BATTERIES

We use two basic battery types in our RV's:

1. Engine start in a Motor Home or Tow Vehicle (Starter Battery)
2. Coach unit for running 12 volt appliances, lights and various electronic boards (Deep Cycle Battery).

To obtain the best performance and optimum life each of these battery types represents a completely different design. In small boat applications, where there is only room for a single battery, manufacturers have made a compromise design to serve both functions. In our RV's we have both types. Obviously, the best cost/highest performance batteries will be those optimized for the two separate RV functions.

Starter Battery

An engine starter battery provides a very high current for a short time period. For less than 30 seconds, these batteries provide from 400 (car) to over 2000 amps (diesel motor home). To get these high currents the manufacturers use many thin plates to provide the maximum surface area. Once started, you drive off and immediately start recharging the batteries. Starter batteries are rated in Cold Cranking Amps or CCA, defined as the amount of current that can be supplied at 0 degrees F. Your tow vehicle or motor home specifications will provide the required CCA
rating. If more than about 800 CCA is required then two batteries in parallel will be installed. This function is almost always provided by a Flooded Cell battery which can be either non-sealed with filler caps or a sealed maintenance free unit. The so called maintenance free battery, where you cannot add water, is fine for this application. Especially since this type of service rarely results in a battery discharge of greater than 10 or 20%. These can only be properly tested with a high current load of several hundreds of amps which usually means a service shop.

Flooded batteries are low in cost, recharge quickly, require ventilation and periodic maintenance, and self discharge at 6-7% per month when they are relatively new. As they age the self discharge rate will increase significantly, which is why, after a few months of sitting idle, your car may not start. You don't have to worry about a charger since your vehicle alternator system has been designed to provide an optimum charging capability.

Deep Cycle Battery

A Deep Cycle battery provides a low current (10 to 100 amps) for a long period of time in order to run appliances, TV's, computers, lights etc. These are designed with thick plates and thick separators. The heaviest battery usually provides the highest capacity. To maximize life and performance Deep Cycle batteries require sophisticated chargers, usually computer controlled. In this application we are concerned with amp/hours which we take out of the battery (and have to put back in with some type of charger). Deep Cycle Batteries are rated in amp/hours by
measuring the total amount of amps the battery can deliver for 20 hours before the voltage drops to 10.5 volts. If we turn on a small reading light that needs one amp and run it for 4

hours we have used up 4 amp/hours. Run your propane furnace at night (with no 110 VAC shore power) and approximately 56 amp/hours (7 amps for the fan times 8 hours) will be gone from the battery vault. If you watched some TV, read a book and took a shower before you went to sleep you will probably have a dead battery in the morning. It will be in what is called a deep cycle (80% of a full charge is gone). If your batteries are not in good shape (perhaps you forgot to check the water level before you left on the trip) you will get very cold about 2:00 or 3:00 in the morning. When you are dry camping (boondock) in cold weather you always want to fill the battery vault before you stop for the night or else stay in a campground.

Why are deep cycles so important? Because you only have so many before the battery dies. For a good quality flooded battery this is between 150 to 200 cycles, for an AGM battery it is in the 1500-2000 range (more about AGM later). Always buy a good quality battery since it will give you the longest life and the highest number of deep cycles. A cheap battery can fail after less than 50 deep cycles.

As you probably suspected, engineers can design a specific life into a battery. In fact, a 5 year pro-rated battery can be designed to fail in 4 1/2 years so you will go back and get the pro-rated allowance in order to apply it to the purchase of a new battery. Forget the 'years pro-rated' warranties, the spec that counts is the number of 'years for replacement' warranty.

You do not want a flooded (sealed) maintenance free deep cycle battery. They are not truly sealed and have an expansion valve which permits gases to be vented. When you go into a deep cycle and re-charge the battery it will get hot and can easily vent water vapor. Since there is no way to add water, after a number of deep cycles, followed by very high charging rates, your battery can die an early death. Keeping the proper water level in a flooded battery is mandatory. The plates must be covered with the proper water level, as defined by the manufacturer. You should use distilled water so you are not adding any impurities. **Do not** overfill a battery since it will just boil out and cover everything with a corrosive acid that can ruin the battery as well as the surrounding components. The water level should be checked before every trip, before and after storage of the RV and before/after a deep cycle recovery charge.

If you do not want to worry about water levels and want the ultimate in performance then consider an Absorbed Glass Mat (AGM) battery. This is a sealed unit which was originally developed for Military Aircraft. It requires essentially no maintenance and no ventilation. It can be mounted in the RV in any position. It can handle well over 1500 deep cycles with a much longer service life. The self discharge rate for AGM is 1-3% per month. They accept much higher currents and can therefore be charged at a much higher rate. AGM batteries can be charged at 40% of the amp/hour capacity of the battery compared to 25% for the flooded type.
The same computer controlled chargers designed for a flooded cell will work fine with an AGM battery. AGM batteries will not freeze, however, flooded batteries must be kept charged during the winter months. If you cannot keep a trickle charge on them in the RV they should be brought into the house, checked for water level and kept charged.

Gel cell batteries used to be an option because they were much cheaper than AGM and were also sealed. This is no longer true and for several years they have both been about the same price.

This leads to the principle disadvantage of the AGM battery, cost. A good quality group 27 size flooded cell will cost between $60 to $100, while an AGM will run from $175 to $300. The three to one cost factor is about right for any battery size which essentially means that you can have three sets of flooded batteries for the cost of one set of AGM's. You will get more years of operation out of the AGM's but not three times as much. If you want more amp/hour capability then the, two batteries supplied with your trailer can provide, any add-on units must usually be installed in the RV. Since you can only have sealed units in the RV they must be AGMs. All of your batteries must be of the same type and size so you will also have to replace the factory supplied flooded batteries as well.

The key to long life and best performance start with purchasing good quality batteries that are the largest size you can fit in the compartment. Securely mount them in a vented compartment (flooded type). All batteries should be mounted so that the water levels can be easily checked, the terminals can be kept clean and the connections can be tightened. You should periodically check the terminal connections by removing them, cleaning the terminals and the posts, applying silicon dielectric and retightening. Keep the compartment and batteries clean and acid free to prevent corrosion of the cables and terminals. After you check the battery cables be sure and do the same cleaning and inspection for all the ground cables to the chassis. For deep cycle batteries try to limit the depth of discharge to 50% or less. If you only discharge to 50% most of the time, your battery will last five times longer. Finally, provide a quality charging system and periodically test the battery condition with a digital voltmeter.

Measuring Battery Condition

Figure 1, Battery Voltage Testing, illustrates the voltage measurement you get at various states of charge. This chart is based upon 10.5 volts being considered a dead battery with 0% charge. As you can see, the range from fully charged to 50% is 0.8 volts. To make this measurement you will require a digital voltmeter with at least 3 1/2 digits. Accuracy is important, but you can get

by with a $15 meter by simply having a friend calibrate it with a higher accuracy instrument. Figure 2, illustrates the temperature sensitivity of a battery. At 70 degrees F, you get 100% of the batteries voltage while at 32 degrees F you only get 78% of the voltage. The lower the temperature, when you winter camp, the lower will be your available voltage and amp/hours. Further, the lower the battery voltage the higher the requirement for battery current thus depleting the battery much faster.

State of Charge	12 Volt battery	Volts per Cell
100%	12.7	2.12
90%	12.5	2.08
80%	12.42	2.07
70%	12.32	2.05
60%	12.20	2.03
50%	12.06	2.01
40%	11.9	1.98
30%	11.75	1.96
20%	11.58	1.93
10%	11.31	1.89
0	10.5	1.75

Figure 1. Measured Battery Voltage versus Percent Charged

The most accurate measurement is with a Hydrometer which measures the specific gravity of the acid mixture. Besides having to withdraw fluid and return it, this measurement is very sensitive to temperature. I prefer leaving this type of measurement to the professional and going with the relatively easy digital voltmeter. With a 0.5% calibrated meter the results are more than adequate for the RV owner to take care of his batteries. Besides, the multimeter will become an important trouble shooting device for his tool box.

Time for some Ohm's Law:

Power = Volts X Current and Volts = Current X Ohms P = E X I E = I X R

Let's examine what this means to you. If I want to run the furnace at night and it requires 90 watts to function, with a 12.7 volt battery it will draw about 7 amps. So if we run the furnace all night we will consume 7 X 10 hours or 70 amp/hours. Now let's assume it goes down below freezing (32 degrees). At this temperature the battery is only putting out 78% or 9.9 volts of its room temperature capability. Watts are absolute and they must be provided regardless of the battery voltage or ambient temperature. So 90 watts divided by 9.9 volts means the heater will require 9 amps. This means we will be taking 9 X 10 or 90 amp/hours out of the battery. This is why the battery will not last the night. Further, many other devices may not function properly with less than 12.0 volts of supply voltage (like the refrigerator

electronics). Remember you also need to run the furnace during the day to keep the pipes above freezing. Figures 2 and 3, illustrate how your battery voltage (state of charge) will vary with temperature. Winter camping not only requires some heat source for the campers but also requires a good, well charged, set of batteries to provide sufficient voltage to run all of the other critical appliances.

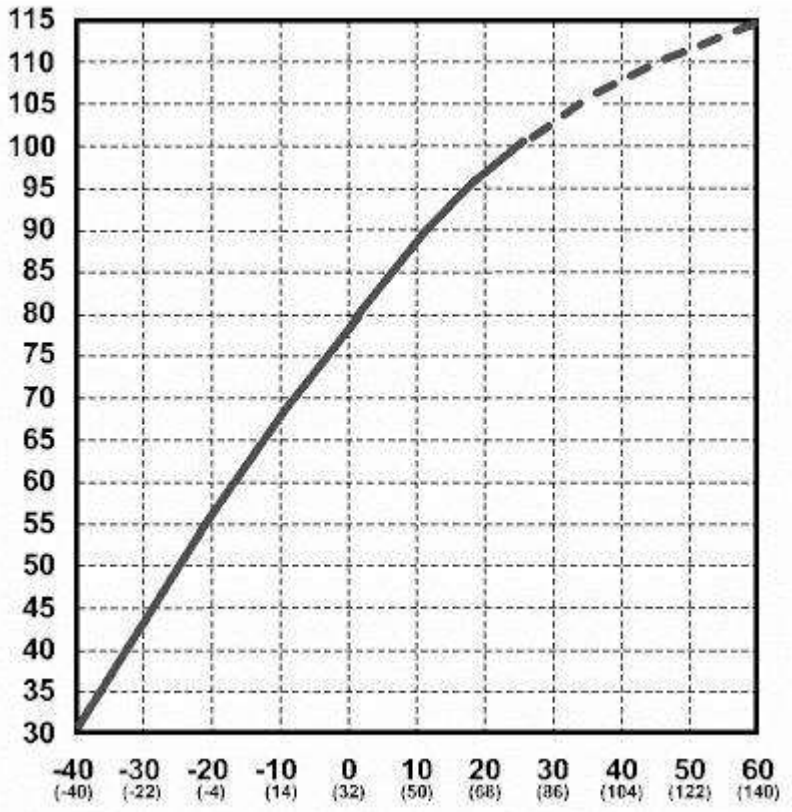

Figure 2. Percent of Fully Charged Battery Versus Temperature

TEMPERATURE COMPENSATED BATTERY STATE-OF-CHARGE (SoC) TABLE

Electrolyte Temperature		Wet Low Maintenance (Sb/Ca) or Wet Standard (Sb/Sb) Battery										Wet "Mainteneance Free" (Ca/Ca) or AGM/Gel Cell VRLA (Ca/Ca) Battery				
		Specific Gravity Reading					Open Circuit Voltage Reading					Open Circuit Voltage Reading				
Degrees Fahrenheit	Degrees Celsius	100% SoC	75% SoC	50% SoC	25% SoC	0% SoC	100% SoC	75% SoC	50% SoC	25% SoC	0% SoC	100% SoC	75% SoC	50% SoC	25% SoC	0% SoC
120	48.9	1.249	1.209	1.174	1.139	1.104	12.663	12.463	12.253	12.073	11.903	12.813	12.613	12.413	12.013	11.813
110	43.3	1.253	1.213	1.178	1.143	1.108	12.661	12.461	12.251	12.071	11.901	12.811	12.611	12.411	12.011	11.811
100	37.8	1.257	1.217	1.182	1.147	1.112	12.658	12.458	12.248	12.068	11.898	12.808	12.608	12.408	12.008	11.808
90	32.2	1.261	1.221	1.186	1.151	1.116	12.655	12.455	12.245	12.065	11.895	12.805	12.605	12.405	12.005	11.805
80	26.7	1.265	1.225	1.190	1.155	1.120	12.650	12.450	12.240	12.060	11.890	12.800	12.600	12.400	12.000	11.800
70	21.1	1.269	1.229	1.194	1.159	1.124	12.643	12.443	12.233	12.053	11.883	12.793	12.593	12.393	11.993	11.793
60	15.6	1.273	1.233	1.198	1.163	1.128	12.634	12.434	12.224	12.044	11.874	12.784	12.584	12.384	11.984	11.784
50	10.0	1.277	1.237	1.202	1.167	1.132	12.622	12.422	12.212	12.032	11.862	12.772	12.572	12.372	11.972	11.772
40	4.4	1.281	1.241	1.206	1.171	1.136	12.606	12.406	12.196	12.016	11.846	12.756	12.556	12.356	11.956	11.756
30	-1.1	1.285	1.245	1.210	1.175	1.140	12.588	12.388	12.178	11.998	11.828	12.738	12.538	12.338	11.938	11.738
20	-6.7	1.289	1.249	1.214	1.179	1.144	12.566	12.366	12.156	11.976	11.806	12.716	12.516	12.316	11.916	11.716
10	-12.2	1.293	1.253	1.218	1.183	1.148	12.542	12.342	12.132	11.952	11.782	12.692	12.492	12.292	11.892	11.692
0	-17.8	1.297	1.257	1.222	1.187	1.152	12.516	12.316	12.106	11.926	11.756	12.666	12.466	12.266	11.866	11.666

www.batteryfaq.org

Figure 3. State of Charge for Flooded, Low Maintenance and AGM versus Temperature

Let's try a microwave which requires 1200 watts. Assuming a 120 volt AC supply the microwave will draw 10 amps from the receptacle (These are not exact because of many other factors but are more than adequate for learning how to size your system). Now let us take an

Inverter which changes 12 volts DC to 120 volts AC and hook it up to the microwave. Since the microwave is really being powered by the battery we will need about 1200 watts divided by 12.7 volts or 94 amps and in cold weather 121 amps. Even a small microwave (700 watts) will require over 50 amp/hours. We may only have to run these for a short time but even 20 minutes will require 31 to 40 amp/hours for the 1200 watt and 17 amp/hours for the 700 watt appliance.

How well are we charging our trailer batteries from the tow vehicle? Reference 1, (http://www.powerstream.com/tech.htm , Wire Gauge and Current Capability Chart) lists the losses for AWG wire from 000 to 40. For number 10 wire size the loss is 1 ohm per 1000 feet. The distance from the battery terminals (front of the tow vehicle) to the trailer batteries is about 30 feet. This means our loss will be 30 divided by 1000 or .03 ohms times 30 amps or 0.9 volts. Actually twice as much if we consider the losses in the positive and negative leads. This means we will reduce our charging voltage of 14.3 volts (from the alternator) to just above 12 volts.
We left out the connectors and we also assumed you ran a separate ground as well as a direct line to your engine battery. You are not going to get much battery charging at that level. If your coach batteries are not too run down you may only need 10 amps which will just reduce the charge voltage by only 0.6 volts.

If you can only get 10 amps into the battery you will have to drive for ten hours to put 100 amp/hours back into the battery vault and there is no way you can take the batteries out of a deep cycle. What to do? Increase the wire size to number 6 which is 0.4 ohms per 1000 feet or a voltage drop of only .7 volts and you have a chance.

By determining the watts required by the stuff you want to run, considering the power source and environmental temperature, allowing for the wire line losses you can determine the amp/hours, number of batteries, solar panel sizes, etc., etc. that have to be put in your RV's. Let's try a starter battery. Assume you have developed a very small resistance in your terminal to cable clamp or your ground strap to chassis connection of 0.003 ohms. Since we require 400 amps to start the engine we will have a voltage loss of .003 X 400 or 1.2 volts in the bad connection. Do you think your engine will start with 11.5 volts even if the battery is fully charged? You cannot check the battery connection by trying to move it or by turning on the headlights to see if they are bright. If the terminals are clean with no corrosion then put the proper wrench on them and tighten them up.

Alternators can supply higher voltages by changing the voltage regulators. Every once in a while you will run into a boom box that looks like an automobile, that can blow your ear drums. These have been modified with new adjustable regulators that can supply up to 18 volts. A friend did this to his diesel tow vehicle and in addition ran a separate high current line and plug to his trailer. When he has a severely depleted battery he simply adjusts the regulator for higher charging voltage.

Get a digital multimeter so you can properly test your batteries and provide the measurements you need to troubleshoot problems and test your systems. The multimeter will allow you to check fuses, bulbs, wire runs, shorts, AC voltages, etc. Buying a single DC or AC volt-meter for monitoring on a continuous basis is not cost effective since you can get all of the same information, when you need it, plus much more with a multimeter. A multimeter is

essentially an Ohms Law measuring device which can provide current, resistance and voltage. It will also provide continuity, which tells you if two points are electrically connected. You can make voltage tests by simply touching the probes to the two points whose voltage you are trying to determine. If you need to measure current you must break the circuit and insert the meter. In many cases it is a lot easier to insert a small resistor (called a shunt) in the circuit and measure the voltage across it to determine the current. This is a particularly valuable technique with large currents (in the hundreds of amps) as well as monitoring amps into a battery.

Learn how to use it before you have to use it.

I have never understood why people purchase good measuring devices and then put them away in the tool box in the original shipping packages. At least take out the instruction manual and try to read it. Try a few measurements on some batteries. Get comfortable with checking your RV 120 VAC input level. Test a bulb and a fuse.

Reference 2, (http://www.ladyada.net/learn/multimeter) provides a very well done, easily read training manual. Examples of all of the different measurements are illustrated with excellent pictures. Links are provided for several well done training videos.

A hydrometer with a built in thermometer provides the most accurate measurement of a batteries condition. However, it cannot be used with a sealed battery, since you have to suck up some
acid from the battery to make the measurement and then return it. Not my favorite approach. An accurate digital voltmeter (also a cheap calibrated one) will give a good enough measurement for your purposes and is a lot easier to use. Immediately after a charge cycle you have a surface charge on the batteries which will give you readings in the 13 plus voltage range. You must remove this surface charge by turning on a bunch of lights for several minutes. The battery will settle down below 13 volts and can now be measured. The best approach is to do the test with a load on the battery. Harbor Freight makes a battery load tester ($25-$30) which can be kept on for 10 seconds with a good/bad scale. Use this, simultaneously, with your digital voltmeter and you will get a good measure of the battery condition. You should disconnect the batteries from each other as well as from the coach and solar panels before you make any measurements.

Always remove the ground terminal first when you are removing a battery or separating two of them for making measurements. When you are re-installing the battery or re-connecting them hook up the ground last. After cleaning the terminals and tightening them you should coat them with a good quality battery terminal spray (silicon dielectric included in the spray).