All You Need To KNOW

David Gale begins a new series of 'technical' articles. This month — 'Nicad batteries'.

Depending on your views, there are two major components which determine the performance of an electric car on the race track, motors and batteries. Over the next few months we will be looking at batteries, in an attempt to try and answer some of the most commonly asked questions.

The humble nickel/cadmium, or nicad, battery has been used to power radio control model cars for at least the past 15 years and in the process has increased in useful capacity from around the 900mAh mark, right up to the current high levels of 2100mAh. Of the various manufacturers, only Sanyo has been consistently at the forefront of RC car technology, in the process accounting for every World Championship available to battery operated cars — quite an achievement really. What the future holds, only time can tell, but imagine cells with twice the current capacity, and think what this could do to the enjoyment of our hobby. Incredible as it may seem, such cells have already been produced in development form, and only time will tell whether or not these will become readily available.

How are cells rated?

Manufacturers Capacity Rating

The way that cells are rated is by their capacity in mAh, or milli-Amp-hours. A Sanyo SCE has a rated capacity of 1700mAh, and all this means is that a fully charged cell would be able to supply a current of 1700 milli-Amps (mA) for a period of one hour before going flat. Note however that the manufacturers rating is a guaranteed minimum figure, and that a 'typical' cell will be well above this figure. It is also worthwhile noting that the manufacturing processes used cannot give totally repeatable results, and this is why it is very important that the cells we use are tested and 'matched' for similar capacity.

If we discharge at another rate, we can calculate the discharge time in hours, by dividing the rated capacity in mAh by the discharge current in mA.

For Example: Suppose that we connect a load of 6.8 amps (6800mA), to a cell of 1700mA capacity, how long will it take before a fully charged cell goes flat?

Answer:
by dividing 1700 by 6800 we get 0.25 hours, or more conventionally 15 minutes.

Alternatively, we can calculate how much current can be supplied for a given period.

For Example: Suppose we are to race for six minutes with 1700mAh batteries, what is the average discharge current?

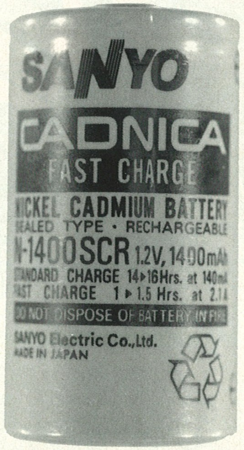
Answer:
1) Convert six minutes to hours = 0.1 hours
2) Current = (1/0.1) * 1700mA = 17000mA
or more normally 17 Amps

Note however: In practice as the discharge current increases, losses within the cell increase and it is likely that we will not be able to achieve the calculated figure (typically 20% less over a five minute discharge).

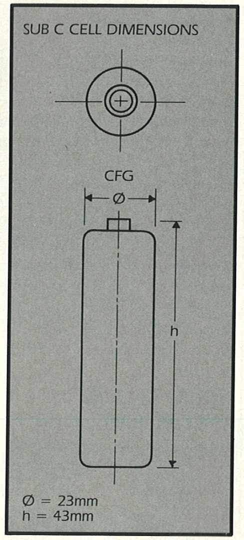
What types of Nicad cell are available?

Perhaps before we continue we should look at the types of cell available and how they differ. Looking primarily at the Sanyo range, we find that there are four basic types of cell sold for use in the model car market, SCs, SCRs, SCEs and SCKs. Straight away we notice that all these types start with the prefix, SC, which is simply an abbreviation for Sub C. No this doesn't have anything to do with waterproof batteries, it simply defines the physical size of the cell in common with all other battery manufacturers.

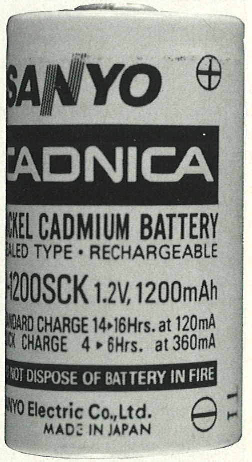
The SC cell has been around longest, and is normally sold with a 1300mAh capacity, but for many years it was rated at 1200mAh. This is perhaps the most widely used Sanyo cell, being by far the cheapest, and as such has found favour in rechargeable household appliances. Six years ago this cell was universal at all levels of RC car racing, but nowadays they only tend to be sold at 'starter', or 'beginner' level.



The R in SCR denotes that this cell is designed for 'high "R"ate' applications. This is without doubt the best suited cell for use in the model car arena, as it is the only cell specifically designed to withstand anything like the currents we require. Originally rated at 1200mAh, the latest cells have a capacity of 1400mAh. However whilst it has a very low internal resistance, meaning that it is a very 'punchy' cell, the lack of capacity relative to the SCE means that at top level it is not very popular, although at club level this trend is probably reversed. The 1200mAh cell was not that much more expensive than an SC cell, but the latest 1400mAh cells cost significantly more.



This is the cell most of us use as it has the highest rated capacity at 1700mAh. The 'E' suffix stands for 'E'xtra, to signify the additional capacity. Without a doubt this cell has totally changed the face of electric racing, as the added capacity has increased the speed of the cars dramatically. However such benefits do not come cheaply, as the SCE cell is by far the most expensive, and due to its construction is not as robust as many would like. In terms of characteristics, it is very similar to the original SC type cell, maybe slightly less punch, but of course with much better duration. These characteristics have radically altered the motors we use, as to get maximum power we now need to run much hotter winds (fewer turns), and this explains why 10 or 11 turn motors are becoming the norm rather than the exception.



This is a relatively new type of cell, the 'K' suffix referring to the fact that it is designed for high temperature use. Again it has characteristics similar to the SC type cell, but has the advantage that it can still accept useful charge at relatively high temperatures (most other types of cell will only accept 60–70% of their full capacity when charged at say 40°). This means that it may be the most suitable cell if you want to charge the battery immediately after finishing a race, for example if you only have one battery pack. It does however have a low capacity, being rated at a miserly 1200mAh.

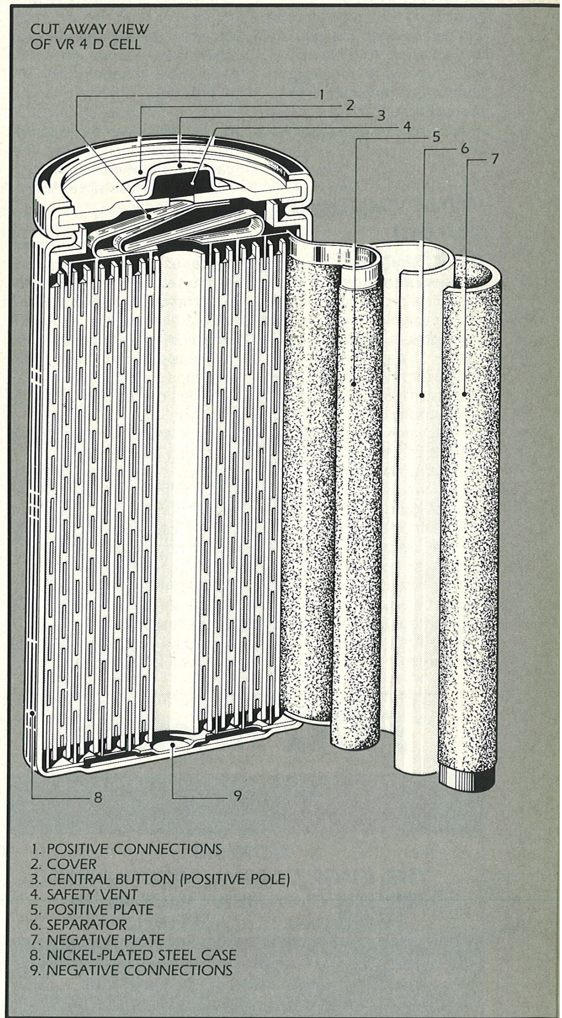
How does a Nicad Cell work?

Most of us will have had some experience with rechargable cells (sometimes called secondary cells), either in the model car, or its full-size counterpart. The basis of any form of rechargable battery is that during the charging process, we pass a current through the battery until it is "charged", and then under discharge we can remove this charge, until it reaches a point at which there is nothing left, in which case it is "flat", or "discharged".

Physically the cell consists of two dissimilar chemicals (in our case nickel and cadmium), which are electrically isolated from each other by a separator. The separator is porous, and absorbs a chemical mixture called the 'Electrolyte' which allows the chemical reaction to take place between the two metals. The electrolyte is usually a paste or jelly, and normally not very pleasant stuff.

What happens during charge?

When we charge the cell, what happens inside the cell is that the current passing through the cells promotes a chemical reaction in the electrolyte, resulting in tiny electrical charges called electrons being transferred from nickel atoms to cadmium atoms by 'ionic exchange'. As long as the charging current is maintained,



this process will continue, until the reaction runs out of nickel or camium atoms to convert. At this point the cell is fully charged. If we continue to charge, then another reaction will start involving any water within the cell, causing hydrogen and oxygen gas to be evolved. This in turn results in a build-up of pressure, which causes the cell temperature to increase. Knowing that the temperature increases only towards the end of the charging process, by monitoring the temperature we can detect when the cells are fully charged. As soon as we stop charging, the hydrogen and oxygen re-combine to produce water, and in doing so reduce the pressure within the cell.

What happens during discharge?

When we discharge the cell, we connect a circuit allowing the electrons which were given to the cadmium atoms during charge, to pass through the circuit, returning to the nickel atoms. Unlike the charging reaction which requires energy, the discharge reaction is capable of supplying large amounts of energy, and it is this energy we use to power the car. Obviously this reaction can only be maintained whilst there are free electrons in the . electrolyte, and, once they have all been used up, there will no longer be any useful capacity left, and the battery will be 'dead', 'flat', 'dumped' or 'discharged'.

An important fact to note is that we do not 'fill' the cell with electrons as many people believe. What actually happens is that we move from one part of the cell to another, and as such there is no change in the total number of electrons within the cell.

Obviously the capacity of the cell depends on the number of atoms which can accept or donate electrons, and there are physical limits on just how many can be crammed into a cell. This is one reason why larger cells tend to have more capacity. Equally important is how close the atoms are to the +ve and −ve terminals (electrodes). If they are too far away, then under discharge, it is more difficult for these atoms to relinquish their charge. This can result in the cell having a high internal resistance. Also, if the electrodes are manufactured so that they are very thin (thereby leaving more space for the electrolyte), then this will also result in a cell with a high internal resistance. A cell with a high internal resistance will tend to lack "punch" and hence acceleration when used in a model car.

When this is taken into account, it can be seen that there is an inverse relationship between capacity and "punch", ie high capacity cells suffer from lack of "punch", and high "punch" cells suffer from lack of capacity. This is clearly demonstrated by the characteristics of Sanyo SCR (1200mAh), and Sanyo SCE (1700mAh) cells. It also leads us to the first practical rule regarding Nicads, ie "you don't get something for nothing!"

Safety Considerations

As we all know hydrogen gas is highly explosive, as demonstrated by the Hindenberg airship disaster. It stands to reason that we must be very careful when charging cells not to over-charge, as this is the point at which hydrogen gas is evolved. If we continue to charge the cells past this point, the pressure inside the cell will build to enormous levels, and if it wasn't for the safety vent built into the cell, it would eventually explode. However whilst the vent prevents a 'physical explosion' due to internal pressure, the gas released will contain hydrogen, and could possibly ignite if there is a flame or spark present.

Under normal conditions, it is unlikely that this could happen, although if the cells get too hot, the heatshrink cover will split apart. Depending on the construction of the pack, it may be possible for some of the cells within the pack to short out. If this happens they will supply huge currents, in the process heating to red hot any connecting wire, etc, which could ignite the hydrogen.

My advice to anyone regarding charging, is never to leave the cells totally unattended. During charging monitor them regularly for signs of becoming too hot.

If you ever get to the point where they start to vent (a loud warning hiss), or the heatshrink cover starts to split apart, then the best thing to do is to follow the procedure below.

1) Turn off charger.
2) Leave well alone for at least an hour.
3) Discharge gently.

If they have to be moved, be very careful to shield your eyes from any liquid which may be forced out of the cell during venting, as one of the chemicals within the electrolyte is pottasium hydroxide.

This is a very strong bleaching agent, but stronger than the household type. Also note that cadmium itself is a very poisonous metal, and as such you should never attempt to cut open a cell. If the battery shows any signs of leaking, then it should be disposed of, making sure that you wash your hands thoroughly.

NEXT MONTH:
Charging Techniques