Batteries for Emergency Communications

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http://www.k3emd.com/Technical%20References.htm

Overview

The purpose of this paper is to provide a basic understanding of the different types of batteries available on the market today so the reader can make an educated decision about what type of battery will best meet their needs for Amateur Radio emergency communications. Some thoughts on battery chargers and inverters will also be presented. This paper concludes with an explanation of how to compute the battery capacity required to meet your emergency communications needs.

Terminology

Amp Hours (AH) - For 12-volt batteries, the total amount of current a battery can deliver over 20 hours, at a constant rate of discharge, before the battery reaches 10.5 volts. This means a 100 AH battery can provide 5 amps for 20 hours before the battery is dead. A 50 AH battery can provide 2.5 amps for 20 hours. Note that the output voltage is not part of the AH rating (except that it must be greater than 10.5 volts). Obviously, the voltage will start out at the fully charged voltage of 13 to 14 volts or so, and will be dropping over time until reaching 10.5 volts.

Reserve Minutes - For 12-volt batteries, the number of minutes a battery can run a 25-amp load until the battery drops to 10.5 volts.

Cycles - For 12-volt batteries, the number of times a battery can be discharged through a 25-amp load down to 10.5 volts and then be recharged, until the battery can no longer provide 1/2 of its Reserve Minutes. For example, if a battery has a capacity of 200 Reserve Minutes, and after being discharged 300 times to 10.5 volts and recharged again it can only provide 100 Reserve Minutes of capacity, then the battery is said to be capable of 300 cycles.

Cold Cranking Amps (CCA) - The number of amps a 12 volt battery can produce at 0 degrees Fahrenheit for 30 seconds and not drop below 7.2 volts.

Marine Cranking Amps (MCA) - Also known as Cranking Amps (CA). The number of amps a 12 volt battery can produce at 32 degrees Fahrenheit for 30 seconds and not drop below 7.2 volts.

Reserve Capacity (RC) - The same as Reserve Minutes.

High Current - A load on a battery that would draw the total AH of the battery in a few hours. For example, 5 amps would be considered a high current load on a 10 AH battery.

Low Current - A load on a battery that would draw the total AH of the battery over many hours or days. For example, 5 amps would be considered a low current load on a 120 AH battery.

What is a Battery?

A battery consists of one or more cells. Each cell contains two electrodes of different types of material immersed in a medium (usually fluid or paste) that acts as a catalyst to cause a chemical reaction producing electricity. This electricity-producing medium is called an electrolyte. Each cell produces the same voltage regardless of its size (usually between 1.2 and 2 volts depending on the technology) and multiple cells are connected in series to provide higher voltages. For example, typical Lead Acid batteries generate 2 volts per cell and combine 6 cells in series to produce 12 volts of electricity. Larger cells produce more current than smaller cells of a given battery type.

For the purpose of this paper, all batteries are divided into two categories: Disposable and Rechargeable. Disposable batteries, sometimes also referred to as Primary batteries, are used one time and then discarded, whereas Rechargeable (or Secondary) batteries can be recharged by applying a voltage to the electrodes to reverse the chemical reaction so the battery can be used again.

Disposable Battery Technologies

Zinc Carbon batteries (also known as carbon batteries) are the inexpensive disposable AAA, AA, A, B, C and D size batteries we use in household appliances and toys. They are made from zinc and carbon electrodes with an acidic paste between them. These batteries provide the lowest current and limited life of any battery listed here. Your emergency communication plan should not count on these batteries, but they may be used in some situations as a last resort if no other options are available.

Alkaline disposable batteries employ zinc and manganese-oxide electrodes with an alkaline electrolyte between them to provide more current that Zinc Carbon, and last longer. These batteries should not be recharged. There is a different type of Alkaline battery that is rechargeable and is discussed below.

Lithium (lithium-iodide, lead-iodide, lithium-thionyl-chloride) disposable batteries come in several different flavors and provide more power than alkaline, but are more expensive. They are useful for high power items like camera flash units. Some of these batteries may burst into flames if you attempt to recharge them.

Zinc-mercury Oxide batteries and Silver Oxide batteries provide low current output over a long period of time for their size and are usually used in hearing aids and smoke detectors.

Rechargeable Battery Technologies

Rechargeable Alkaline Manganese (RAM) also known as Alkaline rechargeable, are similar to NiCad in temperature range and power output, but not as popular as other rechargeable batteries because they can only handle a limited number of cycles. They produce approximately 80% of the power of a disposable Alkaline battery, the first time they are used. They can provide consistent power for over 200 shallow cycles (125 mA for 4 hours), but only 40% of the power of a disposable Alkaline battery after 20 deep cycles (125 mA for 10 hours). They do not suffer from "memory effect". An advantage over other battery types, is that they can be charged and maintain their charge well at temperatures above 113 degrees F making them a good choice if you recharge batteries using a solar battery charger (which tend to get hot in the sun) and need a long shelf life. They are well suited for emergency lighting in buildings or for applications where they are required to provide very little current before being recharged (i.e. brownouts and brief blackouts).

Nickel Cadmium (NiCad or NiCa or NiCd) rechargeable batteries contain electrodes made of nickel-hydroxide and cadmium with an electrolyte of potassium-hydroxide. These are the most common and inexpensive rechargeable batteries. They operate over a very wide temperature range from -20 C to +60 C and can provide very high current. Unfortunately, they can sometimes die suddenly and unexpectedly. These batteries are commonly advertised as having a "memory-effect" meaning that if they are not completely discharged before being recharged, they will remember the point at which they were recharged and not provide current beyond that point in the future. However, they should never be discharged below 1 volt per cell or they will be permanently damaged. The 2002 ARRL Handbook says the "memory effect" of these batteries is a myth and not substantiated in research. The conflicting information may be due to different manufacturing processes resulting in batteries with different performance characteristics.

Nickel-metal Hydride (NiMH) rechargeable batteries are generally thought to not suffer from the "memory-effect" of NiCad batteries and can be recharged after very little discharge without affecting the performance of the battery (although one source claims these batteries do suffer from a "memory effect"). They can be recharged 500 to 1000 times and are lighter and smaller than NiCads. They may not function in sub zero temperatures and do not provide as much current as NiCad batteries. If a high current load is applied it may provide less than half the rated AH, and may reduce the lifetime of the battery by 65% or more. These batteries are better than NiCads for low current draw over long periods of time.

Lithium-ion (Li-ion) rechargeable batteries last longer, are smaller and lighter than both NiCad and NiMH batteries, but are more expensive. These batteries have a very good power to weight ratio and are frequently used in laptop computers and cell phones. They do not provide as much current as NiCad batteries and if a high current load is applied they can die within seconds. A big plus to the environmentally conscience is that there is nothing poisonous inside a Li-ion battery (note that some other Lithium batteries besides Li-ion are toxic). They can be disposed of by throwing them in the trash.

Zinc-air rechargeable batteries are very lightweight, have a long 5-year shelf life and contain no hazardous materials. They can operate in temperatures from -10 C to 60 C. A three pound 12 volt battery can provide 5 amps for 4 hours. They are good for military applications because of their low weight, and are also used in some electric vehicles.

Silver-zinc batteries are used in aeronautical applications because of the good power to weight ratio.

Mercury Chloride rechargeable batteries are used in electric vehicles.

Flooded Lead Acid Starting batteries are the type of battery used in your car. The electrodes are lead and lead dioxide plates submerged in a solution of approximately 35% sulfuric acid and 65% water. They should never be drained of more then 10% of their power (AH) as they will be unusable after 5 or 10 of these cycles. They are more hazardous than some other types of batteries for three reasons: 1) they contain toxic lead and an acid; 2) unless they are "maintenance free" sealed batteries, the acid will run out if tipped; and 3) they produce an explosive hydrogen gas off the negative plates while being recharged. If used in an enclosed area they should be stored in an airtight container with a vent to the outside. Also, they should be kept vertical so the acid covers their plates or reduced power and damage may result. Since they are vented and give off gas while recharging, they must be periodically replenished with distilled water (mineral or tap water can cause damage). They are best suited for very brief, very high amperage requirements and are a compact, cost effective solution for those applications. They will self discharge at 6% or 7% per month.

Flooded Lead Acid Deep Cycle batteries are similar to Lead Acid Starting batteries in every way, except they are capable of being discharged to 50% or so without damage. Deep Cycle batteries have thicker plates so they do not generate the high amperage as starting batteries, but will not be damaged as easily by being deeply cycled. Many Flooded Lead Acid Deep Cycle batteries can be recharged over 1000 times. They are also perhaps the most cost effective way of storing a large amount of power, primarily because of their relative low cost.

Gel Cell Deep Cycle batteries use a gelled electrolyte instead of a liquid acid. They are comparable to Flooded Lead Acid Deep Cycle batteries, except they are usually sealed and therefore safer for use in closed areas. They will self-discharge at a slower rate (3% per month at 68 degrees F) and are slightly more expensive than Lead Acid Deep Cycle batteries. It is very important to note that they must be recharged at a lower voltage (14.2 volts max, 13.7 volts float) than other batteries and hence require a special battery charger. Recharging at a higher voltage can cause venting of hydrogen, overheating and severely affect the number of times it can be cycled.

Absorbed Glass Matt (AGM) Deep Cycle batteries are similar to Lead Acid Deep Cycle batteries except that an absorbent glass matting material is stuffed between the plates to hold the acid in place and provide support for the plates to protect against damage due to vibration. They were originally designed for the military. Like most Gel Cell batteries, AGM batteries are sealed and designed such that the oxygen and hydrogen produced during recharging is recombined back into water reducing the need for maintenance and making them safe for indoor use. Like other sealed batteries, they do have a vent that is used to release pressure to prevent the battery from exploding during overcharging. The escaped gasses then cannot be replaced. The dense glass packing between plates also lowers the internal resistance resulting in faster recharging rates, longer discharge and higher amperage output than other deep cycle battery technologies. They will self-discharge at 3% per month at 77 degrees F.

Battery Chargers

Each type of battery requires a different recharging profile. Even the same type of battery, for example Li-ion, from different manufacturers, may differ in the recommended recharging algorithm. This is because different manufacturers may employ different methods for recombining discharge by-products. Follow the recharging instructions you receive with the battery. The safest bet is to use a charger manufactured or recommended by the battery manufacturer. Never use a battery charger designed for one type of battery on another. For example, many NiCd battery chargers will damage Li-ion batteries and a Lead Acid battery charger will damage Gel Cells.

The best battery chargers recharge the battery in stages. They may apply a very high current, high voltage output until the battery reaches a certain voltage level, then step down in phases until the battery is "floated" or "pulsed" to receive its full charge. Continuing to provide a high current, high voltage output will damage some batteries, although Lead Acid and NiCd batteries are the most forgiving. Gel Cell batteries should never receive a voltage above 14.2 volts or permanent damage will result.

Quick Charge battery chargers, unless recommended by the battery manufacturer, usually will significantly reduce the number of cycles for a battery. It is best for the battery to use a battery charger that requires between 8 to 12 hours to charge a battery. Longer, slower chargers are okay for most types of batteries. If you need a quickly rechargeable battery, consider NiCd or Lead Acid, which are the most forgiving.

Inverters

An inverter converts 12 volts of DC electricity to 115 volts AC. There are two types of inverters: Modified Sine Wave and Sine Wave. All inverters will cause some type of radio interference, although the amount of interference can vary significantly.

Modified Sine Wave Inverters create a square (or nearly square) wave AC output. These are the most popular type of inverter because they are very inexpensive. They work fine with incandescent light bulbs, radios and televisions, but are not suitable for use with appliances with some types of electric motors or compressors. To do so may damage or significantly reduce the life of the appliance. Do not plug battery chargers into Modified Sine Wave Inverters, as some chargers will be damaged or damage the battery being charged. Some low power recharges producing voltages less than 30 volts may be okay. Although a Modified Sine Wave Inverter will work for most computers, you should check with your computer manufacturer before trying it. Modified Sine Wave Inverters should not be used for: stereos, copiers, laser printers, light dimmers, some fluorescent lamps, pellet stoves and other appliances with internal computers, digital clocks, bread makers with multi-stage timers, medical equipment and variable speed tools. Also, do not use them for rechargeable tools such as flashlights, electric razors and toothbrushes that are normally recharged by plugging directly into the AC outlet.

True Sine Wave Inverters are much more expensive but can be used for any 115 volt device. If you are considering using this as a backup power source for your house, it is more cost effective to purchase a generator. A 1500 watt true sine wave inverter will cost over $1000 and require a sizeable battery bank costing just as much to last any significant amount of time. On the other hand, a 5000 watt gasoline, propane, or natural gas generator can be had for about $500 and run much longer on a few dollars of fuel.

What Type of Battery Should I Use?

The type of battery you choose will be based on your operating environment and power requirements. For emergency power in the home, refillable Flooded Lead Acid Deep Cycle batteries are the most cost effective solution provided you store them in an air-tight box that is top vented to the outside (hydrogen gas is lighter than air). Otherwise, use the same type of battery recommended for cost effective high power emergency communication applications in a shelter: sealed Gel Cell, sealed AGM or sealed Flooded Lead Acid Deep Cycle batteries. For low power applications where batteries are small, the more expensive NiCad, NiMH or the very long lasting Li-ion batteries would be most convenient.

Sealed Lead Acid batteries are a very inexpensive compromise for medium power requirements. These are commonly available in self-contained auxiliary power packs with battery charger built in and provide many more AH than a comparably priced NiCad. These small power packs can provide up to 17AH for about $50 and include a built-in 72-hour battery charger. They are great for the rare emergency, but do not take more than 10 or 20 deep cycles.

How Much Battery Power Do I Need?

To calculate your power requirements for a 3 day emergency communication scenario you will need to determine:

1. What transmit power setting you will have to set your radio to in order to communicate with your intended destination (e.g. 5 watt PEP, or 15 watt PEP, etc.).
2. How many amps your radio uses to transmit at that power setting. Radios may draw twice the transmit power or more. For example, to transmit at 5 watts PEP your radio may draw 2.5 amp at 12 volts which is 30 watts. This was not documented in my user manual so I had to use the amp meter on my power supply to measure this.
3. How many amps your radio uses to receive a signal. This also was not documented in my user manual so I used the amp meter on my power supply to measure this as well.
4. How many hours you want to operate without electricity.
5. How many minutes of each hour you expect to spend listening verses transmitting (50 minutes listening and 10 minutes transmitting is reasonable for a RACES deployment, except for net control and EOC operators who may be speaking more often than most).

<u>To Determine Battery AH Rating</u> required for your situation use the following formula:
Battery AH = (((Rmph x Ramps) + (Xmph x Xamps)) / 60) x H

Where:
Battery AH = The AH rating of the battery you will need to purchase. Rmph = The number of minutes of each hour you want to listen to your radio. Xmph = The number of minutes of each hour you want to transmit on your radio. Ramps = The number of amps your radio draws when receiving. Xamps = The number of amps your radio draws when transmitting. 60 = The number of minutes in an hour (to get Amp Hours) H = The number of hours you want to remain operating.

<u>For Example</u>, when using my Kenwood TM-D700 mobile rig on low power (5 watts) for a 72 hour RACES deployment my battery power requirements will be:

Battery AH = (((50 min x 1 amp) + (10 min x 2.5 amps)) / 60 min) x 72 hours Battery AH = ((50 + 25) / 60) x 72 Battery AH = (75 / 60) x 72 Battery AH = (1.25) x 72 Battery AH = 90

This means I should purchase a 90 AH battery (or set of batteries) just to provide power to my radio during a 72 hour power outage so I could transmit at 5 watts PEP 10 minutes of each hour. If I had other equipment I wanted to power during that time (i.e. FM radio, light, etc.) I would need more battery capacity. For RACES deployment one should expect to keep their radio on all the time, whereas for your home calculations you may only plan on operating your radio for 24 or 48 hours over the 3-day emergency since no one will be manning your radio while you sleep.

Keep in mind that this calculation is just an estimate and it is always better to be prepared with extra battery capacity. Remember that the AH rating is calculated based on running the battery down to 10.5 volts, yet according to the user manual for my radio it will stop functioning at 11.7 volts. This would suggest that my radio would stop functioning long before the 72 hours had elapsed.

On the other hand, also consider that the AH rating on a battery is based on a full discharge in 20 hours. This means that my 90 AH battery can supply 4.5 amps continuously for 20 hours before going dead. Since I am only planning on drawing 1.2 amps per hour, this will increase the total amp hours available for most batteries. Remember that most batteries produce more AH at less current draw. Some battery manufacturers provide a data sheet that will contain a series of graphs depicting the voltage over time for different current loads. This would give me a very accurate indication of how long my radio would keep working (i.e. find a chart with a 1.2 AH load, see where the line drops below the 11.7 volts required by my radio, and see how many hours that is on the graph).

The very best way to be sure you have ample power to operate your radio in an emergency is to test it. For me, that would mean to apply a 1 amp load to the battery for 50 minutes then a 2.5 amp load for 10 minutes. Repeat until the voltage drops to 11.7 volts and note how long it took.