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LEAD ACID BATTERIES

How is it made and how does it work ?

The lead acid battery is made up of a series of identical cells each containing sets of positive and negative plates.

In semi traction cells flat plate construction is used. Each positive plate is a cast metallic frame which contains the lead dioxide active material. The negative plates contain spongy lead active material. also on a similar frame. Both plates usually have the same surface areas.

In practice a typical cell is constructed with many more plates than just two in order to get the required current output. All positive plates are connected together as are all the negatives. Because each positive plate is always positioned between two negative plates, there is always one or more negative plate than positives.

The resultant voltage of lead acid cell is normally 2 volts In order to achieve the voltage required for the application each cell is then connected in series by substantial metal straps to form a battery. In a typical monoblock battery, such as that used in a car for starting, the voltage required is 12 volts, achieved by connecting six cells together in series and enclosing them in one plastic box. Leisure batteries where a sustained current requirement is needed and a deep cycle, the ability to be discharged to 90%, have a different make-up to that of a traction battery that is used in a car.

The cell containing the plates is filled with an electrolyte made up of sulphuric acid and distilled water with a specific gravity of 1.270 at 60deg F (15.6deg C). Sulphuric acid is a very active compound of hydrogen and sulphur and oxygen atoms. Sulphuric acid is a very reactive substance and because of its instability it is able to distribute itself very evenly throughout the electrolyte in the battery. Over time, this action ensures that an even reaction can occur between all the plates. producing voltage and current. The chemical reaction between constituent parts of the electrolyte and the 1. spongy lead of the negative plates and 2. the lead dioxide at the positive plates turns the surface of both plates into lead sulphate. As this process occurs the hydrogen within the acid reacts with the oxygen within the lead dioxide to form water. The net result of all this reaction is that the positive plate gives up electrons and the negative plate gains them in equal numbers, thereby creating a potential difference between the two plates. The duration of the reactions producing the cell voltage is limited if there is no connection between the two plates and the voltage will remain constant.

If a connection (a load) is placed between the positive and negative plates the chemical reaction is able to continue with electrons flowing through the circuit from the negative plate to the positive. The flow of electrons is in fact the current produced by the cell. Only when the supply of electrons becomes depleted i.e. when the active material on the negative plate has been used up, and the within the electrolyte has mostly been turned into water will the battery fail to produce any current. During the chemical process different levels of heating can occur and the faster a battery is exhausted the greater will be the heating and thus the efficiency of the system will be reduced.

Care and Maintenance of Flooded Lead Acid Batteries

The most important aspects of care for these and all other types of batteries concern both charge and discharge as well as the mechanical treatment of the batteries i.e. keeping them topped up with water etc.

It is important to consider that lead acid (pb) batteries are, as we have seen above, quite delicate chemical factories.

Discharge

Lead acid batteries should never be run flat. The maximum recommended discharge is 75% of the total. This means that the battery should have a minimum of 25% of charge remaining when it is put on charge.

Lead acid batteries once filled with electrolyte, should always be regularly charged even if they are not in use. When left idle a filled battery will self discharge because of its own internal resistance. left long enough a battery can go completely flat without ever having been put into service. Storage also affects the rate of discharge. A battery should never be stored directly on the ground and especially not on concrete. The best storage method is wooden pallets which do not conduct or allow damp paths and do allow good air circulation. During storage, most manufacturers recommend a freshening charge once every two months or so.

How to find the state of charge

To easily see the state of charge accurately you should obtain and fit a battery condition instrument such as the E meter or Curtis 901, the former is easily the best but is not cheap. The most accurate way of checking a battery's condition is with a drop tester but this is not a quick and easy method.

The cost of an E meter or curtis may initially appear prohibitive, but you should consider how much its cost will save by preventing the premature failure of expensive batteries.

It is extremely difficult to accurately measure the state of charge of a lead acid battery and to predict the remaining capacity.

Battery capacity is not comparable to a tank full of petrol. A filled petrol tank contains a finite amount of energy which can be used either slowly or fast according to the energy required. Battery capacity is not so simple.

In a battery, the rate of which energy is drawn affects the overall amount of energy available from the battery. For example , a 100 Ah battery rated at 20 hour rate means that over 20 hours there are 100 Ah available, or to put it another way you can expect to draw up to 5 Amps per hour for up to 20 hours, 20x5=100Ah.

If you try to draw the battery down more quickly you cannot expect to get the same amount of Ah from it. For example if you draw it down over just one hour the approximate capacity will become 100 x 0.59 which =59Ah. Putting this another way means that you can connect a load on the battery which will draw 59 Amps for just one hour. If you discharge over just half an hour you can only expect to get around half (47%) the capacity from your batteries.

With most uses the rate at which a battery is discharged varies enormously , you can see that any battery condition indicator has to be quite a clever piece of equipment if it is ever going to get close to giving an accurate reading.

The E meter samples the rate of discharge every 4 minutes or so (this can be varied) and recalculates the amount of time remaining before the battery will be fully discharged and also up-dates and displays a 'fuel gauge' bar graph. The combination of the 'fuel gauge' and the time remaining displays along with possible displays of volts, amps. Ah and/or kWh means that the instrument is around 99% accurate and can be relied upon. There is one proviso though, the E-meter must be correctly set up in the first place for the capacity and the type of batteries you are using. It does take a bit of fine tuning to get it set up correctly, but once it is, there is no better instrument that I have come across.

If an E-meter is not available a voltmeter giving the open circuit voltage of the battery can give an approximate indication of battery discharge. This method cannot be relied upon as this voltage will rise if the battery is allowed to rest and then the voltmeter will in effect give a false reading. As soon as the load is reapplied to the battery the voltage will drop and the available charge will then become apparent.

Charging Lead Acid Batteries

Battery vent caps should always be kept in place and tight during both charging and discharging.

For best battery life, i.e. greatest number of charge/discharge cycles and years service most battery manufacturers recommend that you should aim to recharge the batteries when they have reached around 50% discharge. This level of discharge, of course, must be measured according to the rate at which the batter is discharged, which as w have already seen, varies the available total capacity of the battery.

In addition, some battery manufacturers specify that best life will be achieved only if the batteries are discharged sufficiently for a 4 hour bulk charge to take place before the batteries are fully recharged.

A reasonable rule of thumb is that you should aim to charge the batteries only when they are between 70% and 40% discharged. If you charge them then they are only lightly discharged i.e. less than 40% you will end up boiling them unnecessarily which wastes energy in the form of heat and gassed off hydrogen and in turn shortens the life of the batteries. In effect the batteries are being overcharged which can cause degradation and buckling of the plates. In the process some active material is forced off the plates and drops down to the bottom of the battery. If this occurs frequently the eventual result is a build up of a bridge between the plates which in turn can cause a possible short across the plates. This situation leads to the destruction of a cell which then reduces the capacity of the battery.

To confuse matters further, a battery will operate at its most efficient the deeper it is discharged, up to around 75%. The bulk phase of the charge cycle is the most efficient and is proportionately longer the deeper the discharge.

There are many battery chargers available. Today, manufacturers supply automatic chargers which are supposed to ensure optimum battery life. there are numerous charge profiles available and now, with the advent of the electronic switch mode chargers, it is possible to have a fully programmable charger on board your car capable of charging almost any type of battery.

Lead acid batteries must be charged carefully. If the charge is too violent and uncontrolled the batteries can overheat and cause thermal run-away which can result in a possible explosion.

Too gently charging will take too long to get the batteries fully charged with the result that the batteries will end up being used in an under charged state eventually leading to premature failure due to sulphation.

The latest electronic chargers mostly make us the IUI charge profile for standard flooded lead acid batteries. This means that the current drawn by the batteries is allowed to flow at a constant (I) rate while the voltage is allowed to rise of its own accord, which it will do as the battery starts to be charged up. This first part of the charging cycle is known as the bulk charge phase. When a preset voltage has been reached, normally the voltage at which the batteries just start to gas, the charger will switch into the constant voltage (U) phase and the current drawn by the battery will gradually drop until it hits another preset level. This second part of the cycle is really the finish charge where the battery just topped up to the brim very carefully at a much gently diminishing rate. Finally the charger will switch again into the constant current mode (I) and the voltage is allowed to rise again, up to a new higher preset limit, in order to achieve a successful equalization charge.

The Bulk Charge

In this first part of the charge the battery is allowed to have a large draw on the available current. Usually the limit to this current level is determined by the availability of a suitably sized mains outlet, especially on large batteries. It is however, worth noting that that the life of a battery will be greatest if even this first bulk phase of charging is started off gently and the maximum current is limited. If the current is too high the result will be excess heating within the battery which is wasteful and could lead to buckling of the plates and destruction of the battery. Sizing of the charger to suit the batteries is important.

Finish charge

Once the bulk phase has been completed, the finish phase commences and the battery charge is topped off. This phase is very important. If the battery is not topped up gently it will overflow in the form of waste heat and violent gassing of the plates which again can lead to the plates buckling and the battery being destroyed. If the battery is not topped up fully, it will become sulphated after only a few charges and the result will be premature failure.

Equalization

In any cyclic application, a series of batteries will always need to be equalized from time to time in order to ensure that the battery cells remain at the same voltage throughout the pack.

No two battery cells or batteries are created equal. During both charge and discharge each and every cell/battery will react in a minutely different way to its neighbour. This could mean that each battery may be holding a different quantity of charge. In order to get the most out of the total battery pack it is necessary to make sure, as far as possible, that each and every battery is holding a similar amount of charge.

During the charge cycle the voltages of the different batteries will very. In order to bring them all to the same level it is necessary to give some a slight overcharge in order to bring the other up to full charge.

Equalization is done by allowing the voltage to rise while allowing a small constant current to the batteries. The voltage is allowed to rise above the normal finish voltage in order to allow the weaker batteries/cells to draw more current. The stronger batteries will not be adversely affected providing the current is gently and the period and frequency of overcharging are not too high and great respectively. The stronger batteries will absorb the overcharge by giving off heat by gently boiling and gassing more heavily. Once the weaker batteries have absorbed the required current, the equalization charge can be halted. The equalization time should be long enough to bring all the batteries up to a full state of charge. As the time factor will very the most reliable way to check the charge states is by a voltmeter on each cell or individual battery.

Really sophisticated battery charging and monitoring systems do not require the use of an equalization charge and are able to charge all the batteries fully including the weaker ones without overcharging the strong ones.

In these systems, each battery is fitted with an electronic clamp, which gradually reduces the amount of charge going into the fully charged batteries as the finish charge progresses. This means that the weaker batteries receive more current to bring them up to a full state of charge and the strong batteries are prevented from being overcharged unnecessarily. The drawback with these sophisticated systems is their cost. The price of each battery clamp can be in the order of 1/5 the cost of each battery.

Watering

Traction and semi traction batteries are generally supplied with removable vent caps so that they can be kept topped up with water. The action of charging the batteries causes gassing when a certain voltage is reached, usually somewhere around 2.35 to 2.4 volts per cell. The result is that water is depleted of its constituent parts by liberation of the Hydrogen gas plates. Hydrogen is of course much less dense that air and the electrolyte and consequently floats out of the batteries at the earliest opportunity. This water must therefore be replenished from time to time. If you do not gas a battery the chances are that it will become sulphated due to fact that not all the sulphate will be fully removed during the non gassing phase of charging.

It is very important to note that only very pure water is suitable for topping up. It must contain no mineral traces and especially no metallic solids, especially iron. The most suitable form of water is distilled water or water that has been chemically treated and demineralised. Only these types of water should ever be used to top up the batteries. Tap water will quickly corrode the battery and should never be used. The frequency of topping up required for the batteries depends on how they are used. If the are frequently and heavily discharged they will need to be topped up regularly. Perhaps every two weeks to a month.

If the batteries are not charged and discharged frequently then it is likely that they will not require topping up for longer periods of time, say once every two or three months or so.

If the batteries are regularly charged after only short discharges they will use much more water than normally. This type of treatment of the batteries should be avoided. It is most important to make sure that the tops of the plates in a battery never become exposed. They should always be covered by electrolyte or they will quickly sulphate and the battery will fail. If watering is too much of a chore, It is possible to fit either automatic watering systems or catalytic caps. With the former, the battery vent caps are replaced with special caps, which incorporate float valves.

A series of hoses connect the float caps to a single filling point. The filling point can be arranged so that distilled *water* is poured into it from time to time or a reservoir can be fitted to constantly top up the batteries. The catalyst caps prevent the battery charging gases from venting to atmosphere and by chemical action combine the gases back into water. Thus there is little or no water loss. Both the above systems work but there are drawbacks. Lots of hoses interconnecting battery cells and batteries can pose a serious safety threat if one of the cells goes into thermal run-away and the vent caps block and the tubes have no water in them. The result is that ignition from one cell will almost instantaneously result in ignition in all the rest of the cells as the tubes will fill very quickly with hydrogen gas which is extremely combustible and explosive, i.e. like the H bomb! A study by Lucas back in the 1970s showed what can happen. In a demonstration, two batteries were connected via their vent float caps by a 3-mm bore tube of a length of over 60-ft. Combustion was artificially initiated in one battery and within an almost immeasurably short time combustion occurred in the second battery. The moral of this tale is that only vent float caps in first class condition should be used and at around £5-00 to £8-00 each they are not cheap! In addition, should the tubes ever become blocked or the floats fail to operate correctly, it is highly likely that the batteries will not receive the correct supply of water and the result will be failure of at least one cell.

The catalyst caps are possibly a better bet. They are however, even more expensive and do not last for ever. Most sealed batteries make use of a built in catalyst system.

The cheapest method of watering is by hand. It is also the most reliable provided it is done regularly.

Temperature

Temperature affects charging as well as discharge. As a rough rule of thumb, the cooler the temperature the more charge a battery will absorb and the warmer the temperature the more it will discharge. There are of course limits. However it is senseless to charge a battery that has just been discharged fast and has been left out in the sun. In these circumstances it must be allowed to cool before charging is initiated. The ideal charging temperature varies but a reasonable guide is between 15 and 25 degrees Centigrade. Ideal discharge temperatures are between 20 and 30 degrees centigrade. Unfortunately discharging a battery at a higher temperature, while desirably affecting its performance, will adversely affect its life. In fact, so far as I can determine almost every battery manufacturer can work out the number of Ah which can be drawn from any battery over its life under given constant discharge conditions. There does appear to be a finite number of Ah that can be drawn from a battery for a given discharge profile. Predicting this discharge profile is the difficult bit!

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