THE CARE AND FEEDING OF YOUR RV II

Batteries, Chargers, Inverters and Solar Panels

by

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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

$P = E \times I$ $E = I \times R$

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.

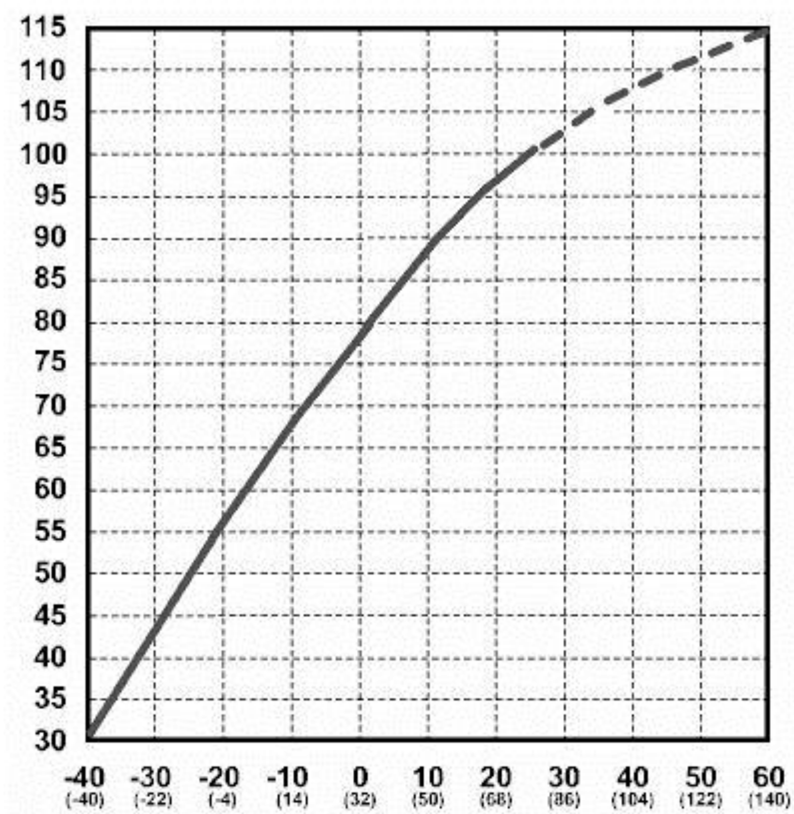

Figure 2. Percent of Fully Charged Battery Versus Temperature

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).

SOME BATTERY SYSTEM TIPS

- A flooded battery will freeze if it is discharged and left out in the winter
- A deep cycle is going below 80% of the batteries capacity
- You should try to always maintain a battery at the 50% or above capacity level for maximum life
- A battery will lose up to 30% of its capacity in cold weather
- A good quality flooded type deep cycle battery can last 4 or 5 years with proper charging and maintenance
- Before buying a battery check the number of deep cycles provided
- Check the water level at least once per month and before/after every trip
- As batteries age they provide less amp/hours under load and are more susceptible to cold temperatures
- A good battery with a proper charger should only require water 2 to 4 times per year
- A battery may test good but can actually become a lower amp/hour unit due to aging or poor care
- After a deep cycle a battery must be fully charged to avoid serious damage
- Most automotive charging systems do not put out sufficient voltage/current to restore an RV battery in a deep cycle unless a special hook up has been provided
- Most of the poorer charging systems cannot restore a battery from a deep cycle or conversely, if they can they usually overcharge the battery if left on charge for long time periods
- Keep batteries/terminals clean and coat connections with silicon dielectric
- Take off the ground terminal first
- Purchase a Digital Multimeter to take care of your batteries and provide a troubleshooting capability for your RV
- Learn how to use Ohm's law to size and check out your battery requirements
- If you need more amp-hours increase the size and/or number of batteries in parallel

CHARGERS

The best chargers provide four stages of computer chip controlled charge current. This type of charger will provide the best battery performance and the longest useful life. They usually have switches and sensors to optimize charge parameters for different types of deep cell batteries and the ambient temperature. This allows you to keep the batteries on continuous charge. If you have a source of shore power your batteries can be left in the RV during the winter months with no danger of freezing. Once I changed to a computer chip controller, I have kept my batteries on charge, continuously, since 1989 . They are always charged and ready to go on one of my winter camping trips.

1. The **BULK** stage brings the battery up to about 80% of a full charge and essentially provides whatever current the battery will accept. The charge current is constant and should not exceed about 20% of the amp/hour capacity of the battery bank. Typically this is about 20 amps per battery which results in a charger capacity minimum of 40 amps for the trailers with Group 27 batteries. The voltage is in the range of 14.2 to 15 volts.

2. The **ABSORPTION** stage where the charger voltage is constant and the current decreases until the battery is fully charged. This represents a voltage of around 14.1 to 14.8 volts that provides the last 20% of recharge.

3. The **FLOAT** (trickle charge) stage is used to keep the battery in a fully charged condition in order to overcome the self-discharge rate. This is typically in the 13 to 13.6 volt range

4. The **EQUALIZE** stage is a controlled overcharge designed to mix the acid evenly in the cells and remove sulfate crystals that have built up on the plates. This is typically in the 15.5 volt range of charge voltage. It can last for 6 hours and should be done every 2 or 3 months. This can bring a seemingly dead battery back to life. Before using this stage the battery should be fully charged and the water levels should be checked (before and after).

These chargers also have sensors, attached to the battery terminals, which change the various stage parameters as a function of the battery temperature. They also have switches which optimize the charge parameters based on the kind of battery being charged (Flooded, Gel, AGM). Yes they are more expensive, but that is how you get the best performance and longest life out of a set of batteries. Reference 3, (http://batterytender.com/resources/battery-basics.htm) provides more details on the charging algorithms.

Figure 4, illustrates how the float voltage (trickle charge) varies as a function of temperature. As you can see there is a wide range of charging voltage as the battery temperature changes. All of the quality chargers, that provide four stage computer controlled voltage, include a battery temperature sensor to modify the output charge voltage. The sensor is bolted to the battery ground terminal with output wires that couple the voltage to the charger. The charge voltage must be significantly increased at lower temperatures in order to get a good charge.

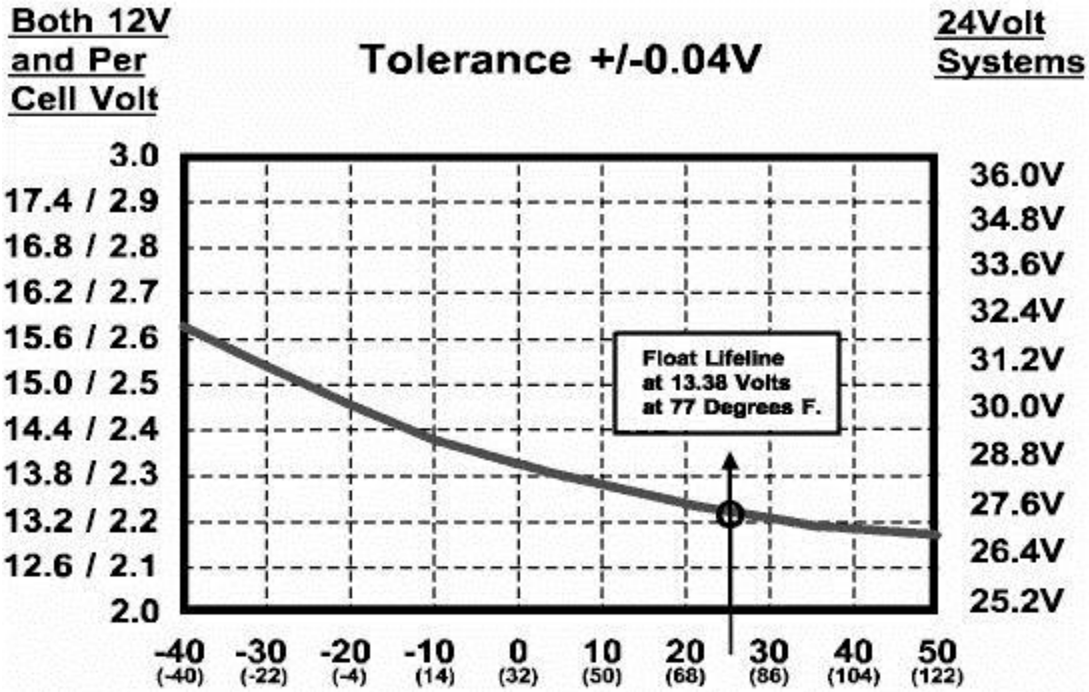

Figure 4. Optimum Charge Voltage versus Temperature

My first Airstream motor home had a transformer type charger similar to the early Univolts. Batteries seemed to last 2 or 3 years, after 2 years they constantly needed water, I had to bring them in the house during the winter because the charger would boil out the water. I finally had enough and purchased a factory rebuilt marine type Statpower (now named Xantrex) charger. This was one of the first available computer controlled chargers. It even had two complete channels so that two sets of batteries could be charged independently. I hooked up one of the channels to the engine start battery and the other channel to the two deep cycle batteries. It included a temperature sensor and an equalize stage which I used once every two months. Now my batteries typically lasted for 5 years and were always fully charged, since I kept the Coach plugged into shore power during the winter months. Twenty years later the charger still worked fine and it is now running around the countryside in England. Remember; **a quality charger can turn a cheap battery into a winner while a cheap charger will turn a quality battery into a piece of junk.**

To fully charge a battery that is in a deep cycle will take about 8 hours. You will need a charger that can supply at least 20 amps to get the charging started. Let's assume your tow vehicle can supply this current level, as long as your starter battery is almost fully charged and you are not using any high current options in the tow vehicle. So, after a night of dry camping you should be able to bring the batteries back up as you drive to the next stop. Not likely, since most tow vehicles do not have either a high enough output voltage or the proper size wire run to deliver that level of current to the Coach batteries. To check this, after a night of dry camping, hook up the trailer and have a friend run the engine at about 2500 rpm while you take your new digital voltmeter and measure the voltage on the deep cycle batteries. You should be getting around 14 volts in order to bring the battery out of a deep cycle.

I am not saying you should throw out your current charger and buy a new one. More recent trailer models have multistage chargers that provide a reduced trickle charge, when needed, and work fine for most applications. Some of the older trailers, however, have way too high a voltage that can lead to battery overcharging, boiling and water loss. If you have to replace the charger, for whatever reason, then you should definitely consider a computer controlled unit. Prices vary from 230-360 dollars for 45 to 80 amps.

INVERTERS

The Converters (chargers) described in the last section essentially convert 120 VAC to 12 plus volts DC. An inverter is just the opposite it converts, 12 volts DC from a battery to 120 VAC to run appliances in your RV. It draws amp/hours from the battery system to power the things we would like when we do not have shore power. Some of our appliances work directly from the batteries i.e. water heater, furnace, refrigerator, lights, radio, etc. (some of them with a little help from the propane). Things we would like to have that cannot be run from DC include, hair dryer, coffee maker, toaster, microwave, TV, Hi-fi stereo, computer, vacuum cleaner, satellite TV, small battery chargers for phones and I-pods.   Large motor homes usually include combination Converter/Inverter units that provide several kilowatts of AC power as well as a computer controlled charger. Some of these include multiple large 4D or 8D batteries that can easily power large microwave units. These are built in with all the needed wiring and control circuits available. Several of the appliances are already connected to the Inverter through multiple use receptacles, that are also shore powered, when it is available. Adding this capability to a trailer or motor home, after the fact, would be an extremely difficult and expensive undertaking which I do not usually recommend.

If you are almost never going to dry camp (boondock) and are always going to stay in Campgrounds with electric then you have no need for an Inverter. Even if most of the time you overnight in a campground but you occasionally do a WalMart or a Cracker Barrel then an inverter could be handy.

Most inverters under 300 watts can be plugged into a cigarette lighter, have a single AC output receptacle and a cooling fan (for the higher rated units) which only operates when the unit gets too hot. When you get above 400 watts you are going to be drawing currents in excess of 30 amps which cannot be reliably handled by a cigar lighter plug. In this case you will have to run suitable size wires (Reference 1) directly from the battery to the Inverter .

Typical costs for non-sinewave inverters are as follows:

300 watts ($40-$60): For household appliances, TVs (up to 27"), VCR, desktop computers, other mobile office equipment. Most of these connect via a 12-Volt cigar lighter plug.

600 watts ($100-$120): For household appliances, large screen TVs, 5-amp power tools, computers, and printers. Most such inverters are connected directly to the 12-volt battery and have three or more grounded outlets for powering several products at the same time.

1750 watts ($199-$380): For household appliances, larger power tools, microwave ovens, toasters, and hair dryers. All of these inverters are designed for direct connection to the battery network and can generally supply 1500 watts of continuous power.

3000 watts ($395-$750): With output power generally rated at 2500 watts for continuous load, these inverters can power virtually all household appliances and office equipment. For loads of this magnitude, special wiring and battery banks will be required.

Usually Inverters provide a modified sine wave output voltage will works fine with most TV's, computers and small heat type appliances. True sine wave inverters can cost two to five times as much as the square wave units. These could be required for fax machines, laser printers, equipment with variable speed motors, plasma displays, some gaming systems and high end audio/video systems. Carefully check out what you want to run before making an inverter purchase.

Because of the wiring problems and multiple locations of the 120 volt AC appliances you might want to run, I usually recommend several small inverters located near the 12 volt sources. Be sure and check your wire sizes for the current capability required. If the appliance is 10 to 20 feet from a DC voltage source make the 12 volt feed lines short and run an extension cord for the 110 volt AC lines (they only have to handle 1/10 of the current). You can easily replace a 12 volt cigarette lighter with a cover plate and binding posts for connecting the larger inverters (if the existing wire is large enough). The larger units come with multiple AC sockets so you can set one up in the front of the rig to run a computer and the TV. A good location would be under the front couch where you will have a very short wire run to the batteries.

SOLAR POWER

When we withdraw amp/hours from our battery vault we have to return them as soon as we have a source available. This could be shore-power, an alternator (from the tow vehicle or motor-home), a generator or a solar panel system. Solar energy is free, however, collecting and processing it is fairly expensive. Let's examine a typical system:

1. Three 130 watt solar panels which can provide 22 amps total

2. A special photovoltaic voltage regulator

3. A monitor system for voltage and current

4. Wiring harness, mounting brackets, stainless steel hardware, fuses

5. Inverter to provide 120 VAC for appliances with a transfer switch

6. Upgrading batteries (2) to AGM type

7. Upgrading the charger to computer controlled type with temperature monitor

The solar panels, regulator, monitor and all needed installation hardware can run about $2500. A 2000 watt Inverter with built in computer controlled charger can add about $1150. Installation and rewiring some of your 120 VAC outlets could easily take a day or about $700. Upgrading your batteries to two AGM Lifelines could cost $550. This represents a total expenditure of around $5000. You can skip the Inverter and just install a solar battery charger but this will still cost about $3750.

Assuming we use about 100 amp/hours in a day our solar system should be able to restore that in about 5 hours of peak sunshine. If we use most of the electricity in the evening than this should work out fine since we will have most of the second day to charge. Solar panels need sun to work not just daylight. You will have a lot more charging time in Florida in the summer than in Alaska in the winter. Your panels must be in direct sunlight all of the time which is why in critical applications moveable platforms, which can automatically track the sun, are used. No more parking under the shade trees, if you want to charge the batteries. Reference 4, illustrates the sun hours per day, high (summer) and low (winter), for major cities in the US. This provides a good guide as to how many hours of the most effective charging you will get.

Don't be fooled by the monitor system's voltage readings. You should have the monitor set for checking charge current which reflects what is actually being put into the batteries. A minimal system, which you install yourself, keep your existing batteries, forget the inverter and provide just 7 amps charge current will run about $1000. If you limit your electric usage to just lights, TV and a laptop computer you could get by with one panel.   One of the advantages of solar is you can start with a minimal system and add on over several years. If you run into several bad weather days, without sunshine, you may have to head for the campground and get a full shore power charge, anyway.

How much battery power do you need? how big a charger? how much solar power, how big an inverter? All of these questions can be answered using an amp/hour worksheet, Figure 6. This provides a list of what you want to run, how many lights you want to use and how long you will run any of the items. Check the back of the appliances or power supplies and use the wattage ratings provided by the manufacturers or if not available use Figure 6. Calculate the amp/hours you will use once you have stopped for the evening and during the night.

Even though a small Toaster requires 800 watts if you only run it for 5 minutes that only requires:

I = P / E, I = 800 / 12 = 67 amps,   5/60 = 1/12 of an hour,   5.6 amp/hours.

While running a 60 watt light bulb for two hours requires 10 amp/hours, an LCD 20" TV (120 watts) running for two hours would require 20 amp/hours. Remember you are drawing the amp/hours from your 12 volt battery either directly or through an inverter.

I remember one Newfoundland Caravan where we had over two weeks of consecutive dry camping. Batteries were dropping like flies. To help the situation we spotted motor homes among the trailers and ran their generators during the day when we were out sight-seeing. For those with batteries in a deep cycle, who did not have good chargers, we collected the batteries in the morning and took them to Canadian Tire for charging during the day. One Caravan member had 6 solar panels and 6 AGM batteries in his rig. One morning he stopped by to ask me to check his batteries since his rig had died during the night. Both rig batteries were completely dead, however, the AGM batteries were fine. After checking the wiring I found out that the Solar Dealer (per the owners directions) had connected the 6 solar panels and 6 AGM batteries only to the TV and Satellite equipment. There was no connection to the rig which is why those batteries died. So he sat there with a dead rig watching TV. You have to decide what is important to you when dry camping in order to size a Solar System.

Is it worth spending the money for a quality Solar System? If you spend most of your time in campgrounds then you won't get much use out of the solar. If you do extended dry camping in the winter and need the furnace you will probably require a generator (at least a small Honda). If you camp in the summer, particularly in the South, and want air conditioning you will need a larger generator (2500 to 3000 watts). Again, solar may not be worth the expenditure.

If you do a lot of dry camping, where generators may not be allowed, and want to spend several days at a wilderness site then a solar system could be justified. If you must have your Satellite TV in the wilderness and money is no object then solar is just the ticket. If most of your dry camping will be on Caravans and it will just involve a day or two, once in a while, then a minimum solar supplement might be adequate (perhaps one panel with a minimum charger). Use the Worksheet (Figure 6) and determine your amp/hour daily needs, decide on the type of camping you will be doing, check your financial status and configure the system. Buy the largest panel you can fit on the rig and a charger that will handle 20 or 25 amps of current. Everyone I know that installed a solar system and purchased one panel eventually wanted at least a second panel and had to throw away the original10 amp charger and purchase a new one.

SOLAR CHARGE CONTROLLERS

Small, 1 to 5 watt solar panels, that provide a trickle charge for the batteries, do not need any voltage regulation. For larger solar panels the output can range from 15 to 20 volts and a charge regulator is required. This can be a conventional charger, as described above, where you set a voltage level and apply it to the battery using a four stage computer chip controlled unit.

The better solar chargers are computer chip controlled, provide the four basic stages of charge and use a pulse width modulation technique (PWM) which is a series of charging pulses sent to the battery. The charger constantly checks the battery, hardware and environmental conditions to determines how fast to send the pulses and how long (wide) they should be.

A PWM charger provides:

1. The ability to maximize battery capacity

2. Increases the charge rate without significant battery overheating

3. Maintains high average battery capacity

4. Equalizes the different battery cells

5. Reduces heating and out-gassing which minimizes water loss

6. Automatically adjusts for battery aging

7. Self regulates for system voltage drops and temperature effects in the panels

This is a much more efficient method than just using a fixed voltage and changing the voltage level as the battery reaches a fully charged state.

For maximum efficiency, solar systems can use MPPT or Maximum Power Point Tracking chargers that are matched to the panel output voltages and the type of batteries being used. Solar panels produce about 17 or more volts of output and require battery voltages that can range from 12 to 15 volts. The MPPT chargers provide operation at the optimum power point to maximize current into the batteries, Figure 5. This takes full advantage of the 17 volt panel supply to get more charge current into the battery and provides efficiencies in the 95% range. These are more expensive but considering that they can provide 15 - 30% more power to the battery they can actually be cheaper by reducing the need for more panels.

This type of charger also uses separate voltage and temperature sensor circuits to optimize the charge current. They have switches so you can set the parameters for almost any type of deep cycle battery used in an RV. They almost always provide the four charging stages described above, in the Charger section as well as the PWM charge technique.

Solar panels produce around 17.6 volts at a specified current. A 130 watt panel will provide a maximum output of about 7.4 amps of current for a 12 volt battery. This is about 89 watts, which means you are losing 41 watts of capability when charging the battery. Figure 5 shows the peak power point at which you can best match to the 12 volt battery. If you use an MPPT charger, that operates at the peak point, it converts the panel output to 10.8 amps at 12 volts. Now you are putting an additional 3.4 amps into the battery for each panel. For a two panel system this is almost like adding a third panel, i.e. two 130 watt panels provide 14.8 amps of charge or two 130 watt panels, with an MPPT charger, provide 21.6 amps. The peak power point changes constantly with available sun light, battery condition, weather, temperature, etc. So the job of the MPPT is to monitor all of these variables and continuously adjust the operating point for the maximum output charging current.

MPPT chargers are about $600 for an 80 amp unit, $525 for a 60 amp, $380 for a 30 amp unit, $250 for a 25 amp unit and $225 for a 15 amp unit. PWM chargers are about $250 for 60 amps, $200 for 40 amps, $140 for 30 amp, $125 for 20 amps and $100 for 8 amps. Standard charge regulators run from 45-60 dollars for 8 to 16 amps. Remote digital monitor meters which, provide voltage and current measurements, can run from 40-90 dollars.

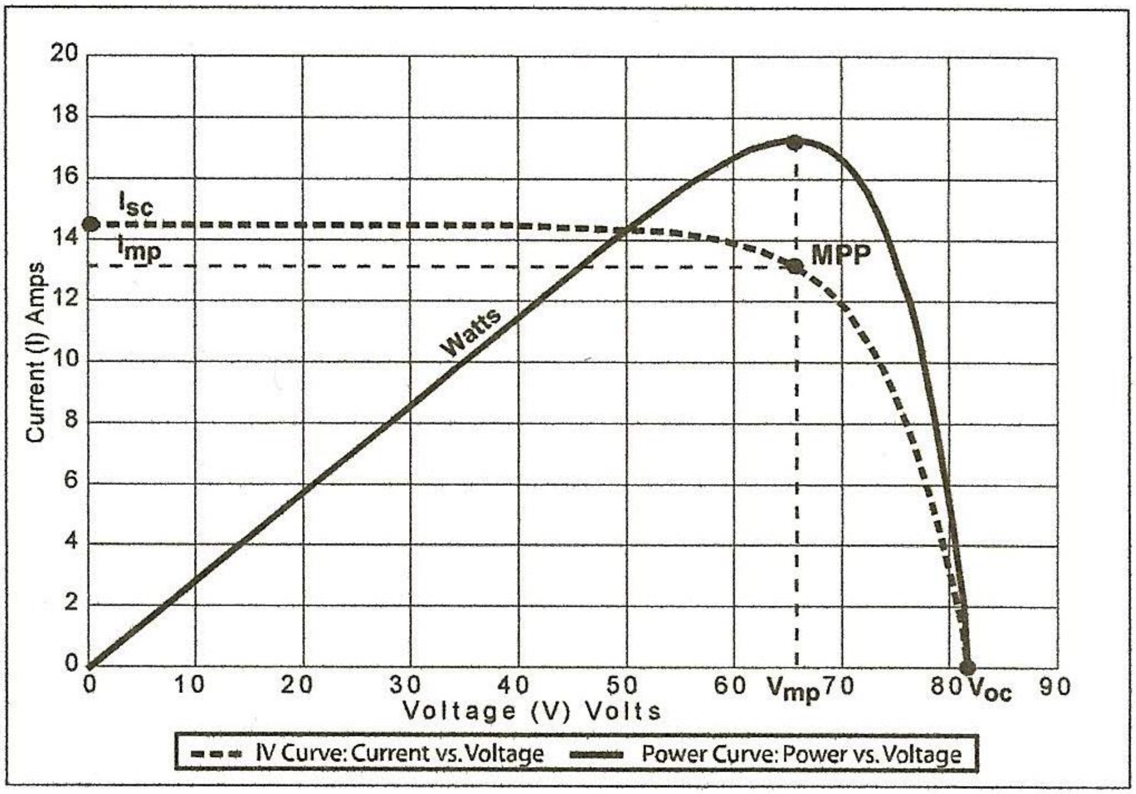

Figure 5. MPPT Optimum Power Point Charging

An MPPT charger is the most efficient and cost effective method for controlling a solar array on your RV. Further, these chargers include all of the latest technology (PWM, computer control and four stage charging) for maximizing battery efficiency, performance and extended life. If you plan to extend your solar system capability in the future to two, three or more panels then you should definitely consider an MPPT controller.

Figure 6 Worksheet For Calculating Power Required for One Day

APPLIANCE	WATTS	AMPS (approx)	Quantity	Hours/day	Amp/hours for one day
Lights					
bulbs	10	1			
	25	2			
	50	2			
halogen	10	1			
	20	2			
fluorescent	10	1			
	15	1			
Entertainment					
19" color	85	7			
20" LCD	120	10			
32" LCD	140	12			
Satellite Rx	50	4			
Quality stereo	40	3			
Cool/heating					
Fans	24-36	2-3			
Furnace	100	8			
Microwave					
small	800	67			
large	1300	108			
Computer	50-200	4-17			
Printer	50-100	4-8			
Vacuum	200	17			
Hair dryer	1000	83			
Water Pump	50	4			
Bed warmer	24-50	2-4			
Refrigerator	72	6			
Toaster	800	67			
Coffee maker	1000	8			

SOME SOLAR SYSTEM TIPS

- Select the largest panels you can mount on your rig
- One panel per battery per person with one extra (quick estimate)
- Keep the panels clean
- Clean and check all connections at least once per year
- Typical Panel voltage is 17 plus volts
- Heavy users will need 3 or 4 panels and 4 batteries
- Forget Air Conditioners, large Microwaves and Furnaces
- Consider Propane catalytic heaters and/or a 12 volt heating bed pad
- Non sinewave inverters work for Computers, TV,s and small appliances
- Use energy efficient lights (fluorescent, LED, halogen)
- Do a Consumption Worksheet and determine maximum amp/hours needed
- Don't forget 'sneak loads' (circuit boards, radio, pilot lights, water heater)
- Buy at least a 20 or 25 ampere charge controller (you will add panels)
- For larger Panel arrays Invest in an MPPT charge controller and remote monitor
- Make sure the proper wire size is used
- Plan for future upgrades when sizing controllers and wire size
- When your batteries need charging stay out of the shade
- After sizing solar consider needs for Air Conditioning, furnace, microwave
- Trade off costs and desires when considering a generator versus solar system
- Consider both acquisition and operating costs for these two approaches
- Evaluate approach based upon expected hours of usage and total investment

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