Photo.1: NiCad Cells as they are delivered from the manufacturer

Battery powered tools are immensely convenient; they can be taken almost anywhere, independent of the availability of mains electricity. There are no trailing cords to trip over or to try to get out of the way when using the tool in a confined space, *and they work*. The earliest tools of this type might have been seen as weak and puny, but those have long since given way to tools that are as powerful as they are easy to use.

Though still less powerful than their mains operated cousins, there are cordless drills that will chew through the toughest hardwood, angle grinders that will chop up 10mm steel and circular saws that will cut a whole wall of pine framing for a house.

Most woodworkers now own at least one battery powered tool, probably a drill. If you have had an opportunity to sample several of the brands on the market, you will have found that the variability in quality, durability and performance is about the same as it is for mains powered tools. And it seems unlikely they will last a shorter time simply because they are powered by batteries.

But cordless tools **are** different. Firstly, the battery must be removed periodically and charged. Secondly, the way in which the battery is charged can have a substantial bearing on the life of the battery and the usefulness of the tool. Thirdly, the battery eventually 'wears out' and must be replaced.

It's when a replacement battery has to be purchased that the owner of the tool confronts a grim reality: *batteries ain't cheap*. In fact, a replacement can sometimes cost almost as much as the complete tool. So learning a little about them and how to extend their life is an attractive notion. So is the possibility of discovering whether a battery can be repaired or rejuvenated and whether there's any alternative to straight out replacement by the same brand.

All batteries work in a similar manner. Each consists of one or more cells and each cell is comprised of three components: an anode, a cathode and an electrolyte. The latter is generally either a fluid or gel that forms an electrical connection between the anode and the cathode allowing ions (charged chemical particles) to migrate through it.

It's the selection of the materials that determines whether the combination of anode, cathode and electrolyte forms a cell. The material chosen for the anode must be one that readily gives up electrons and the material chosen for the cathode must be one that readily accepts electrons. Since there are many materials in each of these categories, there's an equivalent number of 'chemistries' with which battery designers might be able to work. But there are a large number of other factors that determine whether a particular chemistry satisfies all the other criteria for a battery.

There are two chemistries in common use for the batteries used in cordless tools. These are Nickel Cadmium (abbreviated to either NiCad or NiCd), and Nickel Metal Hydride (NiMH). The first is the one used in most tools currently in use but the number of tools using NiMH is increasing.

In the NiCad battery, the anode is made of Nickelic Hydroxide and the cathode of Cadmium. When the battery is charged, chemical changes temporarily store the electrical energy from the charger. The result is that an electric potential exists between the external terminals (connected to the anode and cathode respectively).

For a battery with a single cell, this no-load voltage is determined by the materials used for the anode and cathode. (The no-load voltage is the potential that exists when there is no external connection to the battery. If such a connection exists, electric current flows through the external circuit and back through the battery. Due to the battery's internal resistance, the terminal voltage drops. This means that the no-load voltage is the highest voltage that the cell can produce and is characteristic of that particular cell technology.)

The no-load voltage of a NiCad cell is 1.25V. Although the NiMH (Nickel Metal Hydride) cell employs a different chemistry, it has almost the same no-load voltage, but the no-load voltage of a lead-acid cell is close to 2V. The most common use of the latter type of battery is in motor vehicles, but woodworkers may encounter them in a few cordless tools and in other equipment such as ventilated safety masks.

Another battery type that must be mentioned is Li-ion (Lithium Ion) which has a cell voltage of 3.6V. At present, you are much more likely to find one of these in your digital camera than in your workshop, but that may change sometime in the future.

In the short term, however, the expected change will be from NiCad to NiMH. This is already happening in Eur-

Photo.2: NiCad Batteries in course of production at Akkupak — made up for re-fitting existing cordless tool battery packs

ope where some countries are either outlawing NiCads altogether or taxing them out of existence.

One reason for the movement away from NiCad is that NiMH batteries have a higher energy density. Energy density defines the amount of battery capacity that can be packed into a certain volume. The energy density of NiMH is about 50% better than that of NiCad. An increase in energy density translates into an increase in run time — a longer period of usefulness before the battery must be re-charged.

Another, though less important reason, for the movement away from NiCad is to avoid two of its disadvantages. One is the NiCad's susceptibility to heat, though it must be said that all batteries suffer to some extent from exposure to elevated temperatures. The other is the memory problem. This will be discussed again below, but can be defined here as the tendency for a NiCad battery to 'remember' the last discharge/charge cycle. Within limits, if the battery is only partially discharged, then re-charged, it may chemically 'remember' this cycle and refuse to accept a full charge.

By far the most important reason, however, to abandon the NiCad battery — and the one of most concern to governments — is that it uses cadmium which is a highly toxic metal. If you do any silver soldering, you will already be aware of this since the inclusion of cadmium in silver solder is the reason for the cautions attached to its use.

There are millions of NiCad batteries in use around the world, so here is an ever present danger that discarded batteries will find their way into landfill waste disposal areas. When the battery casing breaks down over time, the cadmium is free to leach into the soil, pollute groundwater and cause environmental problems.

Note: NiCad batteries must never be allowed to wind up in landfill. Fortunately, many local council waste depots offer a battery disposal service — either free or at a small charge. Disposal services are also available for mobile phone batteries.

NiMH and Li-ion batteries mostly overcome these problems, (though not everyone is convinced about their benign environmental credentials). Why then, do we continue to use NiCad?

There are several reasons. The first is that at this stage, at least, they cost less. Considering that a new NiCad battery for your cordless drill might set you back more than $200, it won't be surprising that consumers are generally reluctant to see the price rise even higher.

The second is that, for all their shortcomings, NiCad batteries are great work horses — they are robust and do their job superbly well. While NiMH run times are better, there is debate about whether their cycle life will prove as good. The cycle life is the number of times that a battery can be charged before its run time becomes unacceptable. There is no industry standard for when this occurs, with proposed figures varying from 70% down to 50% of the original capacity. This makes the cycle life quoted by manufacturers a bit rubbery, but it is nevertheless generally agreed that if a NiCad battery is looked after reasonably well, its cycle life will be between 1000 and 1250.

It might also be argued that we know more about NiCad batteries than any of the others with the exception of the lead acid cell. (NiCad technology was developed by the Swedish inventor, Waldmar Jungner, back in 1899 — though the modern, completely sealed form of the battery came much later). At present, manufacturers that service both the US (mainly NiCad) battery market and the European (increasingly NiMH) battery market appear to be hedging their bets and not swinging all their resources into the newer technology.

Photo.3: NiCad Batteries being assembled on the Akkupak assembly line using an electronically controlled spot welder

Battery Charging

When you buy a new cordless tool, your first job is to charge the battery using the charger supplied. This will be from scratch so it will take longer than normal. You will probably have been told what this normal time is, but that may be all you know about the charger.

If the tool is made by a major manufacturer, you can check a catalogue and find out all sorts of things about it — body made of this, gears made of that, etc. — but rarely are there more than a couple of lines about the charger. This is unfortunate because the battery charger is one of the most important factors in achieving satisfaction with the tool, ie. adequate run times and good cycle life.

During charging, chemical reactions occur inside the battery, reactions which are the reverse of those which occur when the battery is working. All of the batteries used in cordless tools, regardless of their type, are completely sealed. Chemical reactions within sealed vessels can be a bit tricky, particularly in this case where gases are formed in one half of the cycle that must be re-combined chemically during the other half. Despite the limitations this places on charging times and currents, the charger must do its job as quickly as possible. It must not overheat the battery — and it most certainly must not overcharge it. Aside from permanent damage to the battery's performance, there is even the possibility that the casing may be ruptured (for a Li-ion battery, that may mean 'explode'). It should be added that manufacturers do allow for some error. A re-sealing vent is usually built into good quality batteries to permit gas to escape if the pressure becomes too high.

Note: Don't try to charge a battery when it is warm and always remove it from the charger as soon as it is fully charged. If it stays on the charger and stays warm to the touch, the charger is not working properly and the battery will be damaged.

The simplest chargers watch the temperature until they see a short sharp rise, then turn off or substantially reduce the charging current. More advanced chargers terminate the process when they detect a particular rate of change of temperature; others watch for the small drop in voltage that occurs at the end of the charging cycle. Even more advanced chargers do the same, but charge in a different manner. They may charge in short bursts, switching off the charging current in-between. They may even charge in short bursts, then discharge for a very short time before charging again. Some of the major brand chargers incorporate a cooling fan to allow higher rates

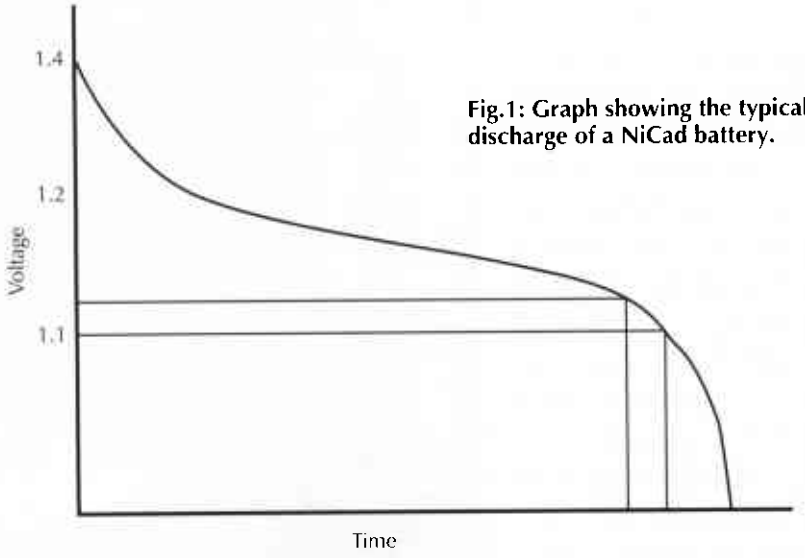

Fig.1: Graph showing the typical discharge of a NiCad battery.

of charge without damaging the battery.

All of these methods are aimed at charging the battery as quickly as possible, getting it fully charged so as to obtain the best run time for the next discharge cycle — and at the same time achieving the highest possible cycle life.

Even the manufacturers of the best quality tools have, to date, been reluctant to put this kind of information out in the market. Clearly they don't want to tell their competition too much — and that was fine while there wasn't much difference between the biggest selling brands. But that's all changed. Now there's a swag of cheapies which are competing purely on price. You don't have to be a genius to figure out that one way to reduce the price of a cordless tool would be to reduce the complexity of the charger. The purchaser won't know the difference until the battery has to be thrown away after only a few hundred cycles. There is no statistical data available to prove this, but anecdotal evidence suggests it is happening.

Photo.4: Quentin Satchwell (Akkupak) demonstrating a test being conducted using his company's Battery Analyzer.

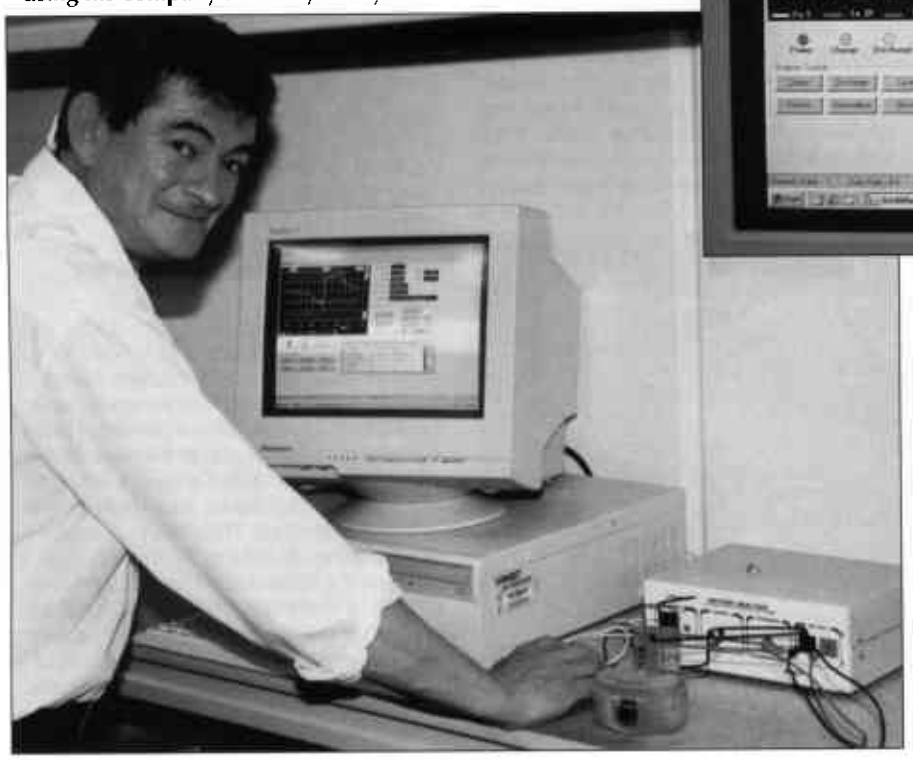

Photo.5: A Computerised Battery Analyzer can be used to check the performance (and in some instances, rejuvenate) rechargeable batteries

If it is, consumers will find out and vote with their feet. The cheapies will redress the issue and become less cheap, but meantime, there's more than normal reason to be very careful in the purchase of cordless tools at the low priced end of the market.

Even the batteries on these low priced tools may be suspect. Quentin Satchwell of Akkupak, a battery supplier and battery maintenance specialist in Sydney, says there are only four manufacturers of batteries in the world, outside mainland Asia. Just how many there are in Asia is anyone's guess but the experience of companies like Akkupak is that their products — at least as received so far in Australia — are not yet up to the accepted standards of the rest of the world. But that too,is probably changing even as this article is being written.

Using your Batteries

NiCad batteries, in particular, like to be worked. They dislike being idle, generally losing 10% to 15% of their capacity in the first 24 horus after charging. Then their charge will drop by a further 10% or more each month.

The best way to keep your batteries healthy is to use them in the tool for which they were designed. First charge the battery fully, then work it until the charge has dissipated to the point that the tool is no longer usable.

A typical NiCad battery discharge is shown in Fig.1. When it first comes off charge, the cell voltage is about 1.4V, but this quickly falls to between 1.25V and 1.2V. The voltage then declines slowly as the tool is being worked until it reaches 1.1V when it is fully discharged. Ideally, work should stop just short of this, approximately at the point shown above 1.1V on Fig.1.

Much has been made of the memory problems of NiCad batteries and there are some who try to overcome them by tying the trigger of the tool in the 'on' position to continue the battery discharge down beyond 1.1V. This kind of deep discharge is neither necessary nor advisable and can seriously damage the battery. Individual cells may reverse polarity so that the battery cannot reach its nominal capacity.

The memory effect is caused by the build-up of chemicals on the internal active surfaces of the battery components. If it occurs, the best way to overcome it is to cycle the battery as many times as necessary — full charge followed by full discharge, the meaning of the term full discharge being as defined above, when the battery no longer functions in the tool.

Battery Maintenance

Inevitably, every battery reaches the point where it spends as much time (or more!) on the charger as it does actually working. When this occurs, you throw it out and buy a new one. Or do you?

A small number of companies offer a battery assessment service usually with the option to purchase a new battery should the old one prove unable to be revived.

To find out how these services work, *The Australian Woodworker* visited the Dural (Sydney) office and production facility of Akkupak. This company is an Authorised Distributor of Panasonic Industrial Batteries. In addition, it sells batteries (not just for cordless tools) from other major manufacturers and a comprehensive after-market range. The company also re-packs batteries using high quality cells from major manufacturers.

Aside from these re-packing services, Akkupak will test used batteries and provide a written report at a cost of $25 — though part or all of this will be credited against other amounts that may become due as a result of the assessment.

The tests are performed on a Battery Analyzer, the read-out from which can be seen on an accompanying computer.

The Analyzer is first set up for the particular type of battery and the nature of the tests to be conducted. The parameters used include the chemistry of the battery, number of cells and rated capacity. A profile is established for the tests to be carried out — the charging current to be used, the point at which charging is cut-off, the time over which the battery is to be discharged and so on.

As can be seen in Photo.4, the Analyzer provides performance figures and a graph for each phase of the process. The printed report sent to the battery owner includes the principal performance figures, a graph of a full charge/discharge cycle and notes on the significance of the results.

If the battery does not respond at all, it may suffer from nothing more serious than a broken internal connection. This can then be repaired using Akkupak's high current Spot Welder (Photo.3).

Alternatively, the condition of the battery may be due to memory and it is not uncommon for several cycles on the Analyzer to restore the battery to a sufficient level of performance for it to be put back into service.

If, however, the battery cannot be resuscitated, Akkupak may offer to re-pack it (particularly if it is an unusual and hard to get type), supply either a battery from the original equipment manufacturer, or a (sometimes less expensive) after-market battery, if this is appropriate.

For further information about the services described above, contact:

Akkupak
Unit 7B/256 New Line Road
New Line Business Park
Dural NSW 2158
Ph: 02 9651 3404
Fax: 02 9651 4088
Email: sales@akkupak.com.au

Battery Definitions

Battery Capacity

The standard measure for battery capacity is the ampere-hour — or in the case of small batteries, milliampere-hour.

If, for example, a battery is rated at 2.4 ampere hours, it could theoretically deliver 2400mA (milliampere) for one hour, 1200mA for two hours or 600mA for four hours and so on. The theoretical performance may not be achieved in practice since factors other than simply battery capacity come into play, particularly at high and low currents.

Sometimes an alternative method of rating is used. This is the actual amount of electrical energy that a battery can contain and is measured in coulombs. One coulomb is the equivalent to 6,250,000,000,000,000,000 electrons; it is, however, more useful to remember that an ampere-hour is equal to 3600 coulombs.

Another measure of capacity should be mentioned since it sometimes turns up in cordless tool technical literature. This is the C-Rate which is expressed in multiples of the charge or discharge current. If, for example, a battery is rated at 1.5 ampere-hours, the 0.1C discharge current for that battery is 150mA (ie. 1.5A x 0.1). The capacity of a cell is not the same at all discharge rates; it generally increases with decreasing rate.

Battery Voltage

For a time there was a race as each manufacturer leap frogged the others in a quest for higher and higher voltage. It slowed down around 24V, though some cordless tools now have batteries with voltages of 36V or more. The reason voltage is important is the connection it has with the power available from a tool. It's certainly not the only factor, but one of the most important.

As a guide, there's an accepted rule of thumb that says that to successfully drill 20mm holes in concrete demands a drill with a 24V (or larger) battery.

Run Time & Cycle Life

Run Time is the operating time taken for a tool's fully charged battery to reach full discharge — the point at which the tool almost ceases to work.

Cycle Life is the number of 'lives' that a battery achieves — from full charge to full discharge. The highest Cycle Life is obtained by always allowing a battery to discharge fully (see above) before charging to its full capacity.

Comments on DIY

Unless you have the necessary knowledge and equipment, it is not wise to mess about with the innards of a cordless tool battery.

The Akkupak spot welder shown in Photo.3 is an essential accoutrement for this kind of work. Soldering, even silver soldering, is not sufficiently strong and the process will probably heat one or more cells causing either immediate or premature failure.

As an example of how easy it is to get into trouble, many amateurs have tried soldering cells in parallel, in an attempt to increase the capacity of a battery. This is dangerous. The internal resistance of NiCad cells is very small, so when they are connected in parallel, any small difference in charge level between the cells will produce slightly different voltages and a heavy current can flow from the higher voltage cell to the lower voltage cell. The result can be a catastrophic fire.