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Cell Construction

Broadly speaking the cell voltage is controlled by the cell chemistry, the capacity is governed by the weight of the active chemicals and the current carrying capacity (or power) is governed by the area of the electrodes. To a lesser extent all three of the above parameters as well as the thermal properties are affected by the [internal impedance](#) of the cell and this depends on the conductivity of the electrolyte and the layout and resistance of the components in the current path.

Thus the size shape and materials used in its construction all affect the ultimate electrical performance of a cell.

Internal Construction

Electrodes (Energy/Power Trade-Offs)

For a given cell chemistry and within the space available inside a given cell case, the cell performance can be optimised for capacity or power.

- Increasing the surface area of the electrodes increases the cell's current handling capability. Thus the cell can both deliver more power and it can be charged more quickly.
- Increasing the volume of electrolyte in the cell increases the cell's energy storage capacity.

The prime trade off is between the area of the electrodes and the volume of the electrolyte which can be contained within the volume available in the cell case.

High power cells require electrodes with a large surface area as well as enlarged current collectors which take up more of the available space within a given cell, displacing the electrolyte and reducing the cell capacity.

The effective surface area of an electrode can be increased without increasing its physical size by making its surface porous and using materials with very fine particle size. This can increase the effective surface area of the electrodes by 1000 to

Mpower does not
monitor or record these
emails

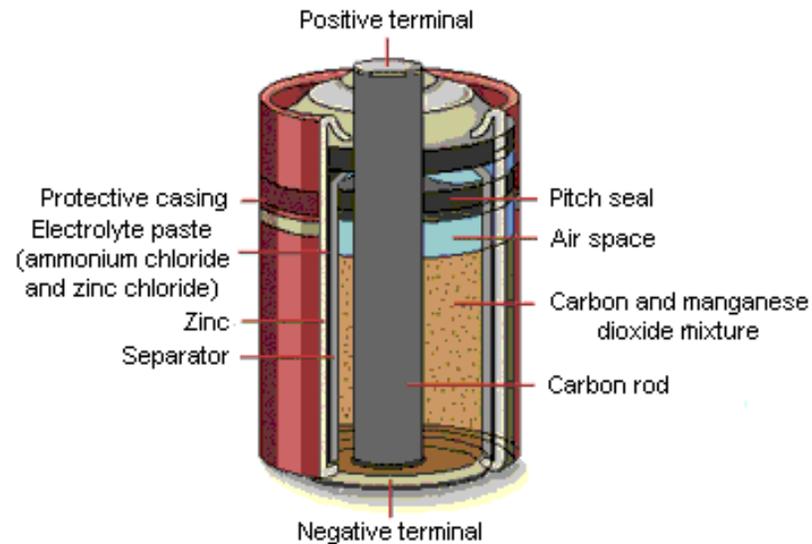
100,000 times enabling higher current rates to be achieved.

High capacity cells require large volumes of electrolyte which must be accommodated between the electrodes. This has a double effect in reducing the cell power handling capability. First, the electrodes must be smaller and further apart to make space for the extra electrolyte and hence they can carry less current. Secondly, because of the increased volume of the electrolyte, it takes longer for the chemical actions associated with charging and discharging to propagate completely through the electrolyte to complete the chemical conversion process. (More details are given in the section on [Charging Times](#)).

As an example - Lithium Ion cells optimised for capacity may typically handle peak currents of 2C or 3C for short periods, whereas Lithium Ion cells optimised for power could possibly deliver pulsed currents of 30C to 40C.

Four of the most common constructions are shown below. Over the years there have been many thousands of variants of these basic types used for many different cell chemistries.

Bobbin Electrodes

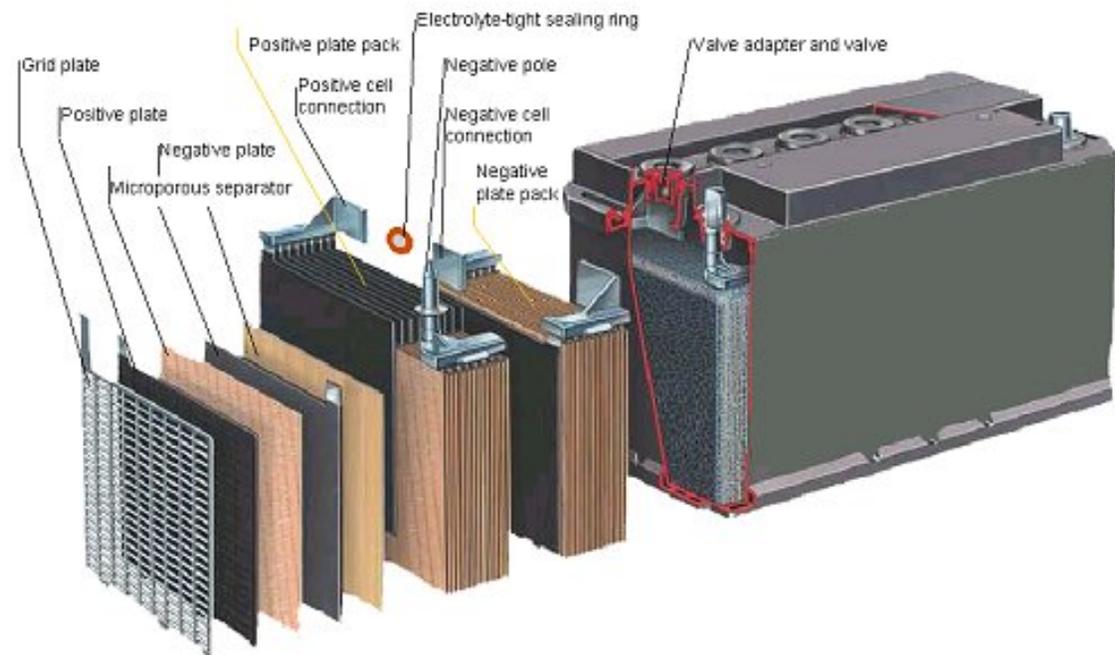


Zinc - Carbon (Leclanché) Cell

The bobbin construction has been used for over a century since the introduction of the Zinc- Carbon (Leclanché) Cell and a more recently with the newer Alkaline cells which use a more complex version of this type. It is a cylindrical construction utilizing an internal cylindrical electrode usually in the form of a rod which is immersed in the electrolyte which is in turn contained in an external electrode in the form of a cylindrical cup arranged as a sleeve inside the cell container. A separator sheath prevents contact between the electrodes.

Its advantage is that it is simple, it stores a large amount of electrolyte which gives it a high capacity and hence long life but the electrode surfaces are very small which results in a high internal resistance and limits the currents it can deliver. However, this small area also results in a low rate of self discharge and these batteries therefore have a long shelf life. It is ideal for many applications requiring primary cells and is manufactured in very large quantities.

Flat Plate Electrodes

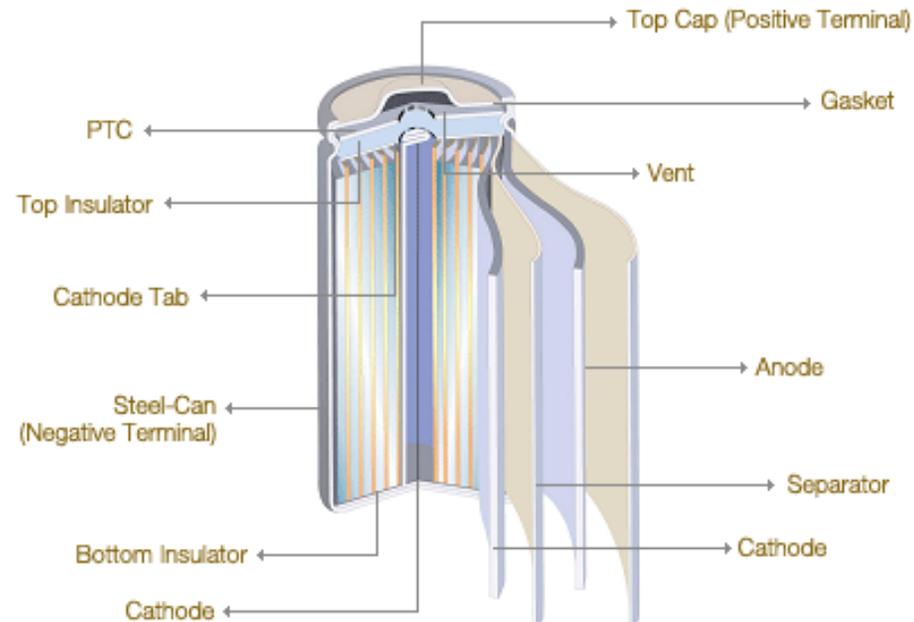


Cells Used in Lead Acid Battery

Source [Eurobat](http://www.eurobat.com)

Flat plate cells typically used in Lead Acid batteries also have over a hundred years of history and development. The electrodes are made in the form of flat plates suspended in the electrolyte which is held in a suitable container which does not usually take part in the chemical reaction. A separator between the plates prevents them from touching each other and short circuiting. This is another simple construction which is also used by many different cell chemistries. Its main advantage is that it can be scaled up to very large sizes, larger plates providing for higher currents and larger containers allowing high storage capacities.

Spiral Wound Electrodes (Also called Jelly-roll or Swiss-roll construction)



LG Spiral Wound Cylindrical Cell

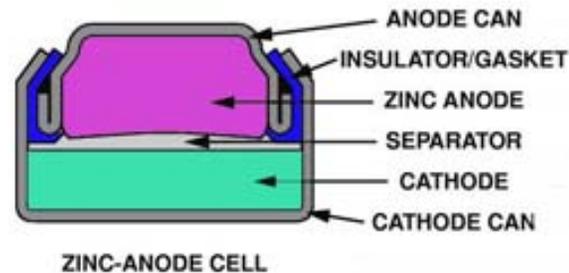
In the quest for higher current carrying capacity, it is necessary to increase the active surface area of the electrodes, however the cell case size sets limits on the size of electrodes which can be accommodated. One way of increasing the electrode surface area is to make the electrodes and the separator from long strips of foil and roll them into a spiral or cylindrical jelly-roll shape. This provides very low internal resistance cells. The downside is that since the electrodes take up more space within the can there is less room for the electrolyte and so the potential energy storage capacity of the cell is reduced. This construction is used extensively for secondary cells. The example above shows a Lithium-Ion cell but this technology is also

used for NiCads, NiMH and even some Lead acid secondary cells.

Spiral wound construction not limited to cylindrical shapes. The electrodes can be wound onto a flat mandrel to provide a flattened shape which can fit inside a prismatic case. The cases may be made from aluminium or steel.

This construction is ideally suited for production automation.

Button Cells and Coin Cells



Most button and coin cells follow the same basic layout in their construction as shown in the diagram above. They are used where small size is required. As with bobbin cells they have a relatively high capacity but deliver low power.

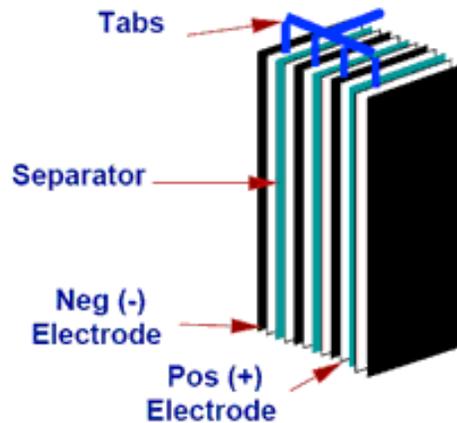
Multiple Electrode Cells

- **Monopolar configuration**

In this configuration the battery is constructed from individual cells with external connections joining the cells to form series and parallel chains.

- **Stacked Electrodes**

Prismatic Cell Electrode Stack



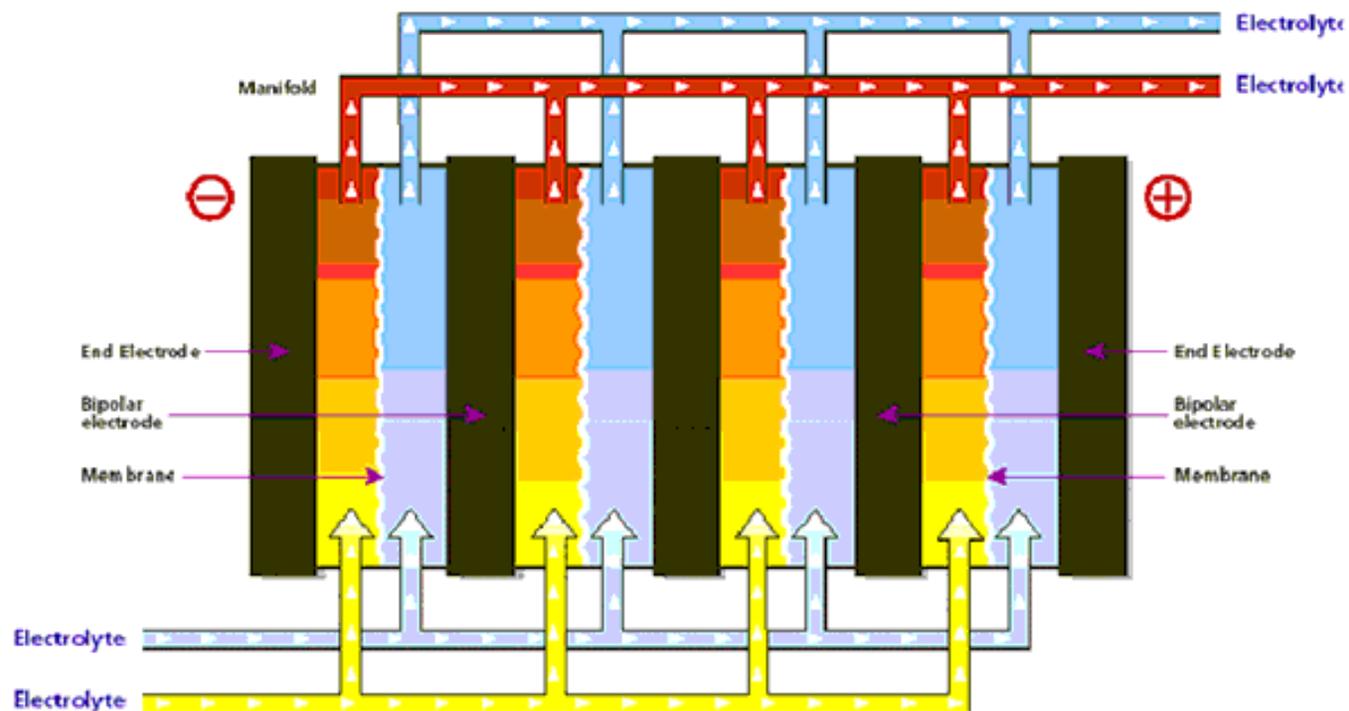
This is an example of monopolar configuration. Reminiscent of Voltas pile, the positive and negative plates are sandwiched together in layers with separators between them, inserted into the case, and sealed. This construction provides an energy efficient form factor and is typically used in high power Lithium Polymer cells with the solid polymer electrolyte separating the cells.

- **Bipolar configuration**

In bipolar batteries the cells are stacked in a sandwich construction so that the negative plate of one cell becomes the positive plate of the next cell. Electrodes, often called duplex electrodes, are shared by two series-coupled electrochemical cells in such a way that one side of the electrode acts as an anode in one cell and the other side acts as a cathode in the next cell. The anode and cathode sections of the common electrodes are separated by an electron-conducting membrane which does not allow any flow of ions between the cells and serves as both a partition and series connection.

This is an efficient design which reduces the number of plates and eliminates external connections, reduces the weight of the battery, increases the energy density and reduces costs. The current pathway is also shorter and resistance losses will be less enabling the battery to handle higher power. Bipolar construction is usually adopted for Fuel Cells and [Flow Batteries](#) in which the electrolyte flows over, or is pumped through the cells, but the technique has recently been trialled on much simpler, smaller scale automotive and portable batteries with several

other cell chemistries using single electrolytes.



Bipolar Cell Construction In a Flow Battery

Source: Regenesys

Bipolar cells suffer from higher self discharge due to the shunt current which occurs through the electrolyte manifold because the electrodes of the same polarity are at different potentials.

Bipolar batteries are also called "Layer Cells" and "Stacked Wafer Cells"

Electrode Interconnections

The internal resistance of the cell and the distribution of the currents and potentials within the cell are affected by the cell geometry which must be optimised to provide robust connections, minimum length current paths, and even distribution of currents to avoid local hot spots and uneven potentials which could give rise to unbalanced, damaging chemical reactions at different parts of the electrodes.

Sealed Cells and Recombinant Cells

Most batteries these days seal the electrolyte into the cell case. This is to prevent leakage of electrolyte and to prevent any gaseous products of charging and discharging from escaping into the atmosphere. The cell may also include a catalyst to promote recombination of these gaseous products. Such cells are called recombinant cells.

Safety Vents

When a cell is sealed, high internal pressures may build up due to the release of gases and due to expansion caused by high temperatures. As a safety precaution sealed cells usually incorporate a [safety vent](#) to allow excess pressure to be reduced in a controlled way.

Cell Casing

As with the internal cell construction there are many variants of case designs. Some standard, low power packages are shown below.

Cylindrical Cells



The picture above shows the most common cylindrical cell sizes from a range of manufacturers. The shapes may be

standardized but the voltages and chemistries are not. The four largest sizes can each house Leclanché, Alkaline, NiCad, NiMH and Lithium chemistries with voltages ranging from 1.2 to 3.7 Volts. The first two chemistries are used for primary cells and are based on a bobbin construction. The remaining chemistries are used for secondary cells with spiral wound electrodes. Care is needed to match the chargers to the appropriate cells.

Cylindrical cells provide strong mechanical stability, good energy density and low costs.

It is estimated that 90% of portable, battery-operated devices require AA, C, or D battery sizes.

Multi-cell Batteries

The two batteries shown above are actually made up from groups of cylindrical cells. The type 23A contains eight 1.5 Volt cells and the PP3 contains six 1.5 Volt cells.



Common Household-Battery Sizes

Size	Shape and Dimensions
D	Cylindrical, 61.5 mm tall, 34.2 mm diameter.
C	Cylindrical, 50.0 mm tall, 26.2 mm diameter.
AA	Cylindrical, 50.5 mm tall, 14.5 mm diameter.
AAA	Cylindrical, 44.5 mm tall, 10.5 mm diameter.
PP3	Rectangular, 48.5 mm tall, 26.5 mm wide, 17.5 mm deep.

Button Cells and Coin Cells



Button and coin cells are available in a range of sizes, voltages and cell chemistries. (Zinc -Air cells are also available but not shown)

Pouch Cells



Valence pouch cells

Pouch casings are typically used for Lithium Polymer cells with solid electrolytes, providing a low cost "flexible" (sometimes in unintended ways) construction. The electrodes and the solid electrolyte are usually stacked in layers or laminations and enclosed in a foil envelope. The solid electrolyte permits safer, leak-proof cells. The foil construction allows very thin and light weight cell designs suitable for high power applications but because of the lack of rigidity of the casing the cells are prone to swelling as the cell temperature rises. Allowance must be made for the possibility of swelling when choosing cells to fit a particular cavity specified for the battery compartment. The cells are also vulnerable to external mechanical damage and battery pack designs should be designed to prevent such possibilities.

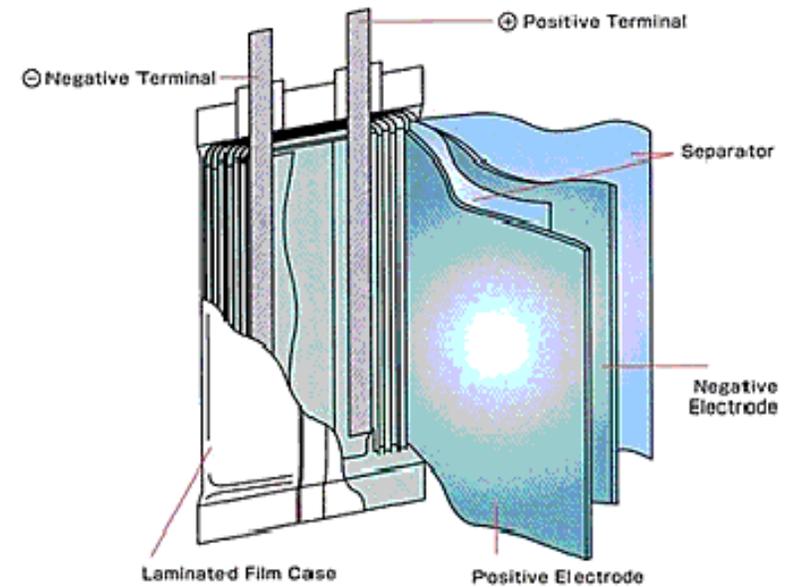
The GS-Melcotec example illustrated uses spiral wound electrodes and a solid polymer electrolyte.

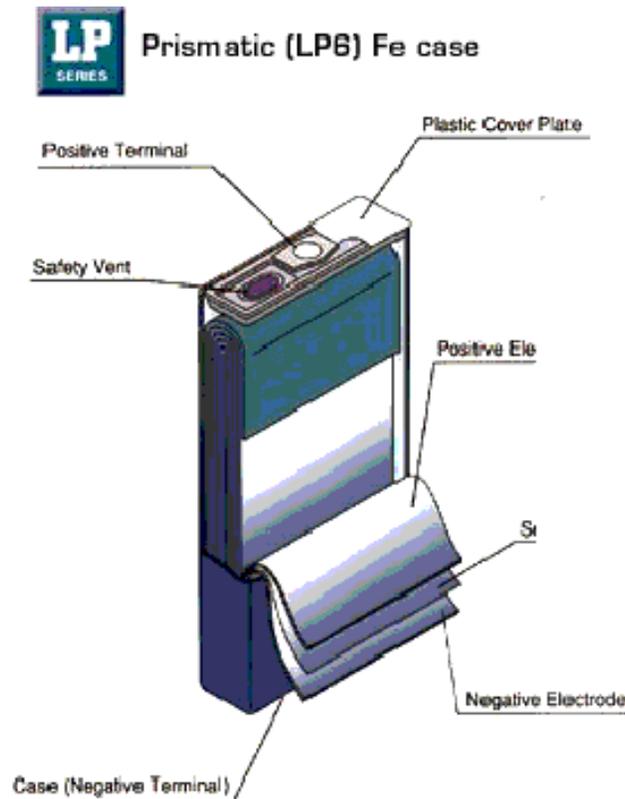
This construction, using stacked electrodes is suitable for making odd shaped cells but few applications make use of this opportunity.

Prismatic Cells



Aluminum Laminate Package





Prismatic cells are contained in a rectangular can. The electrodes are either stacked or in the form of a flattened spiral. They are usually designed to have a very thin profile for use in small electronic devices such as mobile phones. Prismatic cells provide better space utilisation at the expense of slightly higher manufacturing costs, lower energy density and more vulnerability to swelling, but these are minor effects which don't constitute a major disadvantage.

This example from GS-Melcotec has a steel can with spiral wound electrodes and a liquid electrolyte.

Thin Film Batteries

Thin film printing technology is now being used to apply solid state Lithium polymer chemistry to a variety of substrates to create unique batteries for specialist applications. Thin film batteries can be deposited directly onto chips or chip packages in any shape or size, and flexible batteries can be made by printing on to plastics, thin metal foil or even paper. Because of their small size, the energy storage and current carrying capacity of thin film batteries is low but they have unique properties which distinguish them from conventional batteries including:

- All solid state construction
- The battery can be integrated into the circuit for which it provides the power

- Bendable batteries are possible
- Can be made in any shape or size
- Long cycle life and operating life
- Operate over wide temperature range
- High energy and power densities
- Cost and capacity are proportional to the area
- No safety problems

Thin film batteries have a wide range of uses as power sources for consumer products and for micro-sized applications.

The battery on the right from Oak Ridge Micro-Energy is designed for use in implantable medical devices.



Other applications include non-volatile memory backup and sensors.



Flexible film batteries like that shown on the left from Infinite Power Solutions are suitable for powering smart cards and radio frequency identification (RFID) tags.

Under development for ten years, thin film batteries are just recently becoming available in commercial quantities.

High Power Batteries

While there is at least some standardisation with low power cells, the same can not be said for high power cells which are made in a wide range of sizes using many different construction techniques. These include foil pouches, plastic or glass box like structures and cylindrical steel tubes.

The large cells on the right are 3.7 Volt Lithium cells. The cylindrical cell has a capacity of 60 Ah, while the prismatic cell has a 200 Ah capacity. The small cells in the foreground for comparison purposes are AAA size.

Low [internal resistance](#) is an important requirement of these cells and this in turn requires thick current carriers and low contact resistances between the electrodes and the interconnections. Because these cells are designed to carry high currents which cause them to heat up, the cells usually incorporate features to allow for expansion of the contents and to avoid swelling. There may be voids inside the cell or there could be special clamps around the outside of the cells to constrain expansion to a particular direction.



Nomenclature

Cell identification.

There is considerable confusion about naming standards for cells with different systems used in Europe, the USA and Japan as well as manufacturers' own standards.

One convention is two letters followed by a series of numbers.

The first letter represents the cell chemistry. The second letter represents the shape of the cell.

The numbers represent the dimensions of the cell in millimetres. For cylindrical cells the first two digits are the diameter and the remaining digits the length. For prismatic cells the first two digits represent the thickness, the second pair the height and the last pair the width.

Because of the plethora of "standards" the only safe course in identifying a cell is to consult the manufacturers' data sheets.

Examples

- **Common Primary Cells**

See [Battery Case Sizes](#) for dimensions of common primary cells.

- **Cylindrical Cells**

LC18650 is a common Li-ion cell in a Cylindrical can Size (diameter18mm height 65.0mm)

See [Cylindrical Cell Sizes](#) for a listing of typical cylindrical cell sizes and capacities

- **Prismatic Cells**

LP083448 is a Li-ion cell in a Prismatic can Dimensions(thickness 8mm height 48mm width 34 mm)

See [Prismatic Cell Sizes](#) for a listing of typical prismatic cell sizes and capacities.

See [Power Cell Sizes](#) for examples of high power prismatic cells. (High power cylindrical cells are also available)

See also [Battery Pack Design](#)

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