SEAPAC.BATTERY BASICS

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Battery Types Covered In This Workshop

- Will cover 12 volt **Lead Acid Batteries** and the newer **LFP Batteries**
- Will also include 5 volt **USB portable power banks** used for charging cell phones and tablets, and the **Petzl Core battery**
- LFP = **L**ithium **F**errous **P**hosphate, the stable lithium battery

Advantages And Disadvantages Of Lead Acid Batteries

- Lead-acid battery **advantages**
- 1) Will probably still work if we experience an EMP blast or solar flare, has good reliability
- 2) Wide availability during a disaster
- 3) Cheaper price
- 4) Been around for a long time and is well known

Advantages And Disadvantages Of Lead Acid Batteries

- Lead acid battery **disadvantages**
- 1) Very heavy
- 2) Must be stored in a fully charged condition to help prevent sulfation
- 3) Low specific energy to weight ratio
- 4) Much shorter life cycle when deeply discharged than LFP batteries

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Advantages And Disadvantages Of Lead Acid Batteries

- 5) Takes more time to charge to full capacity, needs to go through an absorption phase to top off the battery
- 6) Flooded batteries give off Hydrogen and Oxygen when charging and must be kept away from ignition sources
- 7) Flooded batteries require regular maintenance
- 8) Flooded batteries must be kept upright or they can spill sulfuric acid on the ground

How Does A Lead-Acid Battery Make Electricity?

- Lead-acid batteries have **two types of plates** and are filled with water and sulfuric acid
- The **negative plates** are **porous lead**
- The **positive plates** are **lead dioxide**
- In the **liquid**/electrolyte there is **two active materials**
- Charged **sulfate** ions
- Charged **hydrogen** ions

How Does A Lead-Acid Battery Make Electricity?

- A) At the **negative plate**, a charged **sulfate** ion **approaches** a **lead atom** on the surface of the plate and then forms a **bond** with the lead atom, forming **lead sulfate**
- B) **2 electrons then transfer** from the sulfate to the lead plate
- C) The **two electrons** then travel to the battery negative terminal **then across** your power cable

How Does A Lead-Acid Battery Make Electricity?

- D) The 2 electrons then reach the **positive terminal** of your battery and **flow down to a lead dioxide plate**
- E) Charged **sulfate ions** and **hydrogen ions** approach the positive plate which has 2 electrons
- F) The 2 electrons transfer from the **lead dioxide plate**, reactions happen and water and lead sulfate is formed
- Both the negative plate and the positive plate are covered with lead sulfate in a **soft form**

Major Event Happens And The Grid Goes Down

- Batteries become really important when there is a grid failure…but what if the grid stays down for awhile?
- 1) How **full** is my battery on **Day One** when the event happens?
- 2) **How much energy** can I get from my battery?
- 3) If **solar power** is my only means to charge my battery, I want to know **how fast can I charge my battery** before the sun goes down?

Battery Voltage And **SOC** (State OF Charge) For A Lead-Acid Battery At Rest

• 12.6v or more	100%
• 12.4v	75%
• 12.2v	50%
• 12.0v	25%
• 11.7v	0%

At Rest Battery Voltage As A State Of Charge

- **Lead-acid battery** at 77 degrees F and the battery has been at **rest** for 2-4 hours, not a surface charge
- **Note that every 0.2v drop is equal to a 25% loss in effective battery capacity**
- **If someone brings you an extra battery, ask if it has been in use within the last 2-4 hours**
- **It is very helpful to know the SOC of a battery when you start using it in an emergency, use your VOM to test it**

Battery SOC Impacts Radio Voltage Needs

- Most of our radios require 13.8 volts +/- 15%
- That is **11.73** volts to **15.87** volts (13.8v +/- 2.07 volts)
- Our **lead acid** battery voltage when its full is about 12.7 volts
- Do not include the “surface charge”
- If you take a “**Fully Charged**” lead-acid battery (12.7 volts) and you subtract the minimum voltage needed for the radio (11.7 volts) = You get 1 volt

Radio Voltage Needs

- That means we have a **1.0 volt "window"** that we have to use wisely, or our radio might not work properly or even just shut off
- 11.7 volts to 12.7 volts is our "window"
- Think of 11.7 volts as our radio "cutoff" voltage

How Much Energy Can I Get From My Battery

- Lead acid batteries are rated by the amount of energy capacity stored in the battery expressed as **amp-hours**
- Amp-Hour (Ah) = if you have a constant load of one **amp** for a period of one **hour**, that is 1 Ah(3600 Coulombs)
- Examples of 10Ah = 1 amp constant load x 10 hours or 5 amp constant load x 2 hours

Typical Battery Rating Example

- “100 Ah battery with 20 hour rating” means the battery should be able to provide a 5 amp **constant load** for 20 hours, and the voltage at the **end** of that time period while still **under load** would be **10.5v**, (this voltage is too low for most of our radios, and we do not want to ever discharge a battery that far, unless no other choice)
- (100Ah/20 hours = 5 amp constant load)

How Many Electrons Travel Out Of Your Battery Per Second?

- Its all about the electrons, somebody may ask you a trivia question like, “How many electrons travel in the wire per second with a 1 amp load?”
- 1 amp load = 1 coulomb per second
- 1 coulomb is 6.25 x 10^18 electrons
- **6,250,000,000,000,000,000 electrons per second** flowing out of your battery and through your wire with a **1 amp load**

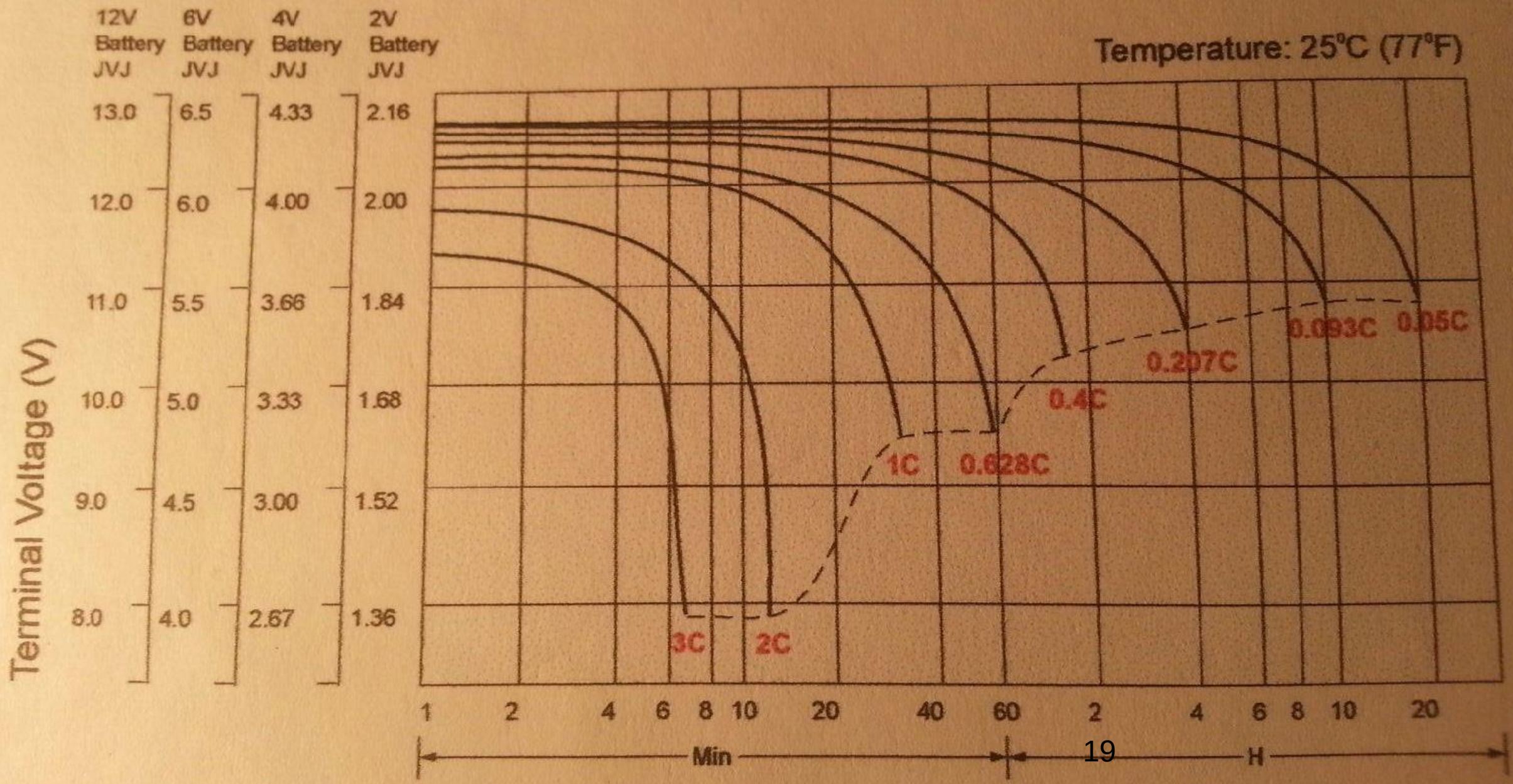
Welcome to the C-rate

- **Is your battery just a "bucket" full of energy?**
- With a 5 gallon "bucket" of water, you can pour it **all** out as fast as you want and **fill it up** as fast as you want. **Not true with a battery**
- The rate that you charge(Fill) and discharge(Pour out) energy from your battery is called the "C-rate"
- The "**C**" in C-rate is the battery **capacity** in amp-hours, when you look at a chart that uses the term "**C**", they are referencing the amp hour **C**apacity of your battery

Discharging A Battery At A Certain C-Rate?

- “0.1C” means “0.1 x C”…C is the Ah capacity
- Now look at an example of a 100Ah battery and a rate of 0.1C for the discharge rate
- 0.1 x 100 Ah(C) = 10 amps is the 0.1C rate or C/10
- 0.2C (20% of C) rate would be 0.2 x 100Ah = 20 amps (C/5)
- Battery discharge C-rates on a **battery discharge characteristics chart**

Discharge Characteristics



Battery Cutoff Voltage

- Our 12 volt lead acid batteries also have a “Cutoff voltage” which if the battery is taken below this voltage, can result in damage to your battery
- The cutoff voltage is actually higher when lower discharge rates are being used because the active materials in the battery have been efficiently used
- The dotted line at the end of each of the represented discharge curves, in the earlier slide, is the battery cutoff voltage

Lead-Acid Battery Discharge Info

- The faster you drain a battery, the less overall amp-hours are available
- How many amp-hours you will get depends on the **load**, **ambient temperature, age** of your battery and your **state of charge**
- There is parameters used for how you get to publish a certain battery "**amp-hour rating**"
- Deep cycle batteries are usually discharged with a constant load over a **20 hour period** to get their rating

C-Rate And Time With A 55Ah AGM Battery And Voltage > 11.7 Volts

C Rate	Constant Amperage	Time with battery = or > 11.7 volts
2C	110 amps	~ 2 minutes
1C	55 amps	~ 15 minutes
.628C	34.5 amps	~ 25 minutes
.4C	22 amps	~ 60 minutes
.207C	11.4 amps	~ 2.5 hours
.093C	5.1 amps	~ 7 hours
.05C	2.75 amps	~ 15 hours

Battery Capacity Misunderstandings On The Internet

My 100Ah lead-acid battery will provide **100 amps** for 1 hour to my radio station? False, more like **14 minutes** above 11.7 volts

My 100Ah lead acid battery will provide **40 amps** for 2.5 hours to my radio station? (40 x 2.5 = 100) False, more like around **60 minutes** above 11.7 volts

A Different Way To Visualize A Battery

As mentioned, some people think of their battery like they do a 5 gallon bucket of water, they just keep "pouring out" the power till all the energy is gone

Oh, I have 11.7 volts still, I can just keep running my battery down until I have 5 volts, and then stop discharging the battery? Right?

I would like propose that you think of your battery like you do a water tower

Think Of A Battery Like You Do A Water Tower

- Water tower at 130’ with every 2.31 feet = 1 psi of water pressure, 130/2.31 = 56 psi static pressure
- Bottom of the water tank is 110’ or (110/2.31 = 48 psi of water pressure)
- (This example does not include the “water tank” sitting on the ground, up on a hill above the local population)…so our water system “gravity only” water tower looks like a “**mushroom**” in our neighborhood

Water Tower Example

- Think of elevation as voltage in this example
- Once you drain the **water tank down to the bottom** of the tank high above you, the **pressure drops dramatically**, as you are now draining the water from the **vertical supply pipe** in the center of the structure

Water Tower Example

- Your battery starts out at 12.6 volts (130’), it slowly drops in voltage till about 10.5 volts under load (110’, bottom of the water tank)
- **Then it drops like a rock** (tiny amount of water in the vertical supply pipe)
- If you stop the load at 10.5 volts, as the battery comes to rest, the voltage will rise back up to about 11.7 volts

Battery Discharge Voltage Sag At The Battery Terminals

- As we deplete the battery, the battery terminal voltage will sag lower and lower each time we key the mic
- That 12.6 volt battery under load can drop below the minimum voltage for the radio, unless we have a **big enough Ah** rating for our battery, or use **less power** on the radio, or have **larger size wire** or **shorter power cable** length

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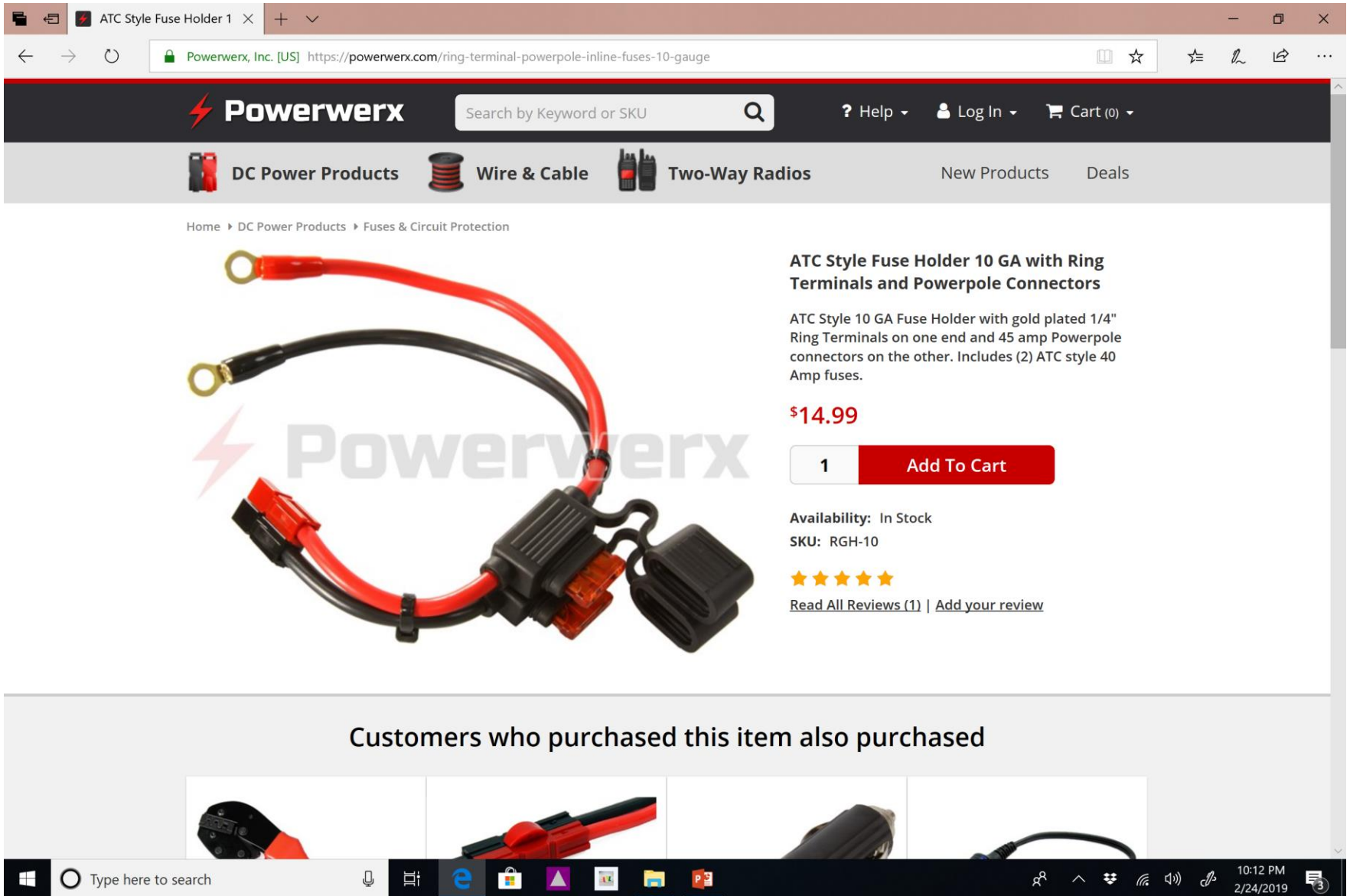
Battery Voltage Drop In The Power Cable And A Fuse For Safety

- The **size** and **length** of your **power cable** from the battery to the radio impacts voltage drop
- It is best if you can have a **fuse** about 6” from your battery
- Recommend using a **short length of #10 stranded wire with an inline fuse** for your battery cable, like the Powerwerx RGH-10

55Ah Deep Cycle AGM Battery With Short Inline #10 Fused Power Cable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Power Cable Voltage Drop (Vdrop)

- Does your power cable size and length make that much of a difference?
- Voltage of your battery **= 12.5 volts**
- Radio load on high power = **22 amps**
- **Power cable,** battery to the radio = **6 feet**
- This example would be for a long haul HF radio station in the field
- How much Vdrop with a 22 amp load?

High Power HF Field Station Vdrop Example

- Six foot distance from the battery to the 22 amp load with **#14g wire**, **Vdrop = 0.66v**
- Six foot distance from the battery to the 22 amp load with **#12g wire**, **Vdrop = 0.42v**
- Six foot distance from the battery to the 22 amp load with **#10g wire**, **Vdrop = 0.29v, much less resistance**

High Power VHF Field Station Vdrop Example

- Battery voltage = **12.5 volts**
- Radio load = **10 amps** on the high power setting
- Distance of the power cable from the battery to the radio = **6 feet**
- Will there be much Vdrop still?

High Power VHF Field Station Vdrop

- Six foot distance from the battery to the **10 amp** load with **#14g wire**, **Vdrop = 0.30v**
- Six foot distance from the battery to the **10 amp** load with **#12g wire**, **Vdrop = 0.19v**
- Six foot distance from the battery to the **10 amp** load with **#10g wire**, **Vdrop = 0.12v**
- Does not include losses from PP connections

My Radio Came With A 10’ Power Cable

- Your OEM 10’ radio power cable is designed to hook up to a car battery/power supply operating at around 13.8 volts, **not a stand alone battery during off-grid operations**
- 10’ run of **14 AWG** wire at **8 amp load, Vdrop = 0.40v**
- 10’ run of **10 AWG** wire at **8 amp load, Vdrop = 0.16v**
- 4’ run of **10 AWG** wire at **8 amp load, Vdrop = 0.064v**

Use A Different Power Cable For Your Radio When Doing Portable Operations

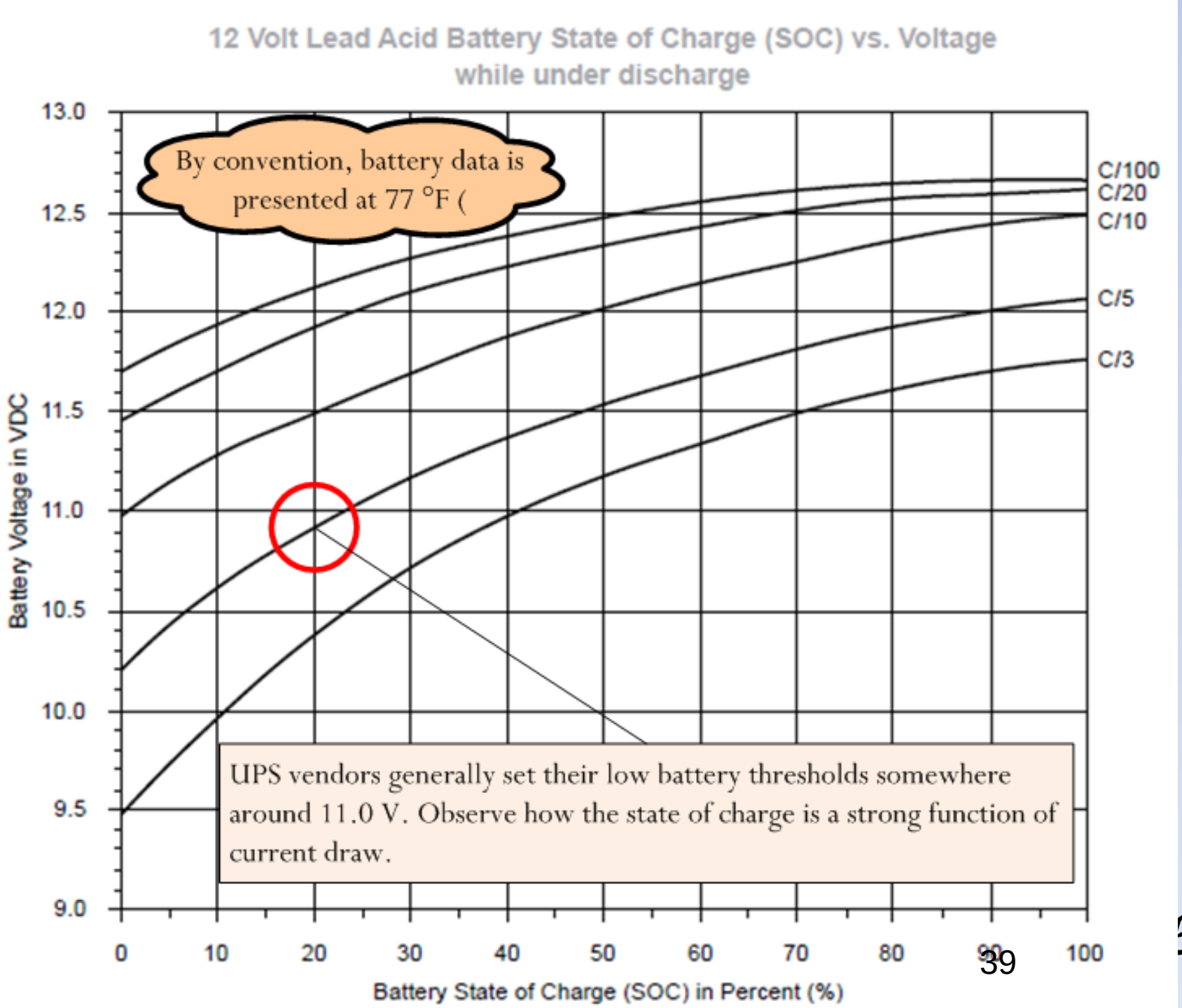
- Recommend you calculate the voltage drop for your radio…choose a shorter power cable with 10 gauge wire
- http://www.calculator.net/voltage-drop-calculator.html

Typical mobile radio loads are:

- 8-12 amp load should provide about 50 watts of FM power
- 6.5 amp load should provide about 25 watts of FM power
- 5 amp load should provide about 10-20 watts of FM power

Battery SOC And Voltage While Being Discharged At Different C-Rates

- It would be nice if we could have a chart that shows what our **voltage** would be as it relates to **battery SOC** and the amount of **load** we have on the battery
- The next chart shows all three
- Note that a C/5 load at 60% SOC shows a voltage of about 11.7 volts, if I limit my transmit amps to C/5 or 20% of the Ah of my battery, my radio should operate ok if I keep the battery above 60% SOC


12 Volt Lead Acid Battery State of Charge (SOC) vs. Voltage
while under discharge
By convention, battery data is
presented at 77 °F (
C/100
C/20
C/10
C/5
C/3
UPS vendors generally set their low battery thresholds somewhere around 11.0 V. Observe how the state of charge is a strong function of current draw.
Battery Voltage in VDC
13.0
12.5
12.0
11.5
11.0
10.5
10.0
9.5
9.0
0
10
20
30
40
50
60
70
80
90
100
Battery State of Charge (SOC) in Percent (%)

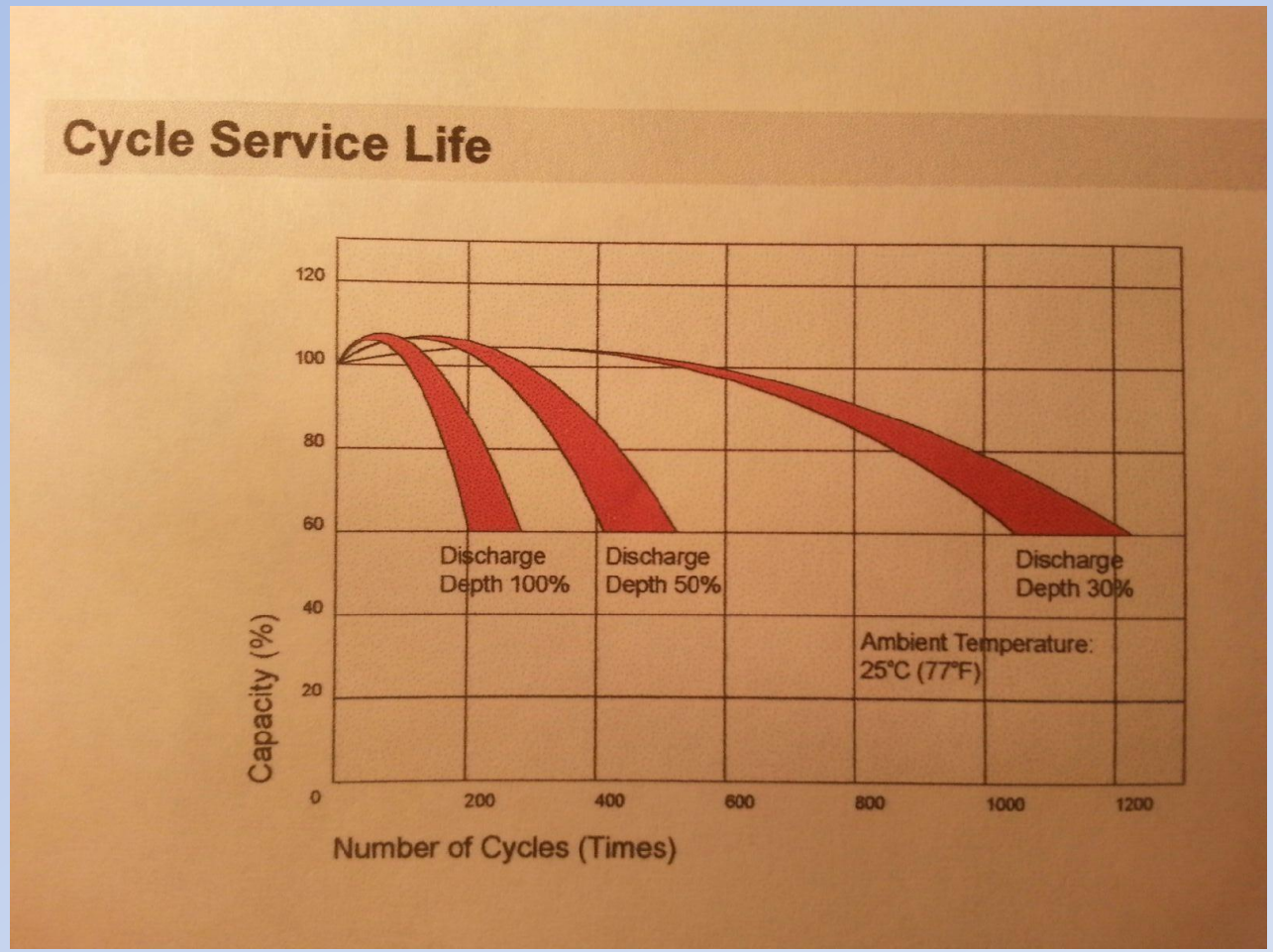
55 AH Battery SOC and Radio Power Example (Voltage > 11.7v)

Load as AH fraction	Load in amps % of Ah C-Rate	SOC % with Voltage > 11.7 volts	Battery power will support
C/3 or 55Ah/3	18.3 amps 33% or 0.33C	Battery SOC ~ 92% or greater	HF 100 watt radio?
C/5 or 55Ah/5	11 amps 20% or 0.2C	Battery SOC ~ 60% or greater	Mobile radio High power (50 watts)
C/10 or 55Ah/10	5.5 amps 10% or 0.1C	Battery SOC ~ 32% or greater	Mobile radio Medium power (20 watts)
C/20 or 55Ah/20	2.75 amps 5% or 0.05C	Battery SOC ~ 10% or greater	FTM 100 low power FTM 400 low power FT-7900 low power

Radio Transmit Current Examples For Reference

FT-7900 Tx AMPS/WATTS RF	FTM 100 Tx AMPS/WATTS RF	FTM 400 TX AMPS/WATTS RF	TM-V7 Tx AMPS/WATTS RF
VHF 2.4 A / 5 W	VHF 2.5 A / 5 W	VHF 2.7 A / 5 W	VHF 3.2 A / 5 W
VHF 3.1 A / 10 W	VHF 4.5 A / 20 W	VHF 4.9 A / 20 W	VHF 4.5 A / 10 W
VHF 4.2 A / 20 W	VHF 9.0 A / 50 W	VHF 9.4 A / 50 W	VHF 8.6 A / 50 W
VHF 7.9 A / 50 W	UHF 2.2 A / 5 W	UHF 3.1 A / 5 W	UHF 3.0 A / 5 W
	UHF 4.0 A / 20 W	UHF 5.5 A / 20 W	UHF 4.2 A / 10 W
	UHF 6.8 A / 50 W	UHF 9.2 A / 50 W	UHF 7.4 A / 35 W
Receive 0.3 amps	Receive 0.28 amps	Receive 0.48 amps	Receive 0.52 amps

Battery Life Is Quoted In Cycles Versus Years



Rule Of Thumb…Lead-Acid Battery Discharge Info

- **Plan to use the top 50% of your lead-acid battery during portable operations**
- Example…**35Ah battery** x .5 (50%) = 17.5Ah available for your operations
- Think of this as how much energy you have in the battery bucket that is "**available energy**", assuming a fully charged, newer battery, and not cold

Rule Of Thumb…Lead-Acid Battery Peak Transmit Current

- **Limit your peak transmit amps to 20% of the capacity of your lead-acid battery**
- Example…**35Ah battery** x .2 (20%)= 7 amps
- 7 amps could provide **medium power** for a VHF mobile radio
- Know your amperage load for each power setting on your radio
- Peak amps = your highest transmit amps you will use

Need More Power?

- You can connect two lead-acid batteries together of the **same age** and **Ah rating**
- Two 55 Ah batteries is easier to move than one 100 Ah battery
- They both must be the same SOC when connected
- Parallel connection is where you connect the positive to positive and negative to negative of your batteries
- **Parallel** connection will **double your Ah** and the **voltage** remains the **same**, the weaker battery might “loaf” slightly

Connecting Batteries Together For More Current…Parallel Connection

- Cross connect the **positive** battery terminal on a **first** battery to the **positive** battery terminal on a **second** battery
- Cross connect the **negative** battery terminal on a **first** battery to the **negative** battery terminal on a **second** battery

Connecting Batteries Together For More Current…Parallel Connection

- With the cables that go to your load, attach the positive lead to the positive terminal of a **first** battery
- Then attach the negative lead to the negative terminal of your **second** battery

Second Method To Parallel Two Batteries

- Just connect both batteries side by side to a distribution block with Anderson PP connectors
- Would plan to have solar and battery connections closer to each other on the distribution block

Connecting Batteries Together For Higher Voltage…Series Connection

- Series connection is cross connecting a **positive terminal** on one battery to the **negative terminal** of a second battery, **just one cross connection**, power cables connect to the open terminals
- Series connection will **double your voltage** and you have the **same Ah rating**, both batteries will "work" at full efficiency
- **Batteries must have the same SOC**, otherwise overdischarge/overcharging can happen on one of the batteries

Series Connection Of Two Batteries

- Cross connect the **positive** terminal of a **first** battery to the **negative** terminal of a second battery
- With the cables that go to your load, attach the **positive** lead to the positive terminal of the **second** battery
- Then attach the **negative** lead to the negative terminal of your **first** battery
- Never cross the remaining “+” and “-” = short circuit

No Disaster Today, The Grid Power Is Working, And I Want To Charge My Battery

- All **lead-acid** battery charging should be done in three stages, **bulk** charging phase, **absorption** charging phase and **trickle** charge phase
- You want a battery charger that does all three
- **Avoid** charging your battery with an **automotive constant output** (example 5 amp output) **charger,** you will kill your battery and it will cost you a lot of money

AC Plug In Battery Charger

Battery Tender Plus

- The Deltran Battery Tender Plus is the best charger I can recommend
- 1.25 amp charger that does temperature compensated “top off” voltage
- 3 stage charger, (technically 4 stage…there is an initial check of the battery when it starts)

Battery Tender Plus For Lead-Acid Batteries

- Constant Current Phase is the “Bulk Phase” = this represents the bottom 80-90% of your battery being charged, constant 1.25 amp charge with rising battery voltage

Battery Tender Plus

- Constant Voltage Phase is call the “Absorption phase”
- The voltage is kept constant, while the current slowly tapers down as the battery is slowly accepting additional charge
- By capping the voltage at a certain point, this helps prevent gassing of the electrolyte in the battery into Hydrogen and Oxygen

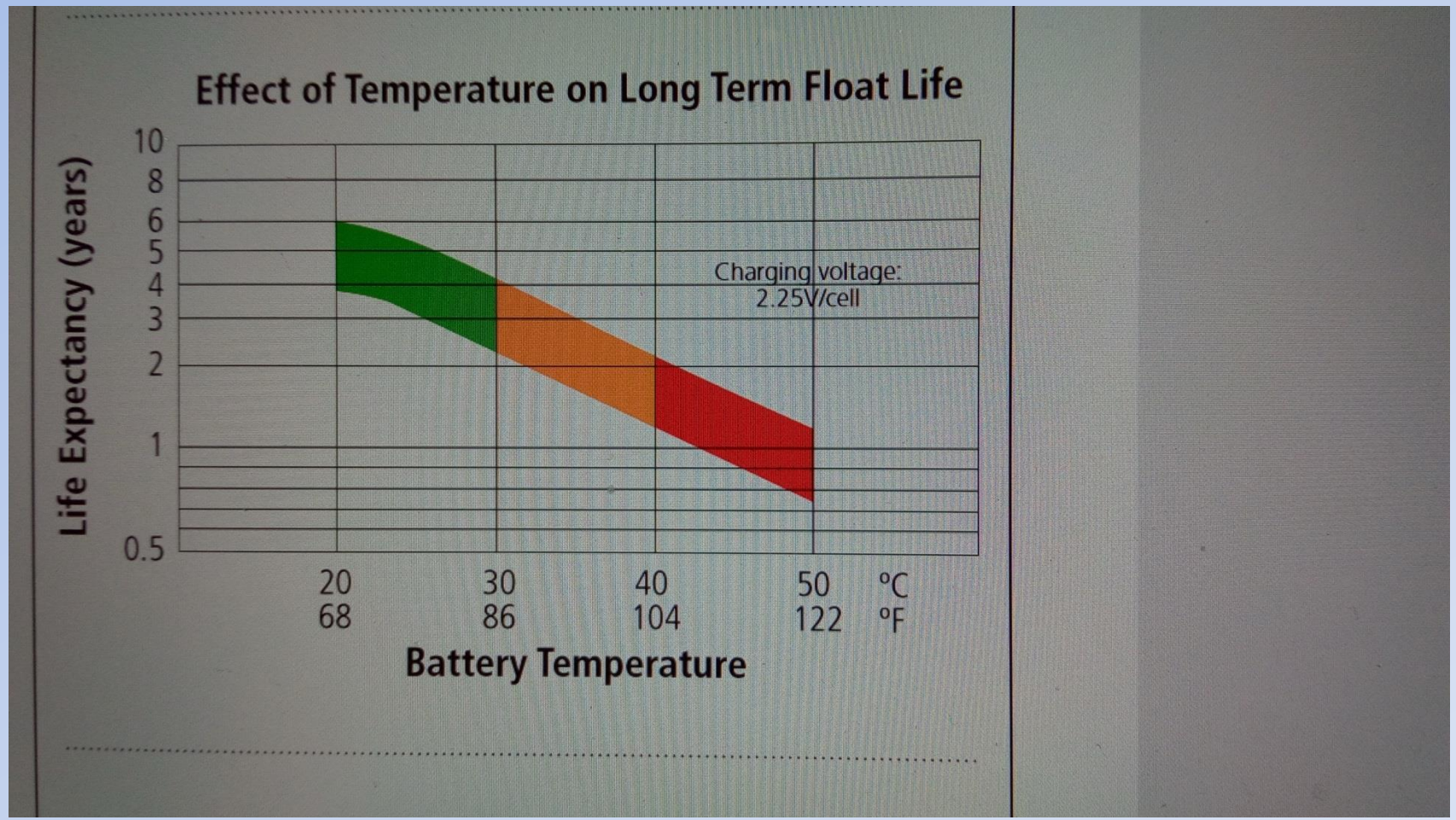
Battery Tender Plus

- “Trickle Charge Phase”, will provide some charge as needed to keep the battery topped off, holds at a constant 13.2 volts
- This charger appears to be the most widely recommended in my literature search

What Your Lead-Acid Battery Wants You To Know

- **Constant Heat** kills lead-acid batteries…you loose 50% capacity for every 15 degrees above 77 degrees F that your battery is continuously stored, could be an issue in your vehicle during summer time
- **Cold** just temporarily reduces available lead-acid battery capacity, more capacity is chemically available once the battery temp rises

Effects Of Long-Term Temp Exposure On Lead-Acid Battery Life



What Your Battery Wants You To Know

- Charging your battery **without** some type of controller, you will most likely **overshoot** the voltage and fry your battery, risk thermal runaway
- Charging your battery with a “cheap trickle charger” could kill/cook your battery because they do a poor job of regulating the voltage
- Battery voltage can slowly rise well above the gassing voltage

Things That Could Hurt You

- **Thermal runaway** is a condition that most often happens in SLA batteries in which the battery temperature increases rapidly resulting in extreme overheating of the battery
- This condition can occur if the battery is at high ambient temps and/or the charging voltage is set too high
- Battery internal resistance lowers when battery temperature rises, more current can then flow into the battery, causing the battery temperature to rise further

Thermal Runaway

- Poorly regulated charge brings the battery voltage to an upper limit and the **electrolyte** begins to boil away, temperature in the battery rises, once the electrolyte is boiled away, the battery temp can climb further to the point of melt down and possible fire
- Keep the battery out of direct sun when used on a very hot day and use a charge controller to avoid this problem

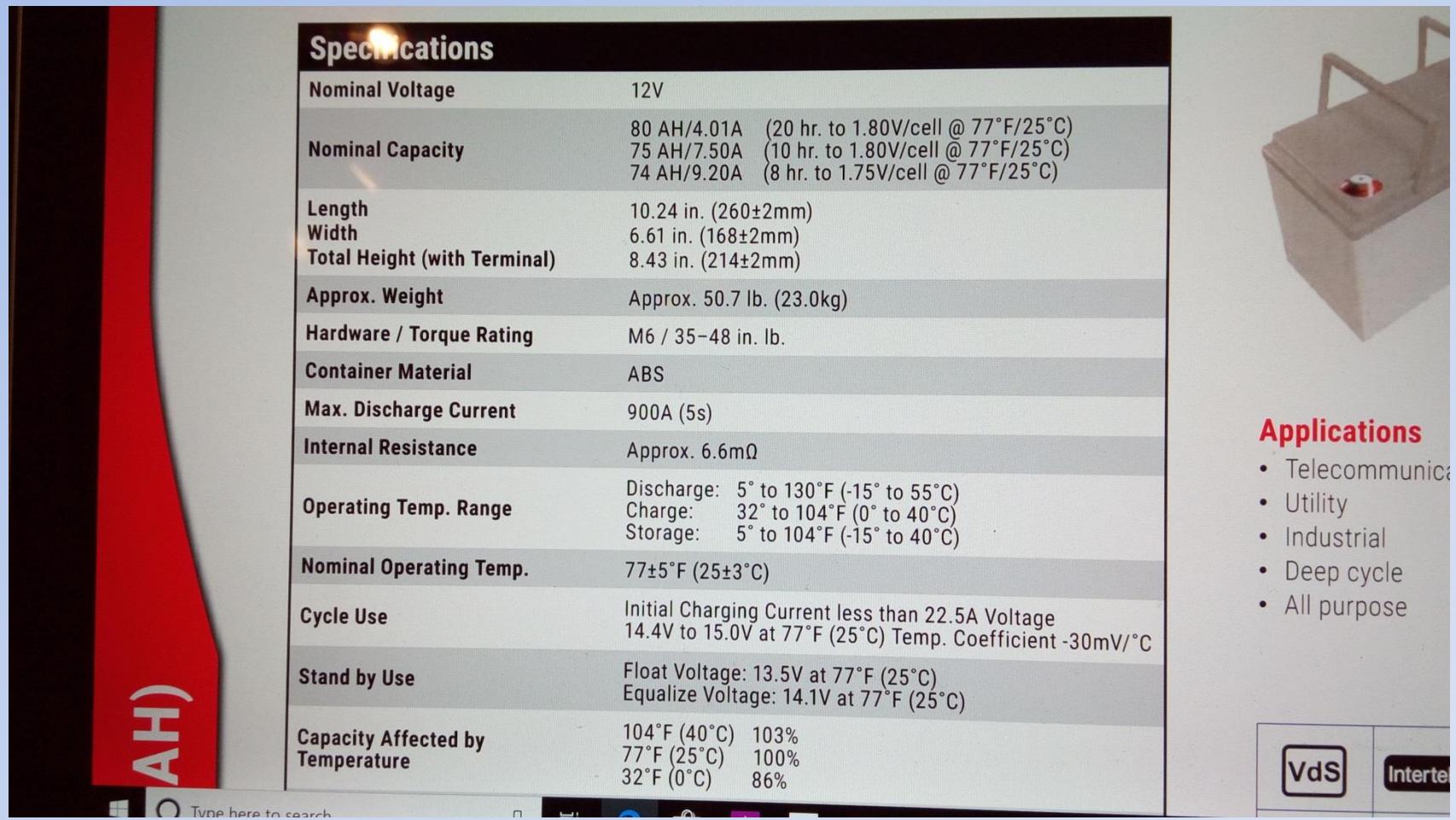
Something Else That Could Hurt You

A number of lead acid batteries have very low internal resistance and therefore are capable of delivering high currents if the battery terminals are shorted

The heat resulting from a **short circuit** could cause severe burns and be a potential fire hazard

Always have a fuse between the battery and your equipment

80Ah Lead-Acid Deep Cycle AGM Battery Specifications…Note Max Discharge Current



Specifications	
Nominal Voltage	12V
Nominal Capacity	80 AH/4.01A (20 hr. to 1.80V/cell @ 77°F/25°C) 75 AH/7.50A (10 hr. to 1.80V/cell @ 77°F/25°C) 74 AH/9.20A (8 hr. to 1.75V/cell @ 77°F/25°C)
Length Width Total Height (with Terminal)	10.24 in. (260±2mm) 6.61 in. (168±2mm) 8.43 in. (214±2mm)
Approx. Weight	Approx. 50.7 lb. (23.0kg)
Hardware / Torque Rating	M6 / 35–48 in. lb.
Container Material	ABS
Max. Discharge Current	900A (5s)
Internal Resistance	Approx. 6.6mΩ
Operating Temp. Range	Discharge: 5° to 130°F (-15° to 55°C) Charge: 32° to 104°F (0° to 40°C) Storage: 5° to 104°F (-15° to 40°C)
Nominal Operating Temp.	77±5°F (25±3°C)
Cycle Use	Initial Charging Current less than 22.5A Voltage 14.4V to 15.0V at 77°F (25°C) Temp. Coefficient -30mV/°C
Stand by Use	Float Voltage: 13.5V at 77°F (25°C) Equalize Voltage: 14.1V at 77°F (25°C)
Capacity Affected by Temperature	104°F (40°C) 103% 77°F (25°C) 100% 32°F (0°C) 86%

Applications
- Telecommunica
- Utility
- Industrial
- Deep cycle
- All purpose

Shorting The Battery Terminals

- The 80Ah lead-acid battery in the previous slide can deliver a “max. discharge current” of 900 amps for up to 5 seconds
- Do not let your screwdriver land next to your battery terminals and turn it into a molten mess, plus, if hydrogen gas is present, could cause an explosion

Release Of Ignitable Gasses

- VRLA batteries produce **Hydrogen** and **Oxygen** while being charged (Valve Regulated Lead Acid)
- The valves keep a slight positive pressure in the battery
- VRLA batteries do not recombine 100% of the gasses, a small amount of hydrogen and oxygen are released from the one-way pressure relief valve
- Sealed batteries keep oxygen out of batteries

Release Of Ignitable Gases

- Do not store a flooded or VRLA batteries in a completely sealed or airtight container because hydrogen can ignite at concentrations as low as 4%
- Hydrogen is a colorless, odorless gas. Human senses cannot detect it
- Electrical energy in excess of what is needed for the chemical reaction, decomposes the water of the electrolyte into oxygen at the positive plates and hydrogen at the negative plates

Flooded Batteries

- Flooded batteries should be able to vent to outside air due to gassing during charging
- Applies to large flooded battery banks kept indoors

Charging Batteries

- The charging rates depend on the type of chemistry involved
- Three different charge rates
- 1) Ideal charge rate
- 2) Fast charge rate
- 3) Max charge rate…the sun is going to go down soon and this is the fastest rate I can apply a charge current safely

Type Of Lead Acid Battery By Application

- 1) Starter Battery
- 2) Marine Battery
- 3) Deep Cycle Battery

Type Of Lead Acid Battery By Application

- The batteries differ mainly due to plate thickness and number of “plates” used inside each cell
- Six battery compartment cells for a 12 volt battery
- ~2.1 volts per cell x 6 = 12.6+ volts and several plates per cell
- The deeper you discharge a battery, the more the “plates” want to bend and flex, further discharging and the plates begin shedding material

Starter Battery

- These are the batteries you find in cars and riding lawn mowers
- They have many thin “plates” which allow a lot of amperage draw, but only over a short period of time
- They should not be discharged more than 20% or they will be damaged
- Overdischarge causes the thin foam like plates to become consumed and fall to the bottom of the battery

Starter Battery

- Can be used for portable daytime operation during an emergency, if you keep them charged while using them
- This is a battery that I would use during an emergency, but **not** a battery that I would **buy** to **prepare** for an emergency
- Used in a deep cycle application, can fail after about 30 cycles
- What if I **had** to use a starter battery?

Starter Battery Use During An Emergency

- Think Cascadia Subduction Zone type earthquake
- Road network not passable due to bridges out and roads damaged or blocked by slides
- There should be automotive 12 volt batteries all over the county
- If you can hike or bike into a damaged area with a 12 volt foldable solar panel, you can use these batteries all day long while in the sun

Starter Battery Use During An Emergency

- Typical small car battery is about 45 Ah
- Plan to use the top 20% or 45Ah x .2 = 9 Ah
- Situation…it is daytime and you have backpacked into an area to assist with comms with your foldable solar panel, mobile VHF/UHF radio, Watts Up meter, charge controller and mag mount antenna + alligator clips with ATC fuse to powerpole connector
- In this location you only have access to car batteries

Starter Battery Use During An Emergency, Backpack Radio

- Using an efficient mobile radio like the FTM 100 radio
- You plan to talk 20% of the time and listen 80% of the time using **medium power**
- Transmit is 20W = 4.5 amps, so 4.5 amps x .2 = .9 amp load
- Receive = .30 amps x .8 = .24 amp load

Starter Battery Use During An Emergency

- Total overall average load per hour is .90 + .24 = 1.14 amps
- Foldable 50 watt solar panel output is ~> 2 amps
- Battery should stay topped off all day if sunny
- Need to use more amps, parallel like sized starter batteries and provide more solar power

Charging A Lead-Acid Car Battery

- You can charge a starter battery at about 10% to 20% of the rated capacity or .1C to .2C
- If the car battery is about 50Ah, your charge current can be 5-10 amps
- However, if you parallel 2-3 like size car batteries, you can use more charge current to support a higher discharge load

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Starter Battery Use During An Emergency

- After dark, nighttime operations might slow down?
- Plan might be to talk about 10% and listen about 90% of the time
- 20 Watt Tx = 4.5 amps…**medium power** VHF
- Tx 4.5 amps x .1 = 0.45 amps…talking 10% of the time
- Rx = 0.30 amps x .9 = 0.27 amps…listen 90% of the time

Starter Battery Use During An Emergency

- 0.45 + 0.27 amps = 0.72 overall average amp load per hour
- 9Ah (single FLD Battery) useable battery capacity / 0.72 Avg amps = potential of 12.5 hours of operation after dark on medium power talking 10% of the time
- Then after sunrise the next morning, start charging the battery up for another day of operation
- Remember to calculate round trip efficiency

Round Trip Efficiency Calculations

- If your lead-acid battery is fully charged and you discharge it once in the field and then return home to fully charge the battery, no round trip efficiency calculation is a concern
- However, if you plan to recharge your battery day after day with solar power, **plug in the round trip efficiency into your daily power calculations…up to 20% loss**
- Day 1 you show 14Ah removed, then 14Ah x 1.2 = 16.8Ah
- Recharge of the battery the next day could need up to 16.8Ah to reach a full charge on your lead-acid battery

Marine Battery

- The battery “plates” are **thin enough** to start a boat engine
- The battery “plates” are **thick enough** to have a greater depth of discharge than a starter battery
- These are a **hybrid battery**, not a true deep cycle battery
- In a deep cycle application, good for about 300-400 cycles

Marine Battery

- This is a compromise battery for our purposes
- Once again, this is a battery that I would use during an emergency, but **not** a battery that I would **buy** brand new to **prepare** for an emergency
- If someone offered a “like new” one for an unbelievable price, and I had the space to store it, I could be tempted, till I had more deep cycle batteries on hand

Deep Cycle Battery

- These batteries have the thickest plates
- DOD – Depth Of Discharge can be as low as 80%
- They are **not** designed to provide as much amperage for starting an engine
- The plates are solid versus being like a sponge
- It is recommended that you only **discharge your deep cycle batteries down to 50% and no more, unless the emergency calls for deeper discharge**

Construction Types Of Deep Cycle Batteries

- 1) **FLOODED**
- 2) **GEL CELL**
- 3) **AGM (Absorbed Glass Mat)**

Flooded Lead-Acid Battery

- Requires a higher charge “top off” voltage and also needs an equalization charge about every 30 days or so due to stratification if in constant use
- Filled with 65% distilled water and 35% sulfuric acid
- Can spill acid if tipped, use ammonia to neutralize

Flooded Lead-Acid Battery

- Cheaper to buy, but more maintenance issues, they gas while charging and need water replacement from time to time
- OK, but not recommended
- Self discharge is up to 15% per month

Gel Cell Batteries

- Very sensitive to overcharge
- Needs a lower charge “top off” voltage and in fact, many chargers will slightly over charge these batteries and they will lose capacity sooner than normal
- Lower charge rates…recombination of gases during charging occurs at a much slower rate because of the highly viscous electrolyte
- Typical charge rate C/20

Gel Cell Batteries

- Charge too fast… gas pockets will form on the plates and force the gel electrolyte away from the plate, decreasing capacity and the damage does not heal
- Output less power, AGM battery will output greater power
- If we are given one, ok, would not buy new
- Risk of undercharging this battery during an emergency due to the very slow charge rate it requires

AGM Batteries

- Absorbed Glass Mat (AGM)
- Uses fiberglass or polyester mat separators between the lead and lead dioxide plates
- The battery is filled to 95% of total absorption with electrolyte solution

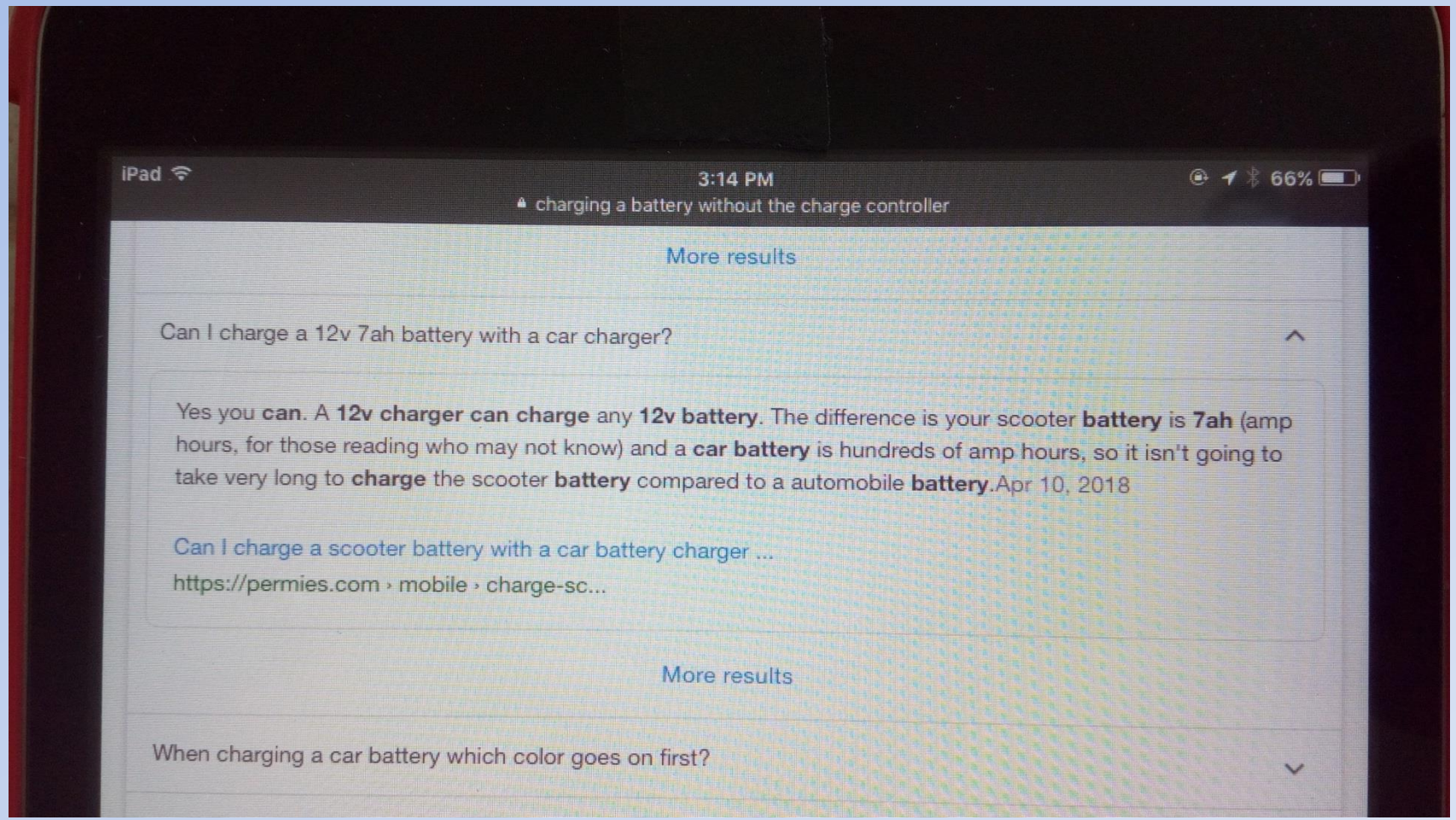
AGM Batteries

- Safer, no acid spill out when tipped
- Do not need watering, they are sealed
- Self discharge is about 3% per month
- Follow manufacturers recommendations on how often the battery should be charged while in storage

Charging AGM Batteries

- This is the **best lead-acid** battery for **portable** operations
- Remember **C** = Battery **C**apacity in amp-hours
- AGM battery **ideal charge current** is C/10
- AGM battery **fast charge current** is C/5
- **Some** AGM batteries have a **max charge rate** of C/3
- AGMs not subject to stratification, but are subject to sulfation if not fully charged after use

Incorrect Battery Charging Information On The Internet



Please Share The Correct Information

- A “12 volt charger” for a car is **not ok** for “any 12 volt battery”
- 7Ah lead-acid battery **ideal charge current** is C/10 or 7Ah/10 = 0.7 amps
- 7Ah lead-acid battery **fast charge current** is C/5 or 7Ah/5 = 1.4 amps
- A “Car battery” is not “hundreds of amp-hours”, but more like about 45Ah

Lead-Acid Battery Profiles

18Ah Lead-Acid Battery At Batteries Plus

Info About The **18Ah** SLA AGM Battery

- Weight = 12.4 Lbs
- Price at Batteries Plus = $60
- Available **energy** at 50% DOD = **9Ah**
- Recommended **peak load** amps = 18/5 = **3.6 amps**
- Recommended **amps** for **fast charging** 18/5 = **3.6 amps**, (C/5), **ideal charging** = 1.8 amps (C/10)
- DOD = Depth Of Discharge, SLA = Sealed Lead Acid

Info About The **18Ah** SLA AGM Battery

- Radio station example FT-7900
- Rx = 0.3 amps on receive
- Tx 3.1 amps at **VHF 10 watts** FM output (**Low Power**)
- Tx 10% and Rx 90%...talk 10% of the time

Info About The **18Ah** SLA AGM Battery

- Tx 3.1 amps x .1 = 0.31 amps…talk portion 10%
- Rx 0.3 amps x .9 = 0.27 amps…receive portion 90%
- 0.31 + 0.27 = 0.58 average amps per hour load
- Available Ah at this C-rate is ~40% x 18Ah = 7.2Ah
- 7.2Ah/0.6 <~ **12 hours** with perfect conditions?

35Ah Lead-Acid AGM Battery At Batteries Plus

Info About The **35Ah** SLA AGM Battery

- Weight = 24.75 Lbs
- Price at Batteries Plus = $95
- Available **energy** at 50% DOD = 35/2 = **17.5Ah**
- Recommended **peak load** amps = 35/5 = **7 amps (pull) down to 40% DOD…C/5 rate**
- Recommended **amps** for **fast charging** = 35/5 = **7 amps (push)**
- **Ideal charging** rate is C/10 or 3.5 amps

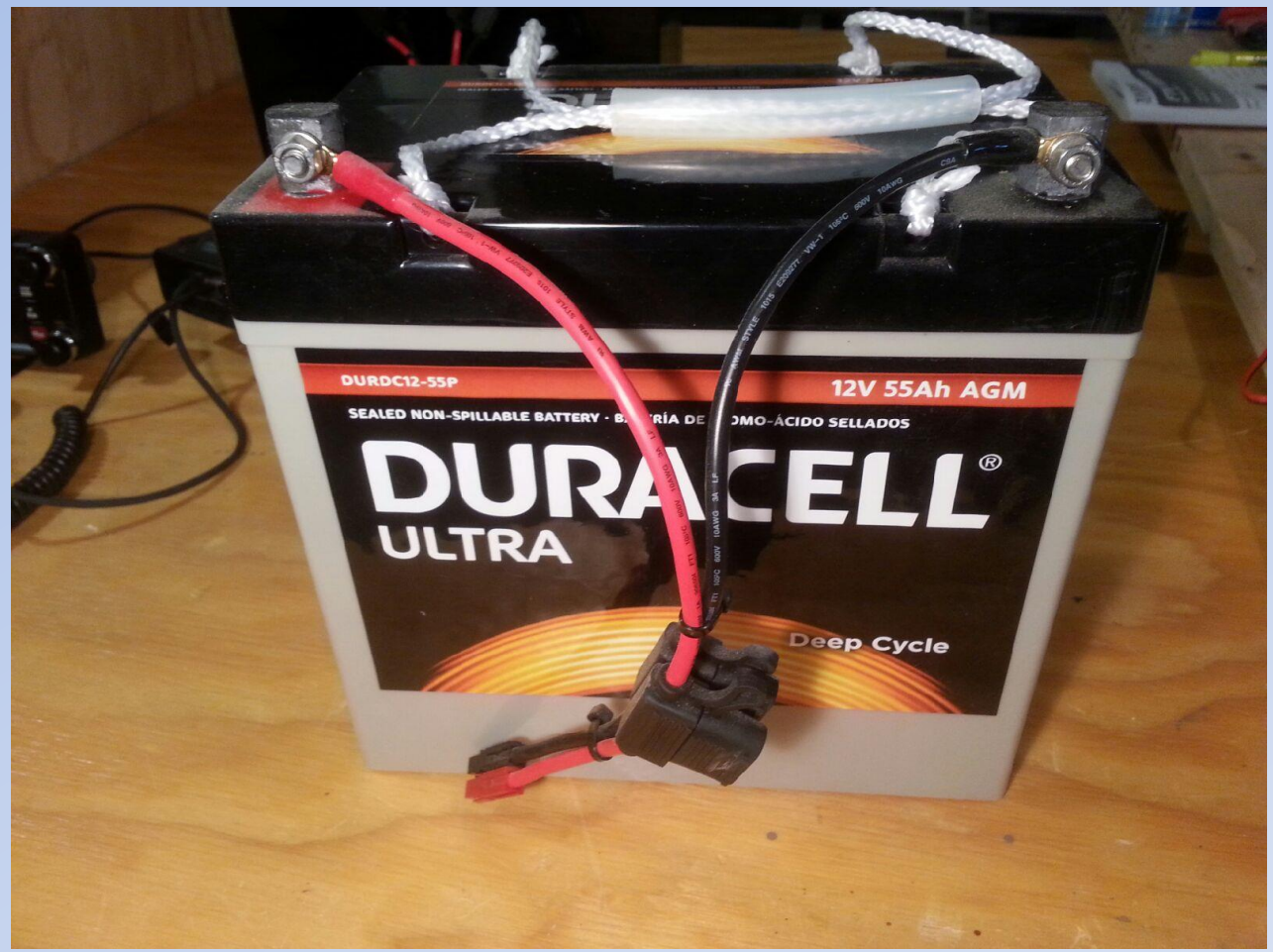
Info About The **35Ah** SLA AGM Battery

- Radio station example FT-7900
- Rx = 0.3 amps
- Tx = 4.2 amps (35Ah/4.2 =8.3 or C/8.3 rate) **VHF 20 watts** FM output (**Medium Power**)
- Tx 10% is peak load and Rx 90% is base load

Info About The **35Ah** SLA AGM Battery

- Tx 4.2 amps x .1 = 0.42 amps…talk portion
- Rx 0.3 amps x .9 = 0.27 amps…receive portion
- 0.42 + 0.27 = 0.69 average amps per hour load
- 17.5Ah/0.7 amps up to ~**25 hours** in perfect conditions

Example Of 55Ah Deep Cycle Battery For Portable Operations



55Ah Lead-Acid AGM Battery At Batteries Plus

Info About The **55Ah** SLA AGM Battery

- Weight = 42.3 Lbs
- Price = $160
- Available **energy** at 50% DOD = 55/2 = **27.5Ah**
- Recommended **peak load** amps = 55/5 = **11 amps down to 40% DOD…C/5 rate**
- Recommended **amps** for **fast charging** = 55/5 = **11** amps
- **Ideal charging** is about C/10 = 5.5 amps

Available Energy Versus Your C-Rate

- The 55Ah AGM battery has about 27.5Ah of available energy if you plan to just use the top 50% of the battery
- However, you can not expect to transmit on high power(C/5) all the way down to 50% DOD…see slide 39
- Perhaps you can **use full power down to 40% DOD**, **then reduce power** to keep your battery voltage above 11.7 volts

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55Ah AGM Battery Discharge With Your Radio On High Power (C/5)

- Radio station example, your generic **dual band** mobile radio Tx on **VHF HIGH POWER** draws **11 amps (C/5)** and **Rx** draws **0.5 amps**, you Tx 10% and Rx 90% of the time
- Tx 11 x .1 = 1.1 amp…transmit portion
- Rx 0.5 x .9 = .45 amp…receive portion
- 1.1 + 0.45 = **1.55** average amps per hour load

55Ah AGM Battery Discharge With Your Radio On High Power (C/5)

- 55Ah x .4(40% DOD) = 22Ah available energy at C/5 rate
- Full power max hours of operation would probably be near 22Ah/1.55 average load per hour = **~14 hours**
- **Talking 10% of the time per hour**

FT-7900 Radio Power Needs On Low Power

- FT-7900 radio receive current is 0.3 amps
- FT-7900 radio low power transmit current is 2.4 amps
- Plan to transmit 10% and receive 90% of the time
- Rx 90% is 0.3 amps x .9 = 0.27
- Tx 10% is 2.4 amps x .1 = 0.24
- 0.27 + 0.24 = 0.51 overall average amps per hour

55Ah SLA AGM Battery Using Low Power In An Emergency

- **What about LOW power VHF in an emergency?**
- The FT-7900 radio on **low power** transmitting 10% of the time is 0.51 average overall amps per hour
- VHF/UHF log periodic gain antenna
- 27.5Ah / 0.51 amps = up to **54 hours**
- Solar power augmentation was a little spotty
- You did not need much solar power ☺

Anderson PP Connectors

Universal connector for amateur radio

Many different sized connectors, these three sizes all plug into each other

- PP15 – 15 amp under load, 20 AWG to 16 AWG wire
- PP30 – 30 amp under load, 14 AWG and 12 AWG wire
- PP45 – 45 amp under load, 10 AWG wire

New Technology…"Bioenno Power" LFP Batteries…A Game Changer

- How new are LFP batteries? Since about 2009
- Company started in 2010, introduced first LFP batteries to the market in 2012
- 7 years of customer feedback on their product
- Supplies 12 volt LFP batteries for the amateur radio market

Demand Building For LFP Batteries

- Up and coming market is the hybrid solar grid-tie and off-grid backup battery power storage for household storage systems
- Provides some energy security during power failures
- LFP uses stable chemical compounds
- Not the same as Lithium Polymer batteries, the ones you read about 3 years ago that exploded and caused fires

Advantages Of Using An LFP Battery Versus Lead-Acid Batteries

- Lighter weight than lead-acid
- Smaller size for the same amount of energy
- Greater depth of discharge, up to 100% DOD
- Longer lifespan…2,000+ cycles versus about 400-500 cycles with lead-acid batteries (at 50% DOD)
- Relatively flat discharge curve at higher voltages
- Able to provide sustained high current

Advantages Of Using An LFP Battery Versus Lead-Acid Batteries

- Does not vent any flammable gasses
- 95+% efficiency versus about 85% efficiency of lead-acid batteries
- Does not have to be fully charged, **can be partially charged** with no damage or sulfating concerns
- **Charge faster** than lead-acid batteries, no absorption phase, can be charged more quickly while the sun is still shining

Advantages Of Using An LFP Battery Versus Lead-Acid Batteries

- No maintenance issues
- Can safely be used indoors
- More efficient at colder temperatures
- **Tolerates warmer temperatures better** than lead-acid batteries…-10C to 60C or 140 F

What Claims Are Industry Making About The LFP Battery…**Large Household Storage Battery**

- Sony claims their Fortelion LFP battery will have **74% of rated capacity** still after 8,000 cycles with 100% DOD
- Did not see documentation of any tests that operated over 8,000 cycles as proof of claim

Info About The Sony Fortelion LFP Battery

- https://reneweconomy.com.au/tesla-vs-lg-vs-sony-vs-storage-goes-head-to-head-at-new-act-test-centre-57155/
- Battery testing of LFP batteries to include the Sony Fortelion

What Claims Are Industry Making About The LFP Battery…**Large Household Storage Battery**

- Other web pages state the Fortelion LFP battery can do 6,000 cycles at 100% DOD and still have **80% of rated capacity**
- Sony claims a service life of 20 years, for **household power storage**
- These are large and expensive batteries for a house

What Claims Are Industry Making About The LFP Battery…**Large Household Storage Battery**

- "**Simpliphi**" LFP batteries for **household battery** backup solar
- 10,000 cycle life @ 80% DOD
- 5,000 cycle life @ 90% DOD
- 3,500 cycle life @ 100% DOD

Simpliphi LFP Batteries

- 10 year warranty
- Expected life of 15-20 years
- Cycle = one to several times per day

LFP Battery For Amateur Radio By Bioenno Power

- You can plan to use up to 90% of the LFP battery capacity, may use 100% of capacity
- Each Bioenno Power LFP battery has a built in **PCM** or **P**rotection **C**ircuit **M**odule which is a **BMS** or **B**attery **M**aintenance **S**ystem built into the battery
- Lithium batteries need some type of **BMS**

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LFP Battery PCM Functions

- The **PCM** provides five functions
- 1) **Overcharge** protection…will turn off the input source being provided if overcharge condition detected
- 2) **Overdischarge** protection…will turn off the output terminals if the voltage drops too low for the LFP cells
- 3) **Overcurrent** protection…will turn off the connection to the LFP cells if the current is too high

LFP Battery PCM Functions

- 4) Has built in **temperature** protection, if the temp rises too high, will turn off the power into or out of the battery
- 5) Provides **cell balancing**, which is done at the top of the charging cycle

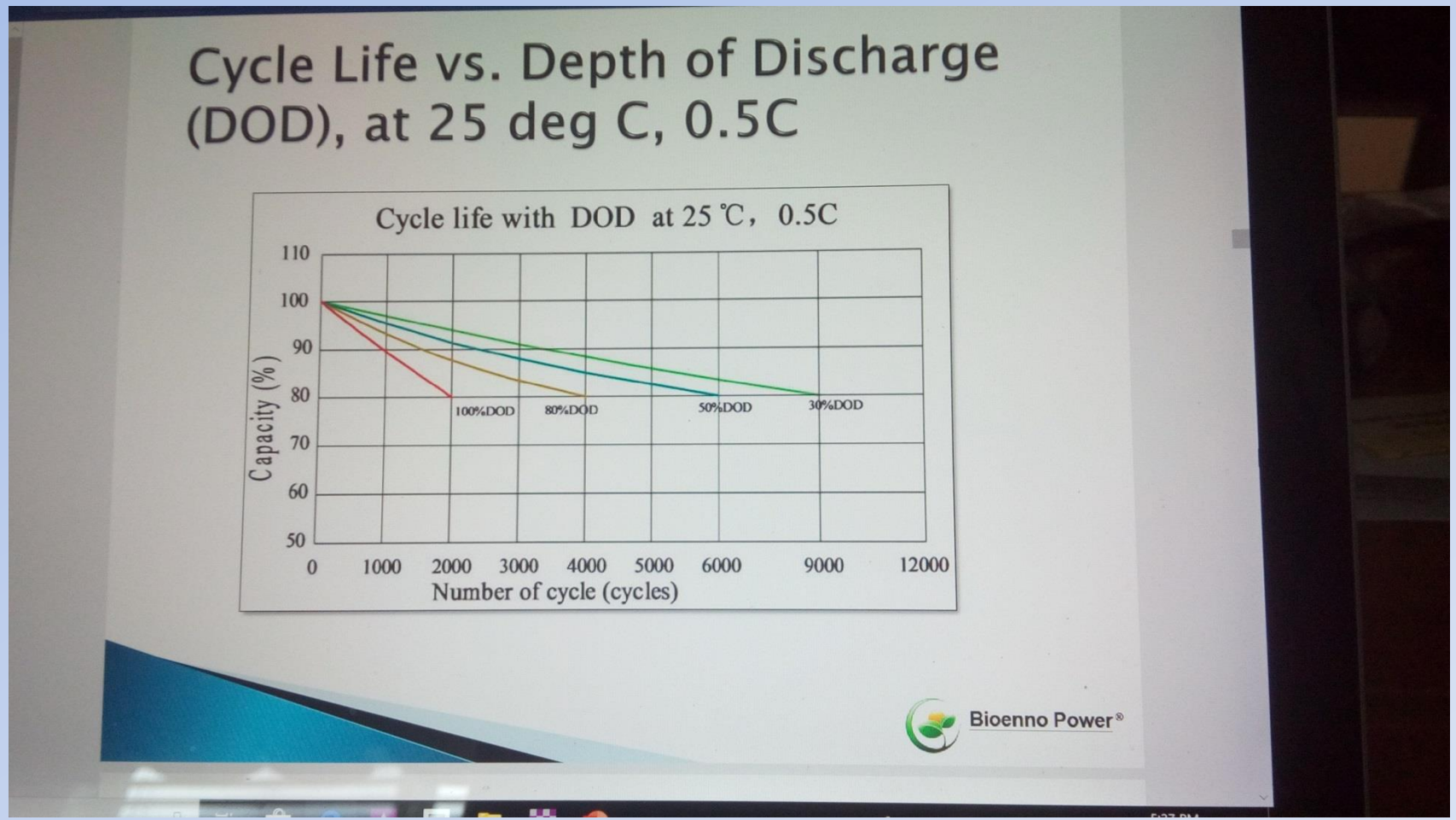
LFP Battery PCM Functions

- **PCM high voltage** disconnect happens at 15.4 volts +/- 0.5 volts
- **PCM low voltage** disconnect happens at 10.0 volts +/- 0.5 volts
- Above is per Bioenno Power representative

Bioenno Power PCM Charge/Discharge Info

- **Charge current** (I use for the LFP battery is typically 0.3C), may go as high as 0.5C before the PCM disconnect happens…**still good for 2,000 cycles per Bioenno Power**
- 30Ah LFP battery typical charging current for me at 0.3C, 0.3 x 30 = 9 amps (120 watts of solar with MPPT)

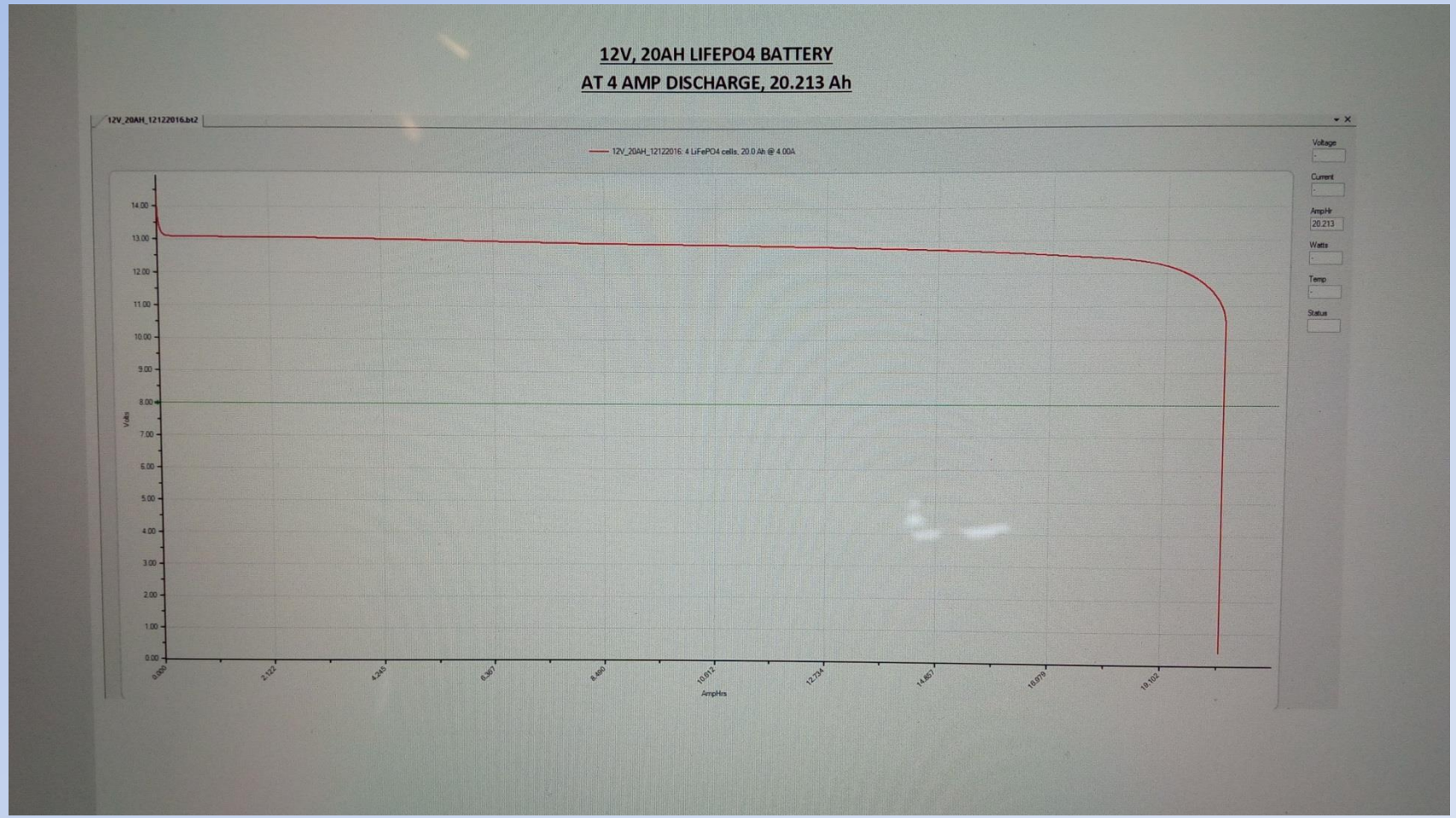
Bioenno Power Presentation Slide On Cycle Life Versus Depth Of Discharge



Bioenno Power LFP Battery Info

- Bioenno Power reports that you can provide a **charge current** on their LFP 12v batteries up to a **max of 0.5C**
- They also report that **each** LFP battery is rated for **different maximum discharge amps** that ranges from **1C to 2C**
- Their batteries are **rated for 2,000 cycles** whether **charged** up to 0.5C or **discharged** at the maximum rated amps and still able to provide 80% of rated capacity after 2,000 cycles
- This information is per their company representative

Bioenno Power 20Ah LFP Battery Discharge Curve With 4 Amp Constant Load



LFP Batteries Have A Two Step Charging Sequence

- **CC**…**Constant Current** charging. Your power source just passes through to the battery
- **CV**…**Constant Voltage** charging. Starts when your wall charger goes from a red light to the constant green light. You are about 95+% SOC and voltage is held at a constant voltage and the LFP cells are now balancing.

LFP Batteries Have A Two Step Charging Sequence

- Once the **green light comes on, wait about 15-20 minutes for the final cell balancing to happen**. You may leave the charger on for several hours, once cell balancing completes, the PCM will disconnect further **input** to the LFP cells, battery output is fully ready

Bioenno Power LFP Battery Charging Information

- Battery needs to see a **charging voltage** of **13.8-15.0 VDC**
- The power supply needs to be **limited to the maximum charge current** for the particular model battery you are charging
- Example is the switching power supply for the 30Ah battery

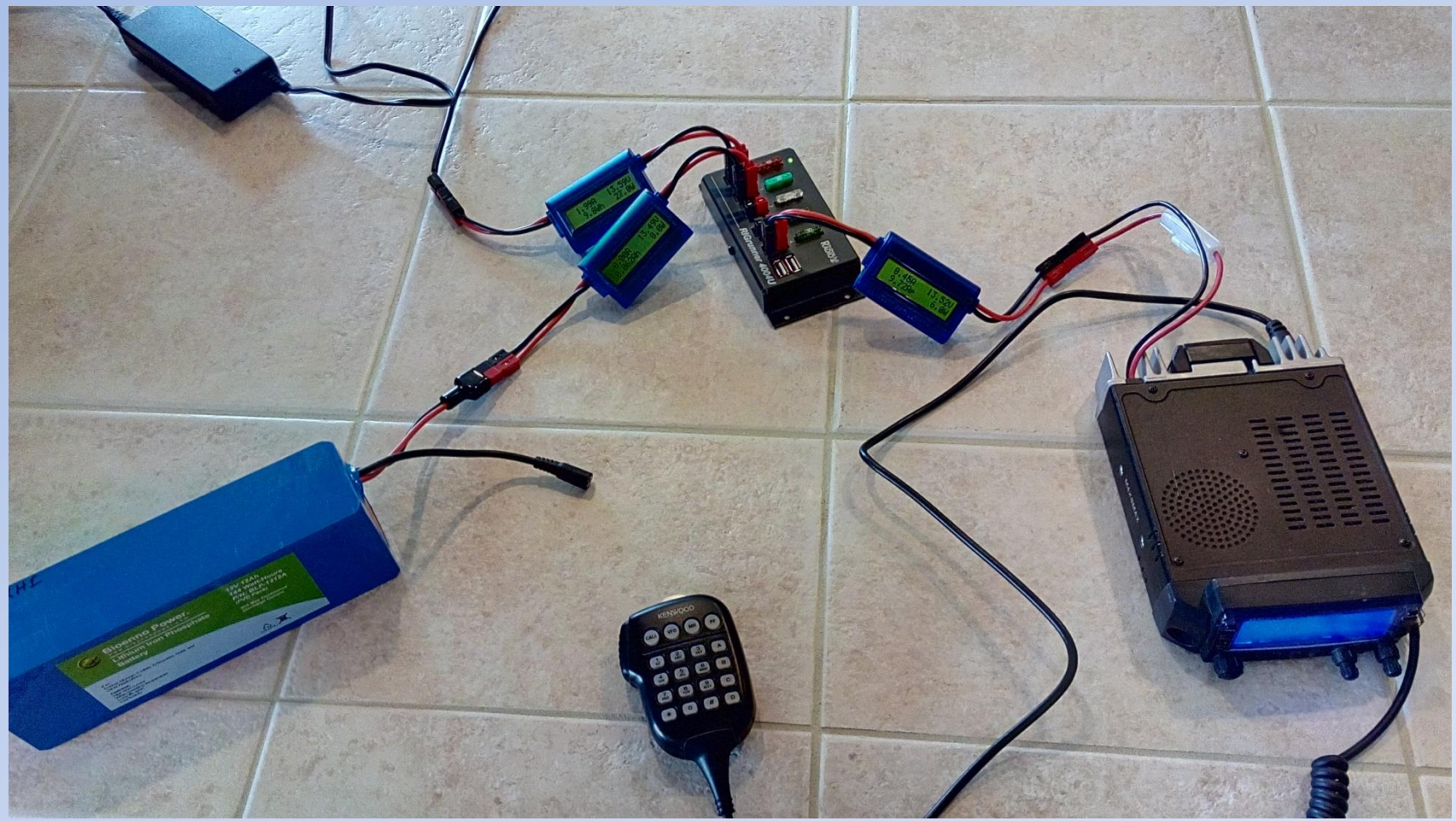
Bioenno Power LFP Battery Charging Information For 30Ah LFP

- Charger is for LiFePO4 14.6 volt batteries
- Output is rated at 15 volts and 6 amps
- The LED light is rated to turn on at 0.4 amps

Bioenno Power LFP Battery Charging Information

- If using your LFP battery with the lithium battery AC to DC charger, plan to top up the battery every 8-10 weeks to complete cell balancing, green light for 15 minutes
- If **using just solar**, while the battery is connected to panel voltage and slowly rising, the charge controller will **limit the voltage to the CV level** and the SOC should rise enough to do cell balancing

12Ah LFP + 2 Amp Power Supply + WMR4004U + Radio + Inline Meters



Flexible Power Source For Your Portable Radio

- 2 Amp power supply for LFP batteries connected to a distribution block
- 12Ah LFP battery connected to a distribution block
- Radio connected to a distribution block
- WMR 4004U distribution block
- 12Ah battery could have inline PP fuse and replace the WMR 4004U for cheaper priced distribution block

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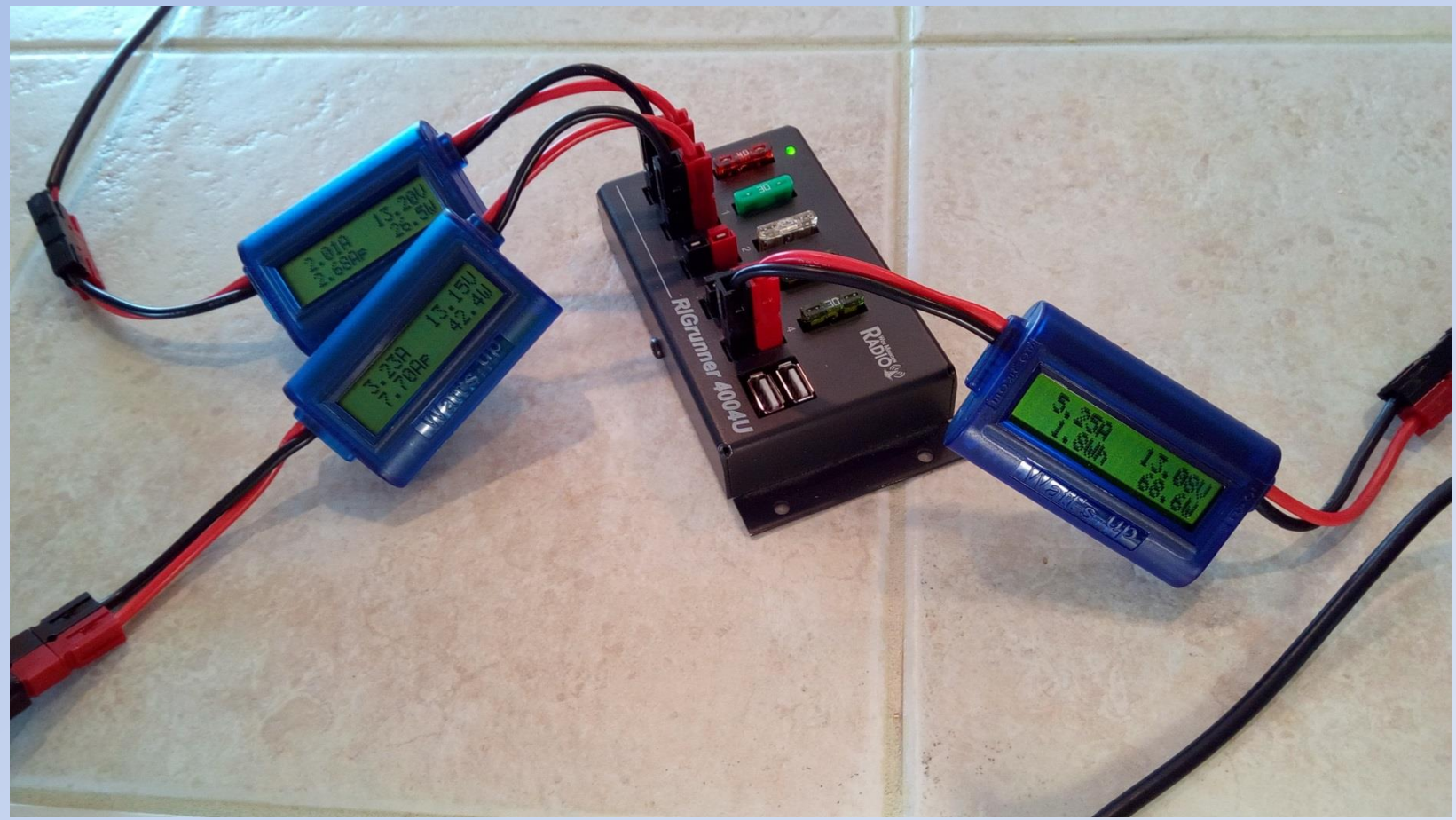
Flexible Power Source For Your Portable Radio

- 12Ah LFP battery has the inline meter connected with battery as the **source** and distribution block as the **load, current will only be measured flowing from the battery to the distribution block during transmit**
- While the radio needs a low current during receive, the LFP battery will be charging if needed…but the LFP meter will show zero amps
- Supply provides 2 amps, radio needs about 0.5 amps, ~1.5 amps can be used to charge your LFP battery

Flexible Power Source

- The 12Ah battery has two power cables, both are connected to the circuit board in parallel
- Enjoy using the radio while on battery power till the battery get low, could measure Ah with inline meter?
- Plug in the 2 amp power supply and enjoy using the radio while the battery charges back up again
- Technically you can plug the power supply into one port and connect the radio to the PP connectors while using an inline fuse

Radio Meter On The Right During Tx, 12Ah LFP Meter Lower Left, 2 Amp Power Supply On The Upper Left



Powerwerx PWRbox Works Real Nice For Quick Deployment

- Powerwerx PWRboxs hold several different size batteries
- 30Ah LFP to 50Ah LFP is one of the sizes
- 30Ah LFP battery goes nicely in the box, room for accessories around the battery
- Plug in the 6 amps power supply and top off the battery

Powerwerx PWRbox Works Real Nice For Quick Deployment

- Power supply meets the current and voltage needs of the battery
- 6 amp power supply and 15 volts output
- You can charge your battery and use your radio at the same time
- Top up your battery and go…easily plug in your radio and begin providing comms

Powerwerx PWRbox

- Has 2 USB charging ports
- Two PP connections
- One automotive power port connection
- Binding post connection
- LED voltage meter
- On/OFF switch to control voltage meter, USB outputs, and Power Port so no parasitic loss

30Ah LFP Battery In The PWRbox All Charged Up And Ready To Go, Note Green LED Light

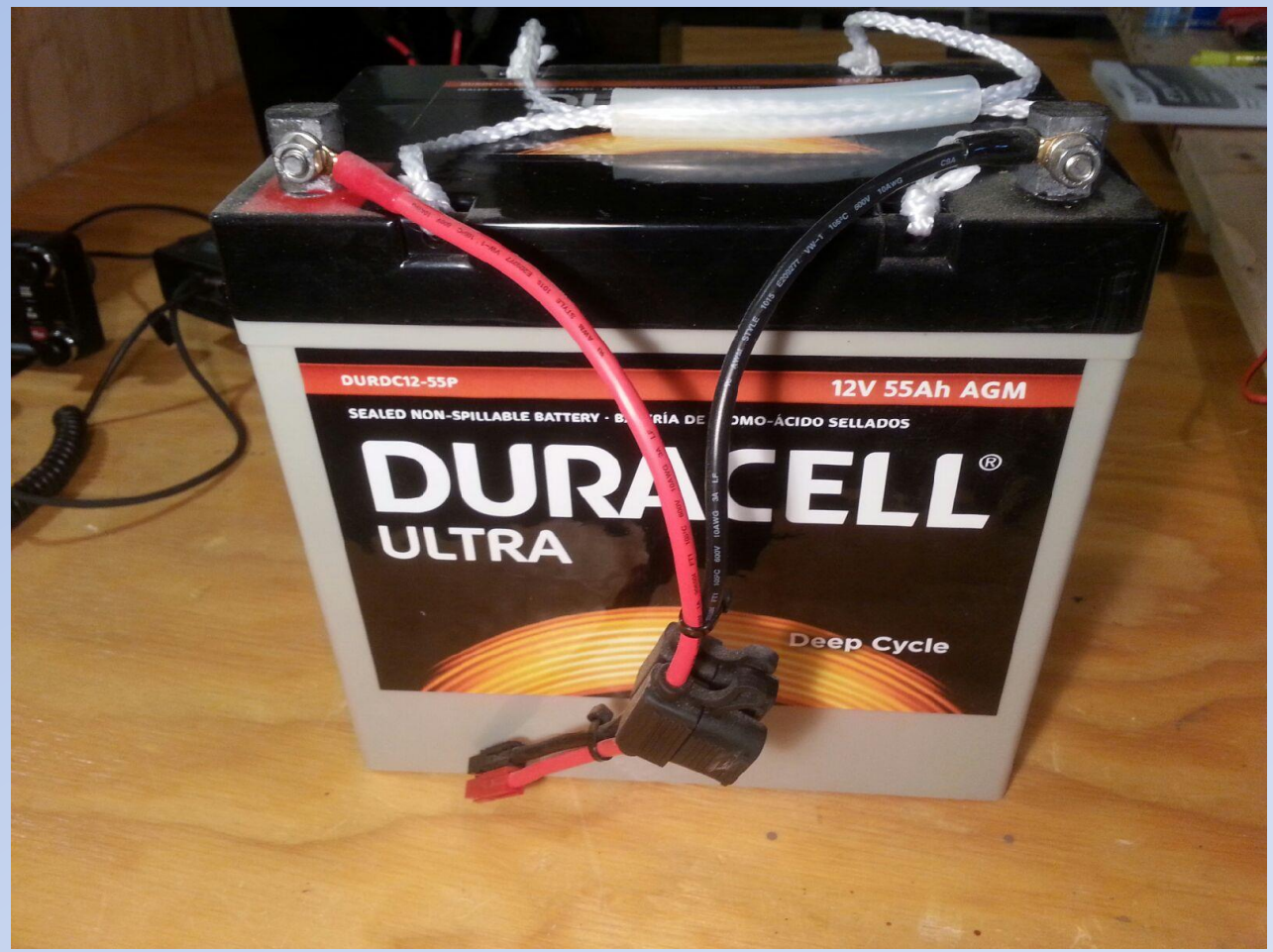
LFP Battery Charging Test

- 30Ah LFP Battery discharged 5.0 Ah over 140 minutes
- Bioenno Power charger then applied with RC Electronics WattsUp inline meter being used in the circuit
- First reading taken just after charger applied
- Full charger output accepted by the battery until the last 12 minutes, no long absorption stage noted
- Charger goes from red to green light when about 0.4 amps reached
- Continue an additional 15 minutes and cell balancing considered complete

30Ah LFP Battery Had 5.0 Ah Removed Over 2 Hours & 20 Minutes…Then Recharge Started

Time	Amps	Voltage	Charging Ah	Power Supply LED
2240 test started	5.7 just applied	13.54		Red
2245	5.53	13.63		Red
2320	5.6	13.69		Red
2327	5.51	13.74		Red
2328 fall starts	5.45 falling	13.75 rising		Red
2331	5.14	13.77	4.7	Red
2333	4.72	13.84	4.87	Red
2335	3.4	14.03	5.0	Red
2337	1.24	14.35	5.07	Red
2338	0.67	14.43	5.09	Red
2338.5 Red to Green	0.46	14.48	5.096	Green
2340	0.27	14.49	5.1	Green
2348	0.1	14.51		Green

55 Ah SLA AGM Battery Weighs 42.3 Lbs



BIOENNO POWER 30AH LFP BATTERY WEIGHS JUST 7.6 LBS

Comparing Lead-Acid Battery To An LFP Battery

	55Ah AGM lead-acid battery	30Ah LFP battery
Weight	42.3 lbs	7.6 lbs
Available Ah	27.5 at 50% DOD	27 at 90% DOD
Cycle life	~500 at 50% DOD	~2,000 at 90% DOD
Discharge curve	Sloping	Nearly flat
If not fully charged soon after use	Sulfation can occur	No problem
Battery protection	None	PCM built in
Round trip fully discharge/charge efficiency	~80-85%	~95+%
Price	$160.00	$280.00 + $20 Charger = $300

18Ah Lead-Acid AGM Battery Weighs 11.9Lbs


Bioenno Power®
www.bioennopower.com
Lithium Iron Phosphate Battery
12V 12Ah
144 Watt-Hours
P/N: BLF-1212A
(PVC Pack)
20A Max Continuous Discharge Current
For:
Energy Storage, E-bikes, E-Scooters, Solar, and Other Applications
Features:
High start current
Wide operating temperature
Long life span
Low toxicity
LiFePO4

Comparing Lead-Acid Battery To An LFP Battery

	18Ah Lead-Acid AGM Battery	12Ah LFP Battery
Weight	11.9Lbs	3.3Lbs
Available AH	9Ah at 50% DOD	10.8Ah @ 90% DOD
Cycle life	~500 at 50% DOD	~2,000 @ 90% DOD
Discharge curve	Sloping	Nearly flat
If not charged right after use	Sulfation occurs	No problem
Battery protection	None	PCM built in
Round trip efficiency	~85%	~95+%
Price	$60.00	$125…with charger $140

12Ah LFP Battery From Bioenno Power

- Weight = 3.3 lbs
- Max **continuous current** is 20 amps
- Max **peak pulse current** is 40 amps (2 seconds)
- **Charging current** is up to 5 amps
- **Operating** temperature is -10C to 60C
- Minimum **charging** temperature is 0C or 32F

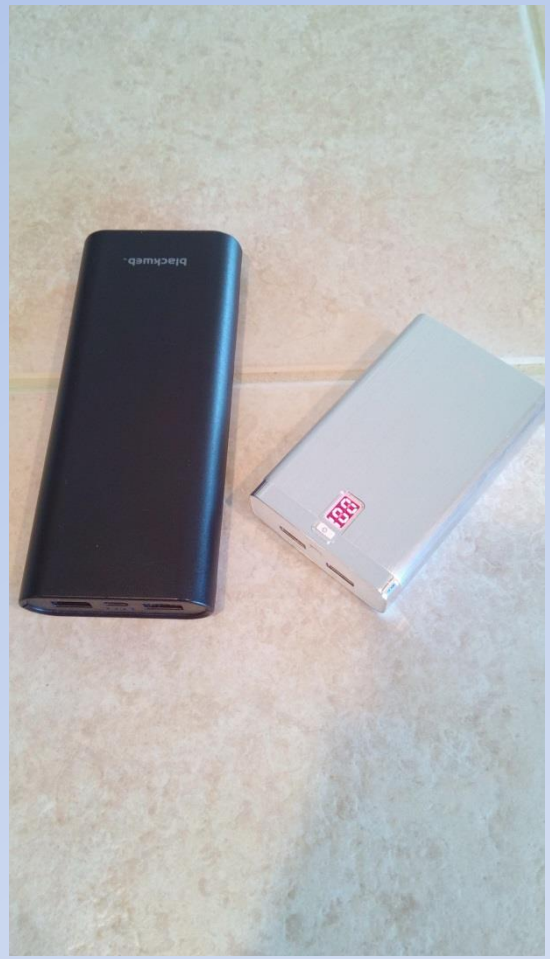
4 Hour Load Test With The Bioenno Power 12Ah LFP Battery

- Started with a fully charged 12Ah Bioenno Power 12 volt LFP battery
- Base load at 2.6 amps, with occasional peak loads of up to 16 amps over 4 hours
- At 4 hours the WattsUp meter showed 11.3Ah used so far, the base load battery voltage was 12.6 volts

4 Hour Load Test With The Bioenno Power 12Ah LFP Battery

- Then applied some peak loads up to 19 amps for the next 7 minutes near the end of the batteries capacity
- When the WattsUp meter displayed 12.0Ah, I then provided the test load of 19 amps again and noted the battery voltage under load was 11.7 volts
- The WattsUp meter then showed 12.1Ah, so returned to a base load of 2.6 amps and the voltage displayed 12.6 volts under load, then stopped the test

USB Power Banks ~5 Volts Output



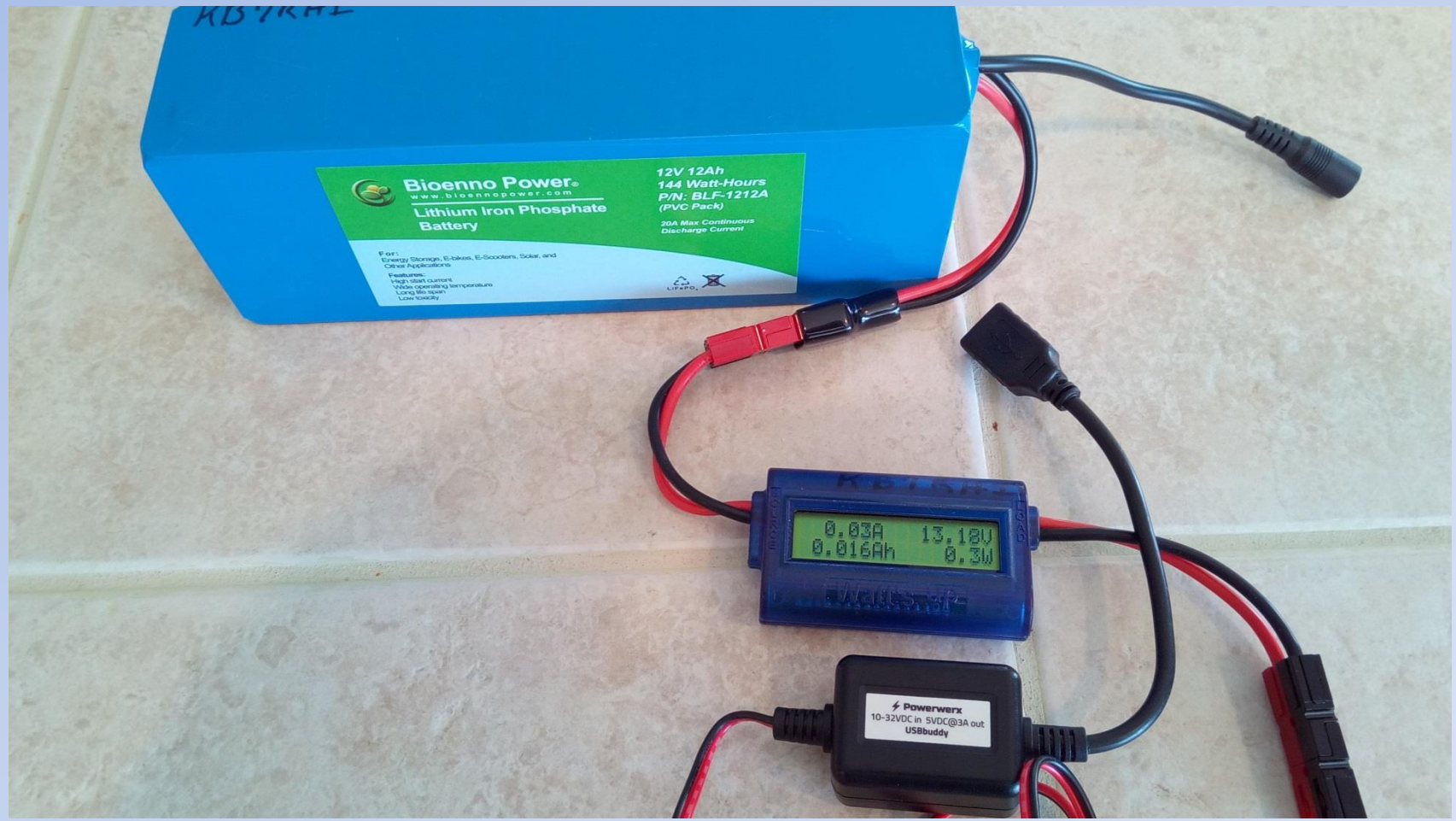
USB Power Banks

- USB power banks are **not** designed to be charging and discharging at the same time
- Provide portable discharge power in the field
- Can easily be charged in the field with power converters
- You can use an inline 5 volt meter like the Drok USB Tester to see how much power is being used

USB Inline Meter Showing Voltage In Red And Amperage In Blue

12 Ah LFP Battery Charging A 20 Ah, 5 Volt Power Bank Via A USBbuddy, About 0.9 Amps

12Ah LFP Battery Connected To A USBbuddy Showing Parasitic Loss Of About 0.03 Amps



USB Buddy By Powerwerx

- Input voltage is 10-32 volts DC power
- Output is 5 volts DC and up to 3 amps
- Uses Anderson PP connectors on the input side

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Petzl Core Li-ion Battery Provides Alternate Power For AAA Powered Petzl Headlamps

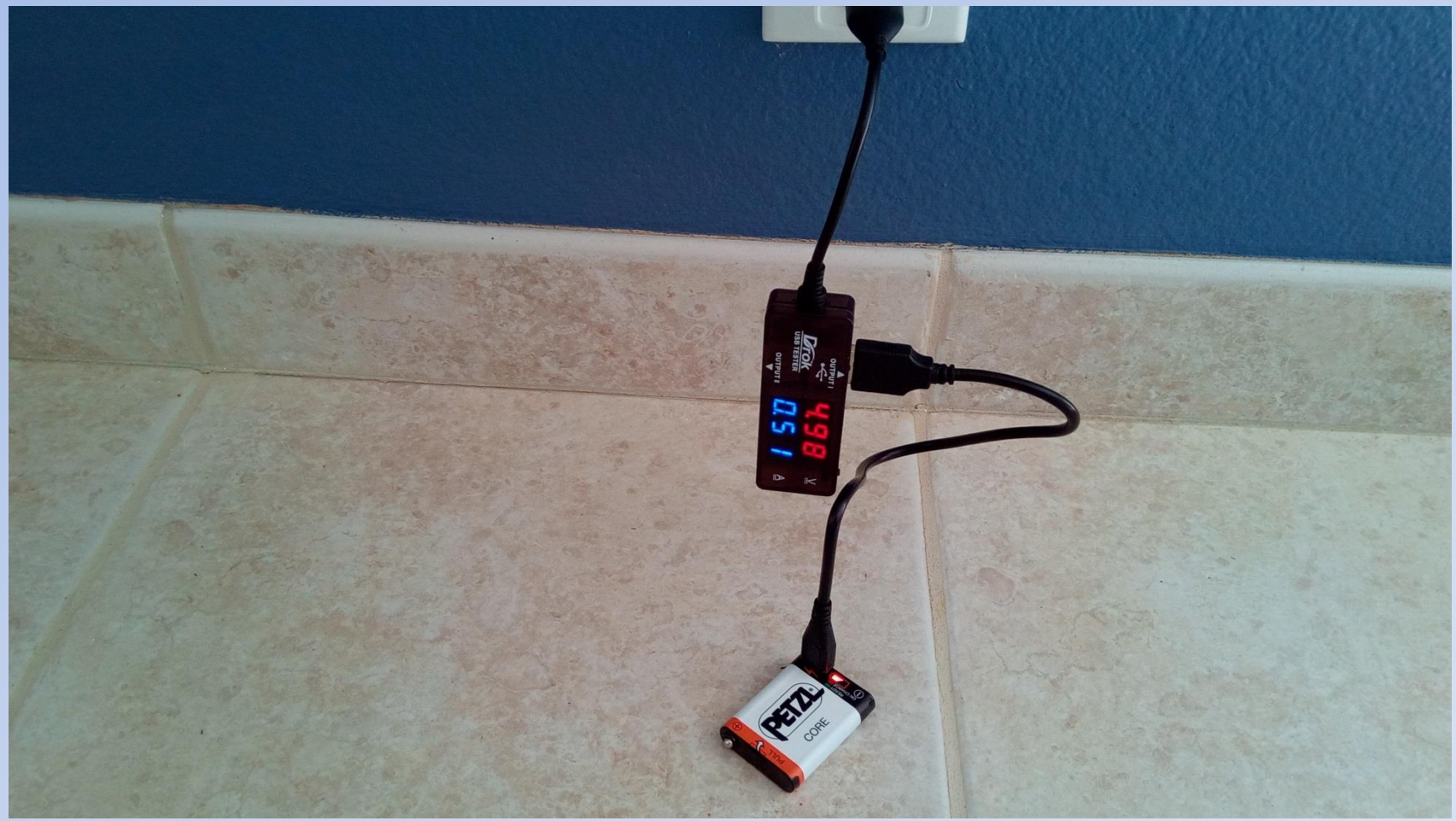
Petzl Core Battery Li-ion Battery…The Size Of Three AAA Batteries Next To Each Other

Petzl Core Battery

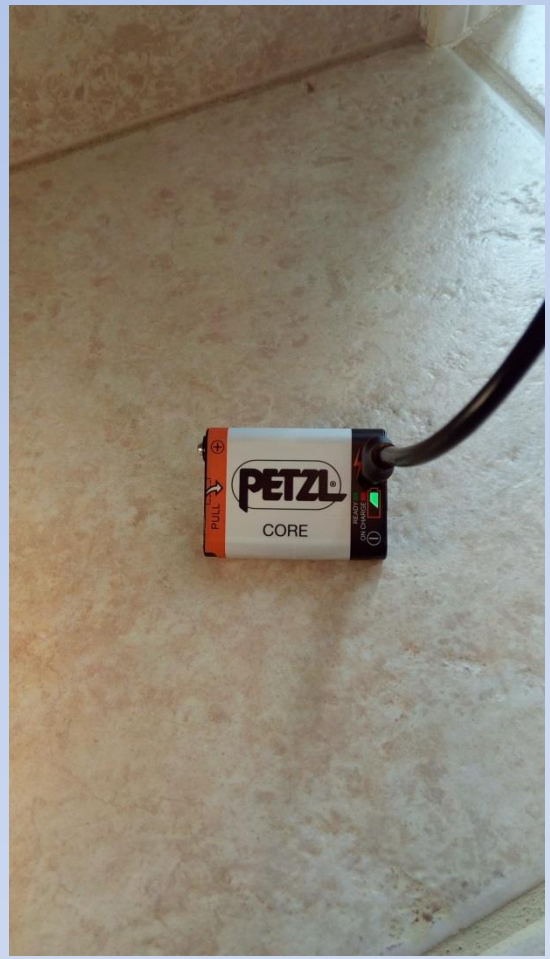
- Rechargeable headlamp battery
- Can recharge up to 300 cycles
- Uses Li-ion chemistry, but is not an LFP battery
- Number of 2018 and onward Petzl headlamps will accept the Core battery…need to check first on the model you will be using
- Has a light that indicates charging status

Charging A Petzl Core Battery, 0.22 Amps On The WattsUp

Petzl Core Battery Being Charged From A Wall USB Power Source



Petzl Core Battery Shows A Green Light When Fully Charged



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