WHICH RECHARGEABLE BATTERY IS RIGHT FOR YOUR STATION?

JUST A BIT OF INFORMATION

Important Factors

- Energy Density +++
- Constant Battery Voltage +
- Fast Recharge +
- High Discharge Current +
- Cycle Life +++
- Warranty +++
- Temperature vs. Operations
- Costs: CAPEX vs. Operational $

MY CHOICE NOW

LFP

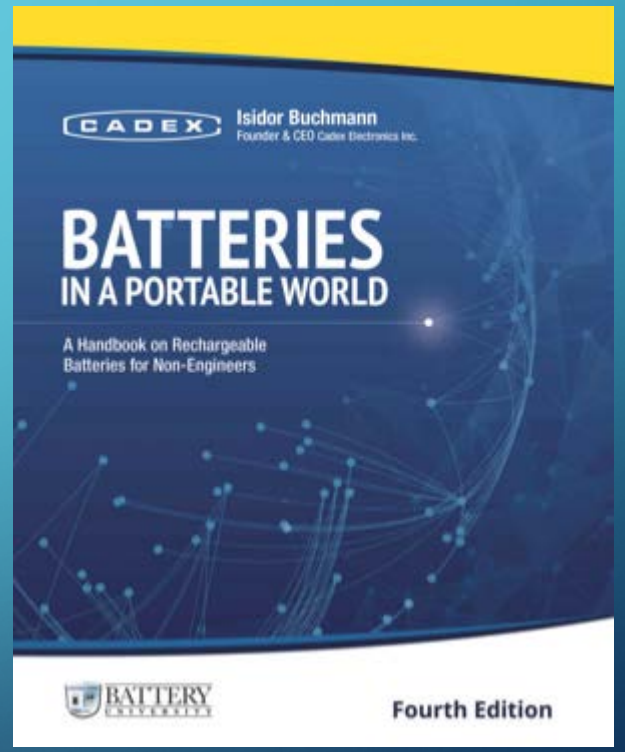
AGM

MY HOME STATION IS POWERED BY A LFP BATTERY

- A 12V 50 AH battery (replaced an aged 80 AH Deka AGM)
- Battery charged by two 100W solar panels in parallel
- Backup 14.6V 40A PS is connected but not powered
- West Mountain Radio EPIC PWRgate controls charge/discharge
- Power system has been operational three years
- EPIC output ranges from 12.8V to 13.3V and topping out at 14.4V with full sun using the MPPT charge controller
- Battery is located under station desk
- EPIC charge max is 10A and passes up to 40A to load

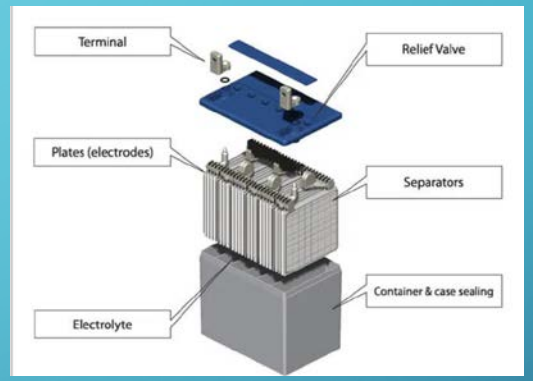
DISCLAIMERS ABOUT PRESENTED INFORMATION

- Lots of Research & Thanks to:
  - Battery University Book and Website
  - Many Manufacture's Websites
- Personal Efforts
  - Trial and Errors
  - Monitoring Battery Operation
- Capturing Results
- No Promises!



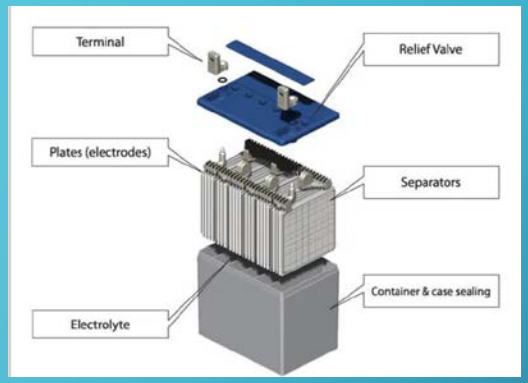
The Book - Battery University

DEEP DISCHARGE BATTERIES FOR ELECTRONICS: SEALED LEAD ACID VS. LITHIUM



- **<u>Sealed Lead Acid</u> (SLA or VRLA)**
  - **☆ Gel (best are pure lead)**
  - **☆ AGM (Absorbed Glass Mat)**
- **<u>Lithium</u> (generic term)**
  - ☆ LMO (Lithium Manganese Oxide)
  - ☆ LiCoO2 (Lithium Cobalt Oxide)
  - **◇ NMC (Lithium Nickel Manganese Cobalt Oxide or Ni-Mn-Co), 3.6 volts/cell**
  - **◇ LFP (Lithium Iron Phosphate or LiFePO4), 3.2 volts/cell**

WHAT IS INSIDE AN AGM BATTERY? (ABSORBED GLASS MAT)



- Sulfuric acid is held in fine fiberglass mat making them less prone to sulphation
- Able to deliver relatively high current and low self discharge
- Can be deep charged while operating safely at low temperatures
- Typically tops out at 100 amp hour (AH) size utilizing six 2-volt cells
- Capability and capacity drop somewhat with high temperatures
- Very sensitive to overcharging, resulting in damage
- Typical charge voltage: 14.4 – 14.8 volts
- Must be stored in a charged state, suggest a trickle charge

WHAT IS INSIDE A LITHIUM BATTERY?

- Multiple 3.2V cells are interconnected to produce desired battery voltage and available AH of capacity
- Four series connected cells when fully charged provide ~13.25V
- When a lithium battery drops to <12.0V, it is at ~20%, a good cutoff point
- Internal Battery Management System (BMS) controls:
  - Cell balance of charge/discharge current and cell temperature
  - Internal short protection
  - Some have low temperature charging cutoff

SO, WHAT IS A BMS AND WHAT DOES IT DO?

- BMS, Battery Management System, is mandatory for all lithium batteries.
- All lithium battery cells are sensitive to over-voltage, under-voltage, and over-current.
- If a Lithium battery is kept under one of the above conditions for a long time, it can easily cause capacity degradation, battery damage, or even the risk of fire.
- The primary task of the BMS is to protect the lithium cells to only work at the appropriate voltage (3.65V), current, temperature and balancing of individual cell's charge.
- For a 12.8V pack the BMS offers protection by:
  - Releasing charge at about 14.2V, waits ~2sec and then resumes charge.
  - Disconnects load <10.8V is reached or current exceeds pack rating.
  - Disconnects charging when pack >75°C (167°F) or <0°C (32°F)
- MOSFETs control turn-on, turn-off and cell balancing load resistors.
- SMART BMS vs. Basic Functions:
  - Control of internal heater to ensure battery is >5°C (40°F)
  - Absolute battery charge cut off below freezing required
  - Bluetooth and/Wi-Fi

LITHIUM BATTERY TYPES, TYPICALLY: LFP OR NMC

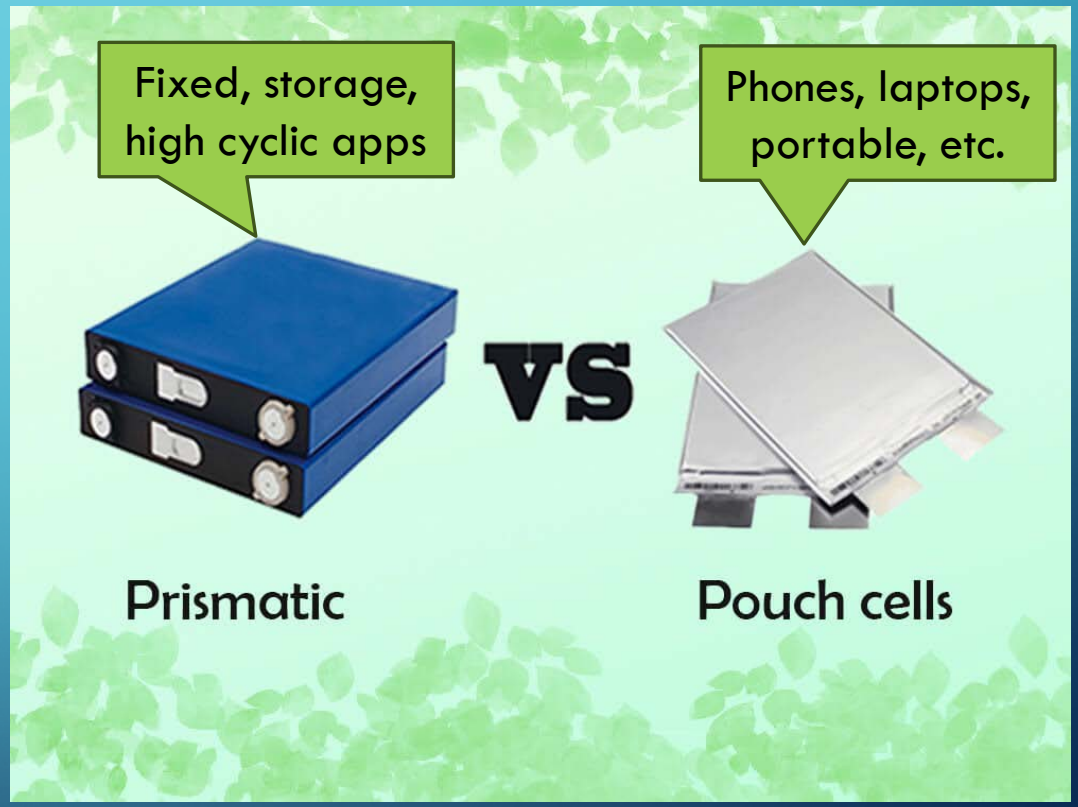
- Each has its best use in various applications. Even with vehicles one may fit better depending on use factors.
- Most portable electronics, including laptops, use NMC because they can easily be mass produced and they are internal with charge/discharge rates easily controlled.
- Due to cost and longer life, LFP batteries are gaining popularity even where NMC has previously been used.
- Power Density: LFP cost $90/kWh vs. NMC at $130/kWh
- Use of Cobalt and Nickel as used in NMC is unsustainable

LET'S COMPARE TWO LITHIUM BATTERY TYPES:

FEATURE	NMC	VS.	LFP
Life Cycle/Span	~800		>3,000-10,000
Energy Density	4X Lead Acid		3-4X Lead Acid
Charging Efficiency	85%		95% (fast)
Raw Materials	33%>Higher $		<$ than NMC
Manuf. Costs	Lower < than LFP		> than NMC
Self Discharge	~20%/month		~ 5%/month
Electrolyte	Liquid		Solid polymer
Safety	High Thermal Issue		Very Safe
Primary Use:	☆ Portability		☆ Vehicles
Feature Plus:	☆ > Current Draw		☆ Longer Life

TWO KINDS OF LFP BATTERY CELLS

- **Prismatic Cell**
  - Mechanical stability
  - Concern for heat dissipation
  - Easiest to interconnect
  - Rigid hard case
  - Lower cost to manufacture
- **Pouch Cell**
  - Smaller size and lighter
  - Customizable to fit available space
  - Higher energy density
  - Higher cycle life
  - Lower chance of fire
  - Less durable

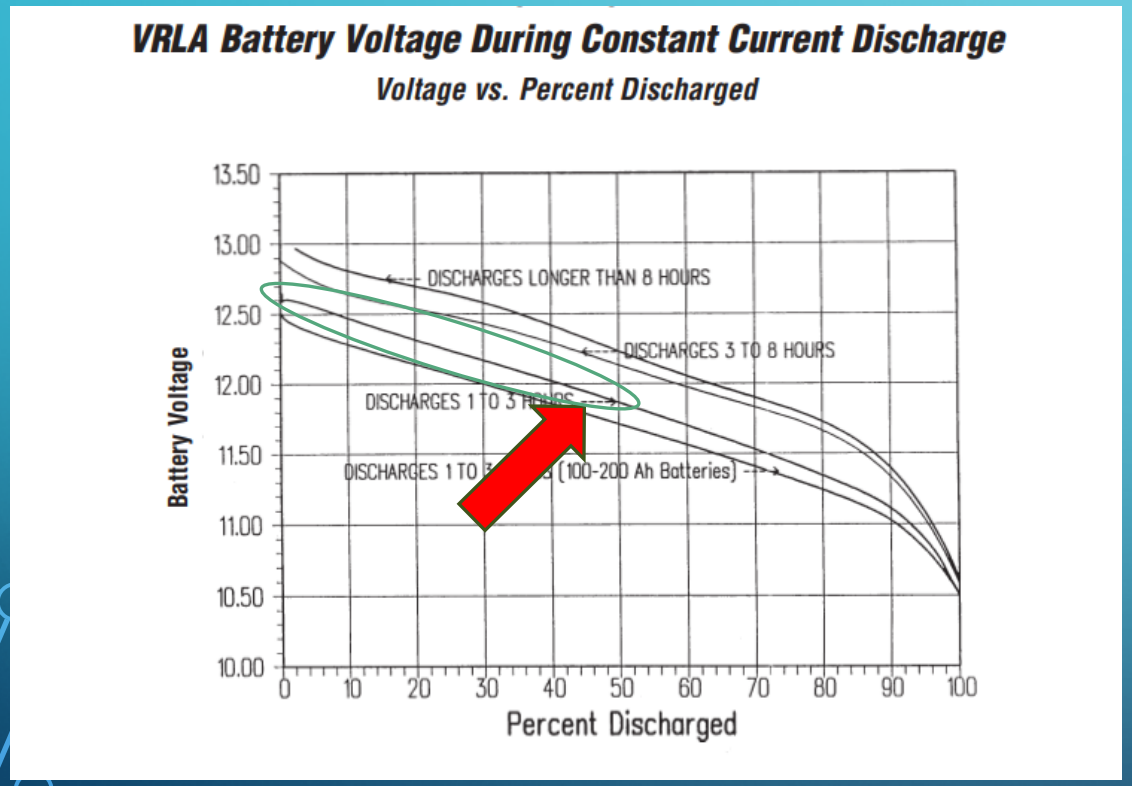


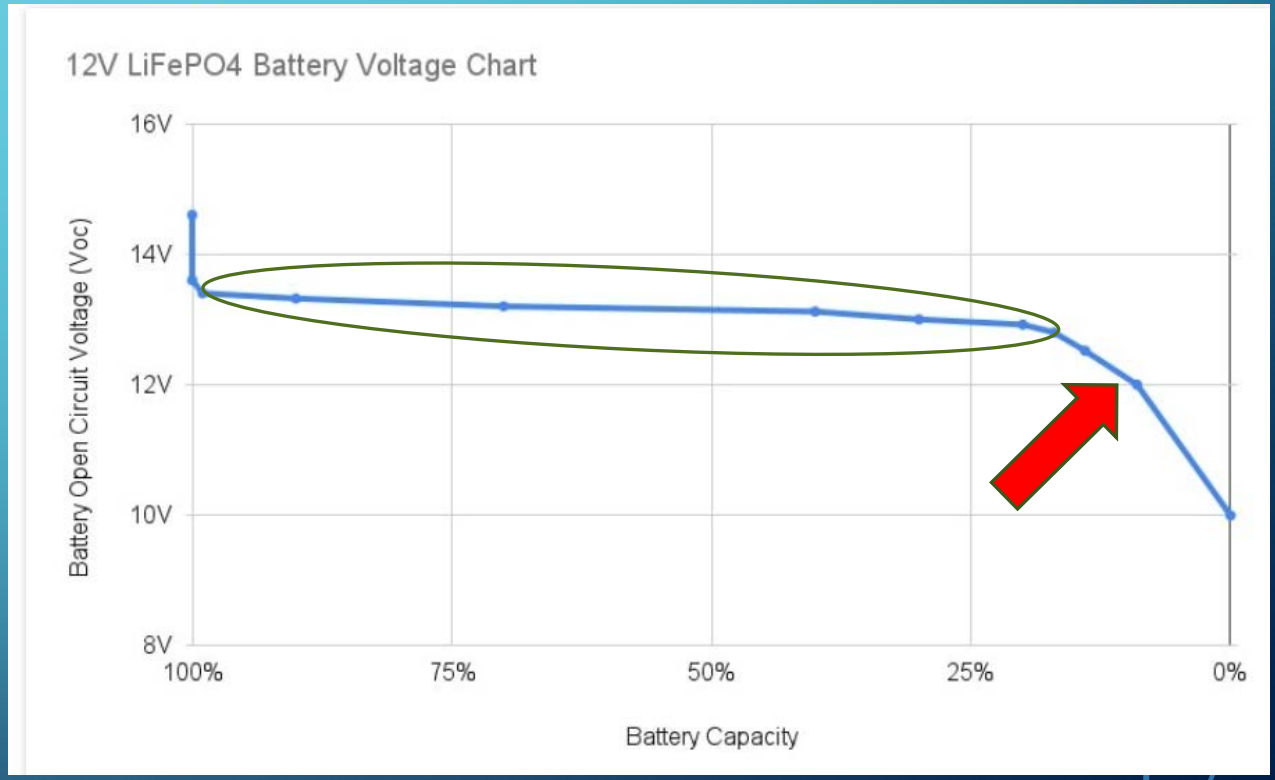
So? Which is best? It depends on the application.

BATTERY TYPES IN ACTUAL USE: AGM VS LFP

- AGM batteries can only be discharged to half rated AH while LFP can go as low as ~5%, though 20% is typically considered for best life
- AGM batteries starts at ~12. volts and radios shut down at ~11.8 volts, which is ~50% of rated battery AH capacity
- High temperature is a problem for both type of batteries both in charging and discharge but about 20% worse using AGM due to efficiency loss
- LFP batteries cannot be charged below freezing
- AGM and LFP batteries require different types of chargers
- AGM and LFP should be stored in charged state, with LFP at about 40%

BATTERY DISCHARGE CURVE
DEKA VRLA (AGM) VS. LFP

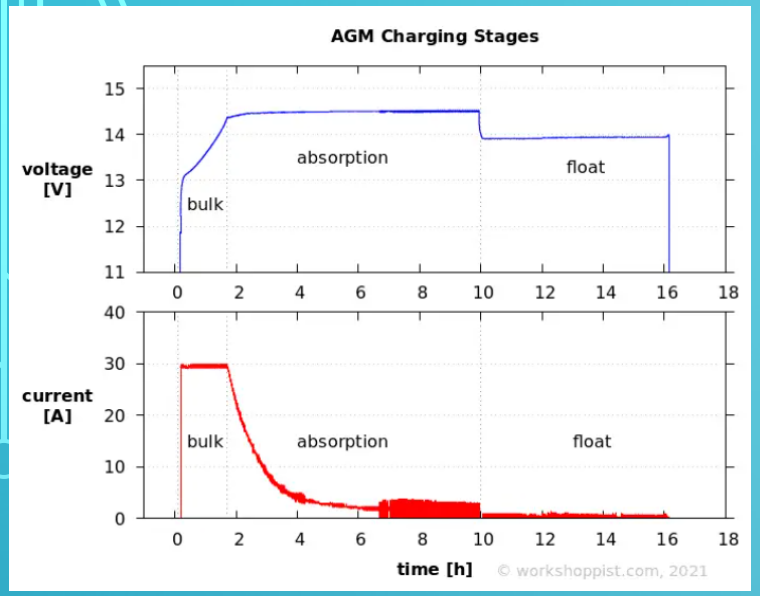




Note: Under load, an AGM battery reaches 11.8V at ~50% while the LFP hits this voltage at 12% DoD.
Just remove the load and AGM will show SOC to be about 12.25V and LFP stays at ~13V.

MORE COMPARISONS: AGM VS. LFP

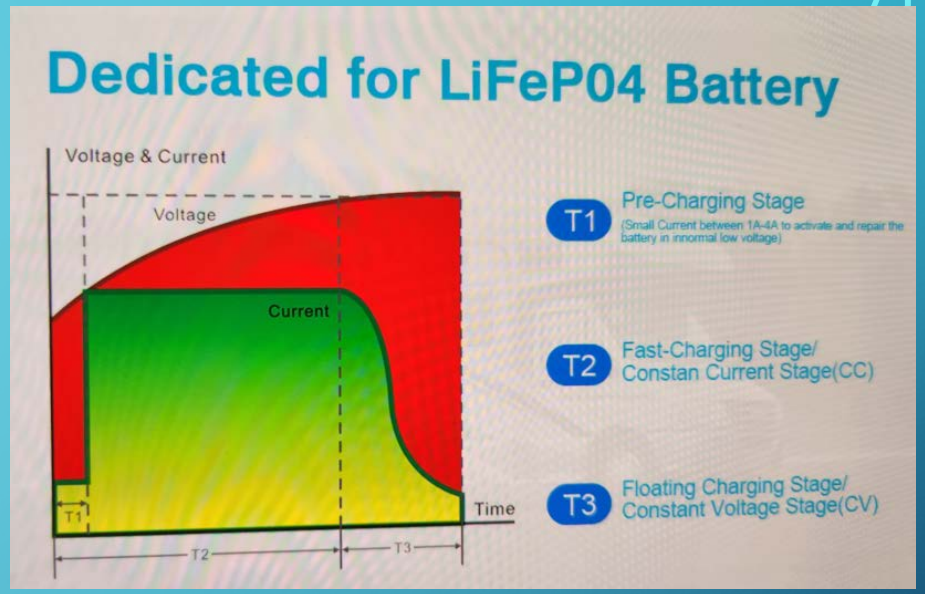
- AGM and LFP batteries can both be discharged when cold with only minor problems.
- AGM charging should use a thermal detector type charger to ensure batteries do not overheat, while the BMS of a LFP battery controls thermal internally.
- LFP batteries start to recharge at ~12.6V, while AGM starts at ~12.0V
- When operating batteries in parallel or series, both AGM and LFP batteries must match very closely, usually best from the same manufacturing lot.



BATTERY CHARGING

AGM

- **AGM battery optimized charger required**
- **Stage 1:** Bulk, where charge current causes high current, then voltage to rise to ~14.6V.
- **Stage 2:** Absorption, preset current for no more than 15 hours.
- **Stage 3:** Float (storage), constant voltage ~13.5-13.8V (self discharge compensation)
- Always recharge every 6 months if not float.

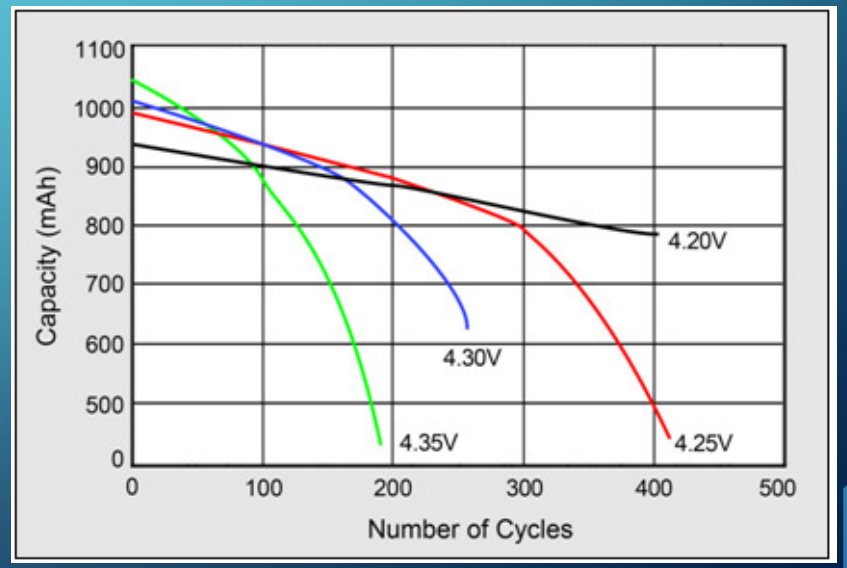


LFP

- **LFP battery optimized charger required**
- **Stage 1:** A pre-charge test, ~1A, then a Constant current (CC) at rated amount until battery =14V
- **Stage 2:** Constant Voltage (CV) 3.65V per cell (14.6V) until battery again = 14V
- **Maintenance:** When current <100ma charging stops
- Charge restarts when battery discharges to ~3.1V/cell

BATTERY CHARGING GOTCHAS

- Charger must match the battery chemistry
- Battery too hot or too cold!
  - Stop the charge until battery within acceptable range.
  - Thermostat (internal or external) can protect the battery.
- Stage 3 charging of a LFP battery while supporting a parasitic load can cause negative effects:
  - Must have high voltage cutoff, recommend <4.2V/cell (3.7V/cell best)
  - How a charger handles final 20% top-off is very important.
  - Possibly a cause of early failure of battery.



WARNING: Never store or hold any battery at 100% continuously, AGM or LFP!

CHARGING VIA SOLAR

- Any battery charging requires a voltage higher than the battery to force current into the battery chemistry and solar panel output varies with the sun
- For solar, best to use a properly programmed MPPT (Maximum Power Point Tracking) charge controller set to the type of battery chemistry (AGM vs LFP)
- A MPPT controller allows the varying solar panel impedance and voltage to be used in a manner than maximizes battery charge and minimizes time
- Some MPPT charge controllers also utilize a DC-to-DC converter to boost the voltage to get the last bit of energy from the sun for the batteries

SUMMARY – WHICH IS BEST? IT DEPENDS!

- LFP has high initial cost (3X) but lasts ~10X longer than AGM, thus LFP wins.
- LFP Energy density twice that of AGM (using equal AH batteries), thus a clear winner.
- Battery Weight: AGM is 50% heavier than equal AH LFP, again LFP wins.
- The internal self discharge of AGM is ~10% and increases with age, thus it becomes less useful, and the design must take this into account, LFP wins again at <3%/year.
- LFP batteries require regulated CC/CV charger and while AGM batteries require a 3-stage charger and external temperature control.
- AGM battery design has mostly topped out, while LFP batteries continue to see more improvements.

HIGH-LEVEL ISSUES FOR CONSIDERATION

1. AGM and LFP batteries cannot be used for high current (>1C), as both generally are used for long run time.
2. AGM battery capacity drops as temperature drops, up to 20%.
3. Freezing temperatures negatively effect both batteries: A deeply discharged AGM can permanently fail when frozen, while a LFP battery can operate at lower temps but cannot be recharged until temperature is above freezing.
4. An AGM battery can be charged and discharged about 300 times through its life, whereas a LFP battery can easily reach 3000+ charge/discharge cycles.
5. Some AGM batteries are guaranteed 2-3 years while LFP 5-10 years.
6. Batteries start aging at manufacture with cycling and usage affecting total life!

WARNING: Never store or hold any battery at 100% continuously, AGM or lithium!

OVERCOMING THE PRIMARY LFP NEGATIVES

Internal BMS uses temperature sensors to control charging & discharge

Battery can be equipped with internal heaters to assure low temp operation

External controls can assure high and low voltage cutoffs [1]

Insulate a cabinet and add fans to hold acceptable operating temps

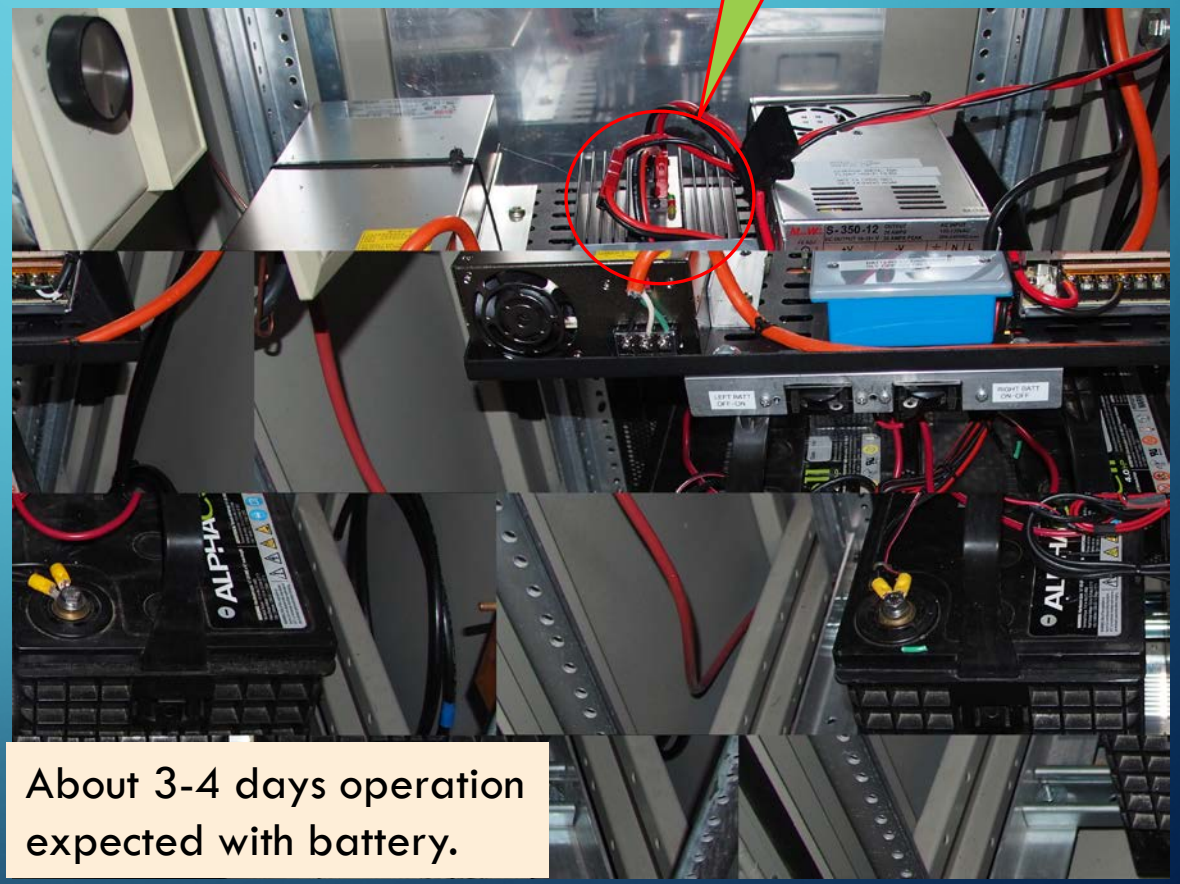
Validate use vs. battery specifications to assure long life

Great care[2] must be taken to operate batteries when in series or parallel

1. Max Charge to <85% (14.6V) and Max Discharge to 20% (12V).
2. Batteries should be of the same lot and tested to assure a very close match to their resting voltage.

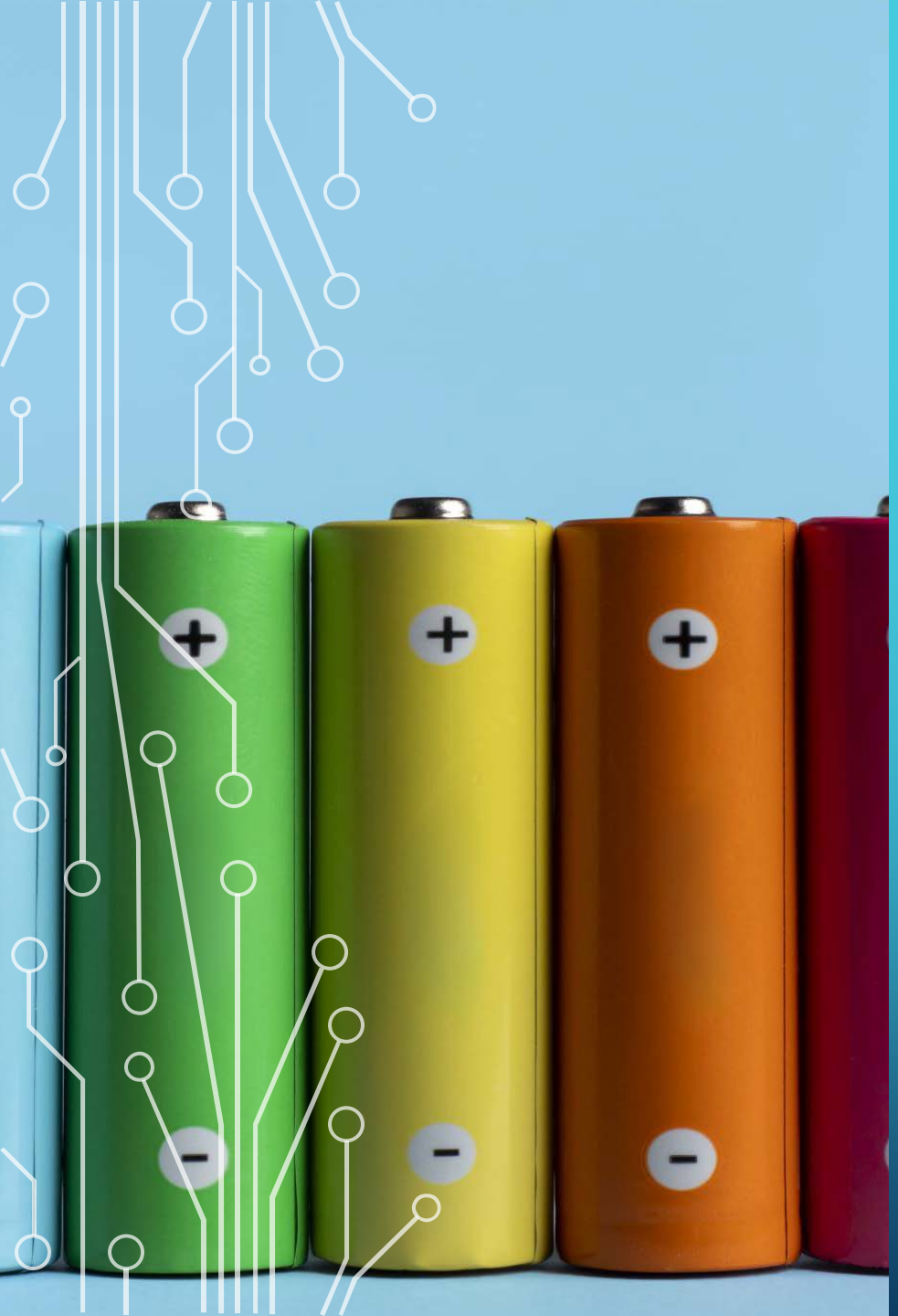
SMARC REPEATER BACKUP BATTERIES

One 80AH AGM. The LPG generator has been turned off



About 3-4 days operation expected with battery.

Two 100AH Pure Lead Gel with external generator inlet



QUESTIONS

What kind of lithium battery is used in laptops and cell phones?

Why do some batteries cost a lot more than other? Cheap vs. Cadillac?

Can I build my own LFP battery? Yes, but – warranty?

What about a “portable battery generator?”

Why LiFePO4 vs. Lithium Ion for ham radio?

Can a power supply be used to charge a lithium battery? It depends!

10 KW WHOLE HOUSE SOLAR SYSTEM USING 34 PANELS

NO BATTERIES

GRID TIE SYSTEM REPLACES ~97% OF OUR ANNUAL ELECTRIC USE

AVE. = $31/MO.
ROI ~10 YEARS