Lithium-Iron Phosphate (LFP) Batteries

Why Do HAMs Like LFP Batteries ???

- LFP batteries are light weight compared to Lead Acid
  - One-half to one-third the weight
- LFP batteries can deliver 85% of their charge capacity
  - Lead acid batteries deliver 50% without risk of damage
- LFP batteries charge faster and more efficiently
  - Typical charge rates, LFP 0.5C, Lead Acid 0.1C
  - Charge efficiencies, LFP >96%, Lead Acid 80-90%
- LFP lifespan
  - LFP 3,000-5,000 cycles, Lead Acid 300-500 cycles
  - A cycle is a full charge, full discharge, and full recharge until deliverable battery capacity has been reduced to 80%
- Minimal to No maintenance

Why Don't HAMs Like LFP Batteries ??

- Initial **COST**
  - 3 to 4 times higher initial cost
- LFP charging equipment is different and may have to be replaced
  - LFP charge voltage 14.6 VDC, Flooded Lead Acid 14.5 VDC, AGM 14.8 VDC
- LFP is different from the Lead Acid batteries they know
- BUT . . . Lifespan Cost is significantly lower
  - LFP Lifespan is 10X longer than Lead Acid
  - LFP delivers 85% of Ahr capacity to Lead Acid's 50%
  - Cost per usable Ahr, LFP $1.13, Lead Acid $4.45, AGM $3.12
    - Cost based on 100 Ahr batteries
    - Data Source – Enexer, Enexertech

Lithium – Iron Phosphate Batteries

- Hams use a number of different batteries and battery types
  - Non-Lithium - NiCad, NMHi, Lead Acid (Flooded & AGM)
  - Lithium – Ion, Polymer, Iron Phosphate, Manganese Oxide
  - There are other lithium formulations in button cells
- Hams Primarily use 12 volt, Lead Acid and Lithium Iron Phosphate (LFP) for power sources in the field and as back-up power in the shack
- Hams also use Lithium-Ion (Li-Ion) and Lithium Polymer (Li-Poly) but the Li-Ion require more care and the Li-Poly are converted RC batteries
- This presentation provides some background on Lithium types of batteries and focuses on LFP batteries characteristics

Lithium-Ion EV Battery Chemistries

Chemistry	Common OEMs	Additional information
NMC Nickel Manganese Cobalt Oxide	BMW Ford GM Hyundai/Kia Stellantis VW	NMC batteries, with varying nickel, manganese, and cobalt ratios, are prevalent in EVs due to balanced performance.
NCA Nickel Cobalt Aluminum Oxide	Tesla Rivian	NCA batteries, utilizing nickel, cobalt, and aluminum, are synonymous with high-performance EVs, exemplified by Tesla's adoption.
LFP Lithium Iron Phosphate*	Tesla Ford Fisker	LFP batteries, characterized by iron and phosphate cathodes, prioritize safety and longevity. While slightly lower in energy density, LFP batteries are gaining traction in EVs, where low cost is paramount.
LMO Lithium Manganese Oxide	Nissan*	LMO batteries strike a balance between power output and thermal stability. LMO are ideal for power tools and medical devices, where the compromise between energy density and safety is critical.

*Newer chemistry not seen in models before 2022

*Early generation

https://www.redwoodmaterials.com/resources/cathode-and-anode/

Lithium-Ion Battery Chemistry Characteristics

Type	Energy Density	Cycle Life	Safety	Best Applications	Cost Level
LCO ($LiCoO_2$)	150-200 Wh/kg	500-1000	Medium	Smartphones, Laptops	$$$
LMO ($LiMn_2O_4$)	100-150 Wh/kg	300-700	High	Power Tools, Medical	$$
NMC ($LiNiMnCoO_2$)	150-220 Wh/kg	1000-2000	Medium	EVs, Energy Storage	$$
NCA ($LiNiCoAlO_2$)	200-260 Wh/kg	500+	Low	Electric Vehicles	$$$$
$LiFePO_4$	90-120 Wh/kg	2500+	Very High	Solar Storage, UPS	$$
LTO ($Li_4Ti_5O_{12}$)	50-80 Wh/kg	3000-7000	Extreme	Industrial Equipment	$$$$

*Cost levels: $=Lowest, $$$$=Highest

UFine Blog https://www.ufinebattery.com/blog/types-of-lithium-batteries/

Lithium – Iron Phosphate Batteries

- LFP cells come in two basic forms
- Cylindrical – Various diameter and length (e.g. 18650, 21700, 26650)
- Prismatic – Rectangular shapes and thickness
- LFP cells are typically packaged in a rectangular shape similar to lead acid batteries for general use
- LFP batteries come in different energy levels described as Ampere-Hours (Ahr).
  - Smaller batteries range from 2 to 5 Ahr
  - Mid-size batteries are 10, 20, 50 Ahr
  - Large-size batteries are 100, 200, 300 Ahr

Lithium Battery Packaging

LiFePO4 battery: cylindrical cells or prism cells?

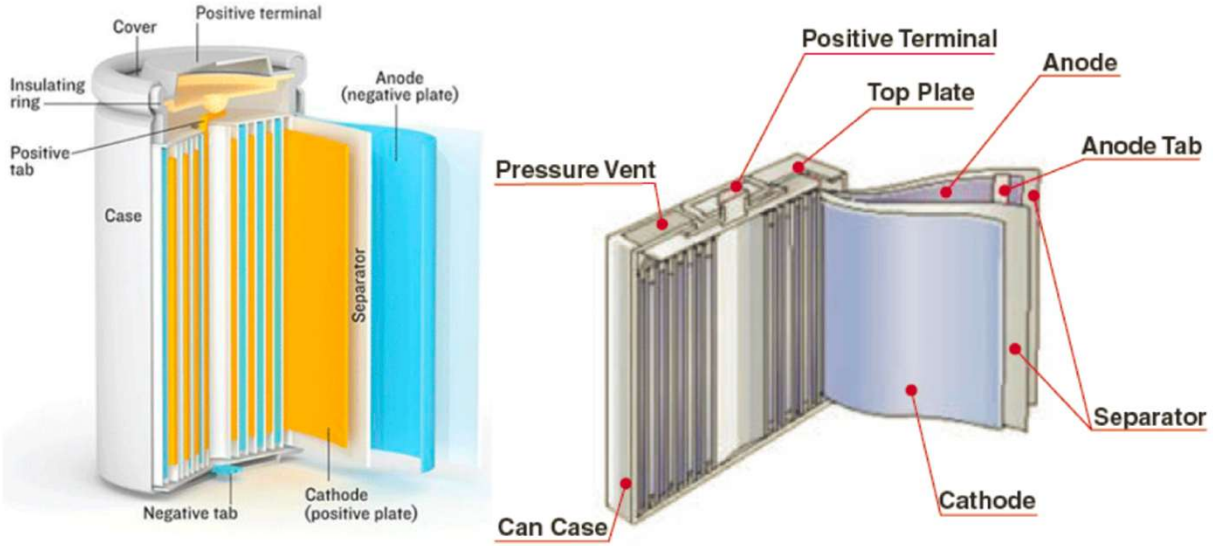


Figure 2. General Construction of a Cylindrical and Prismatic Lithium-ion Cell

Pouch cells are similar to prismatic cells. The active cell parts (cathode, anode, separator and electrolyte) are the same. The prismatic cell has a rigid outer case. The pouch cell uses a film pouch to contain the active cell parts. Pouch cells are built into battery cases to protect the thin pouch membrane.

https://www.exploringoverland.com/overland-tech-travel/2021/3/29/lifepo4-battery-cylindrical-cells-or-prism-cells

LFP Important Characteristics

- Very flat discharge curve versus battery capacity (State Of Charge – SOC)
- The terminal voltage of 4 LFP cells in series (12.8 volts) matches a 6 series cell, lead acid battery
- LFP batteries have longer life cycle times compared to led acid batteries
  - LFP 2000-8000 full charge and discharge cycles
  - Lead acid 200-1000
- LFP has a lower internal resistance than lead acid
  - More current / smaller size

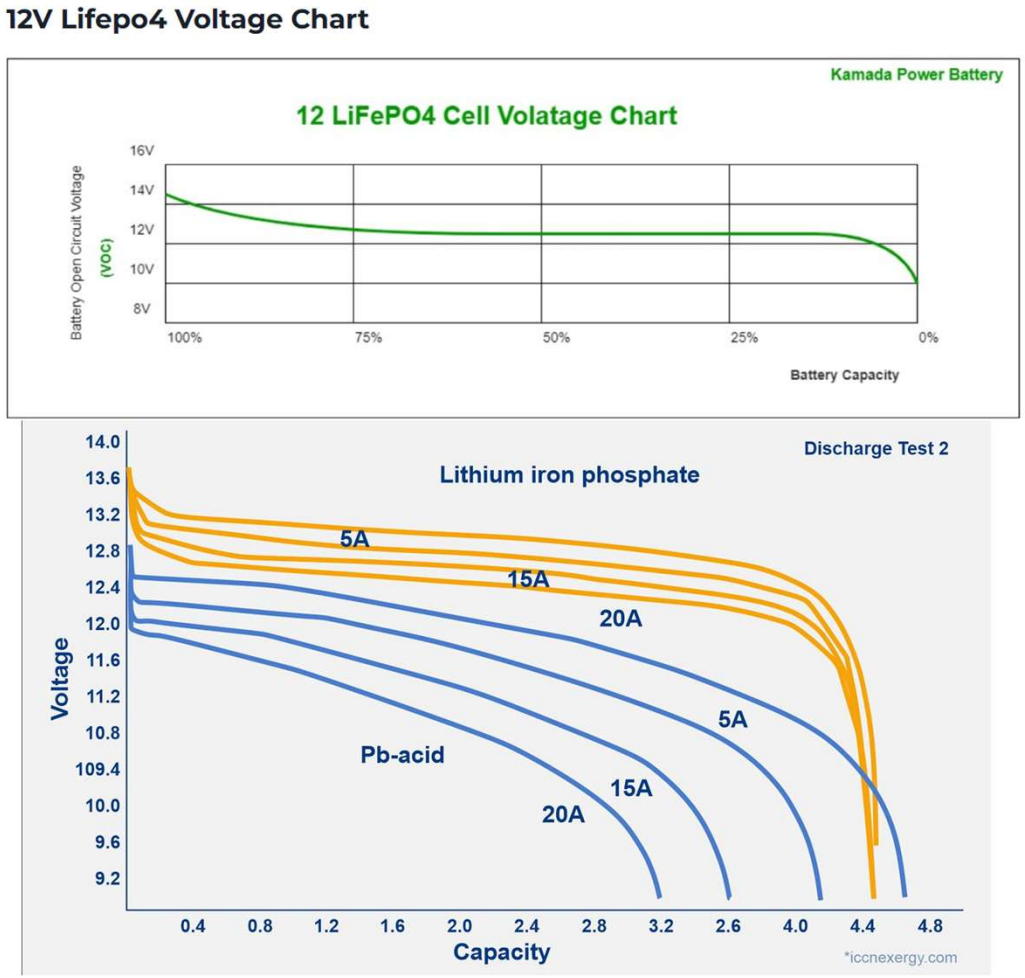
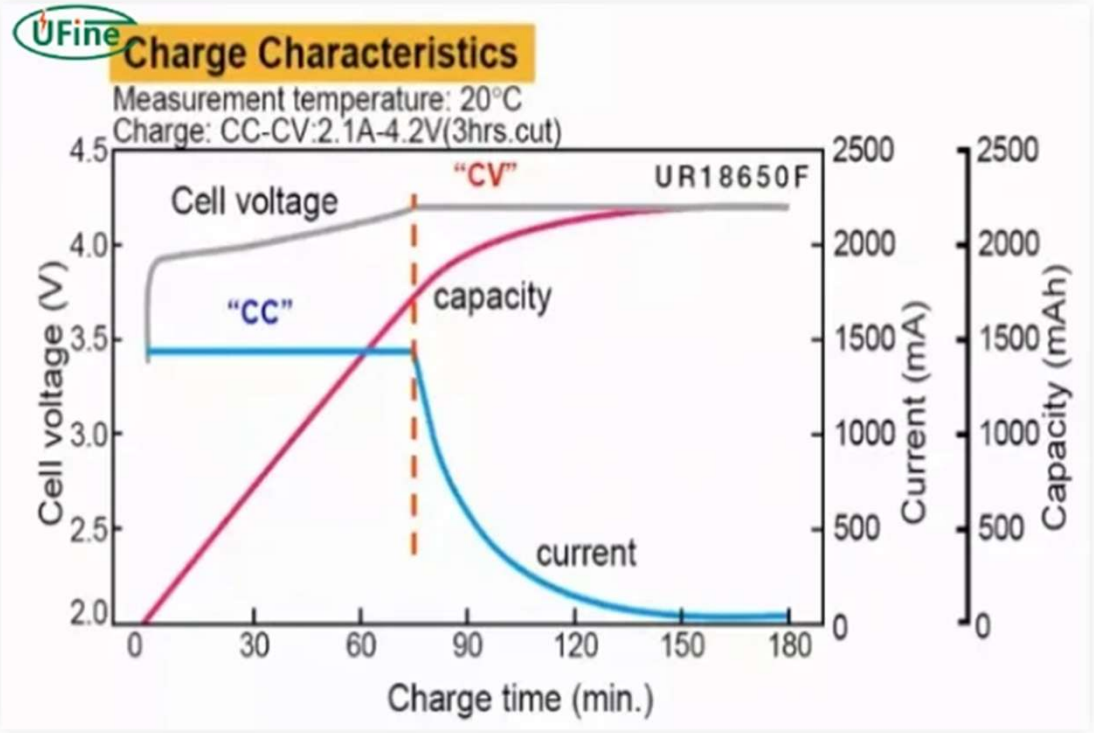


Chart uses a 7Ah Lead Acid battery and a 4.6 Ah LFP battery. The important item is how performance is affected by current. batteryadvancement.ca

LFP Important Characteristics

- LFP charge characteristics are similar to lead acid batteries
  - Figure to the right has the same charge structure as i the flooded lead acid battery presentation
  - Both batteries start with a constant current (CC) charge until the battery reaches transition voltage.
  - The battery then is charge with a constant voltage (CV) until the battery reaches full charge.
  - Charge cycle is completed when the battery charging current falls to a preset limit



LFP Safety Items

- Lead acid battery are hazardous due to the sulfuric acid electrolyte in them
  - Sulfuric acid can cause chemical burns and corrosion if spilled
  - Overcharging or a shorted cell can heat up the sulfuric acid where it will evolve large amounts of hydrogen gas which can rapidly disassemble the battery if ignited
- LFP batteries are hazardous due to the chemical mixtures in their electrolyte
  - If a cell is ruptured, the electrolyte can cause chemical burns and corrosion
  - Overcharging or a shorted cell can heat up the electrolyte where is can evolve large amounts of gas which can rapidly disassemble the battery
  - The electrolyte can evolve hazardous gases when heated

LFP Safety Items

- LFP cells have a high thermal runaway temperature (not a flash point) of 270^{o}C (518 ^{o}F).
  - Thermal runaway is the temperature where the materials in the cell will begin to self heat and result in the cell rupturing itself due to internal pressure
  - LFP chemistry does not generate oxygen during thermal runaway. If a spark is present, fire can result from the electrolyte chemicals and gases. The anode and cathode materials will not catch fire limiting cascading effect of cells
- LFP batteries should have a Battery Management System (BMS)
  - BMS is used to protect the user from damaging the battery by mis-using and mis-charging the battery. This in-turn prevents the battery from harming the user and the property surrounding the battery

BMS Features

- A good BMS has a MOSFET switch which can disconnect the battery
  - When overcharging is detected
  - When charging/discharging currents are too high
  - QUICKLY disconnect the battery during a short
  - When minimum SOC is reached to prevent battery damage
  - When cell/battery temperatures exceed a threshold, typically 60 ^{o}C (140 ^{o}F) Cell balancing during charging
- Cell Balancing
  - Imbalanced cell charges reduce the capacity of the battery. The lowest cell capacity sets the battery capacity.
  - Reduces thermal effects from a cell being overcharged while the other cells are still charging

BMS Features

- Cell monitoring during charging and discharging
  - Disconnecting the battery when a cell voltage is too low prevents battery damage
- Monitors SOC
  - Battery voltage has a small slope during most of its discharge
    - Accurate voltage and knowledge of the cell voltage characteristics is needed
    - Temperature measurement modifies voltage characteristics
  - Coulomb counting (Amp-Sec) allows Ahr usage calculations
- Communicates with outside systems
  - Allows the battery itself to control how it is being charged
  - Tells the user the battery status
    - Generic battery voltage measurements do not indicate battery SOC

Selected Links For More Information

- Battery University
  - Lots of battery information. All types of batteries including lead acid and Lithium
- ReLion
  - Battery seller with lots of information on its website. HAM size batteries as well as big batteries
- CATL
  - Battery manufacture but website is a little intimidating
- EcoFlow
  - Large batteries, think solar and wind storage
- AppBattery
  - Lots of LFP voltage and Soc information. Great site.
- Wikipedia
  - Our friend has lots of info and links to all sorts of places

Questions ????