

Rechargeable Batteries and Cells

NiCd, NiMH & LiPo

New modern electric hand tools batteries have come on along way and the technology has been passed down to the electric models including boats, cars and planes. The limit for more powerful motors keeps going forward every day so the development of more powerful cells to meet this demand is ongoing.

It was the Nickel Cadmium (NiCd) cells that were first used in main stream hand tools, followed by the Nickel Metal Hydride (NiMH). Another cell of choice today is the Lithium Polymer (LiPo) cell.

NiCd & NiMH cells are basically the same construction and use similar materials in construction with respect to the electrolyte used in between the positive and negative plates of the cell.

NiCd and NiMH Cell Care and Feeding

It must be stressed that with fast charging comes a reduced life cycle of the cell, so does the heavy discharging of the cells in conditions such as electric driven cars and planes that demand very high current draw from the power train of the cells.

Like any device, the more stress you apply to it, either mechanical, electrical or in the case of these cells chemically, you risk damaging the cell. However this is a sacrifice you have to make for using this type of power source in the pursuit of your interest. Basically the selection and use of all battery cells is a compromise between cost, weight, power output, reliability and usable life time. Like most things in life, few things are perfect.

NiCds have relatively much lower self discharge rates than NiMH; however NiMH cells have much higher energy density and are more environmentally friendly. Both technologies can have a long, reliable life if used and maintained correctly.

The NiCd & NiMH cell voltage should never be discharged to a level of less than 1.0 volt / cell as this condition would also result in the possibility of a cell going into reverse polarity rendering the cell permanently damaged. A 4 cell pack would be considered fully discharged when it reaches 4.0V.

The charging of these cells also has special requirements such that a dedicated charger must be employed to get the best performance and life cycle out of the cell or battery pack.

There are a number of chargers on the market that meet all the requirements to charge and maintain these cells. One of the requirements of charging these cells is that the charger has a Negative Delta V detection sensing circuit that terminates the charger when the charging is complete.

Negative Delta V for NiCd is 15-20mV per cell and NiMH is 5-10mV per cell. Program 15mV for NiCd and 5mV for NiMH into your Negative Delta V charger.

The maintenance side of these dedicated charges is they also have the ability to cycle the cells in a number of charge/ discharge cycles to ensure the cell is discharged and charged again to the specific voltages (1.0 to 1.45 volts / cell) that govern the good performance of these cells.

Other factors also come into play with using these cells to obtain maximum performance out of them, such as temperature limits, etc. In cold conditions, like most things in life, they don't like giving their maximum performance. Likewise charging a cell that has just come off being used and is very warm to the touch should not be re-charged until it is cooled down.

NB: The full capacity of new cells will be found after several cycles of charging and discharging.

All cells, either it be NiCd, NiMH or LiPo, have a "C" rating and this is in relationship to the indicated Ampere Hour Capacity "Ah " or it may be shown as "mAh which is 1000th of an Amp. This may be shown as, eg. 2400mAh which can be translated to 2.4Ah.

The "C" rating is the stated capacity. In the example case above, 1C = 2400mAh.

Charging

Using a slow charger, the charging of NiCd & NiMH should be set at a range of normal charging which is set at 0.1 C or 1/10th of the C rating, and in the above example of a 2400 mAh cell the charge current would be set at 240 mA for 14 to 16 hours, the extra 4 to 6 hours is required to overcome inefficiencies in the make up of the cell and require a little more charge to overcome the normal "C" rating.

Using a fast Delta V charger, it is good practice to charge standard batteries at 0.5C to 1C.

Fast charging of 1C or more can be applied to specially designed cells that can handle this amount of charge without damage. These are often referred to as Racing or High Performance batteries. Standard cells may be damaged at anything above 1C.

Heat is the enemy of batteries. The charging process of this type of cell will always cause them to heat up. Cells have an internal valve which will operate if internal gas pressure becomes excessive. Any cell with white crystals around the anode connector has a faulty seal and must be discarded. Please refer to other articles on Black Wire Syndrome.

Memory Effect

The word *memory* was originally derived from *cyclic memory*, meaning that a NiCd battery can remember how much discharge was required on previous discharges. Improvements in battery technology have virtually eliminated this phenomenon. If a cell is exercised and fully discharged periodically, memory effect will not occur.

A cell prefers moderate room temperature and, in case of the NiCd battery, requires regular exercise to prevent the phenomenon called "memory". The problem with the modern NiCd battery is not so much the cyclic memory but the effects of *crystalline formation*.

Never keep a NiCd or NiMH battery on float charge. Like humans, cells need exercise. Lack of exercise will cause internal crystal growth which can eventually puncture the separators inside the cell, causing an internal short circuit which will result in the permanent failure of the cell. Crystal formation is reduced by cycling down to 1.0V per cell.

For maximum life, simply fully charge these batteries immediately before use, and allow them to fully discharge before recharging.

Self-Discharge

The NiCd and NiMH battery chemistries exhibit an inherently high self-discharge. If left on the shelf, a new NiCd loses about 10% of its capacity in the first 24 hours after being removed from the charger. The rate of self-discharge settles to about 10% per month afterwards. At a higher temperature or with advanced age, the self-discharge rate increases substantially. Typically, the rate of self-discharge doubles with every 10° C. A problem arises if a battery with good capacity readings goes flat during use through excessive self-discharge rather than by providing power. Such an occurrence is quite common.

The self-discharge of a battery can best be measured with a battery analyser by first charging the battery, then measuring its capacity through discharge. The battery is then recharged and put on a shelf for 24 hours after which the capacity is measured again. If the loss approaches 30% at room temperature, the battery should be replaced. Expect a higher capacity loss with NiMH batteries. Cycling will not correct a high self-discharge condition.

To reduce the effect of self discharge the cells are charged up just before use and allowed to cool down from the charged state to room temperature.

The modern dedicated charger will have a function that will give a reading in mAh that the cells have stored in their fully charged state and the terminal voltages of the pack or individual cell. If the mAh of the battery pack is less than around 75% of the published figure stated on the battery pack label, then the pack should be considered worn out or damaged and should be disposed of.

Soldering to Cells

There is a problem with the use of NiCds and NiMH cells when they are subjected to local heating of the cells as in trying to soft solder terminals to the end of the cells to make up your own battery packs. Never soft solder direct to these cells. Commercial packs are spot welded with the correct equipment where cell heating is minimal. If you wish to make up your own packs, you can purchase cells with tags already spot welded to them.

Long Term Storage

All battery cells use an internal chemical reaction. Warmth will speed up a chemical process, cold will slow the process. Tip - Store unused (spare) alkaline, silver, NiMh, NiCd cells in a fridge in the crisper or meat keeper for maximum life. Keep them dry; consider keeping them in sealed plastic storage bags. Note: NEVER freeze cells, this will damage them. Keep cells cool (10 – 30 deg C) when storing them. Store NiCd and NiMH cells discharged.

To summarise the use and maintenance of NiCd & NiMH cells and battery packs:

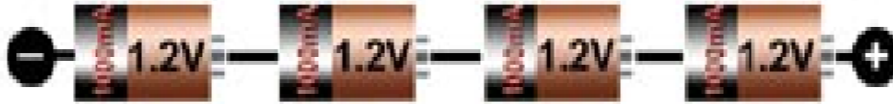
- Use a dedicated charger to charge and cycle the cell or pack to maintain full serviceable capacity, as to run the cell down to only part capacity will result in a “memory effect” that will cause damage and not allow the full capacity to be used.
- It is recommended for NiCd cells that a maintenance deep cycle of charges and discharges using a dedicated charger unit be carried out every 8 weeks to maintain full capacity and prevent crystal formation. The NiMH is also affected by memory but to a lesser degree — it only needs *exercise* once every three months. Because of its shorter cycle life, it is not recommended to over-exercise the NiMH. NB this effect does not apply to LiPo cells.
- Do not discharge the cell or battery pack down to below 1.0 volt / cell and never use an electric light globe, motor or leave equipment running to discharge the cell or pack. This can discharge the pack too deeply and can damage the battery pack. Use a dedicated charger / discharger to do this function.
- Don't soft solder direct to the cells body to make up your own packs as this causes localized heating and causing the electrolyte to expand and start gassing.
- Don't use packs on heavy discharge circuits like a motor if the pack is too cold or too hot and keep them around room temperature for best performance. Let them stand for a while after charging, about 30 minutes.
- NB: Never connect cells or packs in parallel to gain more capacity, they may start a fire or explode.
- Try to charge the cell or pack away from flammable material and where they can be supervised while charging if possible.
- Don't try and increase the recommended charge rate and time so you can get back into the action quicker; this is a sure way to reduce the life of the cells.
- Be responsible when disposing of NiCd type cells so that they don't end up in land fill, the cadmium inside is toxic should be recycled. NiMH can be safely disposed of with the household rubbish.

We all like to have instant this and instant that and it's nice to have a quick charge and be back into action, but this is not good for the rechargeable cells and battery packs we use.

Patience is a virtue and if you don't follow these simple rules you are going to be purchasing a new pack very shortly so why not get a few battery packs so that one is in use while the others are resting and being charged at a slower rate?

Cells Connected in Series (Normal battery packs)

NiCd and NiMH cells have a working voltage of 1.2 volts per cell and can be connected in series that is a number of individual cell can be connected together in a string with the positive terminal of one cell connected to the negative of the next cell giving a multiple of 1.2 volts per cell eg 2 cells connected in this configuration would give 2.4 volts and 3 cells would give 3.6 volts and 4 cells giving 4.8 volts.



Typical NiCd / NiMH 4 cell 4.8volt Battery Pack used in RC Installations

The other thing that can be seen on each cell is the Ampere Hour rating (Ah) this is the ability of the cell to do work over a period of time eg. A 1 Ah rated cell would be able to deliver 1 Amp of current @ 1.2 volts until a set level of voltage is reached normally calculated at the point of design and manufacture for 1 hour.

This rating of the cells must be followed if cells are to be connected in series to obtain a higher voltage as if the cells are not matched the lower rating cell will be discharged first and permanently damaged.

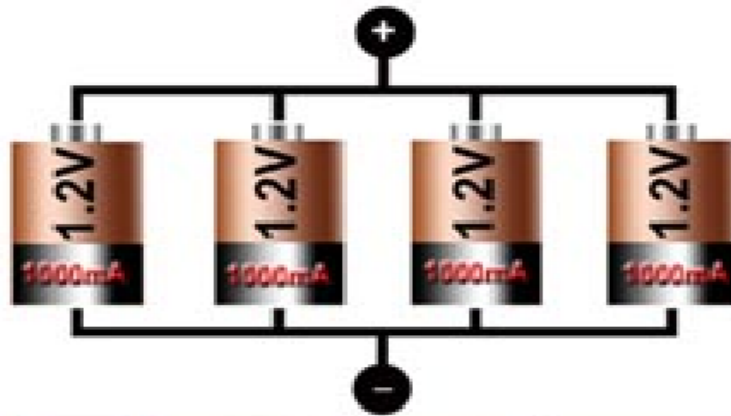
It is therefore best to match cells to the level of the same manufacture and batch number on the cells as if unlike cells are connected together a condition results known as reverse charging were the negative terminal of the cell becomes the positive and that cell now doesn't give any charge or voltage to the series pack. If a voltage reading was taken on say a 4.8 volt pack it would now indicate 3.6 volts or less a loss of 1.2 volts which is one cell out of the 4 x 1.2 volt pack.



Typical NiCd / NiMH 4 cell 4.8volt Battery Pack with a faulty cell giving a reduced level of voltage.

Cells Connected in Parallel

Cells can be connected in Parallel as shown to give a greater capacity but must be of all the same capacity and type and if at all possible same batch number.

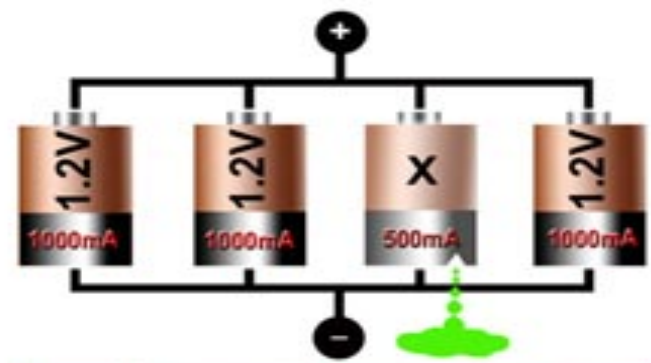


Typical Ni Cad / Ni MH cell connected in Parallel giving 1.2 volts but 4 x the capacity of 1 cell.

Specifically designed cell that have been manufactured and matched can be connected in parallel but not the normal cells we are using here.

NB; never connect these types of cells in parallel e.g. Positive terminal to Positive terminal to obtain a greater capacity as one or more of the cells will never be perfectly matched and will discharge into each other to find a balance point and so doing will self discharge and can in some cases create high temperatures within the cells structure which could cause them to ignite or even explode.

Shown below is a pack of 4 parallel connected cells. With a faulty cell the terminal voltage will still be 1.2 volts but the capacity will be down by the capacity of the faulty cell and in some cases cause the other cells to discharge into that faulty cell again causing heat to be generated while this action is taking place.

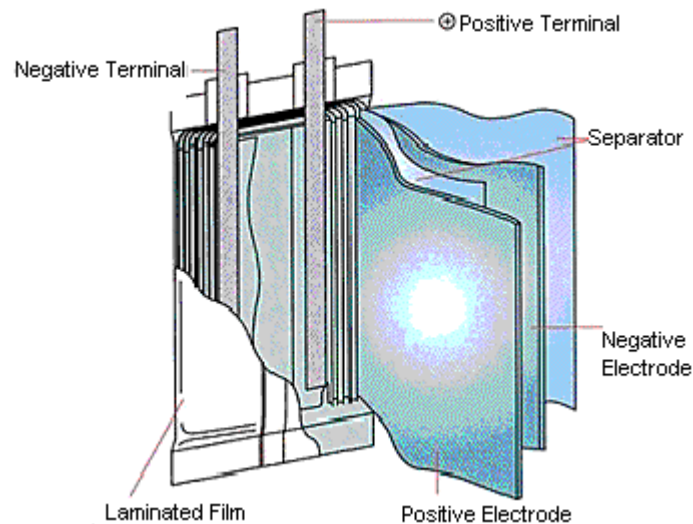


The testing of the terminal voltage or a pack of cells or the individual cell with the basic voltmeter is not sufficient, as this only measures the surface open circuit voltage and does not give a true reading of the cell under load. A load of around 500mA to 1 Amp is required to give you the true load voltage.

Lithium Polymer Batteries, LiPo

The new generation of battery packs are now used in many applications from mobile phones, cell phones, cameras, electric hand tools and model cars, helicopters, boats and aircraft and they are also used in the new hybrid cars on the road.

These batteries are very light. Due to their construction being in the form of a sandwich of very thin material wound in a spiral they can be made into any reasonable shape known as a POUCH CELL. This gives an incredibly small package of high power capacity, simplicity of construction and cost per unit of power to weight ratio.



These cells and packs have their own advantages and disadvantages of use, charge and discharging like any other cell.

NB these cells and pack are to be handled with extreme caution and should only be used by responsible persons or under adult supervision at all times in use and in the charging of.

The LiPo cell produces a working voltage of 3.7 volts, a finish charge voltage of 4.23 volts and should never be discharged below 3 volts / cell as this low state will not allow the cell to be recharged. If this is in a pack it could result in over charging the other cells in the pack.

The charging of these types of cell is critical in the charging state as each cell must be charged to within 0.1 volt of the other cells, if installed in a pack.

The charging cycle of these cells starts with a constant current charge until a pre determined voltage is reached per cell in the charging cycle. The charger then changes over to a constant voltage charge until a finishing voltage of 4.23 volts / cell is reached or the charge rate falls to 10% of the starting current.

This then is the terminating voltage of the charge and the charger automatically turns off the charging to the cell or pack.

While the charge is taking place each cells voltage is monitored and adjusted automatically so all the cells in multiple cell pack are kept within the 0.1 volt range as stated earlier.

The ideal way to charge these cells in a pack is by a dedicated LiPo charger using the Balance Sensing system that uses a separate socket on the pack to monitor the charge of the individual cells so maintaining a constant voltage of each cell to the prescribed voltage and to the limits of 0.1 volt /cell.

NB; Failing to do this, the cell will be out of balance and some cells may overcharge, this causes the cells to gas and results in the cells to start and deform in as much they swell up and become distorted in shape.

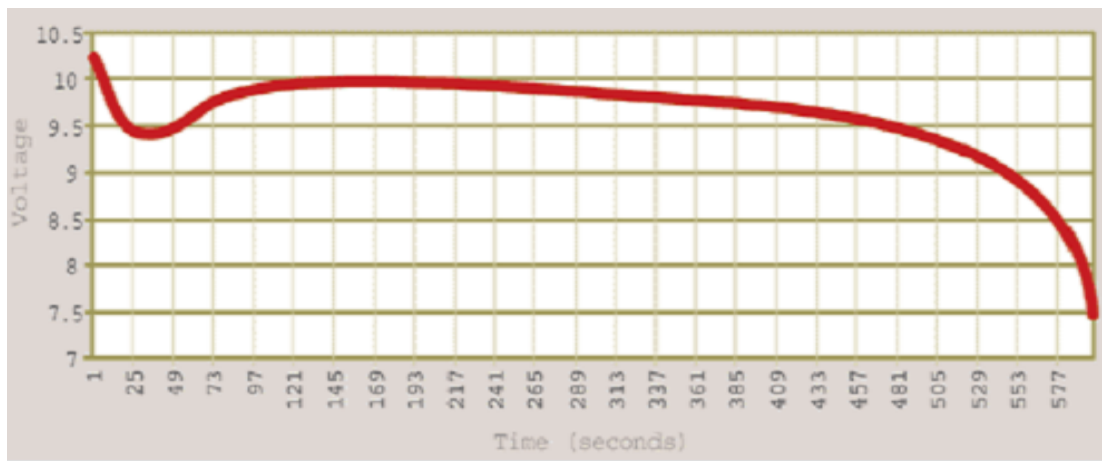
When this happens to a cell or packs it **MUST NOT BE USED OR RECHARGED**, it must be discharged outside by using an electric light globe of the same voltage of the pack until fully discharged, then punch a hole in the cells or drill through the pack and submerge it in bucket of salt water for 1 to 2 hour before disposing of in the garbage bin.

Unlike NiCd & NiMH, LiPo cells can be terminated both in series and parallel so long as they are the same manufacture, capacity and voltage. You will see the following on these packs: The rated voltage in stages of 3.7 volts / cell eg 3.7, 7.4 & 11.1 Volts and so on to obtain the required voltage pack and will have the number of cells indicated by prefix “S” eg; 3S for a 3 cell pack 4S for a 4 cell pack giving 11.1 and 14.8 volts respectively.

The other indication will be “P” prefixes indicating the amount of cells connected in Parallel eg. 2P, 3P.

So a 3S, 2P indicate a pack with 3 cells in series and 2 packs in parallel giving 11.1 volts at twice the capacity of one cell.

Also a maximum “C” rating is also indicated on these cells to show the maximum amount of current that can be drawn from the cell or pack eg; if the pack as a max “C” rating of 25C and the pack has a 2.0Ah or 2000mAh rating the maximum that should be taken from the pack safely is 25 x that rating, which would be 50 Amps.



Typical LiPo 11.1 volt 2,000 mAh battery pack being discharged at 6C which is 6 time the capacity of the pack i.e.12 Amps

The above graph shows how first the voltage drops under very heavy load until the reaction of the chemicals / temperature starts to compensate. A plateau of voltage is then reached over time that falls very quickly when the reaction of the chemicals can't sustain this level of discharge.

LiPo type packs and cells should be stored half charged (not flat or fully charged) at room temperature away from flammable material preferably in a non metallic fire resistant container and stored outside in a secure location.

To summarise the LiPo batteries:

- Never use them for any other purpose to that what they are intended to be used for and replacing other forms of cell such as NiCds and NiMH without instruction to do so.
- The Li-ion battery self-discharges 3 to 5% in the first 30 days, after which it settles to 1-2% per month.
- Where possible, always use a dedicated LiPo battery charger with a balance circuit if charging more than one cell.
- Never let the cell voltage drop below 3 volts and ensure your equipment has a voltage cut off point setting to stop the device dropping the voltage below this level. Always charge them out of the model outside away from flammable material and supervised at all times while in a charging state.
- If the cell or pack gets damaged, remove it from the equipment and do not transport the cell in a vehicle until the cell has been run flat by the electric globe method and it has been seen to be stable for a least 1 hour.
- Cells and packs that are deformed and have a swelling appearance should not be used or charged but discharged and disposed of safely as these cells can ignite without warning.
- These packs are formed into a package that can be pieced easily as they have very little mechanical protection and in no circumstance should the cell or pack be punctured deliberately while in a charged state.
- Store the cell or pack at room temperature in a partially charged state, never discharged or fully charged. Some chargers have the function to partly charge the pack to 3.7 volts/ cell for storage purposes. Spare packs should not be stored in doors if at all possible but in a fire retardant container outside away from pets and children.
- Make sure the use of good quality polarized connectors and that no terminal is exposed on the battery side (female sockets) and (male pins) on the load side.
- Never place any type of battery inside ones clothing such as a pocket as the coming together of items such as keys, coins can instantly weld together and cause severe burns.
- LiPo cells can be safely disposed of with the household rubbish after they have been discharged and rendered safe.

There are now new types of Lithium cells coming on the market called Lithium Manganese Dioxide Li Mn O₂ which offers much the same as the LiPo cells but much safer in operating and storage. Other cell in Lithium range includes Lithium Sulfur, Lithium Titanate and Lithium Iron Phosphate which all have their own place on the market of power cells.

I first stated that development is changing daily and with these power sources and even now some manufacturers are installing balancing devices internally in the battery packs to help charging.

Always treat batteries with the utmost respect as they hold a vast amount of energy and can cause great damage if not treated correctly.

Finally I would like to bring to your attention the carriage and storage of these batteries safely. On no account should they be carried or stored in a location that may cause the terminals to be brought into contact with conductive materials. They can explode if shorted out or misused and only use them for the intended purpose only.

I do hope this article will help to provide you with some information to get the best from your battery packs safely.

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