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 specifi c gravity of the acid mixture. Besides having to withdraw fl uid 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 P = EXI and Volts = Current X Ohms 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.

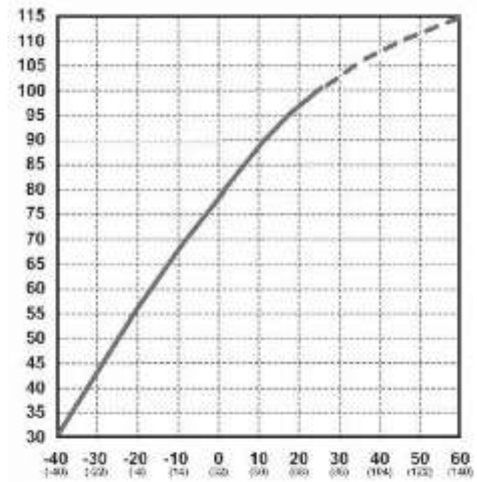

Figure 2. Percent of Fully Charged Battery Versus Temperature

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

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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 RVs. 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 modifi ed 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).