Lithium Rechargeable Cells for Extreme Temperatures –

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Shmuel De-Leon
shmuel@sdle.co.il

The Needs for Extreme Temperatures Lithium Rechargeable Batteries

- Military communication batteries
- Deep-Space applications
- Automotive
- Heat Sterilizable applications
- Car alarm system transmitters
- Container and Cargo tracking
- Deep-Space applications
- Many others

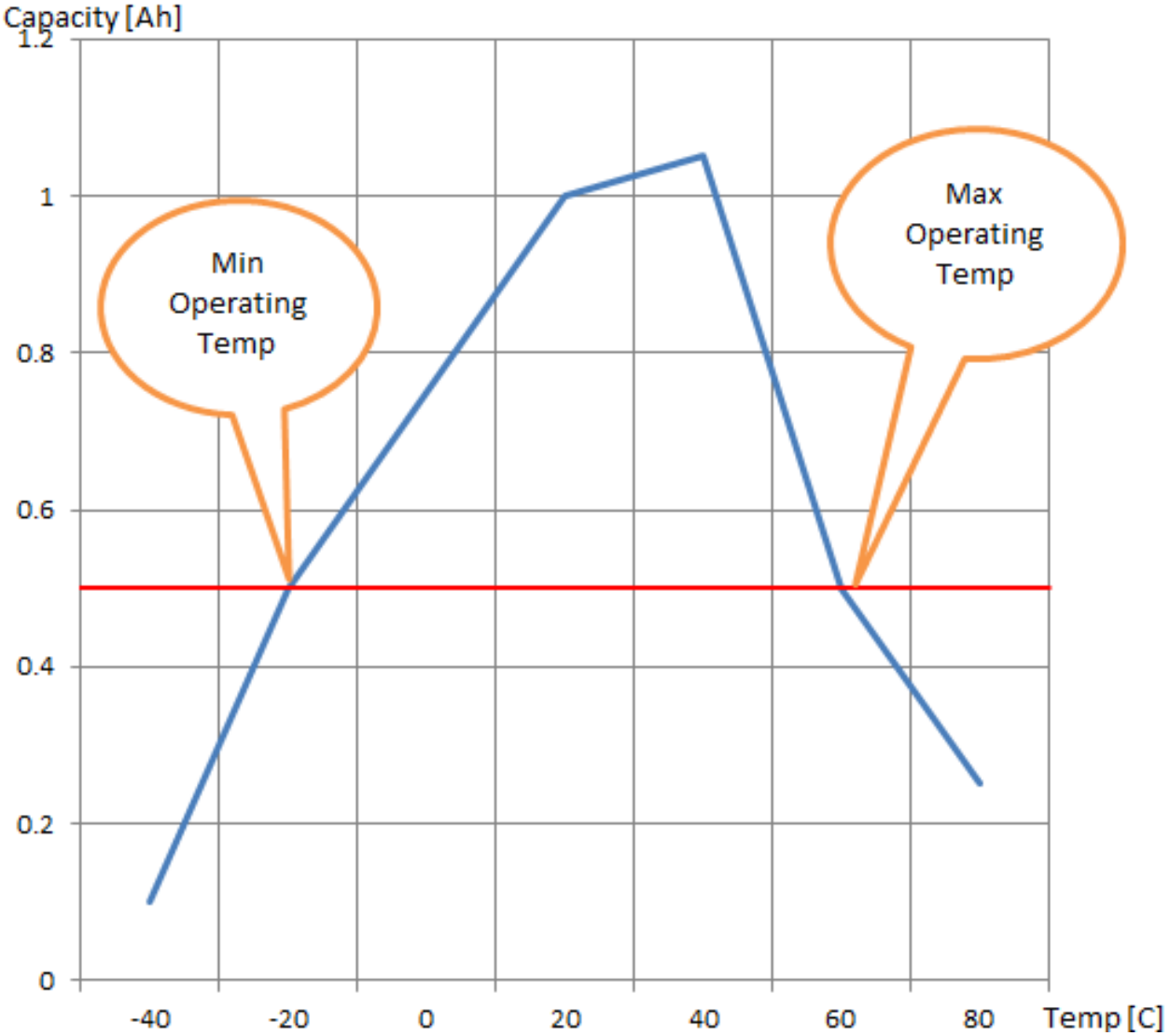
What are Extreme Temperatures for Rechargeable Li-Ion Cells?

	Standard Temperatures Range [°C]	Extreme Temperatures Range [°C]
Discharge	-20 to 60	< -20, >60
Charge	0 to 45	< 0, >45
Storage	-10 to 35	<-10, >35

What a surprise – almost all cell makers define their cells to operate in the standard range!!!.
Is it that real? Or just marketing policy?

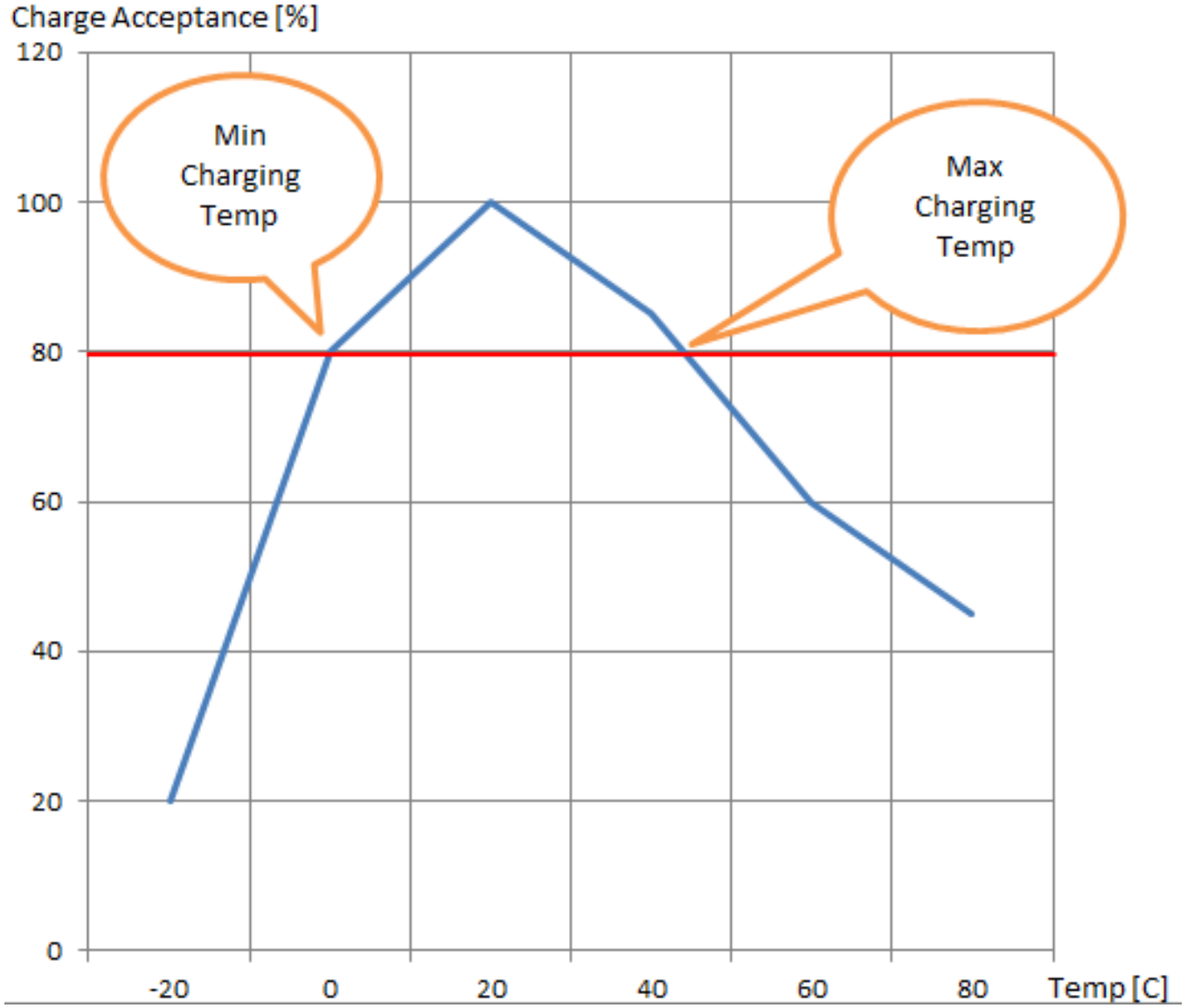
Unofficial Industry Low - High Discharge Temperature Limit Definitions

Max-Min operating temperatures defined where discharge capacity reach 50% of RT nominal capacity and there is no safety risks



Unofficial Industry Low - High Charge Temperature Limit Definitions

Max-Min charging temperatures defined where charging capacity acceptance reach 80% of RT standard discharge capacity and there is no safety risks

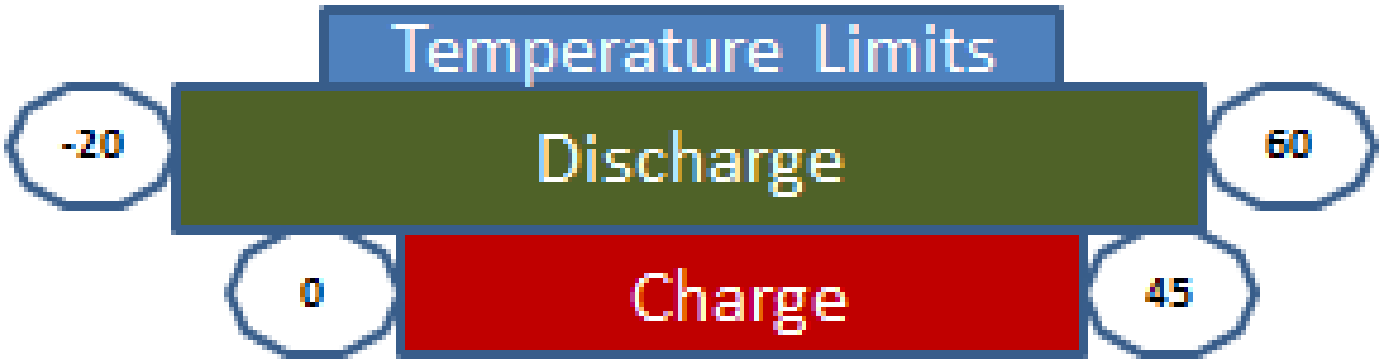


Why Charging Temp. limits are Narrower than Discharging Temp. Limits?

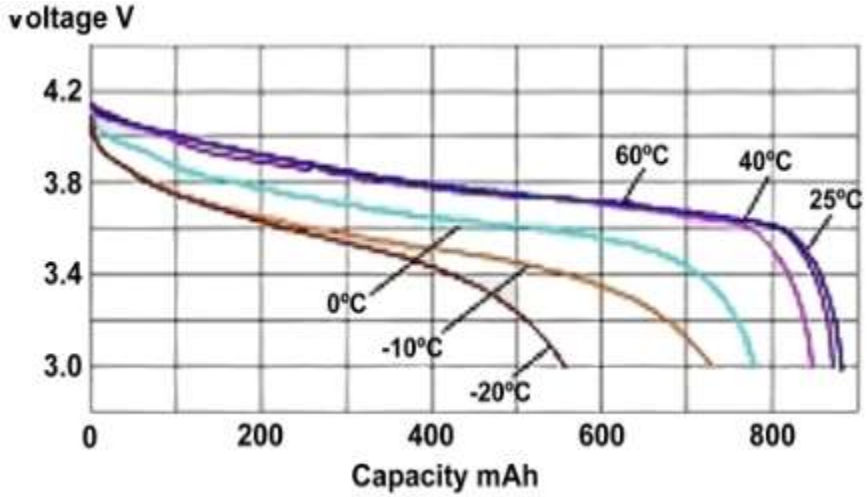
- During charging, cells may face extreme temperatures <u>but also</u> high charging voltage

- Chemical reactions inside the cell are driven faster by temperatures and voltage combine

- High potential for performance degradation and for a safety concern



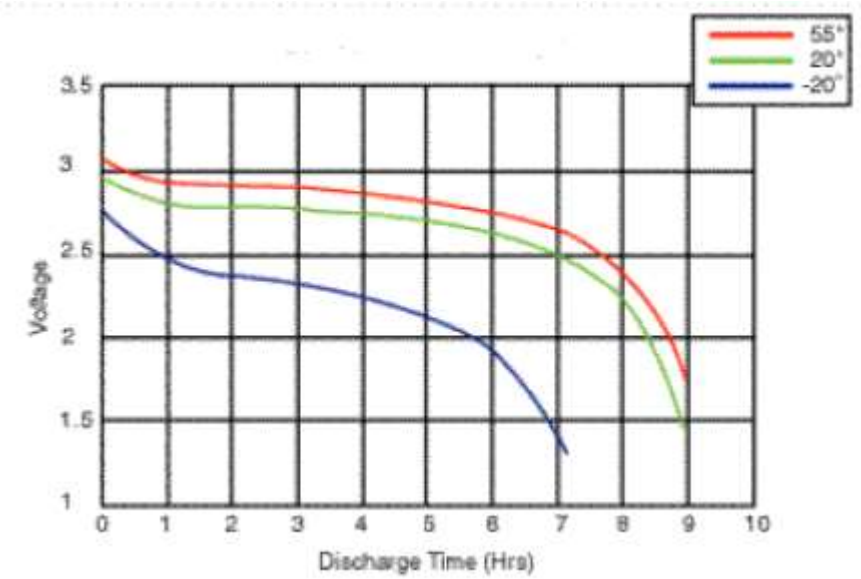
What Happen on Extreme High Temperatures



- Poor discharge capacity
- Poor charge acceptance
- Low cycle, calendar & shelf life
- High self discharge
- Increased internal pressure - Packaging expansion, Separator shrink
  (At around 135 °C the polymer separator melts allowing short circuit between the electrodes)
- Chemical damage - electrode passivation, corrosion and gassing
  (Typically gassing starts on 110 °C but on some electrolytes it can start from 70 °C)
- Internal safety CID and vents may works
- Higher safety risk for thermal runaway - Leaks, Vents, Fires, Explosions

- Positive effect - High operating voltage/more power

What Happen on Extreme Low Temperatures

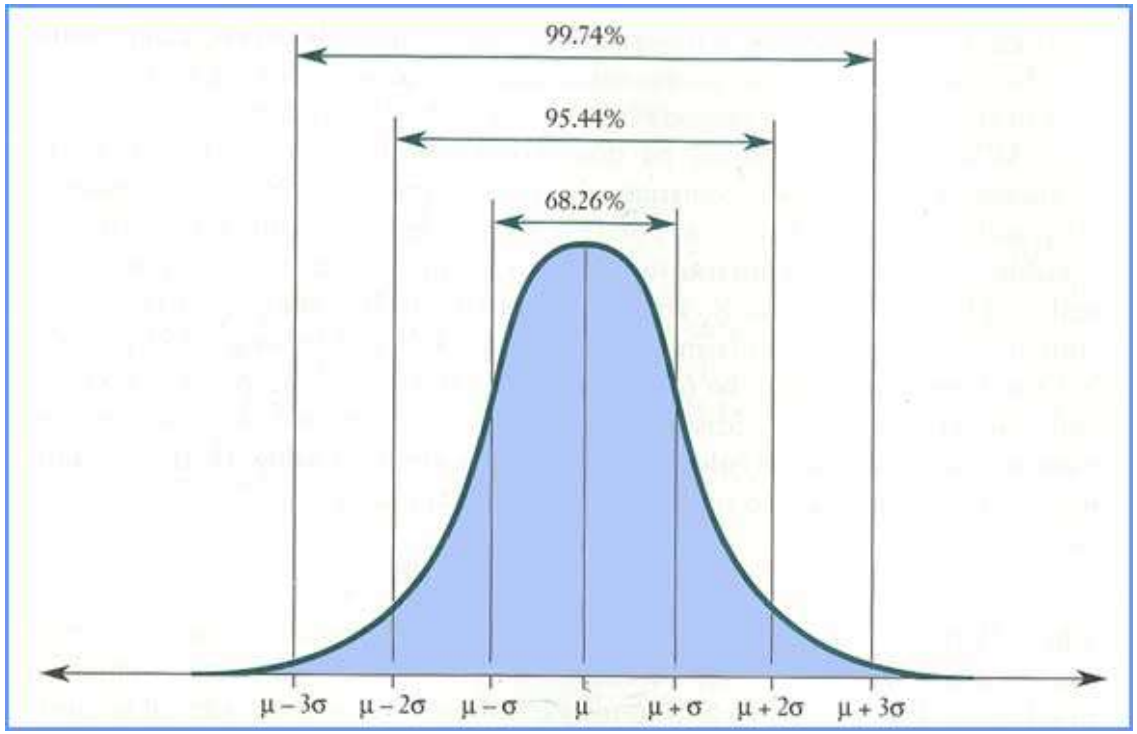


- Poor discharge capacity
- Poor discharge power
- Poor charge acceptance
- Low cycle, calendar & shelf life
- Risk of lithium plating
- Electrolyte freezing - Shorter shelf life and sometime irreversible damage
- Mechanical damage - Packaging shrink especially on pouch's

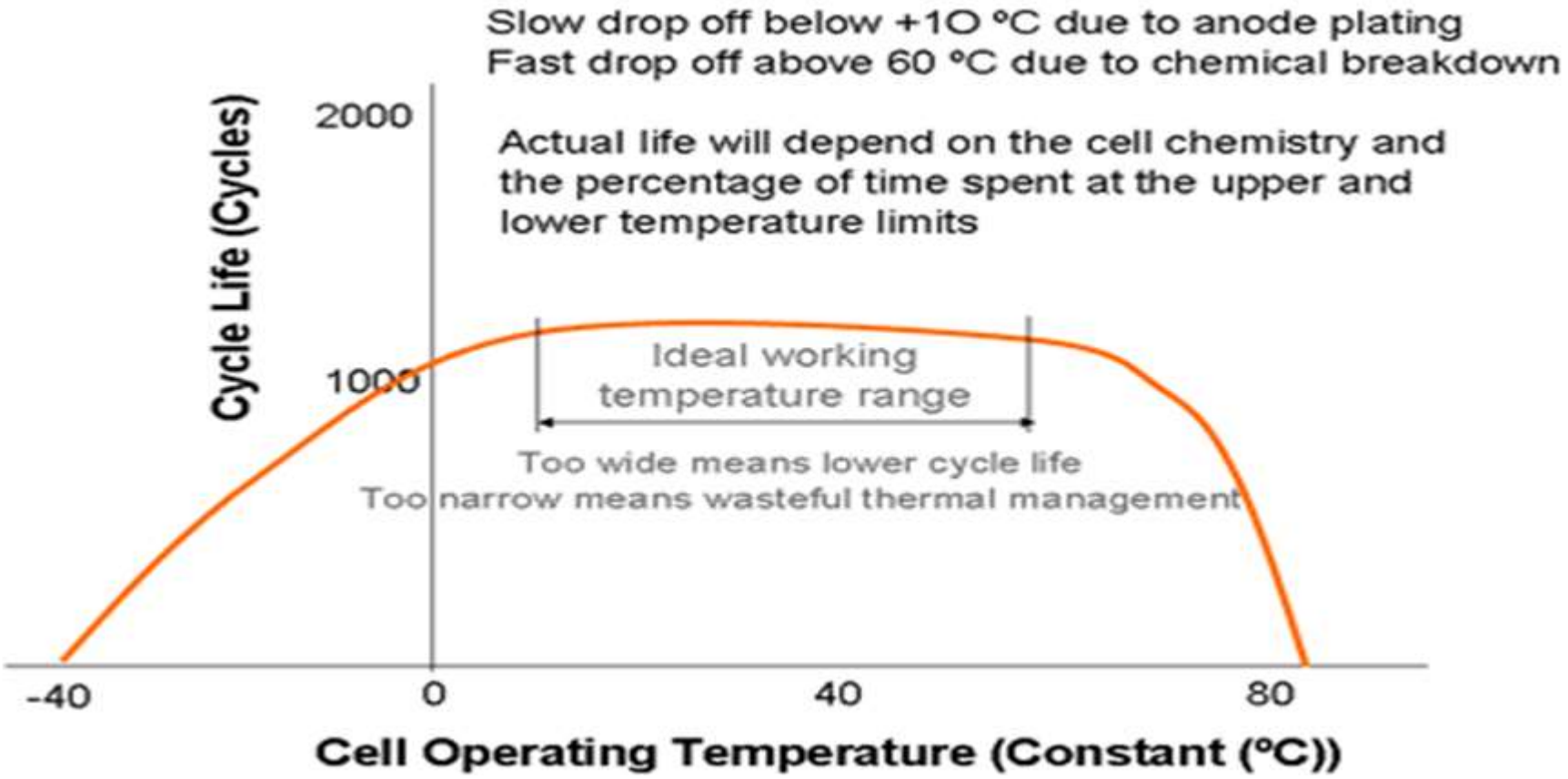
- Positive effect - Low self discharge

Performance Uniformity Damage

- When stressing cells and batteries to their extreme temperatures non uniformity arise
- Performance can be verify by testing.
- BMS balancing and thermal management become more importance for increasing the battery cycle and calendar life.

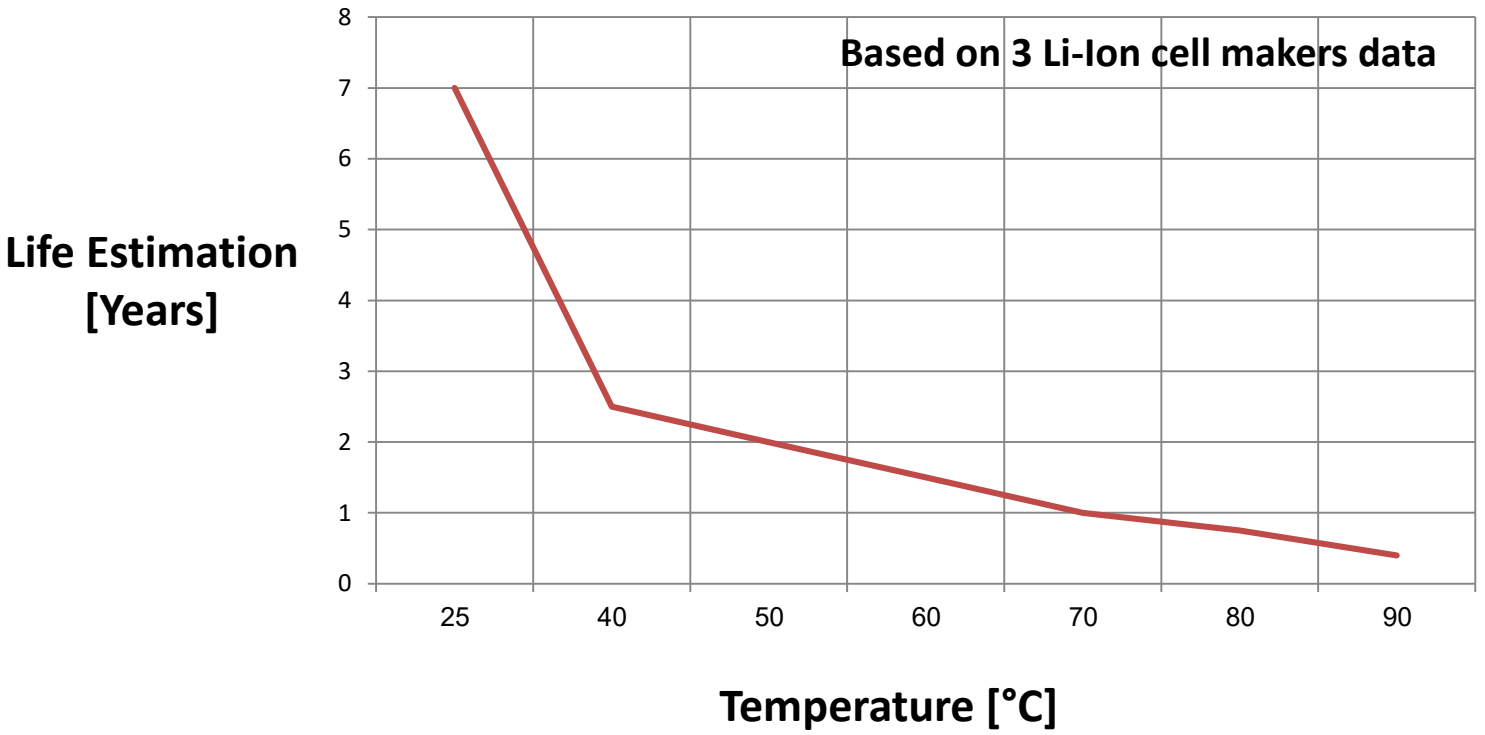


Cycle Life and Temperatures



cycle life mentioned on cell makers datasheets normally assume RT operating – Not realistic for most applications

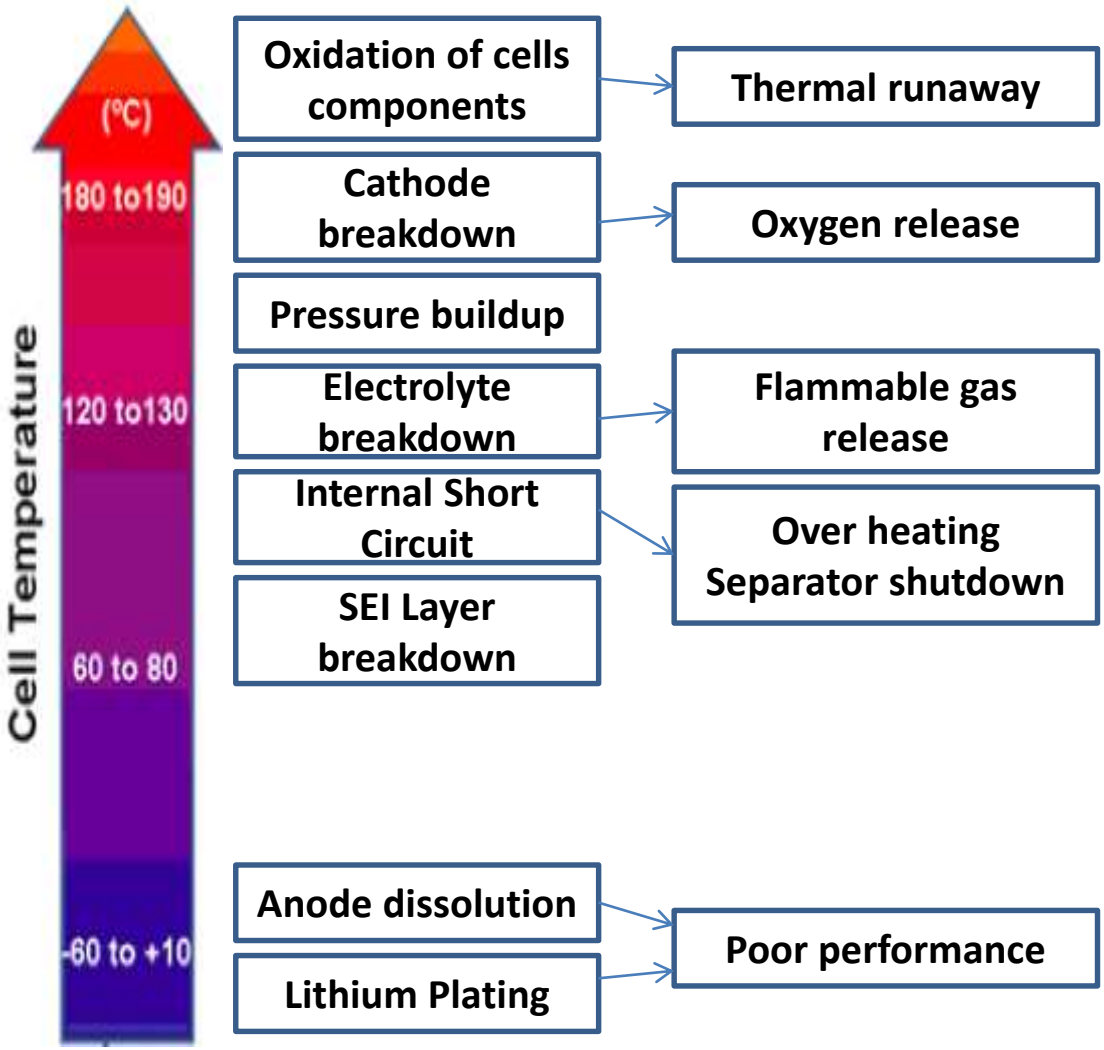
Shelf Life at Different Storage Temperatures



Hyundai provide 10 years warranty for EV battery made by LG Chem cells EV battery, GM and Nissan provide 8 years for batteries with LG Chem and AESC cells.

Li-Ion cells that treat well can survive for longer life time than in the past.

Cell Extreme Temperature Behavior Mechanism



What if We Will Charge a “Standard” Cell on High Extreme Temperatures

- **- The cell still accepts the charged capacity up to ~ 80 °C when charged in low current.**
  - Degradation speed-up.
  - Parasite reaction will grow and charging efficiency degrade.
  - Cell gassing cause higher internal pressure - Safety concern as well as may block the electrodes.

What if We Will Charge a "standard" Cell on Low Extreme Temperatures

- - The cell still accepts the charged capacity if charging temperature is above electrolyte freezing point when charged in low currents (Charge rate of 0.02C at -30°C will charge the cell to 100% capacity at 50 hours)
  - Degradation speed-up
  - Low kinetics reaction will grow and charging efficiency degrade.
  - Deposition of metallic lithium on graphite anode during charging resulting on irreversible capacity loss and safety concern

Extreme Temperatures Performance Test Plan

- **Carefully test, analyze and figure out the operating and storage temperatures limits of your application.**

- **Define the minimum battery performance accepted for the application – Clear pass/fail criteria's.**

- **Test plan should be tailor made and to include safety margin temperature factors above and below the application operating and storage temperatures.**

Extreme Temperatures Safety Test Plan

- Since we plan to use cells in batteries at extreme temperatures we can expect higher than usual safety risks.
- Conducting some relevant safety tests are recommended.

- **Casing:** Strength, Rigidity and Flammability, Mold stress, Venting, Insulation, No leakage, No explosion or fire.
- **Mechanical tests:** Crush, Nail penetration, Shock, Vibration, Impact, Drop.
- **Environmental tests:** Heating, Temperature cycling, Altitude, Humidity, Exposure to fire.
- **Protection:** Short circuit, Over charge, Over discharge, Voltage reversal, High Temperature, Low temperature.

Cells for High Temperature Discharge (> 70 °C)

Company Name	Model	Chemistry	Size	Discharge Temperature Range [°C]
A123	AHR18700m1Ultra	LPF	Long wide A	-10 to 100
EcoloCap	280	Li-Ion Nano	Non Standard Prismatic	-20 to 150
Excellatron	No P.N	Li-Metal	Non Standard Thin film	-40 to 150
Front Edge	012025	Li-Metal	Non Standard Thin film	-40 to 170
GS Nanotech	TFB	Li-Metal	Non Standard Thin film	-30 to 120
Fullriver	502975HT2	Li-Po	Non Standard Pouch	-10 to 85
Infinite Power	MEC120	Li-Metal	Non Standard Thin film	-40 to 85
Prollion	93535		Prismatic	-50 to 100
Prollion	50/125	LPF	Cylindrical non common	-50 to 100
Prollion	50/160	LPF	Cylindrical non common	-50 to 100
Saft	VL 25500-125	Li-Ion	C	0 to 125

* www.batteriesdatabase.com

Cells for High Temperature Discharge (> 70 °C)

Company Name	Model	Chemistry	Size	Discharge Temperature Range [°C]
Tadiran	HLC-1550A	Li-Ion	AA	-40 to 85
Thunder Sky	WB-LYP60AHA	Li-Ion	Non Standard Prismatic	-45 to 85
Thunder Sky	WB-LSP30000AHA	Li-Metal	Non Standard Prismatic	-35 to 85
HYB	IMR-18650PCH-SP	Li-Ion	18650	-40 to 80

* www.batteriesdatabase.com

Cells for Low Temperature Discharge (< -30 °C)

Company Name	Model	Chemistry	Size	Discharge Temperature Range [°C]
Advanced Electronics	AE70160225PT30C	Li-Po	Non Standard Pouch	-40 to 60
Altair-Nano	50ah	LTO	Non Standard Pouch	-40 to 55
Bexel	BXC25470	Li-Ion	C	-35 to 60
Boston Power	Swing 5300	Li-Ion	Non Standard Prismatic	-40 to 70
Chengdu Jianzhong	ICR26650	Li-Ion	C	-40 to 55
Excellatron	No P.N	Li-Metal	Non Standard Thin film	-40 to 150
Front Edge	012025	Li-Metal	Non Standard Thin film	-40 to 170
Infinite Power	MEC120	Li-Metal	Non Standard Thin film	-40 to 85
Lithion	NCP7-X	Li-Ion	Non Standard Prismatic	-40 to 60
Prollion	93535		Prismatic	-50 to 100
Prollion	50/125	LPF	Cylindrical non common	-50 to 100

* www.batteriesdatabase.com

Cells for Low Temperature Discharge (< -30 °C)

Company Name	Model	Chemistry	Size	Discharge Temperature Range [°C]
Prollion	50/160	LPF	Cylindrical non common	-50 to 100
Saft	VL 6A	Li-Ion	Non Standard Cylindrical	-60 to 55
Tadiran	HLC-1550A	Li-Ion	AA	-40 to 85
HYB	IMR-18650PCH-SP	Li-Ion	18650	-40 to 80

* www.batteriesdatabase.com

Cells for High Temperature Charge (> 55 °C)

Company Name	Model	Chemistry	Size	Charging Temperature Range [°C]
Bexel	BXD33600	Li-Ion	D	-20 to 60
Boston Power	Swing 5300	Li-Ion	Non Standard Prismatic	-20 to 60
Cymbet	CBC050	Li-Ion	Non Standard Prismatic	0 to 70
Excellatron	No P.N	Li-Metal	Non Standard Thin film	-40 to 150
Fullriver	502975HT2	Li-Po	Non Standard Pouch	-10 to 60
Saft	VL 3A	Li-Ion	Non Standard Cylindrical	-20 to 60
Tadiran	HLC-1550A	Li-Ion	AA	-40 to 85
Thunder Sky	WB-LYP60AHA	Li-Ion	Non Standard Prismatic	-45 to 85
Thunder Sky	WB-LSP30000AHA	Li-Metal	Non Standard Prismatic	-35 to 85
HYB	IMR-18650PCH	Li-Ion	18650	0 to 80

* www.batteriesdatabase.com

Cells for Low Temperature Charge (< -25 °C)

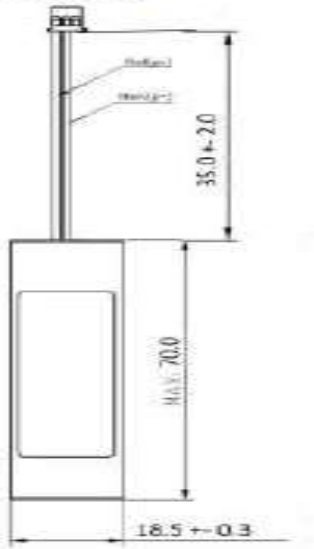
Company Name	Model	Chemistry	Size	Charging Temperature Range [°C]
Altair-Nano	50ah	LTO	Non Standard Pouch	-40 to 55
Excellatron	No P.N	Li-Metal	Non Standard Thin film	-40 to 150
Saft	VL 5U	Li-Ion	Non Standard Cylindrical	-60 to 60
Tadiran	HLC-1550A	Li-Ion	AA	-40 to 85
Thunder Sky	WB-LYP60AHA	Li-Ion	Non Standard Prismatic	-45 to 85
Thunder Sky	WB-LSP30000AHA	Li-Metal	Non Standard Prismatic	-35 to 85

* www.batteriesdatabase.com

HYB IMR-18650PCH-SP

Basic Cell	IMR-18650PCH
Configuration	1s
Dimensions [mm]	
Length (L)	Max.70.0
Width (W)	18.5+-0.3
Weight, approx. [g]	50
Connector	JST PAP-03V-S Wires AWG22 UL1007 35mm Pin1 – not used Pin2 - black=- Pin3 - red=+
Electrical Parameter	
Nominal Values [V] / [Wh]	3.6 / 5.4
Typical capacity [mAh]	1500 (0.2C at 20°C after 4.2V)
Minimum capacity C [mAh]	1450 (0.2C at 20°C after 4.2V)
Impedance initial [mΩ]	Max. 120 @ 1kHz at 4.2V
Max. Charge [mA]	2900
Max. Charge Voltage [V]	4.10
Max. cont. Discharge [mA]	3000
Discharge Cut off [V]	3.00
Life expectancy 0.5C/0.5C [20°C Cycles]	500 >80% of initial capacity
Operating temperature [°C]	Charge: 0 to 80 Discharge: -40 to 80 for 6 hours to 85
Humidity	65 +-20%RH
Storage Temperature	12 month at -20 to +35°C
Safety Parameter PCM	
Overcharge Det. Voltage	4.325 +-0.025 V
Overcharge Release Voltage	4.075 +-0.050 V
Overdischarge Det. Voltage	2.500 +-0.080 V
Overdischarge Rel. Voltage	2.900 +-0.100 V
Overcurrent Det. Range	3-5 A
Delivery Status	
Voltage	3.7 – 3.9V
Capacity	50-60%
Label	
Standard	
Date Code	HYWWYY
Certifications	
Cell	UL1642 MH28822
Battery	UN38.3, ROHS

Mechanical Drawing



http://www.hyb-battery.com/

Summary

- Extreme temperatures lithium cells market is a niche market with a few players, cell models and premium cost per cell

- Most of cell makers limits the temperature operating and storage ranges because of safety concern and poor cells performance

- Customer can use cells at extreme temperatures based on careful operating and safety design approved by relevant performance and safety test procedure when taking into account possible performance degradation

- Conventional Li-Ion cells can better stand extreme temperatures than soft packaging Li-Ion cells.

- The market miss extreme temperature standards and definitions

Comment

- **By using efficient thermal management system we can extend cell and batteries performance**

- **The author is recommend to consult with the cell makers and battery experts on any case of using cells out of their official specifications.**

Thank You for Your Attention

Shmuel De-Leon Energy, Ltd.
Mazal Arie 10, Hod-Hasharon, Israel 45309
Tel/Fax: 972-77-5010792, Mobile: 972-52-8601517
www.sdle.co.il, www.batteriesdatabase.com
shmuel@sdle.co.il

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