What to Know About LiFePO4 Marine Batteries

- Overview of LiFePO4 battery technology
- LiFePO4 performance characteristics
- Comparison – lead acid and LiFePO4
- Designing a LiFePO4 battery bank for your boat
- Installation considerations
- Summary

Slides are available for reference at
custommarineproducts.com

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What is a LiFePO4 Lithium Iron Phosphate Battery?

Li Fe PO

LiFePO Cells (LFP)

+

Battery Management System (BMS)

+

Sealed Case

=

LiFePO4 Battery

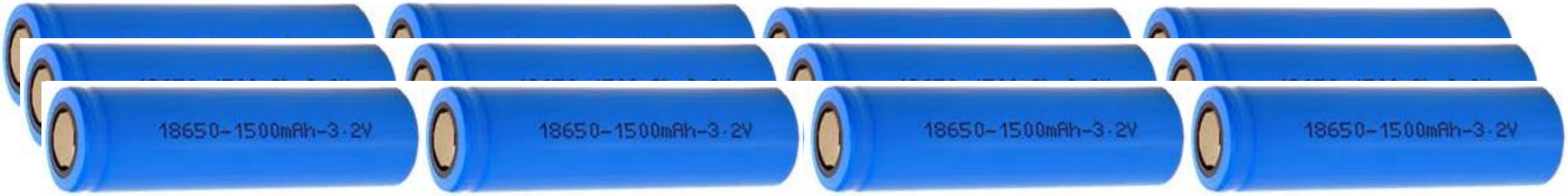
Lithium Iron Phosphate is a lithium chemistry that has excellent thermal and structural stability and excellent power density.

What to Know About LiFePO (LFP) Cells

LiFePO – Lithium Iron Phosphate also referred to as LFP

- LFP is a lithium chemistry that has many advantages
  - High thermal and chemical stability – won't catch on fire
  - Long cycle life - >2,000 charge cycles
  - Constant discharge voltage – full power until discharged
  - High energy density – double lead acid (power stored/weight)
  - Low discharge rate – limited power loss in storage
  - Rapid and efficient charging – >20% more efficient than lead acid
- Disadvantage
  - Should not be charged or discharged below -4 F, -20 C
  - High initial investment
- Commonly used cell models
  - 26650, 32700

What does the ‘4’ mean in LiFePO4?



3.2 V + 3.2 V + 3.2 V + 3.2 V = 12.8 V

Four groups of cells wired in series = 12.8 Volts

What is a BMS – Battery Management System?

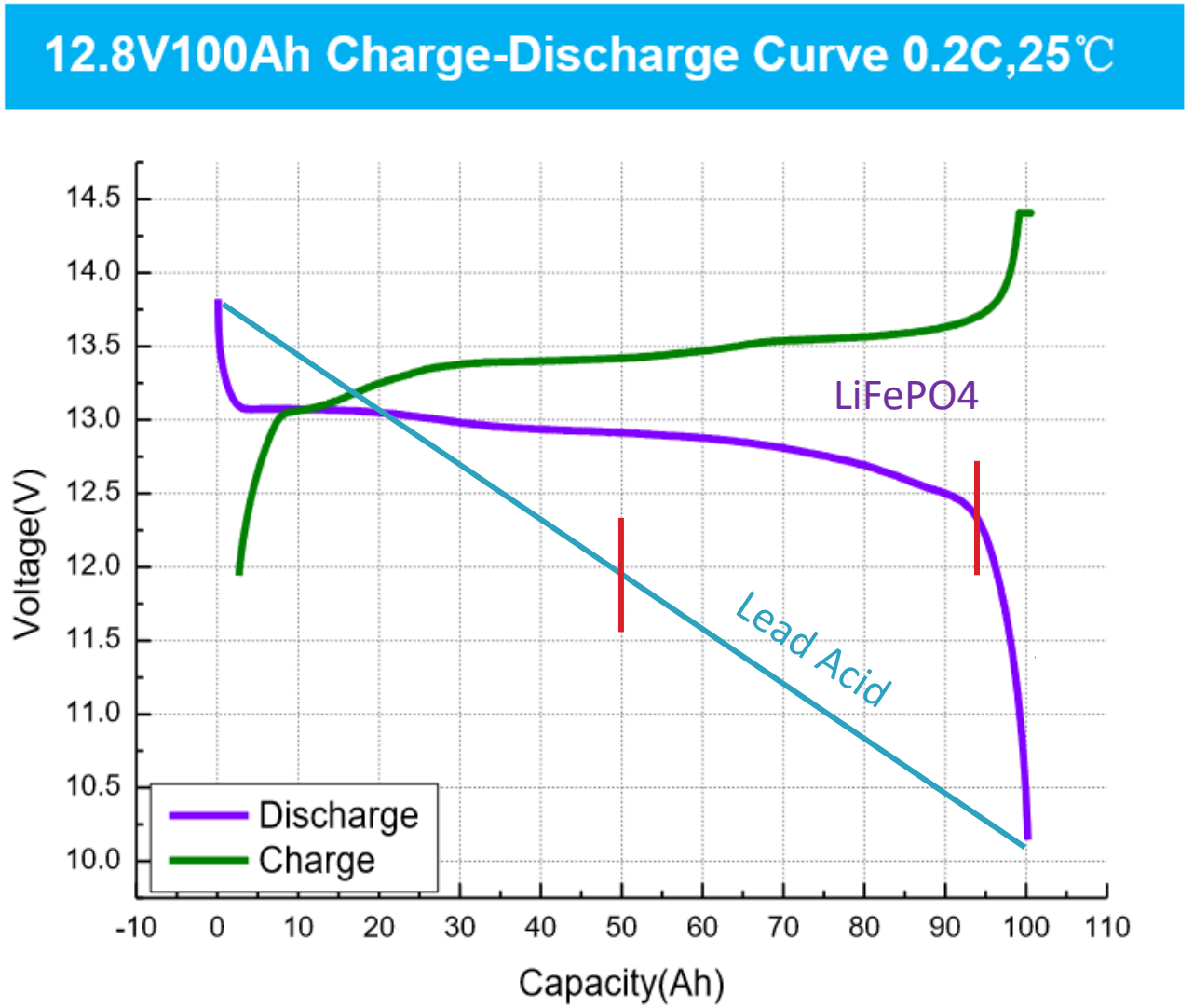
The BMS regulates the power charge and discharge of the battery and protects the cells from being damaged.

- Power regulation for cell protection
  - Over and under voltage monitoring for charge and discharge
  - Low and high temperature during charge and discharge
  - Maximum current draw
  - Short circuit cut off
- Keeps all cells in balance
  - Regulates cell charging so all cells maintain the same charge level
- Enables “drop in” replacement for lead acid and AGM batteries
- Monitors and reports battery functions
  - Some BMS’s report battery State of Charge through a meter or Bluetooth app.

LiFePO4 Battery Discharge Curve

Flat rate of discharge:

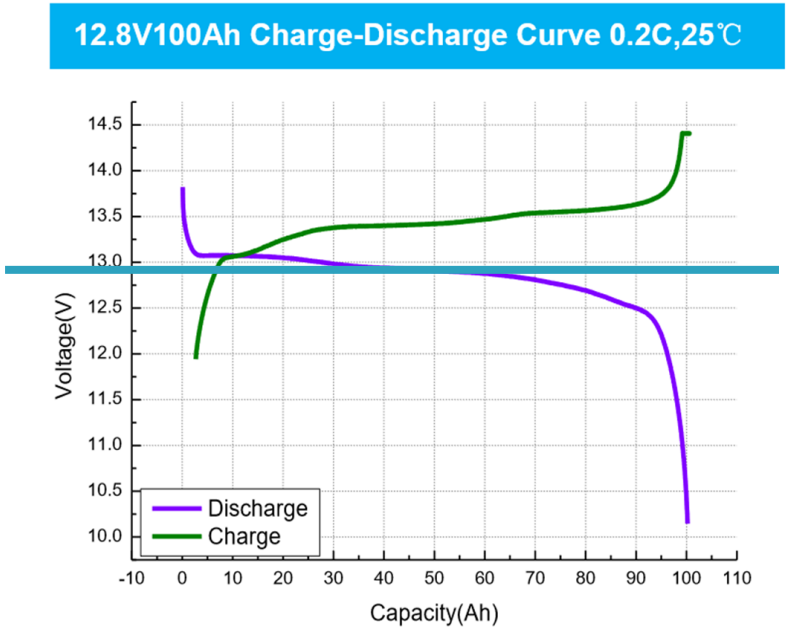
- Appliances run more efficiently
- 95%+ of rated capacity is useable capacity
- Volt meter does not accurately indicate State of Charge (SoC)



'**C**' is the amp hour (Ah) rating of the battery

Why is a Bluetooth Battery Monitor Important?

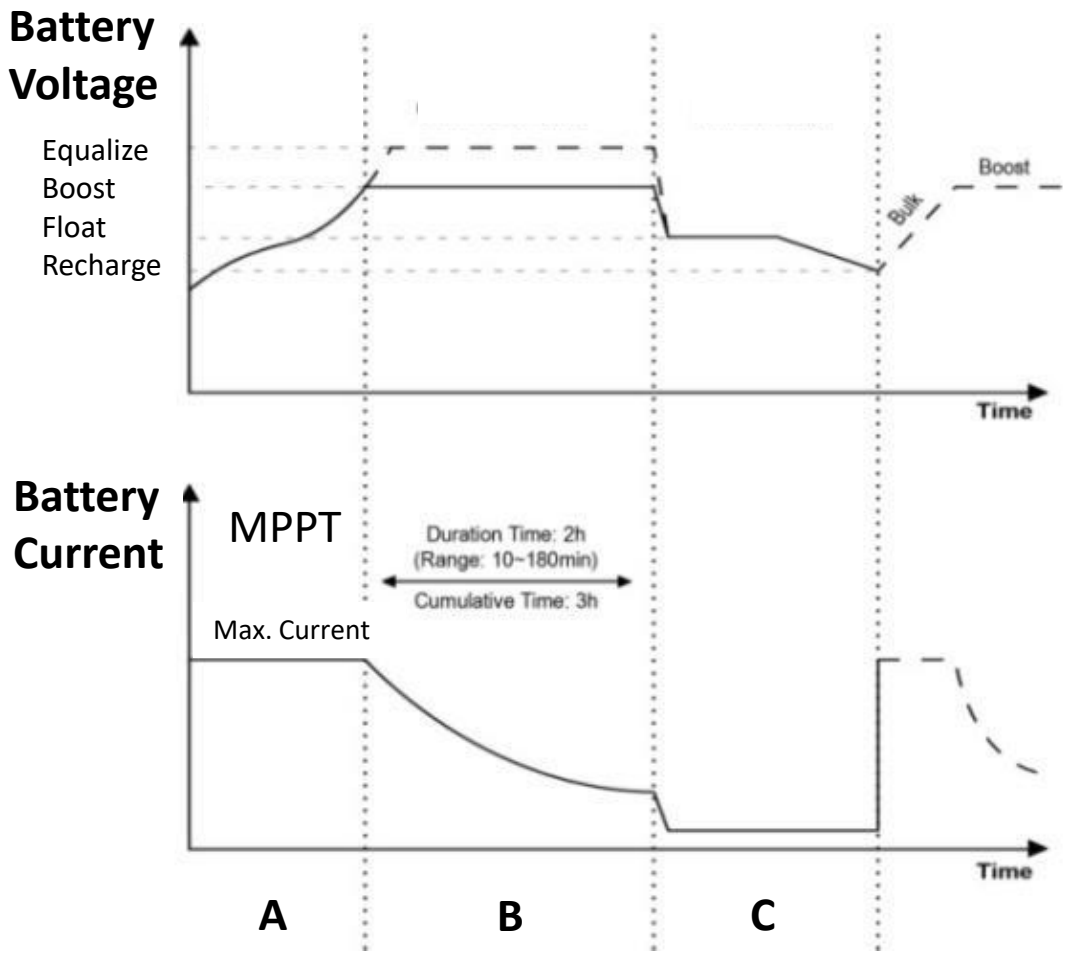
A volt meter is not accurate because the discharge voltage is nearly constant.



An app connected directly to the BMS provides better accuracy than external measuring systems.

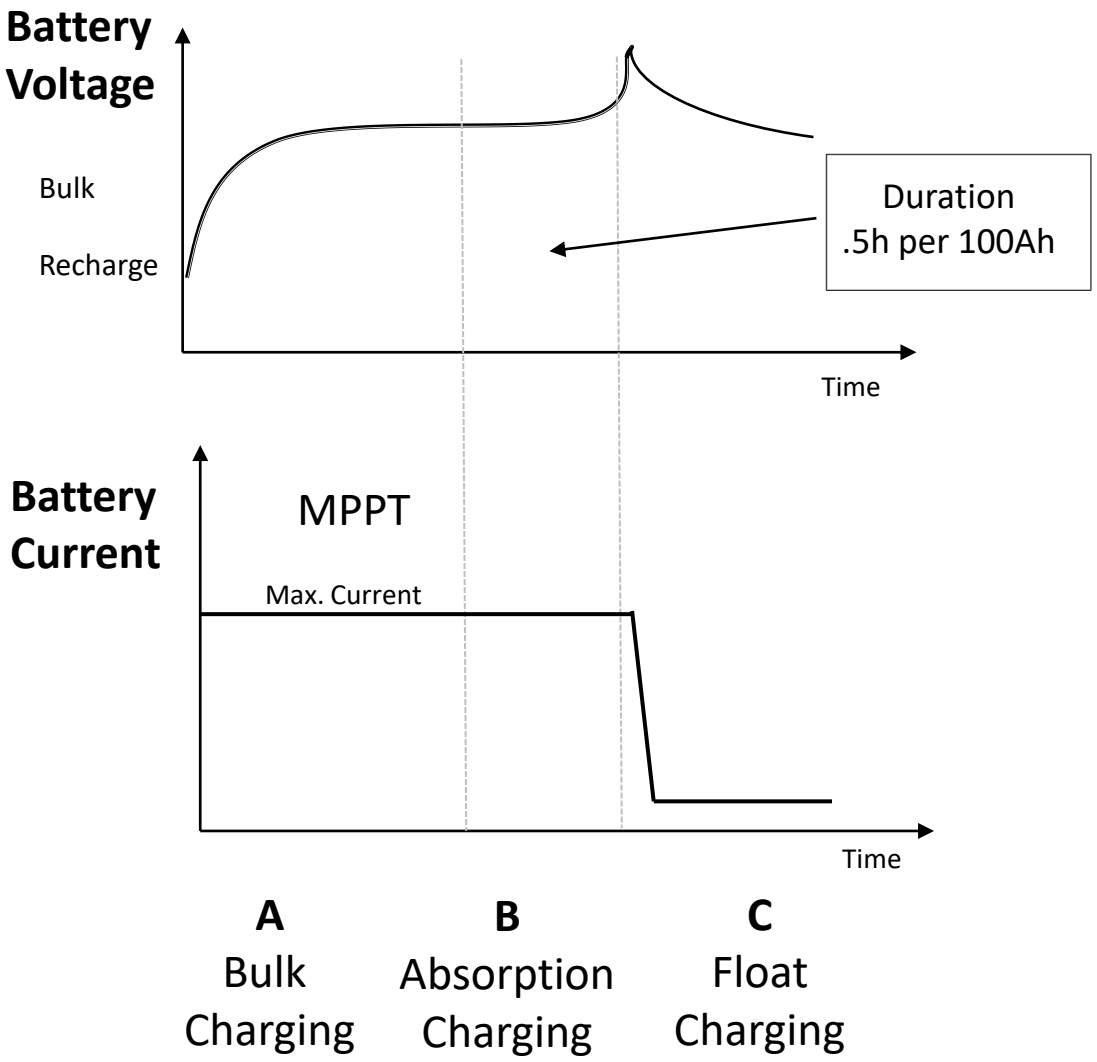
Battery Charging Curves

Lead Acid



EP Solar

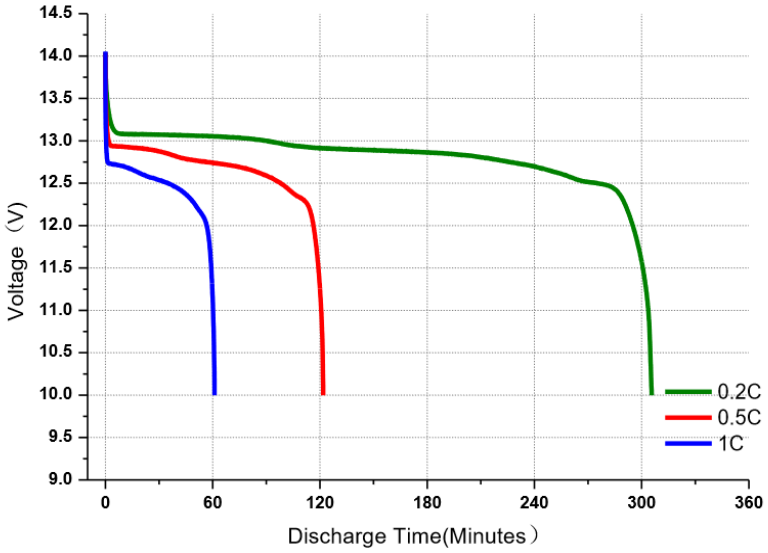
LiFePO4



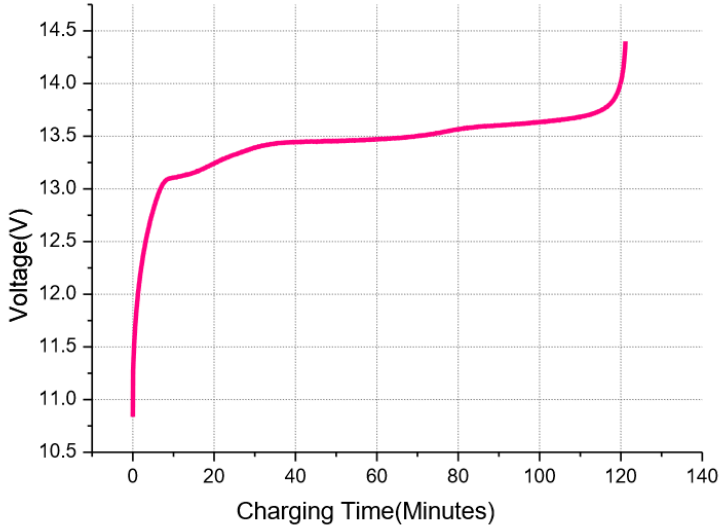
CMPower

LiFePO4 Battery Performance

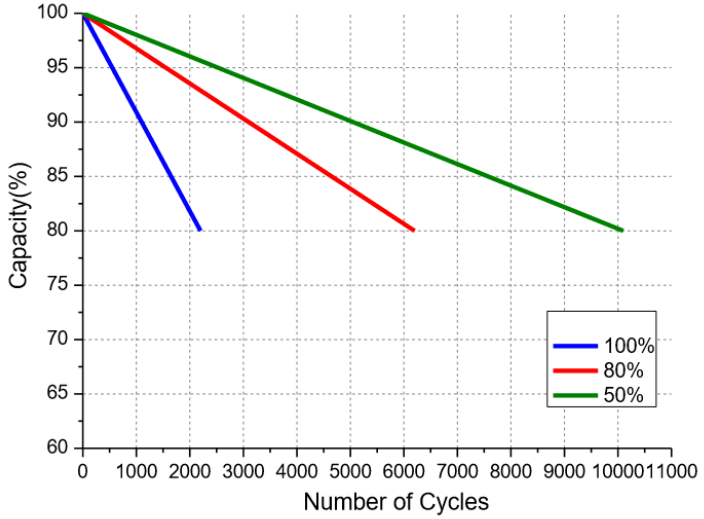
Different Rate Discharge Curve，25℃



Voltage & Charging Time Curve,0.5C,25℃



Different DOD Discharge Cycle Life Curve



‘**C**’ is the amp hour (Ah) rating of the battery

Temperature Impact on Battery Life

Cycling at high charge/discharge rates at extreme temperatures will reduce the number of life cycles, especially at low temperatures.

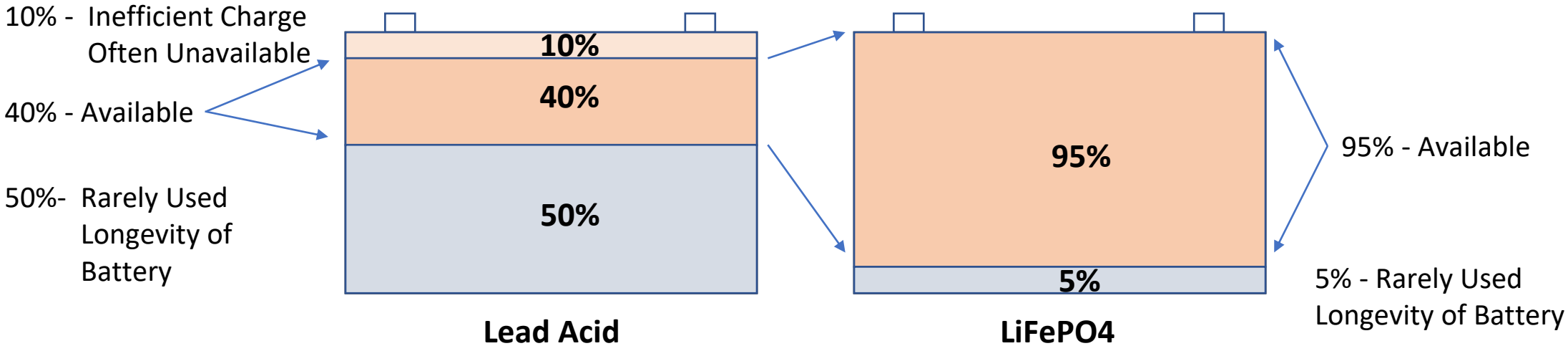
Charge Temperature	32°F to 113°F	0°C to 45°C	
Discharge Temperature	-4°F to 140°F	-20°C to 60°C	
Storage Temperature	-10°F to 104°F	-25°C to 40°C	

Charging and discharging a LiFePO4 battery does not generate heat within the battery.

Example of LiFePO4 Battery Specifications

Electrical Characteristics	CMPower LiFePO4 Battery Specifications							
Rated Capacity	**100Ah**	**100Ah**	**120 Ah**	**150Ah**	**152 Ah**	**180Ah**	**200Ah**	**150Ah**
Nominal Voltage	12.8V	12.8V	12.8V	12.8V	12.8V	12.8V	12.8V	25.6V
Energy	1,280Wh	1,280Wh	1,536Wh	1,920Wh	1,946Wh	2,304Wh	2,560Wh	3,840Wh
Internal Resistance	≤30mΩ							
Cycle Life	>2,000 cycles @ 100% DOD, >3,000 cycles @80% DOD (DOD - Depth of Discharge)							
Self Discharge	<3% per month							
Standard Charge								
Charge Voltage	14.4±0.2V							28.8±0.2V
Charge Mode	CC/CV							
Optimal Charge Current (.2-.5C)	20-50A	20-50A	24-60A	30-75A	30-75A	36-90A	40-100A	30-75A
Max. Charge Current	100A	150A	150A	150A	120A	150A	120A	120A
Charge Cut-off Voltage	14.6V	14.6V	14.6V	14.6V	14.6V	14.6V	14.6V	29.2V
Standard Discharge								
Continuous Current	**100A**	**150A**	**150A**	**150A**	**120A**	**150A**	**120A**	**120A**
Discharge Cut-off Voltage	9V	9V	9V	9V	10v	9V	10V	18V
Environmental								
Charge Temperature	32°F to 113°F 0°C to 45°C							
Discharge Temperature	-4°F to 140°F -20°C to 60°C							
Storage Temperature	-10°F to 104°F -25°C to 40°C							
Water/Dust Resistance	IP56							
Passive Protection	Over charge, over discharge, temperature, short circuit, balance							
Mechanical								
Material System	LiFePO4							
Plastic Case	ABS+PC UL V-0 flame resistant							
Dimensions inches	13 x 6.7 x 8.3 H	13 x 6.7 x 8.3 H	13 x 6.7 x 8.3 H	18.9 x 6.7 x 9.5 H	13x6.8x8.4H	18.9 x 6.7 x 9.5 H	20.5x9.2x8.7H	20.5x10.5x8.7
mm	330x170x210 H	330x170x210 H	330x170x210 H	480x170x240 H	328x172x212H	480x170x240 H	521x233x220H	520x267x220 H
Weight	30.8 lb. 14 kg	30.8 lb. 14 kg	35.3 lb. 16 kg	44.1 lb. 20 kg	36.3 lb. 16.5 kg	52.9 lb. 24 kg	59.3 lb. 26.9 kg	86 lb. 39kg
Terminal	M8							
State of Charge Monitor	Bluetooth app							
Shelf Life	6 months - recharge							

Comparison of Lead Acid vs. LiFePO4 - 100Ah Battery



Useable Amp Hours	**40-50 Ah**	**90 - 95 Ah**

Ah - Amp hours

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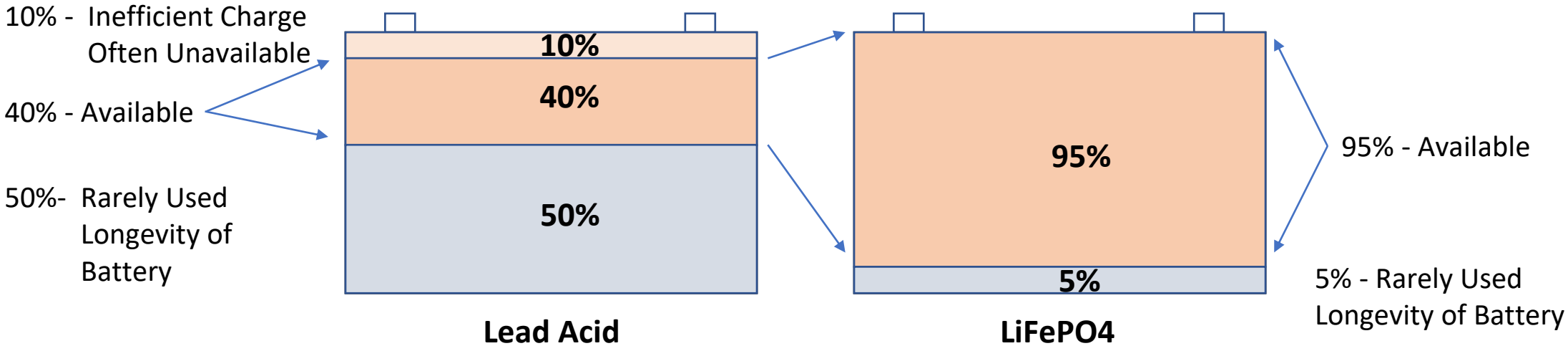

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Weight	**65 lbs.**	**31 lbs.**

lbs. - pounds

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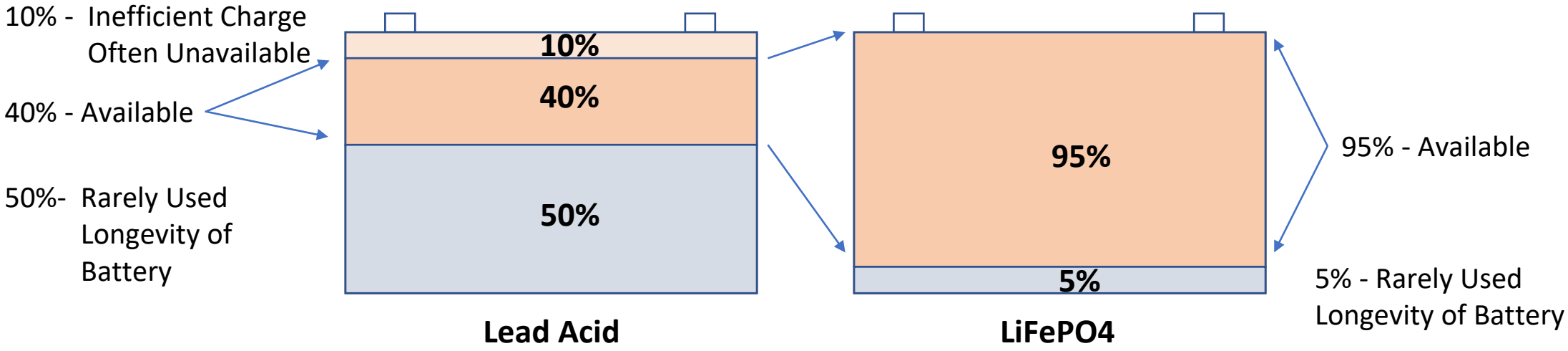

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Energy Density	**9 Wh/lb.**	**39 Wh/lb.**

Wh – Watt hours

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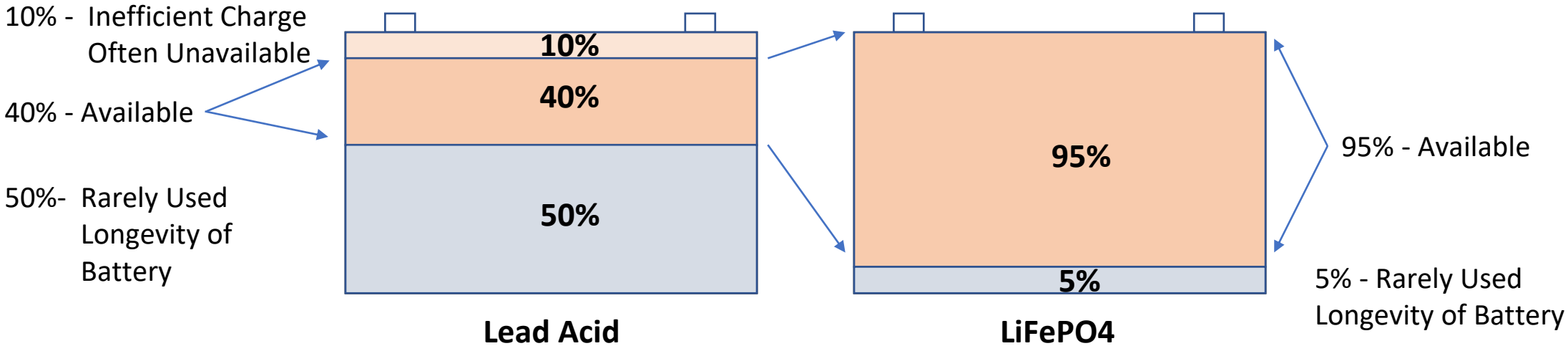

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Charge/discharge Cycles	**<400**	**>2,000**

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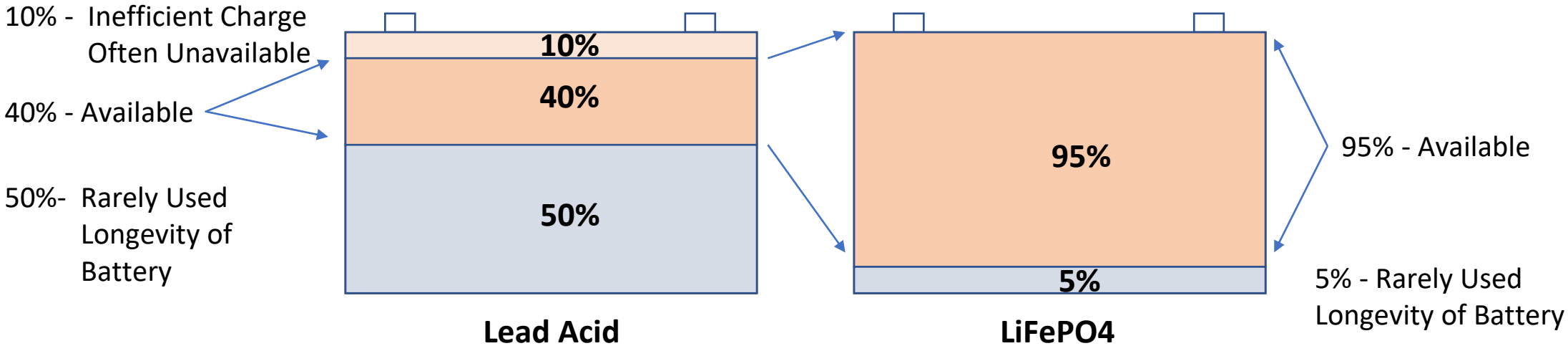

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Weight	65 lbs.	31 lbs.
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Charge Efficiency	**70-80%**	**99%**

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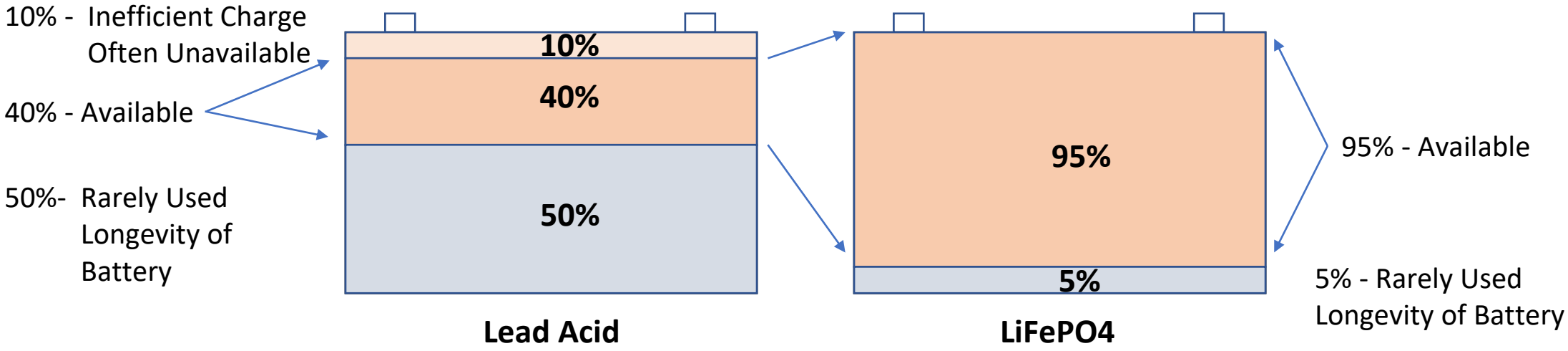

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Weight	65 lbs.	31 lbs.
Energy Density	9 Wh/lb.	39 Wh/lb.
Charge/discharge Cycles	<400	>2,000
Charge Efficiency	70-80%	98%
Self Discharge	**up to 20% / mon.**	**<3% / mon.**

Designing a LiFePO4 Battery Bank for Your Boat

1. Determine power usage for a day

1 AH - Amp Hours - Amps of current consumed in one hour

2 Windlass is often not considered because the engine alternator is running when used

Note:

1,100 watts / 13 volts x 1.2 inverter inefficiency factor

Daily Power Consumption Analysis					Design
Appliance DC	Amps	Hours At Anchor	Hours On Passage	Daily AH *1* At Anchor	Daily AH On Passage
Refrigeration	5	10	10	50	50
Radar	4		4	0	16
Computer - Laptop	4	1	10	4	40
Autopilot	4		10	0	40
Cabin Lights (LED)	1	4		4	0
Nav/Anchor Lights	0.2	10	10	2	2
Stereo	1	3	3	3	3
VHF Radio	0.5	10	10	5	5
Instruments	1		8	0	8
Pressure Water	6	0.25	0.1	1.5	0.6
Phone Charger	1	2	2	2	2
Other				0	0
Other				0	0
Total Amp Hours				71.5	166.6
AC - Equipment powred by an Inverter (Watts)					
Microwave (Watts)	1100	0.1	0.1	10.2	10.2
Other				0.0	0.0
Other				0.0	0.0
Windlass *2*				0.0	0.0
Total Amp Hours				10.2	10.2
Total Amp Hours Consumed per Day				81.7	176.8
Battery Charging Voltage			13		
Total Watt Hours Consumed per Day				1,061.5	2,297.8

Designing a LiFePO4 Battery Bank for Your Boat

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Cabin Lights (LED)	1	4		4	0
Nav/Anchor Lights	0.2	10	10	2	2
Stereo	1	3	3	3	3
VHF Radio	0.5	10	10	5	5
Instruments	1		8	0	8
Pressure Water	6	0.25	0.1	1.5	0.6
Phone Charger	1	2	2	2	2
Other				0	0
Other				0	0
Total Amp Hours				**71.5**	**166.6**
AC - Equipment powred by an Inverter (Watts)					
Microwave (Watts)	1100	0.1	0.1	10.2	10.2
Other				0.0	0.0
Other				0.0	0.0
Windlass *2*				0.0	0.0
Total Amp Hours				**10.2**	**10.2**
Total Amp Hours Consumed per Day				**81.7**	**176.8**
Battery Charging Voltage			13		
Total Watt Hours Consumed per Day				**1,061.5**	**2,297.8**

Designing a LiFePO4 Battery Bank for Your Boat

2. Determine the days of reserve capacity desired
3. Determine optimal useable battery capacity
4. Determine the capacity of the batteries to be used
5. Calculate the number of batteries needed

LiFePO4

		At Anchor	On Passage
Number of Days of Reserve Battery Capacity	2		
% of Battery Capacity Useable	90%		
Rated Battery Capacity Required (AH)		181.5	392.8
Rated Battery Capacity (Ah)	120		
Number of Batteries Required (in parallel)		1.5	3.3

2 4

Lead Acid

		At Anchor	On Passage
Number of Days of Reserve Battery Capacity	2		
% of Battery Capacity Useable	50%		
Rated Battery Capacity Required (AH)		326.6	707.0
Rated Battery Capacity (Ah)	120		
Number of Batteries Required (in parallel)		2.7	5.9

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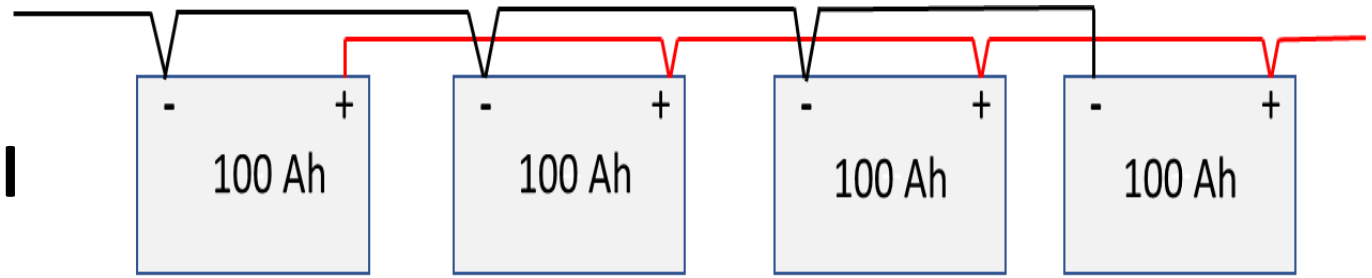
Wiring a Battery Bank

Battery Specifications

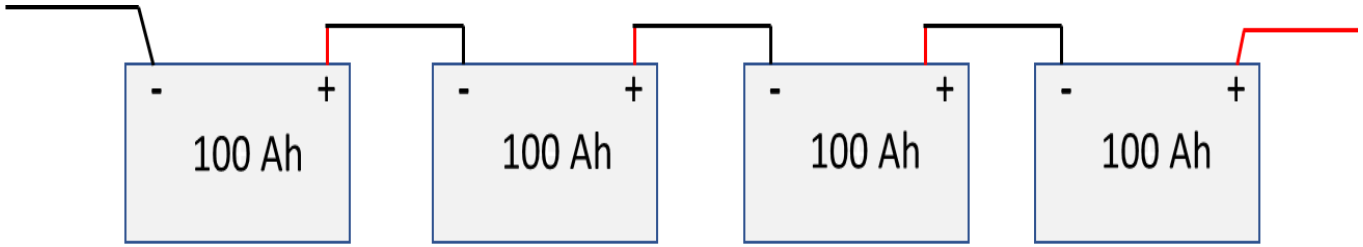
Capacity	100 Ah
Voltage	12 V
Continuous Current	100 A

Parallel



12V **400 A** Continuous Current - 360 Ah Capacity at 90%

Series



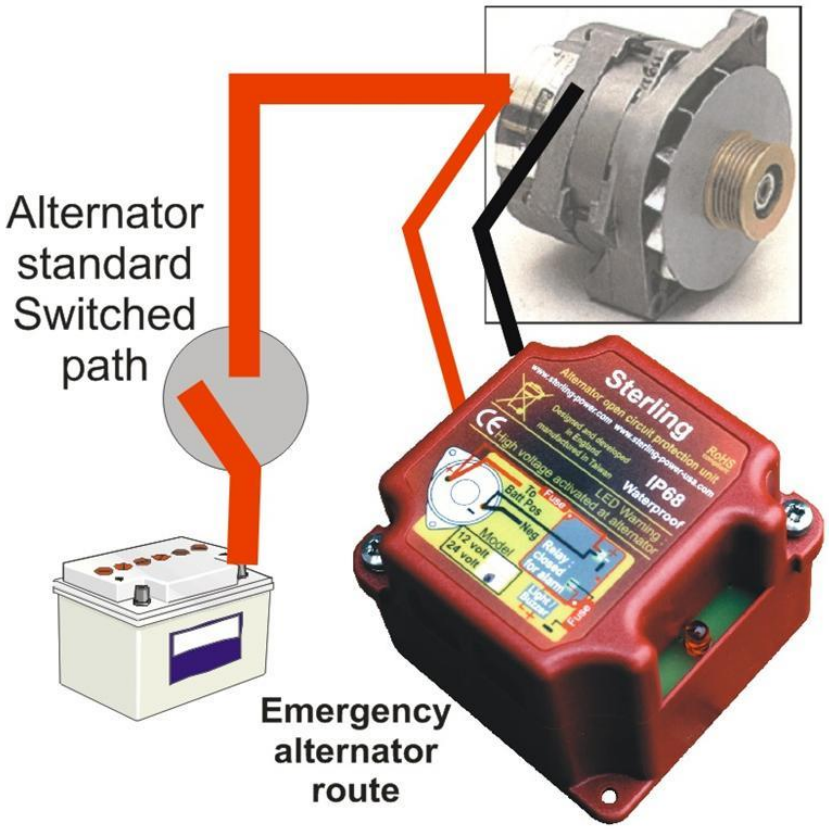
48V **100 A** Continuous Current - 360 Ah Capacity at 90%

CMPower BMS will support 10 batteries in parallel and 4 batteries in series.

Wire batteries together only when their SoC is within 5% of each other.

Alternator Protection

- Abrupt interruption of a load on the alternator can cause a voltage spike that could damage the alternator and possibly damage sensitive electronic equipment.
- Such an interruption could occur when the battery BMS shuts off from high voltage or during switching between battery banks.
- A Sterling Power Alternator Protection Device (APD) absorbs the voltage spike and protects the alternator. Cost <$90.
- Not all BMS's do abrupt cutoff. Batteries wired in parallel will likely have staggered high voltage cutoff mitigating the issue.



Installation Considerations

- Batteries can be mounted on bottom or any side
- Batteries should be mounted in a moderate temperature environment
  - not in the engine room
- All positive wires should be fused per ABYC standards
- All batteries should be within 3% State of Charge before connecting together
- Lead acid or AGM batteries should not be connected with LiFePO4 batteries
- Battery monitor - Peukert constant should be set to 1.04 (1.25 for lead acid)
- Charging parameters for charging sources may need to be adjusted
  - max voltage, etc.

Parameters for Charging LiFePO4 Batteries

If a “LiFePO4” setting is not available on your controller, use the “USER” function to program and set the following parameters:

- **Absorption voltage:** 14.4 volts (acceptable range is 14.4 to 14.6 volts)
- **Absorption Time:** The recommended setting is half an hour per 100ah of LiFePO4 battery
  - (for example: for 2 -100ah batteries select 1 hour).
- **Float Voltage:** 13.5 volts (13.6 volts or lower is acceptable for LiFePO4 batteries although float is not necessary)
- **Equalization voltage: Do not** equalize LiFePO4, turn off the equalize function, but in case it ever runs a cycle or equalization can’t be turned off set to 14.4 volts.
- **Temperature Compensation:** LiFePO4 batteries do not need temperature compensation.
- **Low Temperature cut-off:** -5 degrees C, 20 degrees F

Advantages of LiFePO4 Marine Batteries vs. Lead Acid Batteries

- Lighter than lead acid or AGM (half the weight - 4x energy density)
- Can be drawn down 95% vs 50% (double the usable power)
- Hold a steady voltage through 95% discharge (appliances run more efficiently)
- Generally plug compatible with lead acid chargers (easy installation)
- Charge more quickly than lead acid (less charging time)
- Charge more efficiently than lead acid (ideal for solar and wind generation)

Advantages of LiFePO4 Marine Batteries vs. Lead Acid Batteries

- Up to 10 times more charge cycles than lead acid (could last a lifetime +)
- Nontoxic and safe (very low fire risk, no fumes or acid)
- Low self-discharge (easy winter storage)
- Bluetooth battery monitor built in (accurate State of Charge data)
- Environmentally friendly (no toxic chemicals or heavy metals)

Disadvantages of LiFePO4 Marine Batteries

- Operating temperature range (lead acid can operate at lower temps)
  Discharging below -4F will reduce cycle life
- Some chargers are not be compatible (additional equipment expense)
- Initial investment is higher than lead acid (advantages and longevity significant)
  (concept of a Battery Exchange)

Things to Unlearn When Moving from Lead Acid to LiFePO4 Marine Batteries

- **Constant Voltage** - Voltage does not decrease significantly and battery power is used.
- **Battery charging** – Charging to full is not necessary. 95% of power rating is available, not just top 50%.
- **Battery Charging** – Short absorption stage, no equalization, float stage is not necessary.
- **State of Charge** – 50% State of Charge is fine. 45% of power is still available.
- **Faster more efficient charging** – More power is saved faster.
- **Discharging** – Constant discharge voltage so appliances run more efficiently resulting in decreased power usage.
- **Maintenance** – No toxicity. No water level to check, no heat to be concerned about.
- **Easy Winter Storage** – Simply disconnect until next season.
- **Easy Monitoring** – Bluetooth app displays SoC and power remaining anytime from Smartphone.

What to Look for When Purchasing LiFePO4 Batteries

- Quality of the LFP cells (Lithium Iron Phosphate)
- Quality and functionality of the BMS (Battery Management System)
- Continuous discharge rate, peak discharge rate
  (minimum of 1C or 100A C - Ah capacity, we prefer 120A+ for marine)
- Determine how many batteries can be wired in series or parallel
- Battery monitor - Bluetooth or built in meter
- Compatibility with existing chargers and controllers
- Warranty – battery exchange
- Support

Specifications

Capacity

Ah - Amp Hours

V - Volts

Wh - Watt hours

Performance

A - Continuous discharge amps

Below is contact information should you have questions or comments.

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CMPower™