

Cells and batteries: we survey the field

In a few years time, the science of electrochemistry and its offspring the electric power cell will be 200 years old. At the start of this long evolutionary period things moved very slowly. In the last two or three decades however, our knowledge and understanding of the processes involved when we change chemical energy directly to electrical energy have been revolutionised. As a result, many exciting new power cells and batteries, with specifications which would have seemed impossible a few years ago, are now becoming available.

by **TERRY AYSCOUGH**

Basically, an electric cell is a container which holds two different electrodes and a special type of liquid called an electrolyte as shown in Fig.1.

One electrode, called the anode, is usually metal. The other, called the cathode, is usually a metallic oxide. Some of the latest cells use gas or liquid cathodes instead of metallic oxides, as we shall see later.

Modern convention is to call the elec-

trode connected to the cell's positive output terminal the cathode and the one connected to the negative output terminal the anode. This is the reverse of the convention used in electronics whereby the anode of a device is the positive terminal.

Both anode and cathode are built around current collectors which are immersed in the electrolyte solution containing lots of ionised atoms. Electro-

lytes are often water solutions, but in some cells, other liquids and occasionally, even solids are used.

The anode material is chosen to have a much higher affinity for oxygen than the cathode. This causes the anode to gain oxygen (or become oxidised) and the cathode to lose oxygen (or become reduced) as the cell operates. These reduction and oxidation processes are called redox reactions.

Continuing redox reactions can only occur when there is an external circuit for electron flow between the anode and cathode. In order for the oxygen atoms to combine with metal atoms in the anode, they must give up electrons. These are picked up by the anode's current collector and flow via the external circuit to the cathode, providing a useful electric current in the process. Chemical activity within the cell will continue to supply this current until the cathode has been stripped of nearly all its oxygen and the anode has been correspondingly oxidised. When this occurs, the cell is exhausted and must either be recharged or replaced, depending on its type.

Cells which are thrown away when exhausted are called primary types and those which can be recharged and used again are called secondary types or sometimes storage batteries or accumulators.

A single cell will provide an output of only about 1.5V so groups of cells are connected in series to form batteries. Unfortunately, the word 'battery' is used by consumers regardless of whether they contain one or many cells. In this article we will stick to the correct use of 'cell' and 'battery'.

Although the beginnings of cell technology go back to the late 1700s, it is only in recent years that a true understanding of the complex electrochemical reactions involved has emerged. This has led to dramatic improvements in the variety and efficiency of cells, as we will see in the following sections.

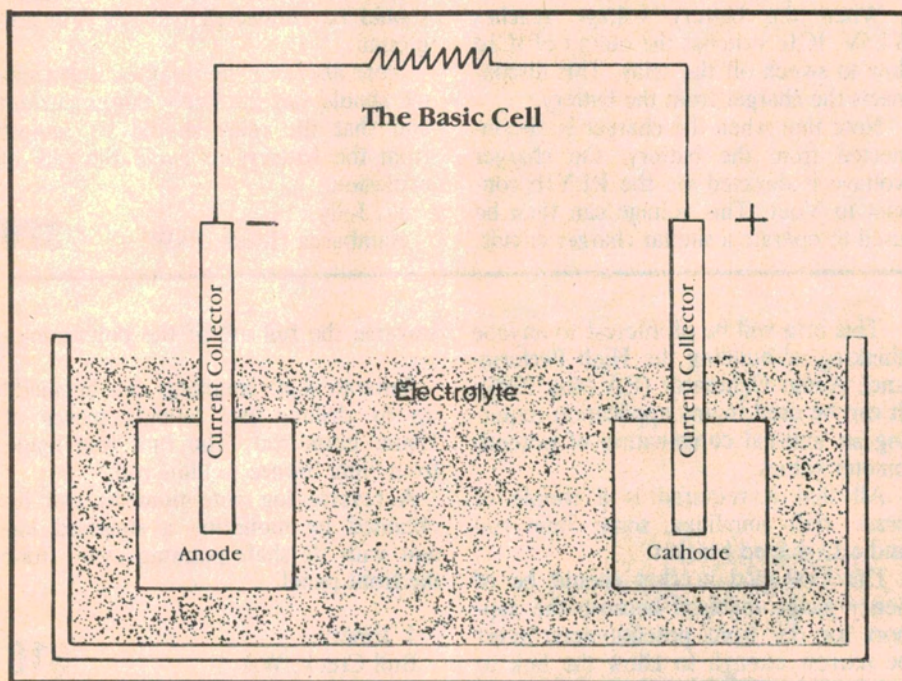
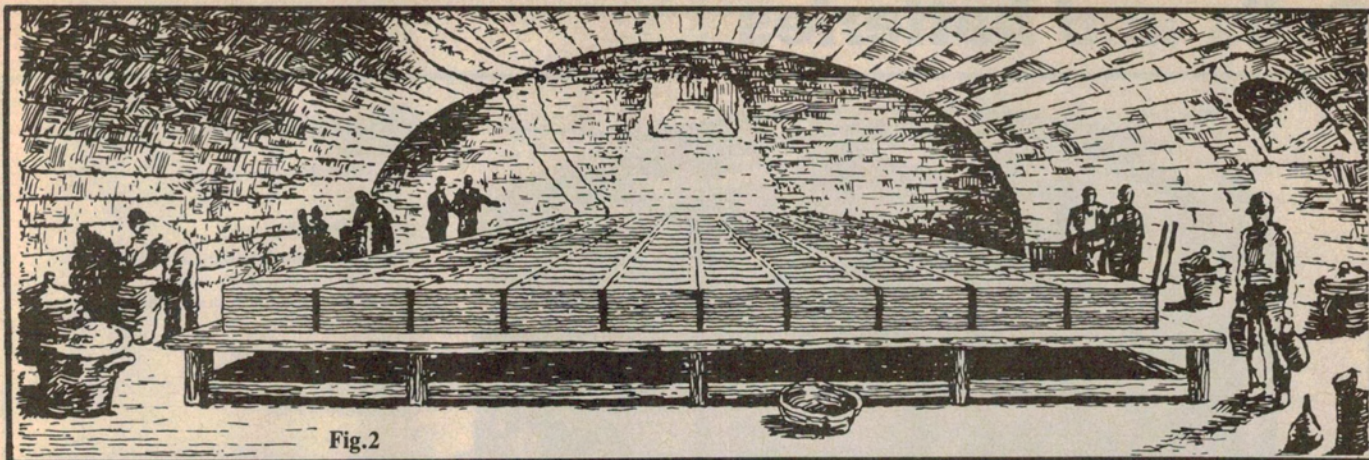


Fig.1: Shows the basic electric cell. Picture courtesy of Duracell.



Early beginnings

The science of electrochemistry had its beginnings between 1790 and 1800 when Alessandro Volta, following up earlier work by fellow Italian Luigi Galvani, constructed his famous Volta pile. This was the world's first battery and consisted of discs of silver and zinc interleaved with absorbent material which could be soaked with an electrolyte, such as brine. The voltage produced when an electrode is immersed in an electrolyte is still known as a Galvanic potential and Volta's name is remembered by its use for our unit of electromotive force or Volt.

Following Volta's discoveries, many different types of cells were investigated. In 1813 a huge battery containing 2000 pairs of plates and with a surface area of 82 square metres was constructed in the cellars of London's Royal Institution. See Fig.2. Michael Faraday later used power from this battery for many of his famous experiments with electromagnetism.

The first really practical cell was developed by Frenchman Georges Leclanche during the 1860s. The original Leclanche system used a zinc rod as the anode and a mixture of manganese dioxide and powdered carbon contained in a porous cup, as the cathode, see Fig.3. A carbon rod running down the middle of the cup served as the cathode current collector. Both electrodes were placed in a glass jar filled with a solution of water and ammonium chloride which acted as the electrolyte. These cells gave an open circuit terminal voltage of about 1.5V.

Many early cells suffered from a problem known as gas polarisation. Whilst the cell was in use, bubbles of hydrogen gas formed on the cathode surface and gradually built up an insulating layer. As a result, the internal resistance in-

creased and output current declined.

Leclanche's use of manganese dioxide as a 'de-polarising agent' overcame the problem and at the time, it was assumed that the oxygen-rich de-polariser was absorbing hydrogen bubbles as they were formed. Recent research has shown however, that because manganese dioxide is a more efficient cathode material than most simple metals, it gives a Galvanic potential above the voltage at which hydrogen is formed.

Over the years, various improvements

to the physical construction and chemistry of Leclanche cells were made. These included developing the shape of the zinc anode, firstly into a cylinder and later into a can, which could be used as a container for the whole cell. In 1888 an unspillable ammonium chloride paste was developed to replace the liquid electrolyte, enabling cells to be sealed and leading to the basic zinc carbon 'dry' cell as we know it today.

Many tens of thousands of Leclanche cells were manufactured to the original

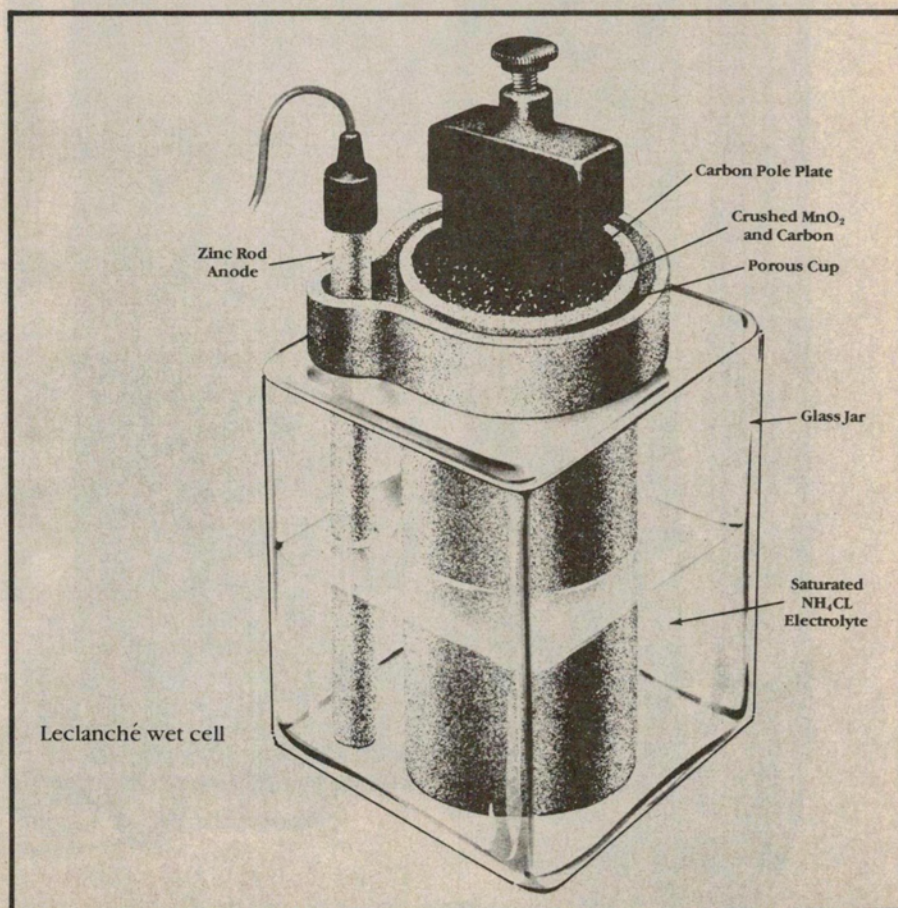


Fig.3: The Leclanche wet cell had a carbon rod as the cathode current collector. Picture courtesy of Duracell.

Cells and batteries

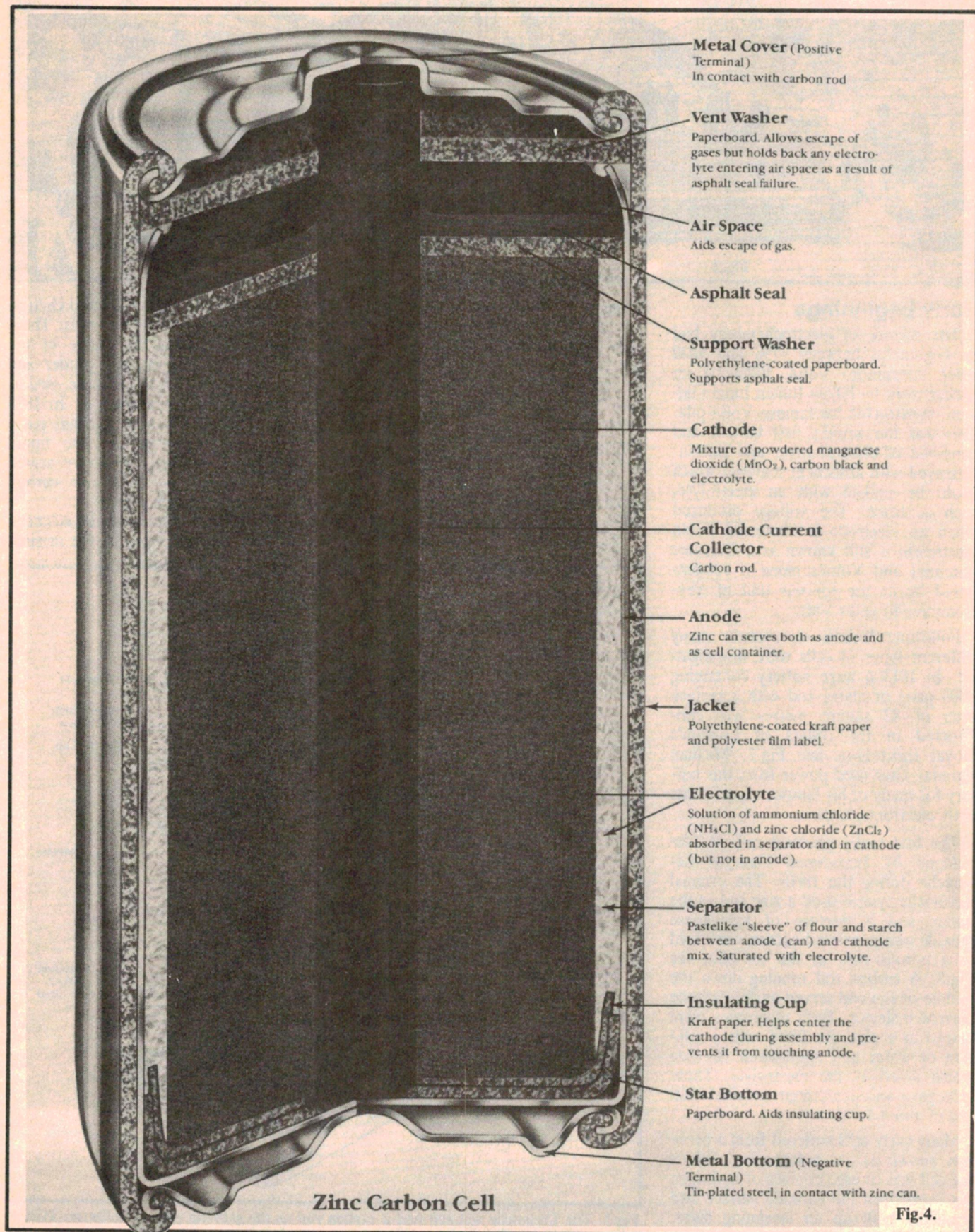


Fig.4.

design. Initially they powered the rapidly growing railway and post office telegraph systems and later the early telephone networks.

The market for dry Leclanche cells was boosted by the invention of the 'flashlight' in 1900. At that time, dry cells had only a fraction of the capacity they do today, so hand torches were only flashed on and off occasionally to conserve the limited power.

Standard zinc carbon cells and batteries

The classic zinc carbon cell has been in production for nearly 90 years and is still one of the most popular types for ordinary consumer applications. Operating on the same principles as the Leclanche cells of last century it uses zinc for the anode (negative terminal), and manganese dioxide for the cathode (positive).

The choice of zinc as an anode material by many early experimenters was fortuitous, as we now know that it provides one of the highest negative Galvanic potentials found in common metals. In addition, it is cheap, can easily be formed into the required shape, is relatively strong and chemically stable. Zinc is by far the most common anode material used today, although it is now being challenged by more exotic metals such as cadmium and lithium, which will be covered later.

Manganese dioxide is also still holding its own as a cathode material in ordinary consumer cells and batteries, because it has proved to be a very efficient provider of oxygen in redox reactions. Cells for specialised applications however, use a wide variety of other metallic oxides, liquids and even gases as the cathode material.

(Although we generally refer to Leclanche-type dry cells as zinc carbon types, the carbon acts only as a current collector for the manganese dioxide cathode and does not play a significant part in the redox reactions which generate electric current.)

Different types of cells are often identified by employing chemical notation for the anode and cathode materials used. The symbols for a Leclanche-type cell are Zn-MnO_2 , with Zn indicating the zinc anode and MnO_2 the manganese dioxide cathode. The electrolyte in standard zinc carbon cells is usually a solution of water, ammonium chloride and zinc chloride. This produces an acidic mixture containing plenty of ions, so the electrical conductivity is good and current can flow between electrodes

inside the battery with minimum losses. Other types of cell may use alkali solutions to produce good ionic conduction in the electrolyte, as we will see in the next section.

A major factor in the continuing popularity of zinc carbon cells is their low cost. The use of the zinc anode to also provide the case for the cell helps keep prices down, but can result in problems. If the zinc fails to oxidise evenly during discharge, corrosion can be excessive in certain spots and pin-hole perforations may occur. This is one of the reasons why old and new cells should never be used together. If a partially discharged cell is placed in circuit with new cells, the anode may be forced to oxidise beyond normal limits, resulting in electrolyte leakage and a sticky corrosive mess to be cleaned up.

Fig.4 shows the construction of a typical modern zinc carbon cell. The inside of the can is coated with a thick paste made from flour, starch and electrolyte solution, which acts as a separator between anode and cathode.

The compressed manganese dioxide cathode is also impregnated with electrolyte solution and has carbon black added to assist current flow to the carbon rod current collector. Steel caps at the top and bottom of the cell improve its strength and provide connections to the external circuit.

Most primary cells are cylindrical and there are two good reasons for this. Firstly, a cylinder is one of the most convenient shapes to manufacture, either by extrusion or moulding and to assemble using automatic machinery. Secondly, it is chemically efficient to have the active materials completely wrapped around each other for maximum interaction.

If a number of cells are to be assembled together to make a battery however, cylinders waste a lot of space, so carbon zinc cell packages are often used in batteries giving 6V or more. Their electrochemistry is identical to that for cylin-

drical cells described above, but their construction is quite different. Each cell consists of a large square or rectangular pellet of electrolyte impregnated manganese dioxide with a thin zinc plate anode in contact with its lower surface. The other side of the plate is covered with either a thin coat of carbon or a graphite filled plastic sheet, which forms the current collector for the cathode of the cell below. Stacks of cells are assembled, one on top of another, to give the required battery voltage.

The open circuit voltage of a zinc carbon cell is 1.5V but on load this falls steadily with time. Optimum performance is obtained at light to moderate discharge rates interspersed with rest-periods to enable recovery to occur. Some typical figures for a D-cell (see Table 1 below) will help illustrate the point.

In the right hand column the load current and useful hours of life have been multiplied together to give a total energy output or capacity figure. This is usually expressed in milliampere-hours (mAh) for small primary cells and batteries or in ampere-hours (Ah) for larger rechargeable batteries.

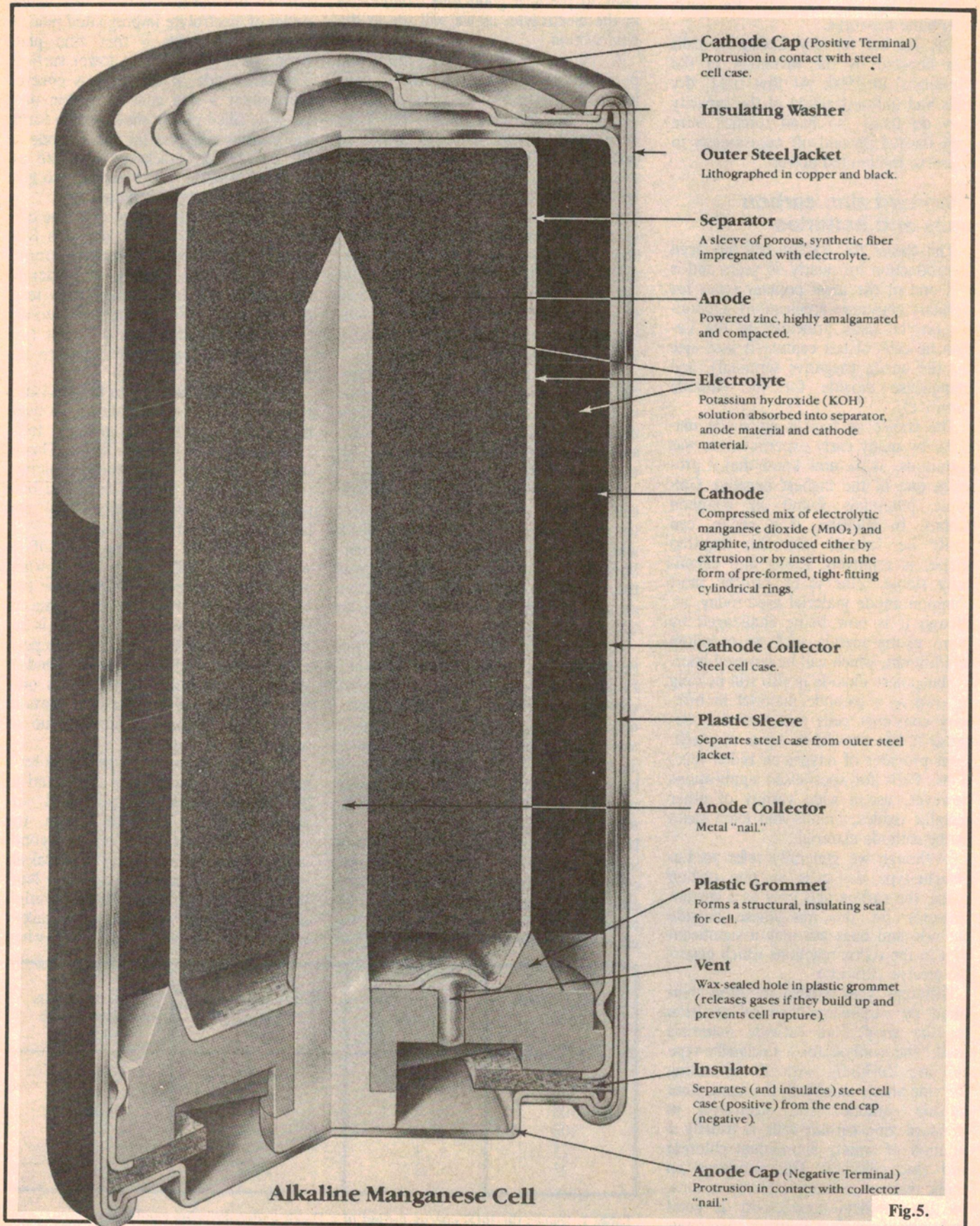
The cell gives only one third of its maximum possible energy output when supplying a current of 300mA for two hours per day, but will give close to maximum total output if its load is reduced to 100mA for the same time periods. Maximum efficiency is obtained at 25mA current drain, but if this is only for two hours per day, the cells starts to show signs of falling capacity due to ageing as well as use.

No electrical energy is produced by a cell or battery unless it is connected to an external circuit through which current can flow. However, from the minute cells are manufactured, secondary reactions and migration of chemicals result in loss of potential capacity. Normally, an unused cell or battery's minimum acceptable performance is taken to be 85% of its performance when

Load Current mA	Use per Day hours	Hours to on load output of 1V	Total milliamps x hours (mAh obtained)
300	2	8	2400
300	0.5	17	5100
100	4	38	3800
100	2	55	5500
25	4	255	6375
25	2	240	6000

Table 1: Shows the total energy output of a D-cell under differing conditions.

Cells and batteries



Cells and batteries

brand new. The length of time for which the cell can be stored before it has deteriorated to this extent is called its shelf life.

The shelf life of zinc carbon cells varies according to size, storage temperature, etc. A typical AAA cell might show serious deterioration after only three or four months, whereas a larger D-cell might still meet minimum requirements after 9-10 months storage.

Heavy duty zinc carbon cells

Heavy duty zinc carbon cells are assembled in the same way as standard cells, but are intended to deliver higher currents for longer periods of time. The electrolyte solution normally incorporates zinc chloride only, which gives better electrochemical performance than the mixture of chemicals used in ordinary cells. It also has the advantage that the electrolyte and cathode become progressively drier during use, which reduces the likelihood of leakage if the cell is totally exhausted by excessive loads. Performance is also improved by the use of a higher quality blend of manganese dioxide in the cathode assembly.

Heavy duty cells give higher peak currents and have about 20% more capacity than ordinary zinc carbon cells of the same size but cost more because of the higher quality materials used. Their main applications are in large torches, portable cassette players and toys where periods of high drain could cause the rapid demise of standard cells.

Alkaline manganese cells

For many decades, the zinc carbon dry cell provided the only practical low cost source of portable power. During the 1940s American Samuel Ruben in association with the Mallory company (Duracell in Australia), developed the first practical alkaline manganese cell for consumer markets. These were first produced commercially in 1949 and have steadily grown in popularity, taking over from zinc carbon cells in many of the more demanding applications. They use some of the same basic ingredients as zinc carbon cells, but are totally different in construction and provide a far more rugged and durable source of packaged power.

Samuel Ruben's major innovation for cells of this kind was the use of the al-

kali potassium hydroxide in the electrolyte, which gives much better ionic conduction than acidic solutions. A highly conductive electrolyte means the cell has lower internal resistance, so the fall in output voltage with heavy loads is greatly reduced. In addition, potassium hydroxide does not undergo chemical changes during discharge, so the cell maintains its high current capability right to the end of its useful life. Another big advantage of alkali electrolytes is that they do not attack steel like the acids used in zinc carbon cells. This means that alkaline manganese cells can have strong, leakproof steel cases.

The internal structure of a typical alkaline manganese cell is shown in Fig.5. In many ways it is the exact opposite to that used for zinc carbon cells.

The anode, which no longer has to serve as the container, is made of powdered zinc combined with a little mercury. It is located in the centre of the cell and has a metal 'nail' passing through it to act as a current collector. This is in contact with a steel cap at the bottom of the cell, so the negative terminal is in the same place as it is on zinc carbon cells.

The cathode consists of a very pure form of artificially produced manganese dioxide, which has a greater oxygen content than natural ore, with graphite mixed in to aid conduction. This mixture is highly compressed, to further increase the oxygen content per unit volume and greatly improve the electrochemical capacity of the cell. The inner steel case acts as a current collector for the cathode and connects to a cap at the top of the cell which acts as the positive terminal. This is also in the same place as the positive terminal on a zinc carbon cell, making the two types readily interchangeable.

Anode and cathode are separated and prevented from short circuiting by a sleeve of porous synthetic fibre. Anode, cathode and separator are all heavily infused with the potassium hydroxide electrolyte to give maximum conductivity.

Higher load capacity

Off-load, alkaline manganese cells give the same 1.5V output as standard Leclanche type cells. With medium to heavy current drain however, the output voltage from zinc carbon cells frequently falls below 1V, whilst alkaline cells will usually maintain their output at 1.1 to 1.3V. All cells and batteries

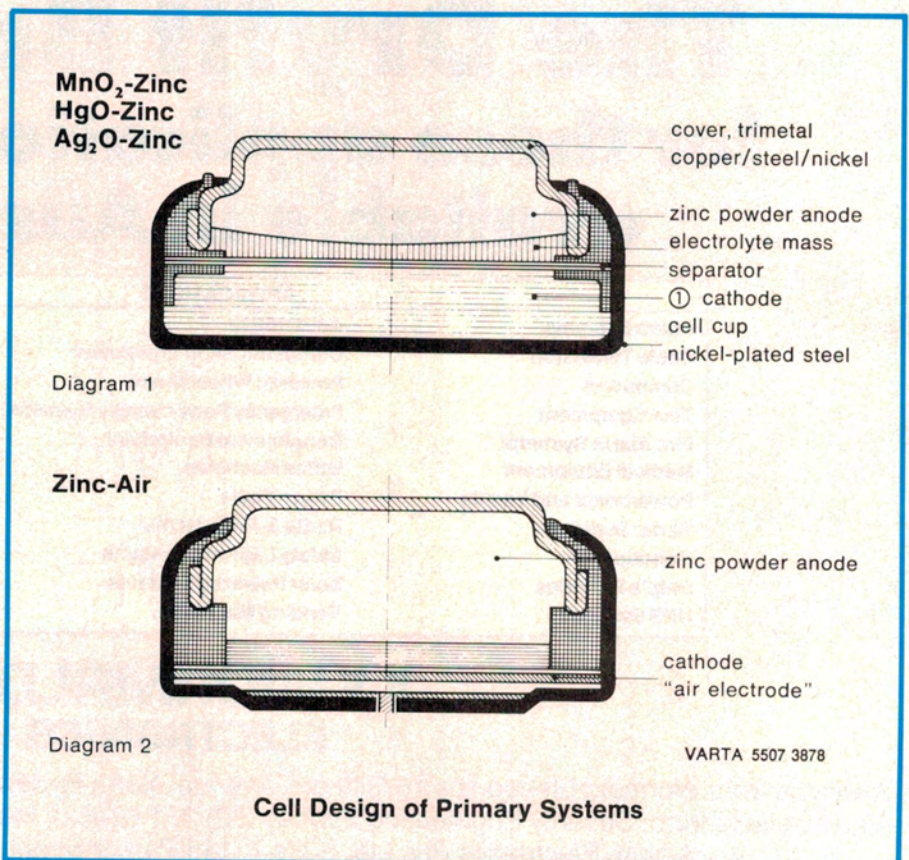


Fig.6a: Shows a mercury button cell and (6b) the zinc air cell. Courtesy of Varta.

show a fall-off in output at low temperatures, but manganese alkaline types hold up better than carbon zinc in this respect.

For high current applications, alkaline manganese cells can provide two to four times the total energy available from a zinc carbon cell of similar size. As a comparison, an ordinary zinc carbon D-cell might be rated at 4500mAh, a heavy duty zinc carbon D-cell at 6000mAh and a similar alkaline manganese cell at 10000mAh.

Alkaline cells generally also have better shelf-life characteristics than zinc carbon systems. Manufacturers' claims for their products vary enormously, but a good average figure would be two years at normal room temperatures.

Of course, the higher quality ingredients and more sophisticated construction of alkaline cells means they are more expensive to manufacture and buy. This higher cost may be justified if heavy current capability or long shelf life is important in a particular application. On the other hand, alkaline cells do not have the recuperative powers of zinc carbon cells when the circuit is switched off, so for some light-current intermittent use applications, the venerable zinc carbon cell could still prove to be a more cost effective source of power.

Button cells

The introduction of electronic watches, pocket calculators and miniaturised hearing aids, meant that a whole new range of small high energy cells had to be developed. Most of these have a flat circular shape and because of this, are known as button cells. Many use quite exotic electrochemical systems and we will take a look at some of these later. The construction of a typical button cell is shown in Fig.6a.

A small range of button cells using the alkaline manganese electrochemical system is available. Their main use is in photographic equipment where the peak current required to drive small motors, shutters and flash units exceeds the capabilities of other low cost systems. The good low temperature characteristics of alkaline manganese cells also make them particularly suited for use in cameras. One of the most popular button cells of this type is about the same diameter as a 10-cent coin and has a capacity of 300mAh.

Mercury and silver cells

We have already mentioned the part played by Samuel Ruben and the Mal-

lory company in developing alkaline manganese cells. Before this significant advance however, they had already started a major revolution in primary cell technology, by developing and manufacturing the world's first practical mercury cells and batteries. These were produced just in time to be used in World War 2 military equipment, such as mine detectors and walkie-talkie radios.

The mercury cell uses mercuric oxide as the cathode material which, although expensive, packs much more oxygen in a given space than manganese dioxide. This is combined with potassium or sodium hydroxide as the electrolyte and powdered zinc as the anode. Open circuit output is only 1.35 volts, but this holds up very well under load until the cell is nearing the end of its useful life. Capacity per unit volume is good, with a typical mercury AA-size cell being rated at 2500mAh compared with 1700mAh for a similar alkaline manganese type.

The chemical symbols used to represent a zinc mercury oxide cell are Zn-HgO.

The high energy density of the zinc mercuric oxide system makes it particularly suitable for miniature batteries and button cells. Fig.6a shows how a mercury button cell is constructed. Most mercury button cells are assembled in nickel-plated mild steel or stainless cans which do not take any part in the electrochemical reactions.

The highly compressed cathode fills the lower part of the can and is separated from the upper zinc anode section by an absorbent separator saturated with electrolyte. This method of construction is common to most types of button cell regardless of the electrochemical system being used and results in the lower can being the positive terminal and the top being the negative terminal.

One disadvantage of mercuric oxide as a cathode material is the rather low 1.35V output it provides, but this can be beefed up to 1.4V by adding a little manganese dioxide. The price that has to be paid for this extra 0.05V is a significant reduction in shelf life however, so it hardly seems to be worthwhile.

Silver oxide cells

First generation solid-state electronic equipment using germanium devices could be made to work quite well with a 1.35V supply and so mercury button cells found widespread use in transistorised hearing aids. Silicon ICs need a

slightly higher voltage and this has resulted in a second generation of button cells using zinc silver oxide cathodes becoming available.

Silver oxide is even more expensive than mercury oxide but raises the cell's open circuit voltage to about 1.6V. Construction is the same as for mercury cells (see Fig.6a), excellent constant voltage discharge characteristics are obtained and a shelf life of two to four years is possible under favourable storage conditions.

The energy density of silver oxide is slightly greater than mercuric oxide, but as some of this energy goes towards giving a higher output voltage, the actual current rating figures in mAh for similar sized cells or batteries can sometimes be a little less. The chemical symbols for zinc silver oxide cells are Zn-Ag₂O or Zn-Ag₂O₂ depending on the type of silver oxide used.

Mercury batteries work well at normal and high temperatures but are not recommended for use below 0°C. Silver cells and batteries have fairly good low temperature performance however, and will give 70% of their maximum output at 0°C.

Despite their higher cost, the superior characteristics of silver oxide button cells have made them the preferred type for use in watches, miniature calculators, and so on.

Mercury reference cells

Long before practical commercial mercury batteries were developed, experimenters were aware of the very stable voltages provided by this cathode material (Fig.7). In 1872 Clark produced a mercury zinc cell giving a standard output of 1.434V and later, in 1892, Weston developed an even more stable mercury cadmium cell, giving 1.0183V. Neither cell was of use as a practical source of electrical power, but both types served as laboratory voltage references until quite recently.

Zinc-air cells

The air we breath contains about 20% oxygen and it seems logical to use this abundant supply to oxidise the anode in a cell instead of depending on the rather restricted quantity available from the cathode material. Work on fuel cells for the Apollo moon landing program greatly advanced our knowledge of the electrochemical processes involved and led to the development and recent commercial introduction of zinc-air cells.

Although the concept is very simple,

Cells and batteries

the complications posed by exposing chemically active sections of the cell to the wide variety of gasses and impurities in the atmosphere created quite a few problems. In button cells, which might be used in any position, it also proved difficult to let sufficient air in without allowing electrolyte to escape. The construction of a typical zinc air button cell is shown in Fig.6b.

If air is prevented from reaching the active parts of the cell, it will remain dormant and have a very good shelf life. During manufacture, the cell is sealed with plastic or foil over the air access holes. When the cell is required for use, the seal is pulled off, to let in air and start the cell working. It will then continue working and cannot be put aside for a time and re-used later, like a normal chemical cell. This means zinc air cells are well suited to applications such as hearing aids and electric fences, where power is required continuously from the time the battery is installed until it is exhausted.

The total energy available from a zinc air cell is somewhat more than from a similar mercury or silver cell in terms of volume and a great deal more in terms of weight. As an example we can compare physically identical mercury and zinc air button cells, designed for hearing aid use, from the Varta company's range. Both cells give 1.4V off-load but the mercury cell has a capacity of 250-mAh and weighs in at 2.6 grams while the zinc air cell has a capacity of 400-mAh and a weight of only 1.7 grams. As no exotic materials are involved in their construction, zinc air-cells also promise to be a fairly economic source of power. Their off-load output of 1.4V

falls only slightly during use, as shown in Fig.7.

Construction details of a large zinc-air cell are shown in Fig.8. The cathode assembly comprises a porous carbon material which acts as the current collector in the same way as carbon particles in ordinary Leclanche type cathodes. An alkaline electrolyte, such as potassium hydroxide is normally used although zinc cells using acid electrolytes have also been developed.

Lithium systems

At the beginning of this article we said that a good anode material should have a strong affinity for oxygen. For many years, scientists have known that of all metals, lithium would make the most electrically efficient anode because of its extreme reactivity to oxygen. The irony was, that this same reactivity made it necessary to keep the metal out of contact with oxygen in either air or water vapour, thus making it very difficult to handle on a factory production line. It is only in the last few years that new techniques have been developed to permit the design and manufacture of lithium anode cells on a commercial basis.

Lithium is only number three in the table of atomic weights for the 92 naturally occurring elements. The gases hydrogen and helium are numbers one and two respectively, so it is no surprise to find that lithium is easily the lightest of all metals. Its galvanic voltage is -3.045V which means that an associated cathode need only make a modest positive contribution to give a total open-circuit cell output approaching 4 volts, more than twice that of all other

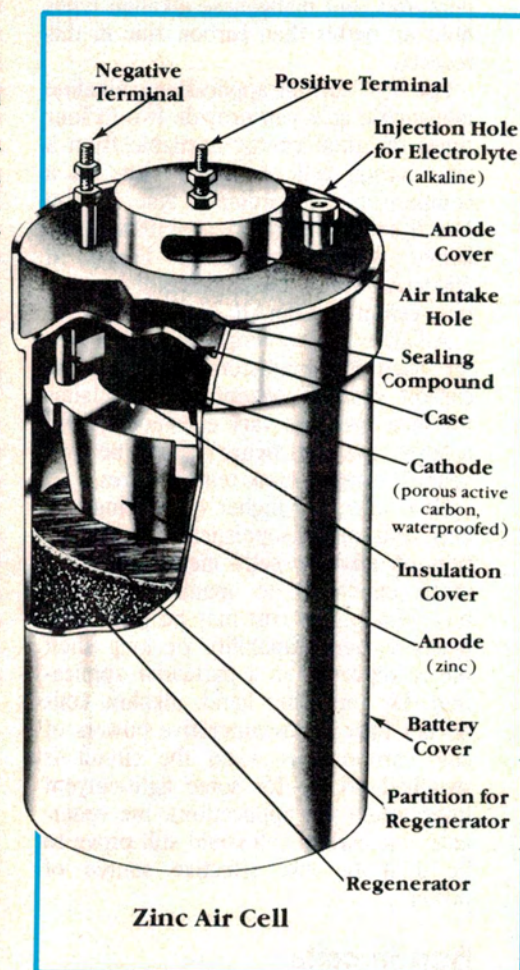
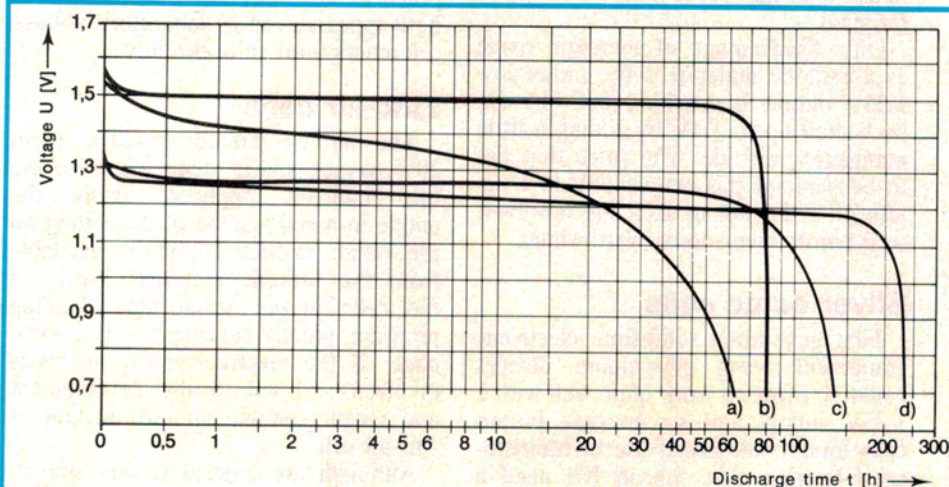


Fig.8: The large zinc-air cell is well suited to continuous power needs.

developed primary systems.

Another area where lithium cells easily outperform other types is their exceptionally good shelf-life. Surprisingly, this comes about as a result of lithium's extreme reactivity, which we might reasonably assume would keep the cell's chemistry simmering away. What actu-



- a) alkaline manganese/zinc
- b) alkaline silver/oxide/zinc
- c) alkaline mercury oxide/zinc
- d) zinc-air

Fig.7: Typical discharge curves of different cell systems. Diagram courtesy of Varta.

Cells and batteries

ally happens is that, as the electrolyte is introduced to the cell during manufacture, an immediate reaction occurs, creating a thin passivation layer on the anode. This layer insulates the anode and completely stops all further chemical action until the cell is put into use.

If the cell is operated at low discharge currents, lithium ions formed on the anode surface can migrate through the passivation layer, without disturbing its ionic lattice structure, so the cell's low self-discharge performance is maintained. When higher currents are demanded however, the passivation layer breaks up, reducing internal resistance and enabling the cell to deliver the current required. Under high load conditions, some lithium cells show a lag in performance, with the output voltage dropping initially for a few seconds until the internal resistance adjusts to the current required.

The voltage nature of lithium means that a little more care is needed when handling and operating cells containing the material. Lithium melts at just over 180°C and if the anode exceeds this temperature, it will flow and react with other materials. This may further increase the temperature, resulting in a runaway reaction causing the cell to vent or explode. In either case, toxic and corrosive gases can be released, so it is important to avoid all situations which might cause cell overheating. These include high external temperatures, short circuits, attempts at recharging or reverse voltages being accidentally applied. Some larger cells and batteries have built in fuse links to protect against excessive current flow and most manufacturers advise against using a soldering iron to make connections directly to cell cases.

Types of lithium cell

Manufacturers catalogs now offer an almost bewildering array of lithium cells but we will categorise them into three basic groups and describe one or two examples of each type. These three groups are cells constructed in the 'conventional' way with solid anodes and cathodes plus a liquid electrolyte, cells using a solid anode but a combined liquid electrolyte-cathode material and finally, some very special devices with solid electrolytes.

One of the earliest cells to be developed uses well tried and tested manganese dioxide for the cathode, but with lithium replacing zinc for the anode.

Chemical shorthand for this system is Li-MnO_2 . We mentioned earlier that lithium reacts violently with the oxygen in water, so the traditional acidic or alkaline electrolyte solutions cannot be used. In lithium-manganese dioxide batteries, the electrolyte is usually a conductive organic liquid having good chemical stability.

Two different cathode structures are used, a pressed powder disc type for low current button cells and a thin grid coated with manganese dioxide paste for high current rectangular and cylindrical cells. The construction of button and cylindrical Li-MnO_2 cells is shown in Fig.9.

Several Japanese companies have been very active in the development of lithium technology. One popular system resulting from this work uses a cathode material called poly-carbonmonofluoride. The chemical shorthand for batteries of this type being $\text{Li}(\text{CF})_n$.

A white fluorocarbon cathode material is produced by chemically combining carbon powder and fluoride gas. This is mixed with acetylene black to improve its conductivity and act as a binding agent, before being pressed into the required cathode shape. The anode is made from thin lithium sheet which has a nickel or stainless steel connection pressure welded on to carry current to the cell's external negative connection.

The electrolyte is based on an organic solvent which has alkali metal salts added to make it electrically conductive. A porous separator, made from polypropylene fibres and impregnated with electrolyte, keeps the anode and cathode apart.

Poly-carbonmonofluoride cells are finding their way into some consumer applications and emphasis has been placed on safety in their design. For example, the cathode material will not decompose at temperatures below 400°C. The organic electrolyte has a boiling point above 200°C and both cathode and electrolyte are non-toxic and non-corrosive. Construction methods are similar to those for the lithium manganese cells shown in Fig.9. Cylindrical batteries are assembled in strong nickel-plated steel cans and button cells are encased in stainless steel.

Both Li-MnO_2 and $\text{Li}(\text{CF})_n$ cells have open-circuit outputs of over 3.0V and working levels of about 2.8V at light to medium loads. The manganese units operate from -20°C to +50°C, which should meet most requirements, but the

fluorocarbon types have a range of -40°C to +85°C. It is difficult to compare the capacities of different systems due to variations in cell size, voltages and discharge rates, but total stored energy for both types of lithium cell described above is about three times greater than for similar alkaline manganese cells. Shelf life is quoted at six years to 85% capacity for lithium manganese cells and a loss of 0.5% per annum, or about 10 years, for the fluorocarbon types.

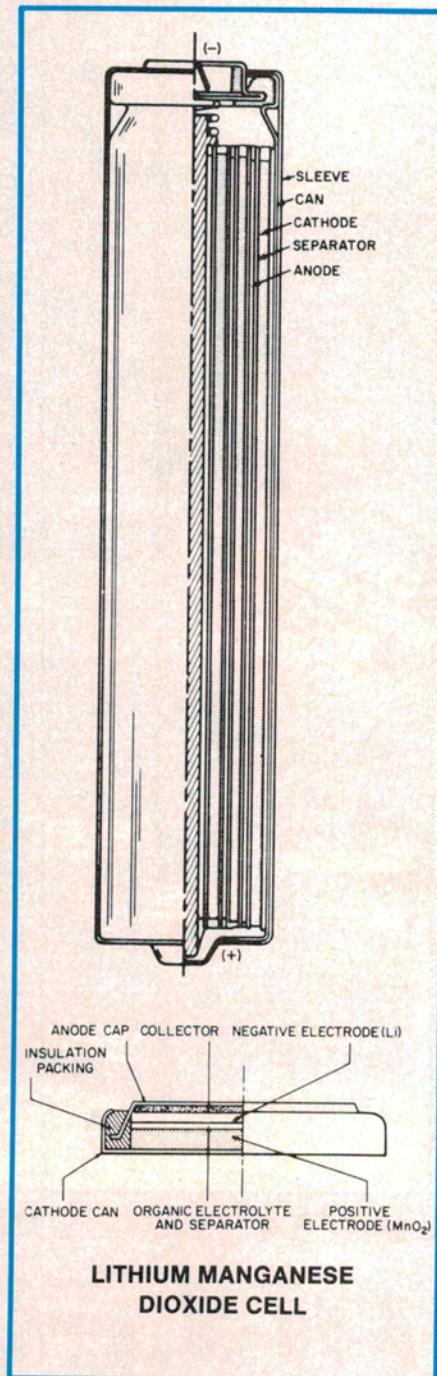


Fig.9: Button and cylindrical lithium manganese dioxide cells.

Cells and batteries

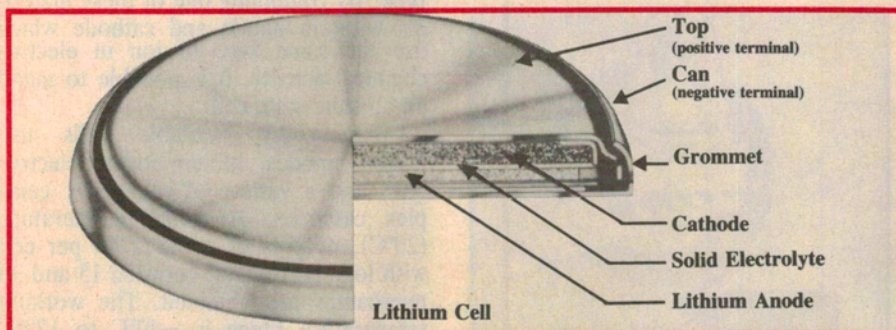


Fig. 11a: Shows the construction of a typical lithium iodide cell. Courtesy of Duracell.

Lithium liquid cathode cells

The second group of lithium cells use a liquid which combines the functions of electrolyte and cathode.

The first system of this type to become popular combined lithium and sulphur dioxide (Li-SO_2). This range of cells has most of the favourable features associated with lithium manganese cells but they are better suited for applications requiring high discharge currents.

The cathode collector is usually a fine aluminium grid coated with a teflon-carbon black mixture. This provides the large surface area and low resistance necessary for high current operation. The anode consists of a length of lithium foil and a microporous polypropylene separator which prevents it coming into contact with the cathode grids. Each cell is assembled in a her-

metically sealed steel can and the sulphur dioxide electrolyte is inserted through a hole in the bottom, which is later welded close. See Fig. 10.

Users of these cells are advised to include fuses in external circuits to prevent excessive discharge current, not to connect cells in parallel, which can lead to one cell charging another and to avoid discharging cells to below 2 volts.

Today's highest performing liquid cathode system and one which is often called the work horse of the range, uses a lithium-thionyl chloride combination (LiSOCl_2). An open-circuit output of 3.65V is obtained and this falls to between 3.5 and 3.0 volts according to load with excellent stability, until the cell is nearing exhaustion.

The higher output voltage of thionyl chloride cells increases the total watt

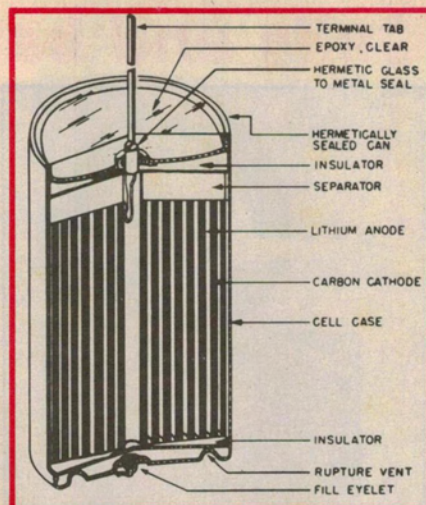


Fig. 10: The lithium sulfur dioxide cell. Diagram courtesy of Duracell.

hours of energy stored by 20 to 25% compared to sulphur dioxide types. Self discharge is low, giving a shelf life of at least 5 years. Normal operating temperature range is from -55 to $+70^\circ\text{C}$ but special types are available for use up to 150°C . Some of the latest designs have electrolytes formulated to overcome initial voltage drop problems caused by the anode passivation effects mentioned earlier. Many smaller cells of

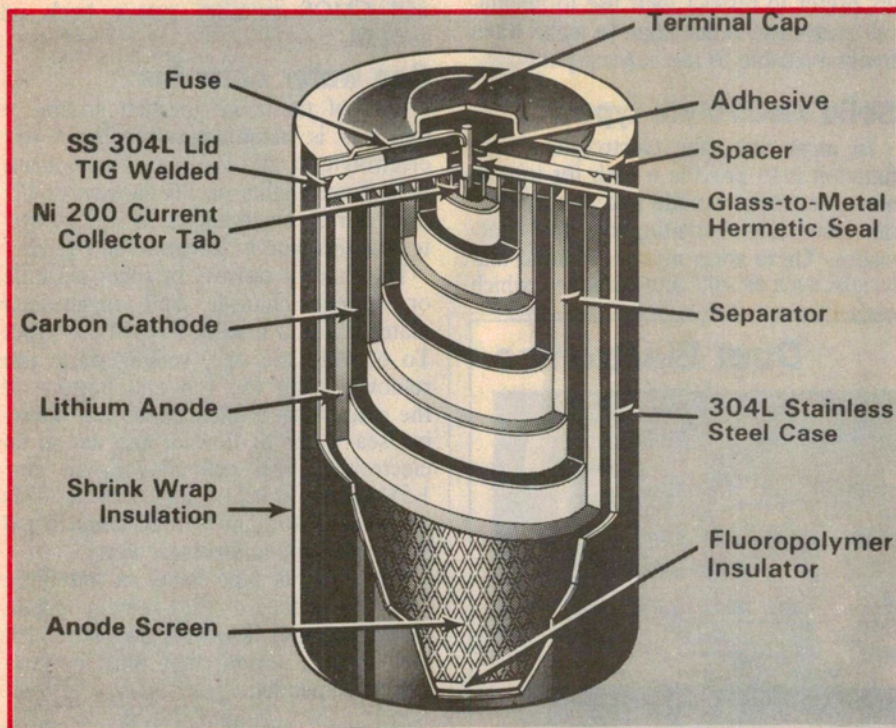
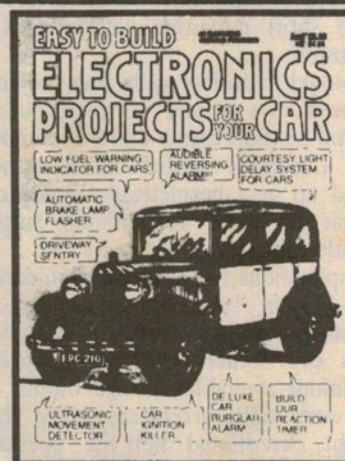


Fig. 11b: The lithium thionyl chloride cell is for low drain 'fit and forget' applications.



With these selected projects from *Electronics Australia* you can add all of the gadgets and gizmos you've dreamed of —

Deluxe Burglar Alarm — Courtesy Light Delay
Audible Reversing Alarm — Headlight Reminder
Transistor-assisted Ignition with Optoelectronic Trigger and many more easy-to-build projects to add value, interest and safety to your pride and joy!

Available from your Newsagent Now! Or send \$3.95 plus \$1.00 post and packing for each title to Electronics Australia, PO Box 227, Waterloo 2017, NSW.

Cells and batteries

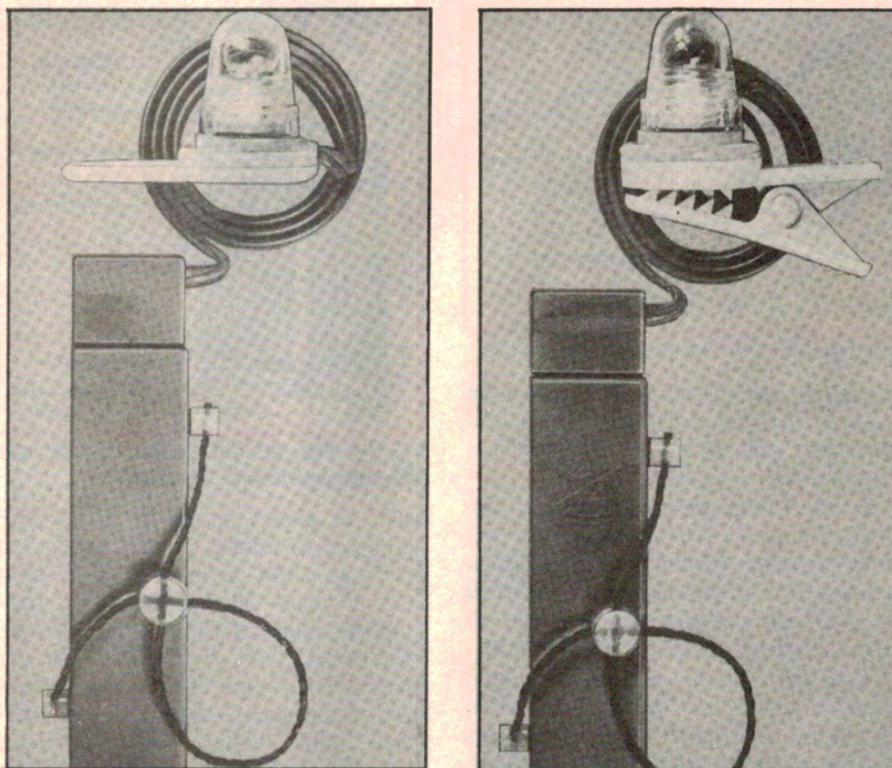


Fig.12: Above is the sea water battery which is manufactured without an electrolyte.

this type are also now designed to withstand short circuiting without risk of explosion.

Thionyl chloride cells can be constructed in a variety of ways, but the normal method uses a lithium foil anode and a carbon coated mesh cathode rolled up in a hermetically sealed can, similar to those for lithium sulphur dioxide cells shown in Fig.10.

Applications for solid and liquid cathode lithium batteries are many and varied. They have some clear advantages over other types which include maximum available voltage output per cell, very high current capability, lightweight, exceptional shelf life, operation

in extremes of temperature and high stored energy per unit volume. On the negative side however, some care is needed to ensure they are handled, used and disposed of in a correct and safe way. As a result, most manufacturers prefer to restrict their use to 'technical' customers rather than to make them freely available to the general public.

Solid electrolyte types

In most cells, the electrolyte's main function is to provide a path for ions to move between cathode and anode without also short circuiting the two electrodes. There are a number of solid materials, such as salts and ceramics, which

have high electrical resistance, but also contain mobile ions of one particular type. By combining one of these materials with an anode and cathode which use the same type of ion in electrochemical activity, it is possible to make an all solid-state cell.

Commercially available cells use lithium anodes, lithium iodine electrolytes and a variety of chemically complex cathodes. At room temperature (20°C), outputs of about 1.9V per cell with load currents of between 15 and 30 microamps are obtained. The working temperature range is -40°C to 120°C with current capability increasing as cells warm up, as this improves the mobility of the ions in the solid electrolyte. At 95°C the current capability is 10-20 times the room temperature figures given above, but at -40°C it is down to only a few percent of room temperature levels. The construction of a typical all solid cell is shown in Fig.11.

Solid electrolyte lithium iodide cells have excellent shelf-life with figures of 20 or more years being quoted. There is no possibility of gassing, leakage or corrosion, even under conditions of severe misuse. The amount of stored energy is very high and as this can only be taken from the cell at a slow rate, due to the low current capability at normal temperatures, the service life can easily extend to 10 years or more.

Typical low drain 'fit and forget' applications for solid electrolyte batteries include heart pacemakers, LCD watches and CMOS memory power back up systems.

Sea water batteries

One of the more unusual groups of batteries is manufactured without any electrolyte at all. Their best known use is to power lights on life jackets or life rafts during emergencies at sea. A system of this type is illustrated in Fig.12.

The battery consists of silver chloride or copper chloride and magnesium plates inside a moulded polythene case. To activate the cell, sealing plugs are removed from the top and bottom of the case which is then immersed, allowing sea water to flow in and act as an electrolyte. The cell shown will give 1.5V output at 0.11A for 20 hours. This is sufficient to light a small lamp to aid location of the unfortunate user.

Cells of this type have an indefinite shelf life as long as they remain sealed. Once activated however, no matter for how short a period, they must be considered expended. EA

(Next month we will conclude our survey with secondary cells and batteries.)

Quality Assembly?

Leave It In Our Capable Hands

The price is right
and deliveries are
always on schedule

Duet Electronics

414 St. Georges Rd.
Thornbury, 3017
480-5803 484-4420

Duet Electronics

