no operation at all, or possible damage to the equipment. Typical ranges for nominal 12 V equipment are 11 V to 14 V or 10 V to 15 V. There is a temptation to replace carbon-zinc or alkaline cells with an equal number of rechargeable NiCad cells but because of the difference in terminal voltage (1.5 V as compared to 1.2 V), a fully charged NiCad battery may not meet the minimum voltage requirements of equipment.

Figure 2 shows the performance of various battery types in a piece of 12 V rated equipment such as a portable transceiver. Note that if provision is only made for eight cells, then replacement with lower voltage types can result in insufficient supply for the correct operation of the equipment. Often, the mere fact that the equipment operates at all under these conditions is more a tribute to the designer than the performance of the power source! On the other hand, replacement of NiCad cells with 'dry' cells could allow the equipment voltage specification to be exceeded.

Replacement or recharging

Which is best here will depend very much on the user requirement. For example, a transceiver used by emergency

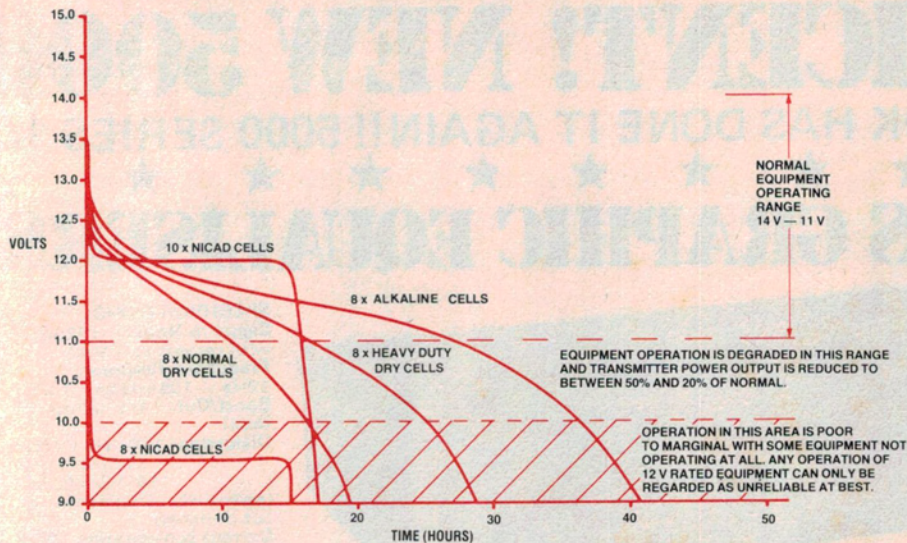


Figure 2. The performance of various battery types in a 12 V operated handheld transceiver. Note that you cannot expect to replace eight dry cells with eight NiCads.

services might be more quickly restored to service by replacement of batteries than by recharging. For personal use, where failure due to battery discharge is not so critical, recharging may be acceptable. If the equipment is in heavy or continuous use then recharging may be a viable alternative to replacement.

The cost of any option will depend on how often replacement is required, the higher initial cost of rechargeable cells, (and you may need more of them), the cost of a charger and the cost of an additional battery pack if operation is needed while recharging is in progress. Another important factor, especially in an emergency environment, is the availability of power for recharging. If such a source is not readily accessible, a user may be ill-advised to use rechargeable batteries at all.

Operational life

The effective operational life of a battery may become very important if access to replacement or recharged cells is difficult. As can be seen from Figure 2, the NiCad cells under this load will supply power for about 15 hours of operation. This is conditional on the battery being fully charged and in good condition. Ordinary carbon-zinc cells will provide about the same service life and heavy duty ones about twice this. Alkaline cells can be expected to have a greater operating life, about three times or better, than either NiCads or carbon-zinc as compared here.

There is a further factor which should be considered where the use of NiCad cells is contemplated. It has become recognised that NiCad cells tend to develop a 'memory' of their usage pattern. What appears to happen is that if a cell is used to say only 50% of capacity and then recharged, after a few cycles of

this pattern the cell then becomes only capable of delivering 50% of rated capacity before going 'flat'. This condition can be reversed by correctly cycling the cell through several discharge and charge cycles, but unless this condition is recognised as developing, it may seriously degrade the operational life of the equipment in which it is used.

Shelf life or self discharge

All cells will discharge by themselves when not in use, to a greater or lesser degree. This self discharge will determine the length of time for which a cell can be left unused and still be able to deliver a reasonable proportion of its original charge. The major factors which influence the rate of self discharge are storage temperature, amount of charge at storage, and the condition of the cell.

The definition of shelf life is somewhat variable, but for carbon-zinc and alkaline cells appears to be the time taken to decrease to 90% of initial capacity. Accepting this definition then gives the following approximate storage lifetimes for cells in good condition.

- Carbon-zinc cell — 8 to 9 months
- Alkaline cell — Over 2 years.
- NiCad cell — 3 days to 4 weeks.

These storage times are based on a constant temperature of about 20°C to 25°C. Storage life may be improved by storing the cells at 5-10°C. Generally, higher temperatures cause more rapid degradation. Storage life is also shown in graphical form in Figure 3. An approximation for a lead-acid car battery type cell is shown for comparison. NiCad cells appear to show up poorly in this regard and some manufacturers now claim to have substantially improved this characteristic. The self discharge of NiCad cells depends on the type of cell, whether it is intended for high or normal current discharge. The condition of the cell is also important, whether it has been cycled correctly, the age (number of cycles), the environment in which it has been used and the state of charge at storage.

Consideration of the information provided here may be able to assist you to make a better informed decision as to the best power source for your battery operated equipment. It is not practical to cover all the eventualities and applications in a short article, but at least this should provide some guide to the cost effectiveness and practicability of the battery that you select. Most manufacturers will provide design and engineering data on request should you need to make a more detailed analysis of your particular needs.

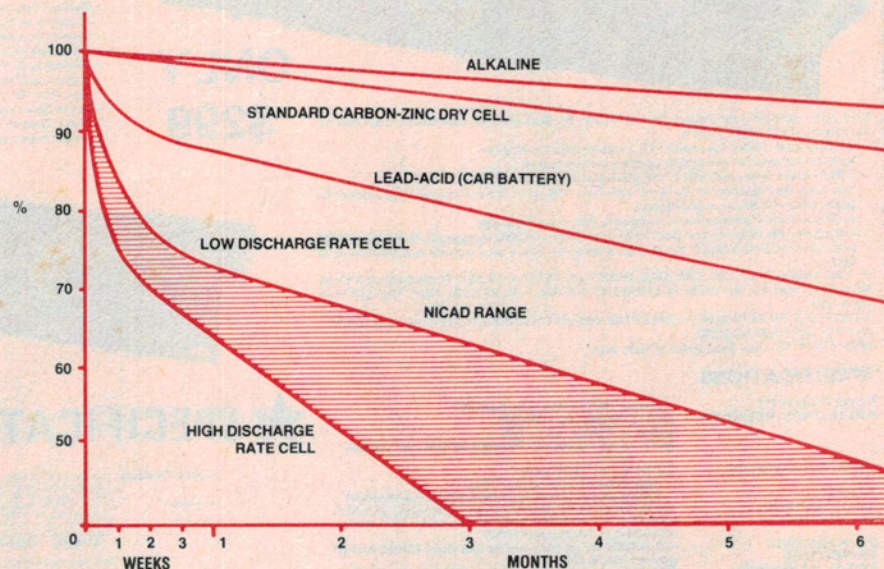


Figure 3. All secondary cells self-discharge, which gives them a certain 'shelf life'. Here, the self-discharge characteristics of the various cells are shown. A lead-acid cell is included for comparison.