batteries

A battery book I recently ordered from our mobile library describes a battery as ‘a reversible method of chemically storing electricity’. Interestingly the last time it was taken out was seven years previously so I am grateful to the library system for not withdrawing it for sale.

Batteries are an integral part of a home-generation energy system (unless you use a grid tie, page 121) and are needed to store the excess power generated during windy or very sunny periods so that power is available all the time.

To get the best out of a home-generating energy system it is important to understand how the wind and solar systems interact with a battery system and how the batteries themselves work. This will help you to prevent battery abuse and reduction in battery life.

Batteries are not just a fit-and-forget item, they are the one piece of the system where care and attention makes a huge amount of difference to the reliability of the whole system. It is this consistency of power availability that we in the spoilt west have come to expect without a thought to the consequences.

There are many types of battery and several chemical reactions that they are based upon and no doubt there will be further developments in this field over the next few years. I hear that the batteries used in some hybrid cars are something special, but expensive. To get back to our level of technology and affordability there are two different chemical types of battery available, namely acid based (lead acid) and alkaline based (nickel cadmium or Ni cads). Ni cads are more expensive and they are not so readily available on the second-hand market as lead acid batteries (see page 92), but before we go any further I think it is necessary to consider some basic battery features and terminology.

cell voltage

A battery consists of several cells – for example a car battery has a nominal voltage of 12 volts, and is made up of a series of six individual 2 volt lead acid cells. This is why there are six little inspection caps on car batteries, unless they are a low-maintenance type. Forklift batteries, which are also lead acid, are made up of large 2 volt cells bolted or lead welded together. Second-hand forklift batteries can be used very effectively in home-generation systems and I will look at these in more detail later (page 105).

fig 33: 2 volt 500 amp hour forklift battery

Each type of cell has its own nominal voltage, for instance lead acid is 2 volts and Ni cad is 1.2 volts. That's just the way it is for their specific chemical reaction. The actual cell voltage varies by quite a large amount depending on whether it is discharged, in the process of being charged, is fully charged or whether it is under load or not. The voltage in a lead acid cell varies between 1.8 volts, which is the 'terminal discharge voltage' – when it has been discharged and is under some load – and 2.6 volts when it is being charged and has reached a fully charged state.

When a lead acid cell is fully charged and then allowed to rest, it will lose its excess voltage over a few hours and revert to an open circuit voltage of about 2.2 volts. In a combined wind and solar generation system this hardly ever occurs because the batteries are being charged and discharged at all times and so the batteries are never in an open circuit situation.

battery capacity

This estimates the theoretical quantity of electrical energy that could be delivered by a battery if one were to discharge it over a set number of hours and is measured in Ampere hours (Ah) – or amp hours for short. The time period is usually something like 10 hours, so the capacity is given in amp hours at, for instance, the 10-hour rate. For example a battery which delivers 2 amps for 10 hours would have a 20 amp hour rating at a 10 hour rate.

The higher the discharge rate the lower the amount of power available, so at the 1-hour rate the battery may only give 50 per cent of its theoretical power before the voltage drops to the on-load terminal voltage. So, for instance, if you try to draw 20 amp hours from this battery for 1 hour, it will only work for something like 30 minutes before the battery voltage drops below a usable amount.

For lead acid batteries to attain long battery life it is recognised that cells should not be discharged below 50 per cent of the theoretical amp-hour capacity on a regular basis. The way to monitor the battery charge levels is something of a black art and involves cell voltage, charge voltage, specific gravity, and battery history – there are some more details on page 100.

Let's work through a system example to explain this capacity thing, using a system with a 48 volt battery rated at 600Ah (amp hours). This means that you could possibly draw 60 amps over 10 hours and so if you only took 50 per cent of the total capacity, because you were protecting the battery, then there would be a maximum of 5 hours supply available.

Now, drawing 60 amps at 48 volts is quite a lot of power especially if it is continuous over 5 hours. We can work out the watts produced by multiplying the amps by the voltage (60 amps x 48 volts = 2880 watts) or 2.88 kilowatts per hour. Unless you are doing something quite outrageous like running electrical heating or have four children watching two televisions each and leaving all the lights on and boiling kettles all the time, then you will not be using that sort of power for general domestic use.

As a guide my household uses about 5 kilowatt hours every 24 hours, which includes lights, fridge, freezer, computer and printer. This means that our ROCs meter registers 5 units on average every 24 hours and we receive a payment of 75 pence for each day.

battery installation

There are things that batteries like and dislike, and I have already stated that batteries require regular attention to keep the system working well. Batteries need to be housed in a separate building which should be dry, warm but well ventilated, and the batteries should not sit directly on a concrete floor.

- the building should be dry to prevent condensation on the batteries that will encourage corrosion of the terminals and connections, and electrical discharge between the terminals. It is important to remove any condensation from the tops, see maintenance section, (page 86).
- batteries lose potential capacity in cold weather so a warm building is important.
- ventilation is required to prevent a build up of hydrogen and acid vapour in a confined space. The hydrogen is explosive and the acid vapour is corrosive.
- the batteries should be at a height so that electrolyte maintenance is easy, and they should be raised off the concrete floor with timber. This timber also acts as an insulator against the cold surface.

- it is ideal if the batteries are fitted in a separate, lockable area to prevent irresponsible fingers having accidents.
- the battery shed should be as close as practicable to the turbine and solar panels. This is to reduce the volt drop as described in the cable-sizing exercise (page 115). Basically, the higher the current, the larger the cable size required to reduce losses. Equally, the lower the voltage, then the higher the current (amps) for a given wattage. So the balance is between distance and cable size, hence the closer to the power source the better. I am assuming that from the batteries to the house, the power is 240 volts produced by the inverter, and so the current is relatively low because the voltage is high, see the *electricity* chapter (page 109).

connections

In years gone by batteries were lead welded together with special pre-cast links. This was excellent for reducing corrosion and electrical resistance in the connections, because, after welding, there were no connections because the battery became one complete unit. The downside of this was that it was complicated to replace a cell, or take the battery apart. The cells were welded together with either a small oxy-acetylene flame, or by the heat produced from a carbon rod powered by the batteries themselves: normally 6 volts was used for this welding process, anymore and the heat was too intense. See fig 34. It is interesting to see this process as there are no great sparks and the carbon rod just gets very hot and melts the lead where ever it touches. Both methods require a controlled pool of molten lead to be created to melt the connection together.

bolted connections

More recently bolted-together cell connections have given more flexibility but at the expense of connection reliability. It is always possible when these are used for corrosion to start and undermine the structural integrity of the connection.

There are two main types of bolted connection. The first is found on large, static, deep-cycle batteries, commonly found in older emergency lighting systems. The terminals are made of a large lead lug with a hole in it for the bolted connection. These work well and the connection is raised up above the battery cover, away from immediate acid contamination.

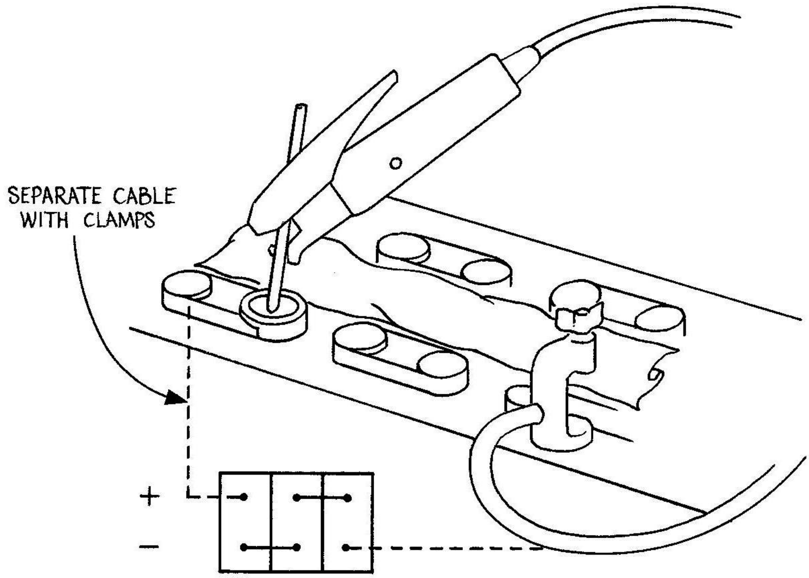

fig 34: carbon rod terminal welding

The second type of connection is where the insulated connector is bolted to a surface-mounted battery terminal fig 43 (page 000). This method is safer because you can accidentally drop spanners on the battery without fear of sparks, explosions, or melted connections and spanners. To clarify this point, if you accidentally put a spanner across the exposed positive and negative terminal of a large battery, then things get quite entertaining and lively. The spanner gets very hot almost immediately, and the ends begin to melt, as do the terminals as a huge current starts to flow. You are effectively trying to flatten the battery in almost no time, and you could get more than a thousand amps flowing until something burns out. The insulated surface-mounted connector means that there are no open connections, but because they are surface mounted it means there is much more opportunity for corrosion to set in.

When bolting batteries together it is important that the connections should be clean and dry. The normal way of keeping these connections in good condition is to coat the bolts and connectors with petroleum jelly. This prevents the ingress of moisture from the air and the acid vapour created during charging.

Care is needed when installing batteries and there are several specific things to bear in mind:

- take due care to use correct lifting techniques, as batteries are heavy.
- wear the correct PPE (personal protective equipment), which should include steel toe-capped boots, apron, goggles, and gloves.
- don't rush and try to get things done when you are tired – that's when you can either hurt yourself, or make silly and expensive connection mistakes.
- keep some water and eye wash handy. There is a chance that stray drops of acid can be released which, if they get into a cut, is an eye-opening event that sends you running for the nearest water butt. Acid in the eyes is very dangerous so make it part of the routine to wear goggles in the battery room.

connecting batteries

The number of connections within a battery bank depends on the system voltage (see page 121) and hence the number of cells. If you are using 2 volt cells there are, of course, more connections than if you were using 6 volt units. In a 6 volt battery there are two internal connections but it still has three individual cells. For all connections the positive terminal of the first cell is connected to the negative terminal of the second cell, and then the second positive terminal is connected to the negative terminal of the third cell. In this way a string, or pack, of individual cells is connected together and the voltage is increased as each cell is added. When all the cells are bolted together you are left with a negative terminal at one end and a positive terminal at the other that can be connected to the charging system.

Fig 35 illustrates this clearly. The negative terminal is on the bottom left and the connections continue negative to positive to a link to the middle row, which is off the edge of the picture. The middle row is placed the other way round so that the batteries can be connected correctly. Then the middle row is connected to the top row through a link, shown top left, and follows through to the positive terminal.

If you have several battery packs of system voltage then the positive terminals of each pack and the negative terminals of each pack can be connected together to create a larger pack with the same voltage but greater amp hour capacity. All the cells must be in good condition or else the pack with a defect will discharge the good packs.

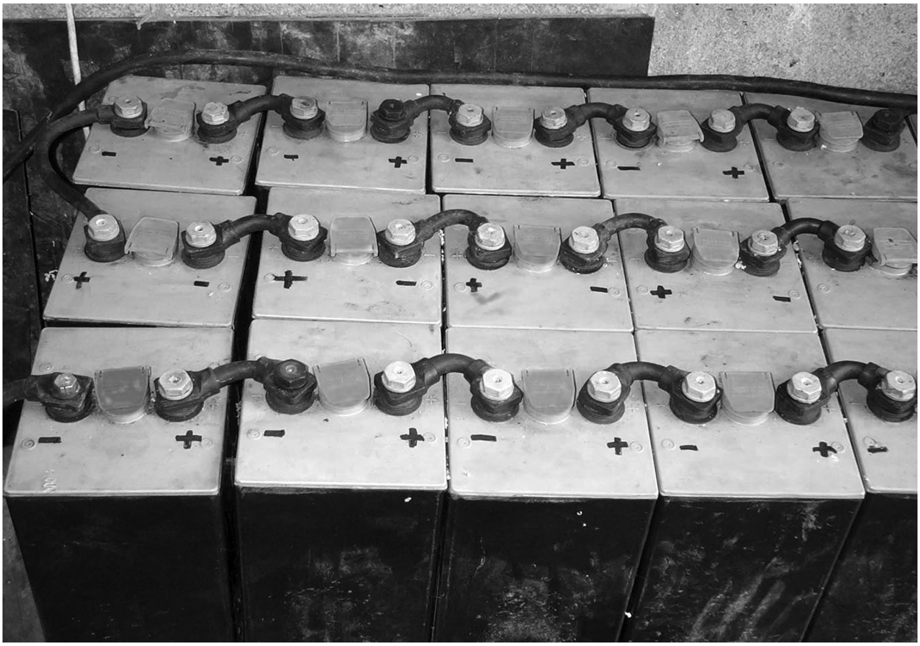

fig 35: battery connections

battery maintenance

The maintenance schedule for the batteries of a wind and solar home-generation system is fairly relaxed, but requires action at regular intervals. Modern inverters and charge controllers prevent much potential battery abuse. The inverters switch off when the battery is flat and the battery volts are low, and the charge controllers can help to prevent overcharging.

Lead acid batteries need an equalising charge at regular intervals, see page 88. This charge takes the voltage above the preset voltage of the charge controller and makes sure all the cells are fully charged.

General maintenance should include checking the following things:

- electrolyte levels should be at least 12mm above the battery plates, but do not overfill. If the cells are filled right up to the top then the cell will overflow during heavy charging. Only use distilled or de-ionised water for topping up; tap water contains impurities which will react with the active material in the cells over time and cause them to self-discharge. I use dehumidifiers to keep various places on the property dry during the winter and the water from these is stored for topping up the batteries. It is less expensive than buying distilled water and you get the added benefit of keeping areas dry where they are most likely to get damp.

- specific gravity tests will show the state of charge and indicate the general health of the battery. The readings should all be similar and any cell with a low reading should be charged individually and marked for reference in case this is an indication of cell failure. If the cell readings vary considerably then an equalising charge is required. It is worth your while recording the readings; if they are consistently low this would indicate that the battery system is mismatched with your power demands. See the specific gravity and voltage section (page 95) for more details.
- taking a meter reading of the overall battery voltage will give an indication of battery charge levels. A permanently-wired meter will show at a glance how the system is behaving at any one time. If the meter reads say, for instance, 47 volts on a 48 volt system then you know the battery is low, but if it reads 58 volts on the same system then you know that it is fully charged and still being charged.
- cell tops should be dry and clean. Wipe over the tops with a clean dry cloth to remove moisture and dust, but try not to smear the petroleum jelly from the connections everywhere. It is interesting to note that as atmospheric pressure changes it can cause moisture from the air to condense on the batteries – which is all to do with the dew point. This is why the battery tops are sometimes damp.
- cell connections should be inspected for any signs of corrosion. This is generally indicated by swelling of the connectors, or accumulations of white or pale blue-green growths. If these are identified the connection should be dismantled and thoroughly cleaned. They are caused by moisture and stray acid in and around the connection. Having cleaned the area it is a good idea to wash the top and the connection with a solution of water and bicarbonate of soda. This solution neutralises the contamination and causes the acid to fizz. It is important that this alkaline solution does not enter the battery, where it would damage the plates.

equalising charge

This form of charging takes the cells above the normal charging voltage that is dictated by the charge controller. All charge controllers have an equalising charge setting. During a charge cycle the voltage is allowed to rise to its maximum (up to 2.7v per cell) and this makes sure that all the lead sulphate deposited on the plates is changed into sulphuric acid and lead oxide, see the next section for details. Effectively it has a cleaning effect on the active material on the plates and ensures that all the cells are at the same charge state: hence the name 'equalising charge'.

An equalising charge can only take place when it is either very windy or sunny, or both, so that charge is greater than load. If your system has not had an equalising charge for the last (say) 4 months then it would be extremely beneficial to artificially create the right conditions so that you can do one. Do this by taking a booster charge off the mains supply or, if you are entirely off-grid, from a generator.

An equalising charge makes sure all the cell specific gravities are high and equal, and that the on-charge cell voltages are high and equal. If you are using second-hand units the section on second-hand batteries (page 105) will shed some more light on this subject.

If your batteries are kept charged at three-quarters of their capacity all the time there is less likelihood of creating individual difference between the cells and equalising charges will not be routinely necessary.

battery internal structure

To get the best out of your batteries it is a good idea to know how they work. The individual cells are made up of flat plates of active material immersed in a liquid. The liquid is called the electrolyte and is composed of dilute chemicals that react with the active material on the plates under charge or discharge. Fig 36 shows the battery plates without their outer casing which, when in place, contains the liquid electrolyte.

The plates are built up in alternate layers, negative – positive – negative and so on, and are separated from one another by microporous material, fig 37 illustrates this. The separators are in the form of a microporous pocket that surrounds the positive plate and prevents any electrical shorts between plates of differing polarity. The plates of the same

fig 36: battery element

polarity are joined together with a large bar conductor to which is attached one of the two external battery terminals. The active material on the negative plate is pasted, pressed and set, on a cast lead grid.

This is also the case with the positive plates used in stationary batteries. The positives in traction batteries, as used for forklift trucks, are, however, made of lead rods cast into the conduction bar. These lead rods have active material packed around them that is retained by a porous, acid-proof tube. The series of tubes is made as one piece and, after the active material is packed in, the open bottom end of each material tube is capped with a plastic plug. The photos, figs 37 and 38, will explain this a bit more.

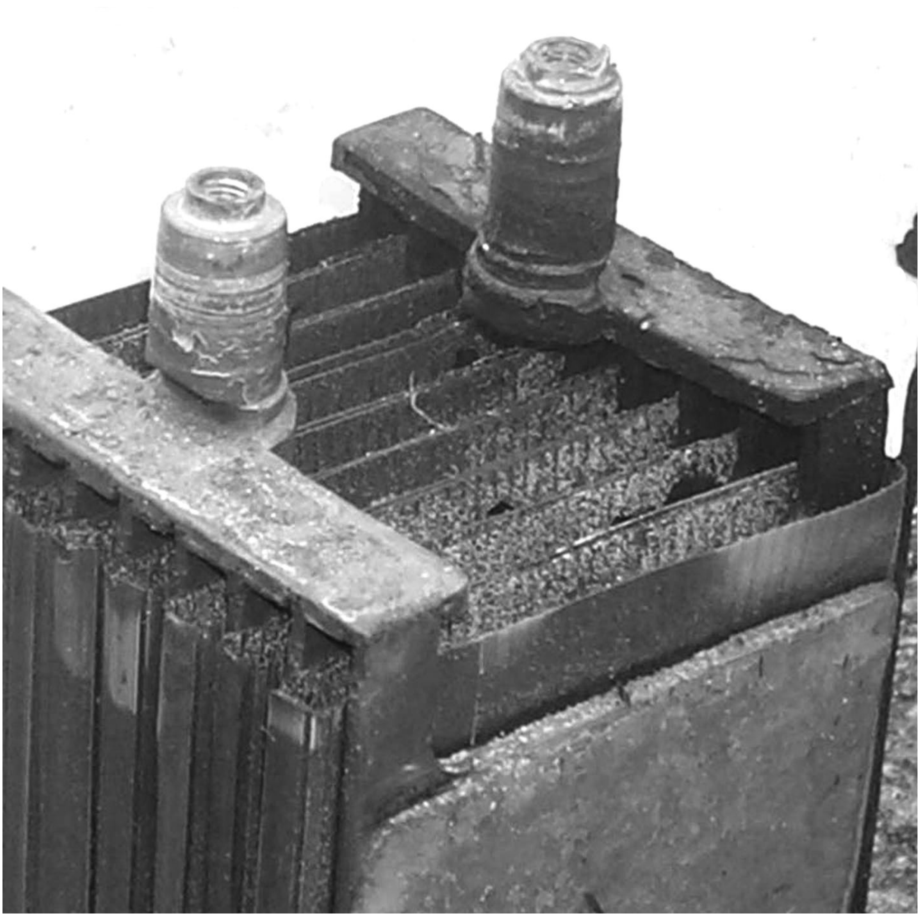

fig 37: battery plates and conducting bars

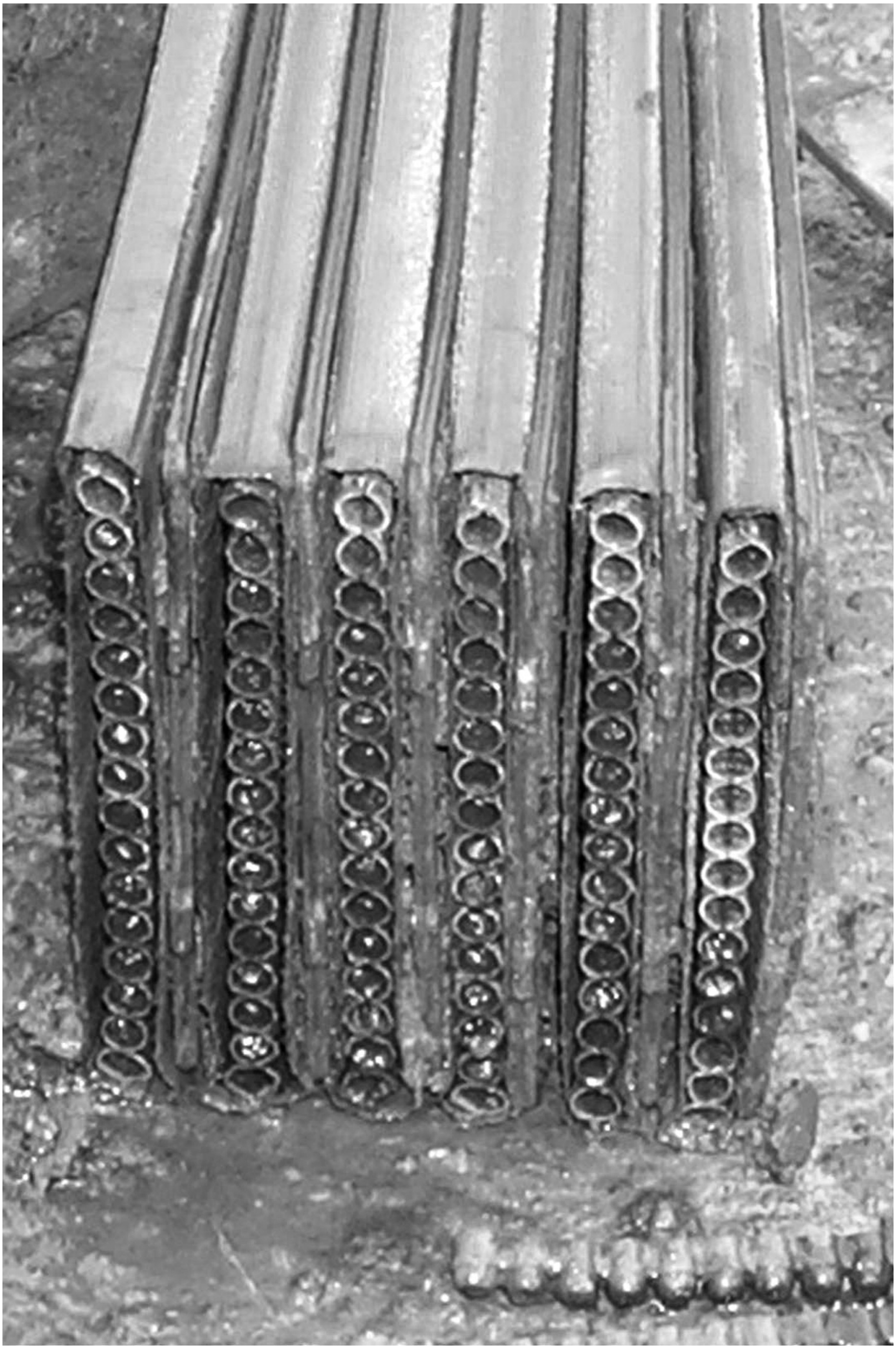

fig 38: bottom view of positive plate tubes with end caps removed

alkaline batteries

As indicated earlier these nickel cadmium or Ni cad (pronounced Ny-cad) batteries have different properties from lead acid batteries. These properties manifest themselves in their charge/discharge voltages and can cause problems with other components within a wind and solar system. Ni cad battery packs need a higher voltage than lead acid batteries to attain a fully-charged status and they also discharge to a lower voltage.

Ni cad batteries have a nominal cell voltage of 1.2 volts and so 20 cells are required for a 24 volt pack, whereas with lead acid cells, which have a nominal cell voltage of 2 volts, only 12 cells are required. This means that if you use the more expensive Ni cads, not only does each cell cost more but you have to buy more of them to attain the right voltage.

So, the problem caused by the higher charge and lower discharge voltages of Ni cads is that inverters have minimum and maximum voltages above or below which they will switch off. On some of the more expensive models these voltages are adjustable, but you wouldn't want to stick excess volts into an expensive inverter without knowing that you aren't going to cause permanent damage.

It is interesting to note that the charge controller voltage for either wind turbines or solar panels should be set below the cut-off voltage of the inverter to prevent unexpected inverter shut down and loss of power.

lead acid batteries

This is currently the battery type most commonly used for wind and solar generating systems. It is useful to have some understanding of the chemical reaction involved in producing the electricity and how that affects the general use and maintenance of a working battery.

The active components of these cells are:

- negative sponge lead plate
- positive lead dioxide plate
- sulphuric acid electrolyte

When a battery is being used and so is 'discharging', the chemical reaction goes like this:

The sulphuric acid electrolyte has a chemical composition of H_2SO_4 – comprising 2 hydrogen atoms, 1 sulphur atom, and 4 oxygen atoms. During discharge, the SO_4 part of the acid moves from the liquid electrolyte to the lead plates. The acid becomes weaker as it loses its SO_4 component. At the same time oxygen is released from the lead dioxide in the positive plate and combines with the 2 remaining hydrogen atoms from the acid to form water. This water further dilutes the acid.

It is important that batteries should not be left in the discharged state, as the lead sulphate blocks up the pores in the plates causing a loss of porosity and expansion of the plate. The loss of porosity causes a resistance to charging, which in high-neglect situations prevents any charge taking place. The expansion of the plates, which is not reversible, causes mechanical loss of plate material and distortion of the plates. Sometimes you see the battery case walls bowed out and the terminals at odd angles, and if you look in the filler cap you can see a white deposit on the dark brown or black positive plates. The white is the lead sulphate, and if you can see it you know you need to take immediate action by charging the batteries.

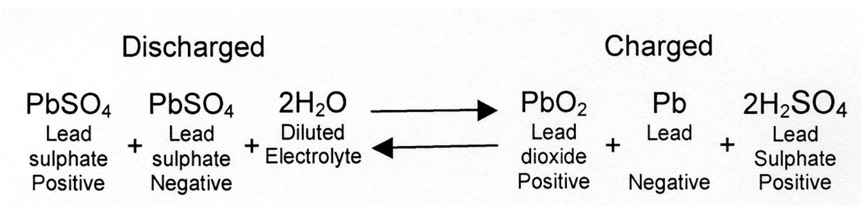

fig 39: chemical reactions of a lead acid cell

When the battery is charged the reaction is reversed and strong sulphuric acid is produced at the plates as the lead sulphate ($PbSO_4$) in the porous plates reacts with the water. This strong acid moves away from the plate (because it can in the liquid electrolyte) to be replaced by weaker solution, taking with it and dissipating heat produced during the reaction.

This movement of the electrolyte is important in both charge and discharge cycles to produce an even electricity flow, see gel batteries (page 97). As the battery charges up the specific gravity of the acid increases until there comes a point where no further chemical reaction can take place. At this point further charging just breaks down the water into hydrogen and oxygen (H_2O = 2 hydrogen atoms and 1 oxygen atoms).

This is where the potentially explosive bit comes in, as an explosion will only happen when the batteries are fully charged and still being charged. Hydrogen is very reactive, and oxygen is needed for any explosion because an explosion is a rapid expansion and burning of gases. So there you are – a mixture of gases just ready for a spark to set it off. I did this accidentally once with a stray spark and it's loud, there is no warning, and there is a taste of acid in the air. The general rule is: don't mess with batteries when they are gassing vigorously.

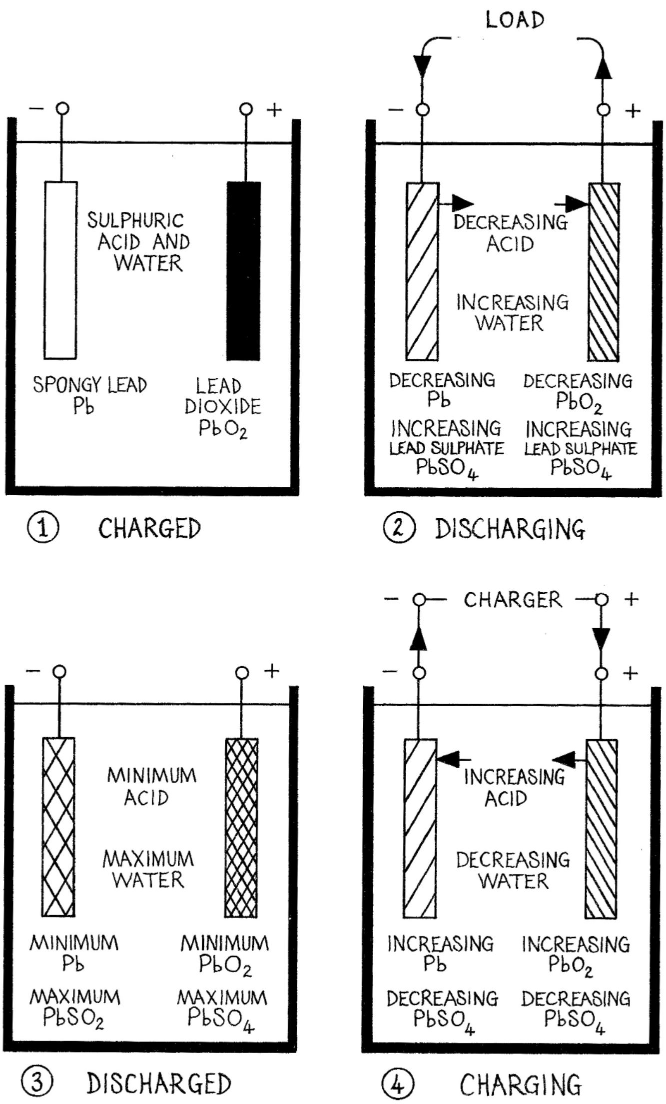

fig 40: battery charge and discharge cycles

This gas production is both detrimental and beneficial. The beneficial bit is that it makes sure all the lead sulphate is removed from the plates and prevents sulphation damage. The detrimental effect is the gradual disintegration of the active plate material caused by copious quantities of gas developing within the pores of the plates. This ‘blown-off’ active material is generally from the positive plate and causes heavy, black sediment to build up in the bottom of the cell. It looks a bit like ‘Marmite’ and if there are large deposits that touch the bottom of the plates it can cause the cell to discharge. For this reason there is a gap between the bottom of the plates and the bottom of the case to allow some sediment to build up without causing any problems.

specific gravity

The varying acid strength that occurs within a battery’s charge cycle can be used to measure the level of battery charge by using a hydrometer. The hydrometer measures the specific gravity, or weight, of a liquid. For more detail see (page 100).

It is also interesting to note that as the acid loses its SO_4 component during discharge the electrolyte volume reduces, which is why it is recommended that cells should not be topped up with distilled water when they are in a low-charge state. If they were topped up to a high level then, as the charge progressed it is possible that the electrolyte could spill out and be lost. This would affect the overall strength of the acid and, if this topping-up method is used continuously, the loss of acid would affect the overall capacity of the battery. For more detail see second-hand batteries (page 105).

battery charging

The charging voltage from a wind turbine or solar panel needs to be greater than the battery voltage for current to flow from one to the other. For an example let’s look at the extremes that can happen with a 12 volt battery. If you try to charge it with a 6 volt charger nothing will happen. If you try to charge it with a 24 volt charger a huge current will flow until either the battery or the charger burns out. So the charge voltage needs to be higher than the battery voltage, but not high enough to create heat in either the battery or the charger. The important thing to remember is ‘voltage drives current’, and we will be returning to this idea from time to time.

types of battery

For most people the closest they get to the kind of batteries we are thinking about is by having one in their car or as a power supply in a caravan, so that's where their level of knowledge and experience ends. There are several types of cell available and each has a specific use.

car and truck batteries

These are designed to give a high power output for a short duration and then be recharged. These batteries are not suitable for slow charge/discharge cycles and fail after only a short time if they are used within a home-generation system.

deep-cycle batteries

These are designed to be cycled, which means to be repeatedly charged and discharged, and so are suitable for wind and solar home-generation systems. Leisure batteries for caravans are described as deep cycle because the power can be used and then the unit is recharged.

sealed or low-maintenance batteries

These are exactly what their name suggests: sealed for life. This is fine if you are using them in a situation where they are not regularly cycled or excessively charged. Problems occur with charging when the batteries begin to gas. The production of gas is a result of the breakdown of the water produced by the chemical reaction in the cell and represents a loss of electrolyte which, in a sealed battery, cannot be replaced.

To clarify the situation: the battery is sealed to prevent loss of electrolyte but is vented to prevent the build up of pressure from gases. The cells eventually dry up and die. You could, of course, drill holes in the top above each cell and top them up.

Another problem occurs with sealed batteries that are discharged by more than 50 per cent of their capacity on a regular basis. This is to do with variation in the individual cell charge. To bring all the cells back to the same level you have to overcharge them by using an equalising charge but this causes loss of more electrolyte in some cells than in others and, because the cells are sealed and can't be topped up, the imbalance can only get worse as the battery continues to be used.

We can see from this scenario that sealed cells are fine for standby situations but not when regular cycling is involved, unless you are prepared to replace them at frequent intervals. See battery problems (page 98).

gel batteries

These are spill-proof because the acid is incorporated into a gel, which is fine in certain applications. They are only suitable for low current use and get hot and pack up rapidly under high current charge or discharge usage. The main problem is that, unlike in batteries with liquid electrolyte, the strong acid produced at the plates during charging cannot move away quickly to be replaced by weaker solution. This also creates areas of localised heating that cooks both plate and gel, destroying the cell and can lead to expansion and cracking of the case, so they ae unsuitable for home-generation systems.

sizing your battery bank

Whatever type of battery you end up using, it will always be a number of cells joined together in series and then perhaps in parallel. To use my system as an example, I have three banks of batteries, one with 24 cells of 400 amp hours (Ah), one with 24 cells of 550 Ah, and one with 24 cells of 600 Ah. Each bank has a nominal voltage of 48 volts and the three banks are then wired in parallel.

In other words the first positive of each bank is connected together and so are the final negatives. This gives a battery with a nominal voltage of 48 volts with a theoretical capacity of 1550 Ah. Bearing in mind that you should only ever use 50 per cent of lead acid battery capacity, that gives 775 Ah and, with 20 Ah to the kilowatt hour at 48 volts, then the system has a practical storage capacity of 38 kilowatt hours. As my household uses on average 5 kilowatt hours in every 24 hours the system has a theoretical seven days storage capacity without charge.

The battery size of any system should balance its charging capacity. In other words it is not that practical to have a 6 kilowatt wind turbine on a 250 Ah battery because the battery will be fully charged most of the time and the load dump will constantly be in operation. I can see situations where this could be useful – for instance if low electrical power is needed and heat is also required.

The other end of the spectrum is worse, for example if there was a 200 watt charging system and a 2000 Ah battery. The battery would hardly ever be fully charged, unless it was used for an emergency back-up situation that is never used, and the charging is only required to keep the battery in good health.

You will get the idea from these examples however; the charging capacity, battery size and electrical demands on a system should balance each other out. My battery bank, to use it as an example again, is charged by 2.5 kilowatts of wind turbine and 0.9 kilowatts of solar panels, and this seems to balance quite well insomuch as it is rare for it to get very low and it only occasionally reaches a high point where the load dump comes on.

battery problems

When problems occur a lot of battery users despair, start losing faith, and end up spending loads of cash unnecessarily. In your imagination you expect a series of battery cells to all behave the same – after all, they are all manufactured the same and have been treated the same since the installation date. Not so, because there can be minute differences which do not show up when the cells are brand new. The differences start to show up if the batteries are continuously overcharged or over-discharged, or both. You must remember that batteries are not fit-and-forget items and if you look after them then they will behave and not let you down. But if you neglect them they will let you down quicker than a comfort break in the frozen wastes.

The first indication of problems is when the batteries don't seem to hold their charge and last as long as you would expect, or seem to go flat quicker. If you check each cell voltage with a multi-meter when the cells are being used you will find that the individual voltages vary. There are usually one or two cells that are dramatically different. The next thing to do is to check the specific gravities of the cells with a battery hydrometer (page 100), and you will find the same cells have low specific gravities.

This is how it goes: you over-discharge the batteries and they do not get fully charged up. Then they get over-discharged again and not fully charged. This cycle, if repeated, will cause some cells to discharge more and charge up less than the rest. It does not take long for the low-charged cells to start to suffer from sulphation (page 92) and so have a resistance to charging. The result will be that the battery cells are out of balance and there could be permanent damage. In the *system components* chapter (page 23) I talk about Variac transformers and how they could be used to make a variable 2 volt battery charger. This is a prime example of why that particular bit of kit is important – to rectify inaccuracies in individual cell voltages if you have not been looking after your battery pack. Fortunately the more expensive inverters have adjustable low-battery cut-off settings to avoid over-discharge, see the inverter section (page 143) for details.

If there is a constant low state of battery charge and an imbalance in the charge/use capacities there are several possible contributing factors to consider:

- a generating capacity that is too small for the daily electrical load
- a battery bank that is too small to tide you over the periods of no charging
- a battery bank that is far too big and starts to sulphate up due to massive undercharging
- no wind turbine to tide you over the winter months
- no solar cells to help in the low wind summer months
- no back-up charging system
- not enough understanding of how the system works

So that has covered the undercharging and so on to overcharging, some of which we covered earlier when we talked about deposits formed in the bottom of the battery case (page 92). Constant overcharging can make the plates swell and bow the case, and can also convert the lead in the plate-connecting bars into lead oxide. This weakens them and causes positive-pole corrosion that distorts the battery top; see the right hand terminal of fig 32 (page 80) for an example. This form of damage also attacks the structural lead in the positive plates and reduces capacity by breaking electrical contact within the plate.

battery testing

There are a couple of tests that can be used on a battery, and the results can be combined to give an overall picture of battery health.

visual

It is generally, but not always, possible to see the plates through the top-up cap. The negative plates should be slate grey and the positive a deep charcoal brown. If the positives are covered in white deposit then that indicates sulphation.

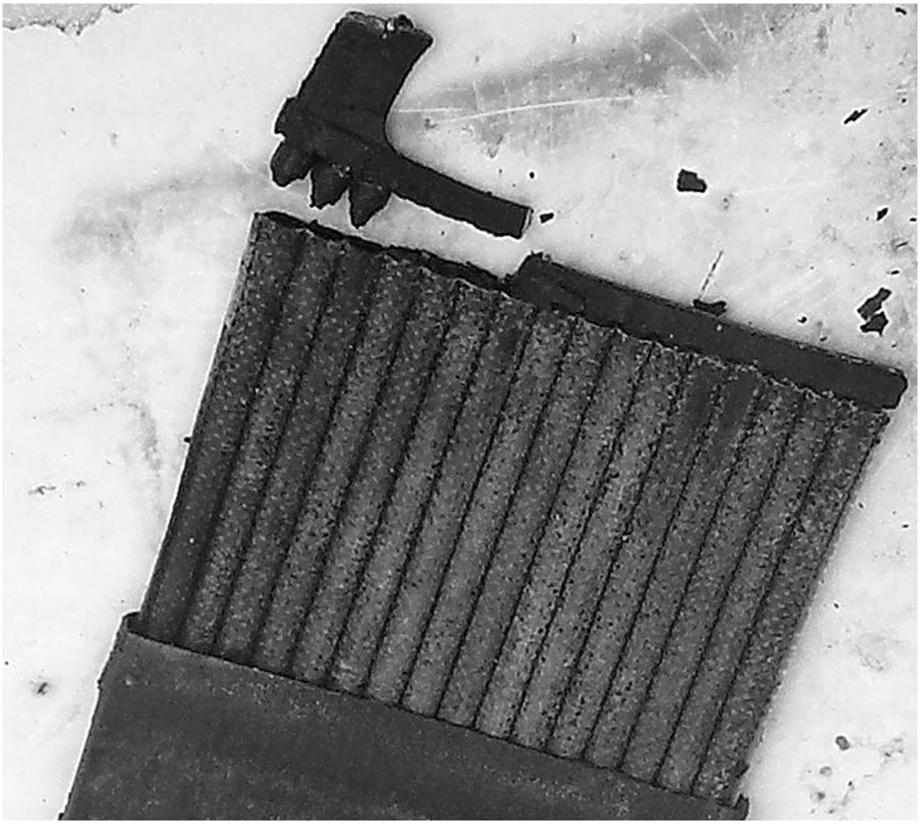

fig 41: positive plate corrosion

The plates should not be flaky or distorted and the case should have no major swelling showing in the side walls. Distorted battery tops are a sign of positive-pole corrosion and can make the cell unusable, see fig 41 and 42.

specific gravity and voltage

A battery's voltage varies with its specific gravity which means that both voltage and specific gravity can be used as indicators of charge level. The voltage changes depending on whether the battery is being used or is in an 'open circuit' situation, so voltage is a less reliable indicator than specific gravity.

Specific gravity is measured using a simple device called a hydrometer. To use a hydrometer you squeeze the rubber bulb on the top and put the nozzle at the bottom of the hydrometer into the electrolyte, having first opened the battery cap. (Hydrometers are, of course, not suitable or usable with sealed or gel batteries.) As the acid is drawn up in the glass tube it causes the calibrated float to, well, float. The reading is taken from the calibration on the side of the glass float at the level of the acid. If the acid is very weak and so the battery is flat, then the float will float deeper in the acid and show a lower reading.

fig 42: positive bar corrosion

fig 43: hydrometer in use

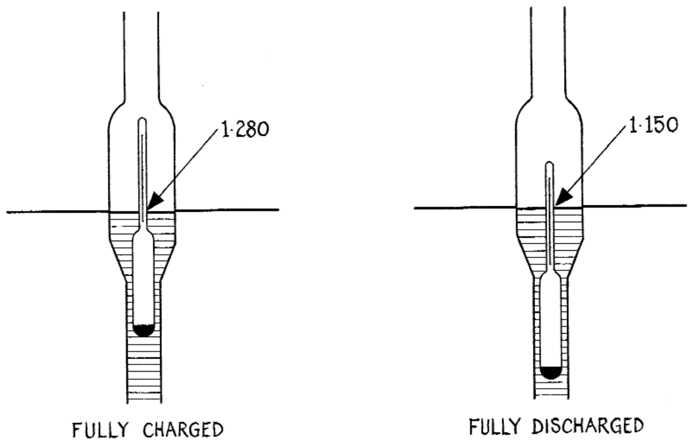

fig 44: hydrometer high and 'needs charging' readings

When taking a reading it is important to keep the nozzle in the acid, otherwise you get a false reading and also spill acid everywhere. This acid is bad for your clothes, take my word for it. Always wear a long waterproof apron or you will get holes in every set of trousers you own. It is not that it starts to smoke as if you are in a 1950s' b-class horror movie but the next day you will notice a bleached area on the cloth which rapidly turns into a hole.

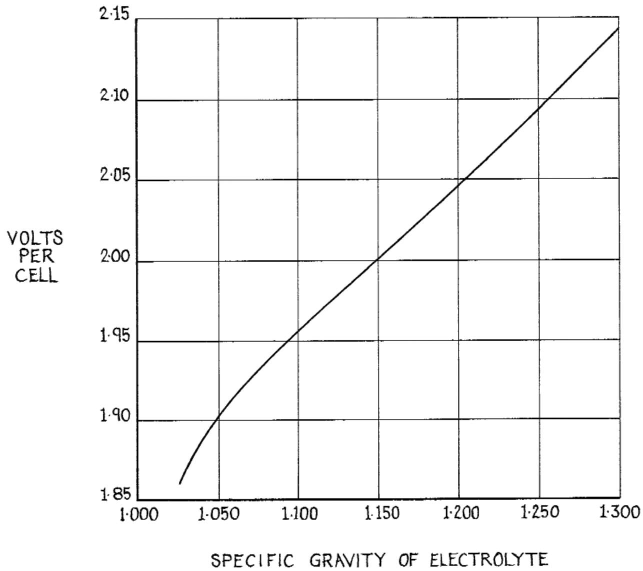

fig 45: open circuit specific gravity and voltage

battery topping up

As the water element of the electrolyte is gradually lost through the action of charging it needs to be replaced. The water used for this purpose needs to be free of impurities to prevent damage to the plates. Distilled water is usually used, but this is expensive especially when you may use fifty litres a year. Dehumidifiers are the answer to this conundrum in that they take water vapour out of the air and condense it. This provides clean water as long as they are operated in a relatively clean environment away from dust and the like. I use these machines to keep certain areas of the house dry during the winter and collect the water on a regular basis for later use. Most modern machines have a humidity-sensitive switch which can be set so the machine only operates when there is plenty of moisture in the air. In this way they are not running all the time and you can be assured that when they are running they are producing water in optimum conditions. It is interesting to note that most dehumidifiers get scrapped because the fan bearings become tight and prevent moist air from being sucked into the machine. It is a simple job to dismantle the fan and lubricate the oilite bushes to rectify this and saves buying a new dehumidifier.

drop testing

This is not, as you might imagine, 'get a battery, drop it on the floor from a specified height and if it still works then it still works'. The drop test means that you make the cell voltage drop under the influence of a large, specified electrical load. This is one way of identifying cells that will not supply enough current, for instance where there is damage to the plate connections and so parts of the battery are no longer connected. The open circuit specific gravity and cell voltage can seem correct, but under the drop test the good cell will show a constant 2 volt voltage, whereas a poor cell will show a falling, low voltage as it cannot supply the current demanded and so the voltage falls rapidly.

Drop testers are available from surplus outlets or battery manufacturers. They are specific to the cell voltage. Don't' leave the tester on too long or everything starts to bubble and get hot.

second-hand batteries

Forklift and other traction batteries are designed for constant cycling which is useful because they are used in great quantities in industry and so are readily available second hand.

Batteries that are no longer up to a full eight hours work between charges with a forklift truck, can be fine in a wind and solar generation system because the charge/discharge regime is less demanding.

If you decide to buy second-hand batteries bear in mind the faults that can occur in lead acid cells, as described earlier in this chapter and summarised below.

- positive-pole corrosion: this shows up with misshapen cell tops and the positive pole may stick up higher than the negative. This is an indication of overcharging, excess acid strength, and general abuse.
- sulphation of the plates: there are white deposits on the plates that show up more on the dark positive. If severe this can prevent the battery from charging. This is an indication of serious undercharging or that the cell has been left in a discharged state for a long period of time.
- sludge build up: this cannot be identified externally but can be one of the reasons batteries self-discharge over a short period of time. This is an indication of continuous overcharging.
- corrosion of terminals: this is mainly found on surface-mounted bolt-on terminals. The acid finds its way past the seals on the post and around the bolt connection. The bolt and the brass-threaded insert in the post can be eaten away rendering the cell useless.
- loss of electrolyte: if there is no sign of electrolyte between the plates it is an indication of poor maintenance and that the cell has been allowed to run dry, either that or the electrolyte has been accidentally spilt. Suspect the worst.
- battery cells are absolutely full of electrolyte: this could mean that the cells have been standing outside in a box that is filled with rainwater, and so the cells filled up. Another reason could be that the cells were attached to a distilled water self-topping-up system when in use, which, when incorrectly used, can cause flooding of the cells and loss of acid.

If you decide to use second-hand batteries then they must necessarily cost something near to scrap value and so if there are any you find you can't use, they can be scrapped and you will get most of your money back.

The first thing to do when faced with a second-hand battery pack or series of cells is to reach for your trusty multi-meter and measure the voltage of each cell. The voltages should be even and any cell that is dramatically lower should be suspect.

Next go for a visual inspection (page 100) and hydrometer test (page 100). Again with this test the readings from the cells should be even although we are not looking for text book figures as the battery could be in any state from freshly charged to having been flat for quite a while. Having identified which cells are suitable and of a similar size, then, after transporting them, it is time to connect them together and give them a good charge. This could quite likely take days and days depending on the output of your charger, but it is best not to charge them too quickly. Charge the cells slowly and you will get a more even and thorough charge throughout the whole pack. This is similar to an equalising charge.

recycling batteries

Most industrial scrap yards will take batteries and, depending on the current economic situation, they will either give you money for them or suggest you just leave them if their value is very low. Quite recently batteries were fetching £200 a ton, but as I write they are only fetching £20. That shows not only their recycle value but also the sort of price variations likely when buying second-hand units.

experiment with making your own battery

I'm not going to go into great detail here but you might want to try making your own battery; it won't be very useful for your system but it is interesting to see how the process works.

If you put two sheets of lead into a vessel of battery acid, using sulphuric acid with a specific gravity of 1270, then you have the basics of a battery.

The lead sheet should not touch each other. If you make three such cells then you can charge them with a battery charger and the action of charging creates active material of the lead sheet surface. This was how batteries were first made and, if you continue to cycle, charge and discharge these homemade cells then their capacity will improve as the active material volume increases. The capacity will not be very great because the surface area of the active material is not large, which is why modern batteries have pasted porous plates with active material all the way through.

Roofing lead and honey jars, with large lids, are ideal materials but remember to work carefully and use your PPE, especially goggles.