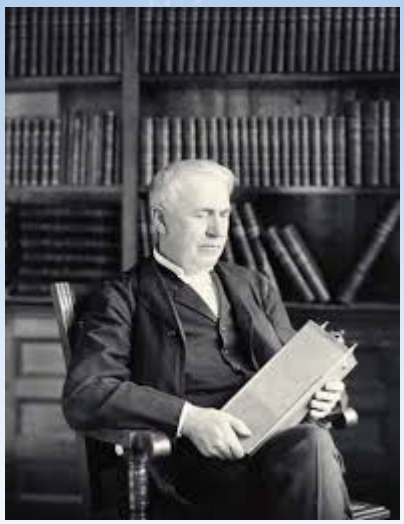
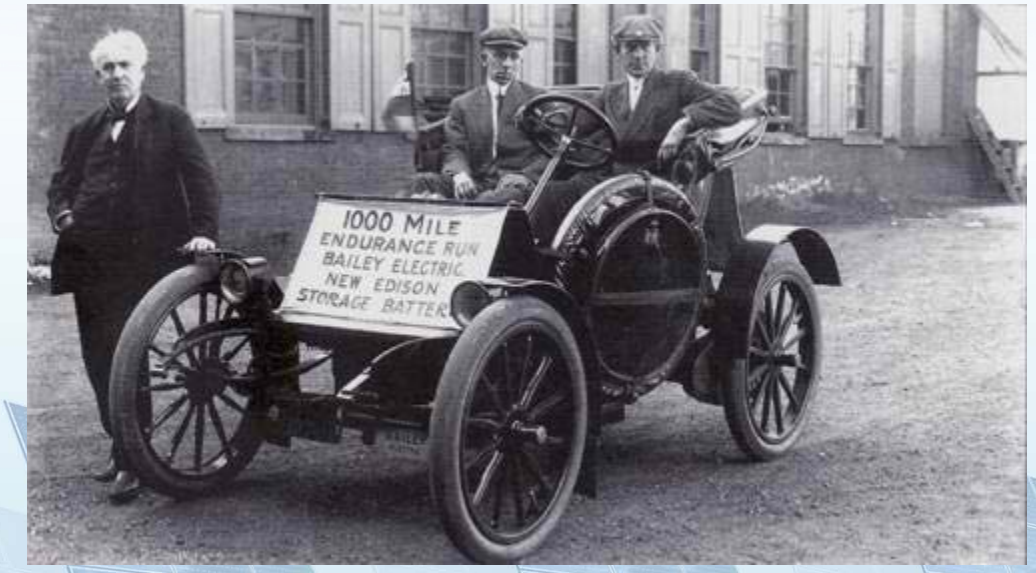
Encell Technology -- Overview

- Founded 2006 – Venture-funded startup to develop scalable energy storage solutions
- Located in former GE / Gates / Energizer battery facility: Gainesville, FL
- Technical Team: Decades of battery experience and successful product launches
- Encell Technology NiFe Battery Applications:
  - Renewable energy storage
  - Hybrid micro grids
  - Emergency backup: communications, data centers
  - Motive applications: fork lifts, utility vehicles

Solar powered cell tower

NiFe Batteries Started With Edison in 1880





NiFe Battery History

The Edison nickel-iron battery (NiFe battery) is a storage battery with

- NiOOH cathode and an Fe anode with a KOH electrolyte,
- Active materials are held in perforated pockets,
- Very robust battery - tolerant of abuse, (overcharge, overdischarge, and short-circuiting),
- Very long life - can be continuously charged and can last for more than 40 years.

Other battery technologies displaced the nickel-iron battery – But Encell Brings it Back

- High costs in traditional pocket design – **Today's Materials and Processing**
- Exide Corporation's decision to abandon the technology in 1975

Edison style batteries still in production

Steel pockets holding
active material powder

Ni-Fe in the 1970's

- **Ni-Fe R&D during the Oil / Energy Crisis**
- 3 Major Programs were launched because of interest in EV (electric vehicles)
  - Eagle Picher & SAB NIFE
  - Sanyo & Panasonic
  - Saft & Varta (now ChangHong in China)

- Each Program ran about 10 years, spent $10 Million and shut down
- NiFe still made today in China using Varta technology
- NiFe still made today in Russia and Ukraine using Edison Technology

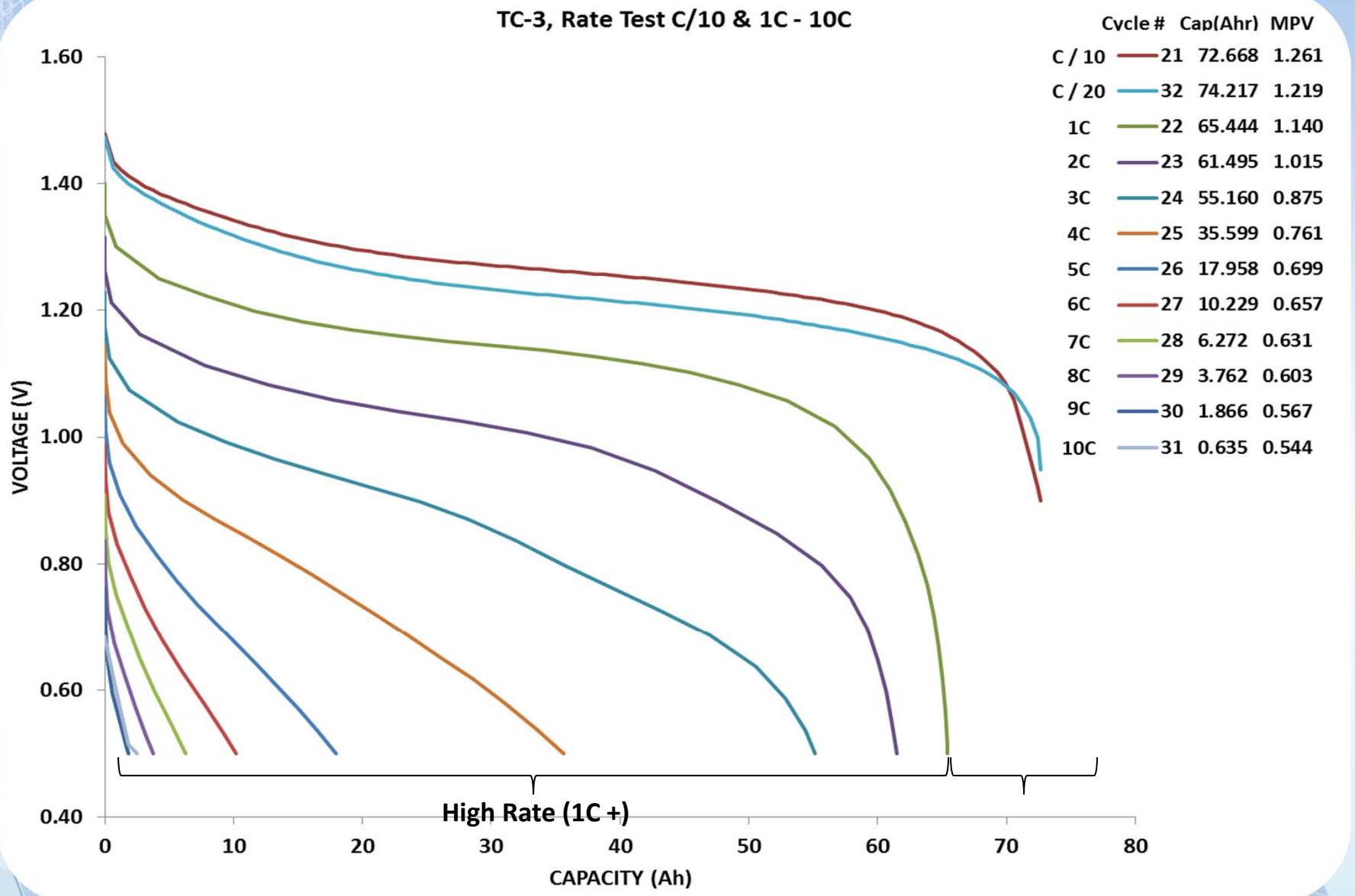
- **Ni-Fe Is In Production and In Use Today**
- **Encell has reinvented the Manufacturing and Performance with Proprietary Technology**

Encell NiFe – Technology/Data Overview

- Discharge Rate Capability
- Temperature Effects
- OCV at Different SOC
- Cycle Life and Accelerated Life Testing

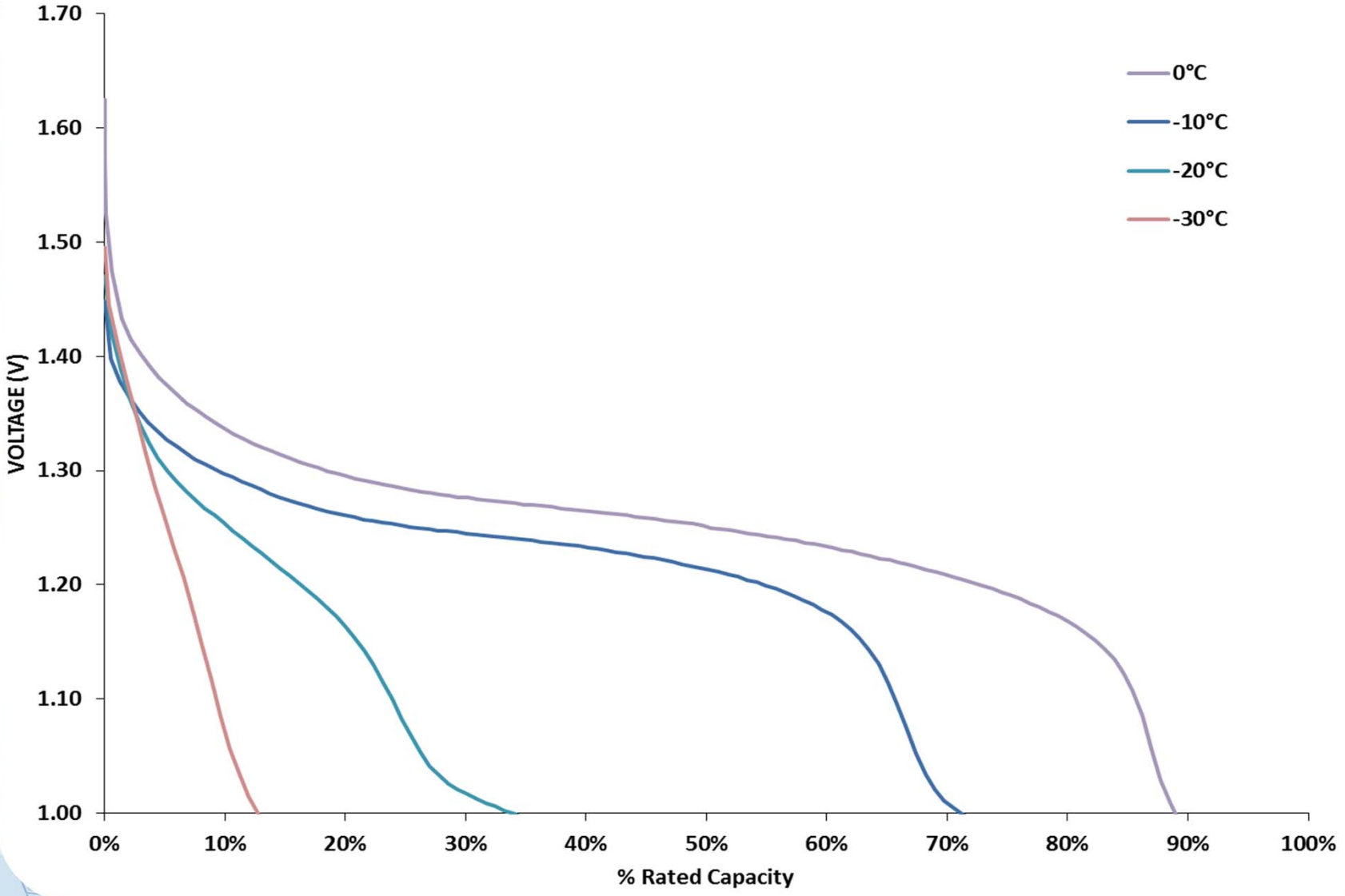
Discharge Rate Capability

Encell (NiFe) Discharge Capability

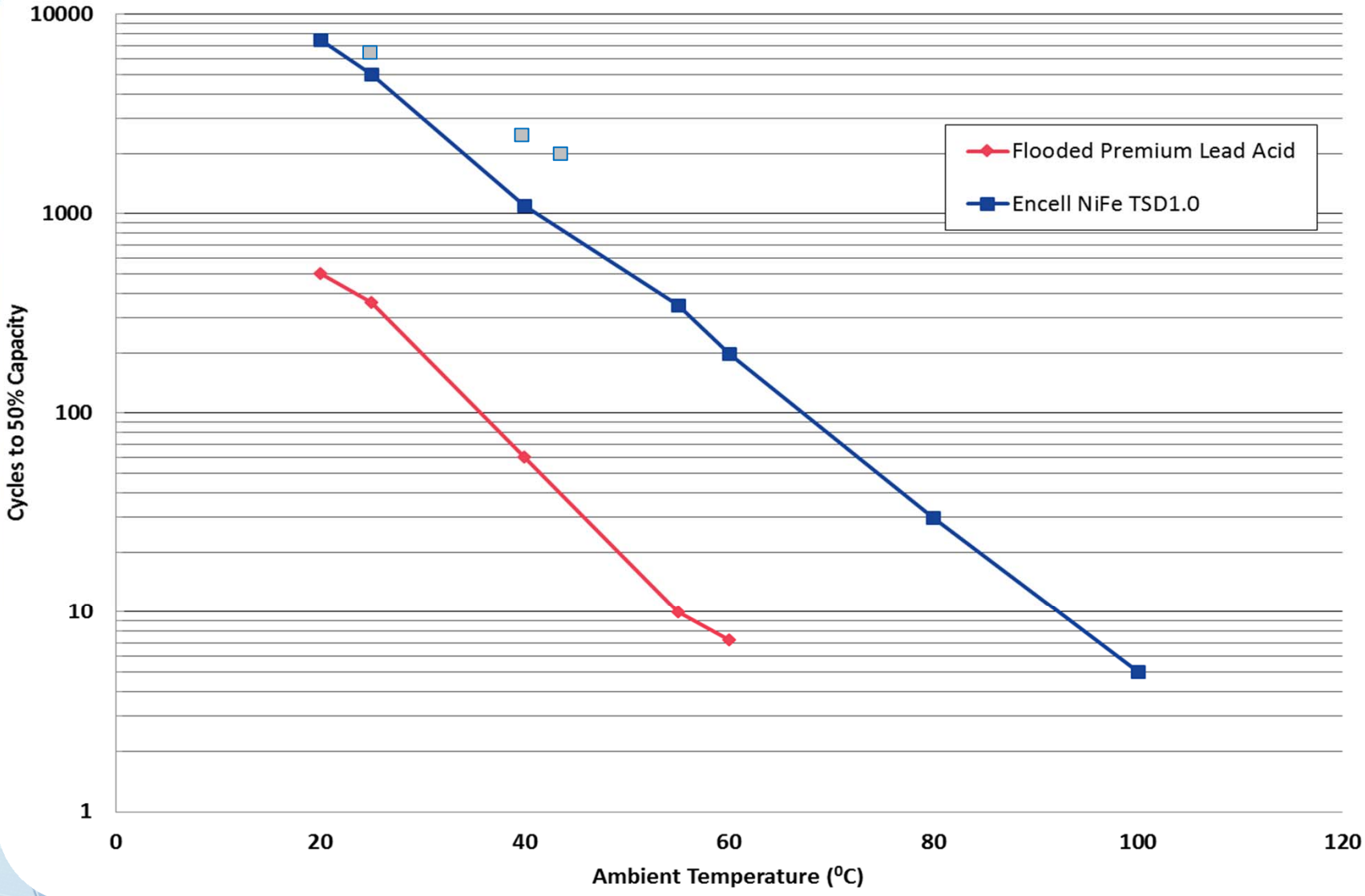


Temperature Effects

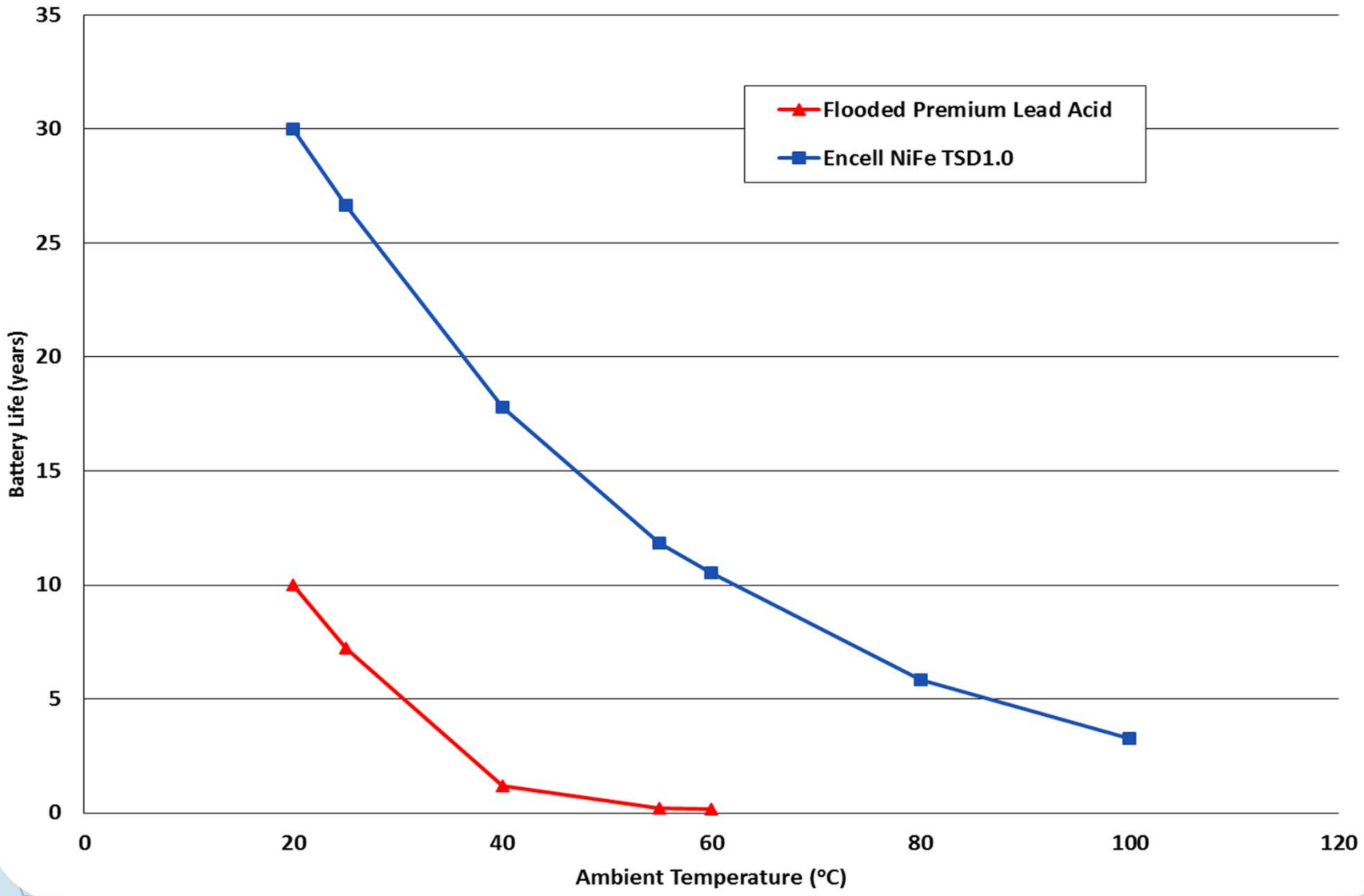
Encell Displays Superior Low Temp Performance



Encell Demonstrates Unparalleled Cycle Life

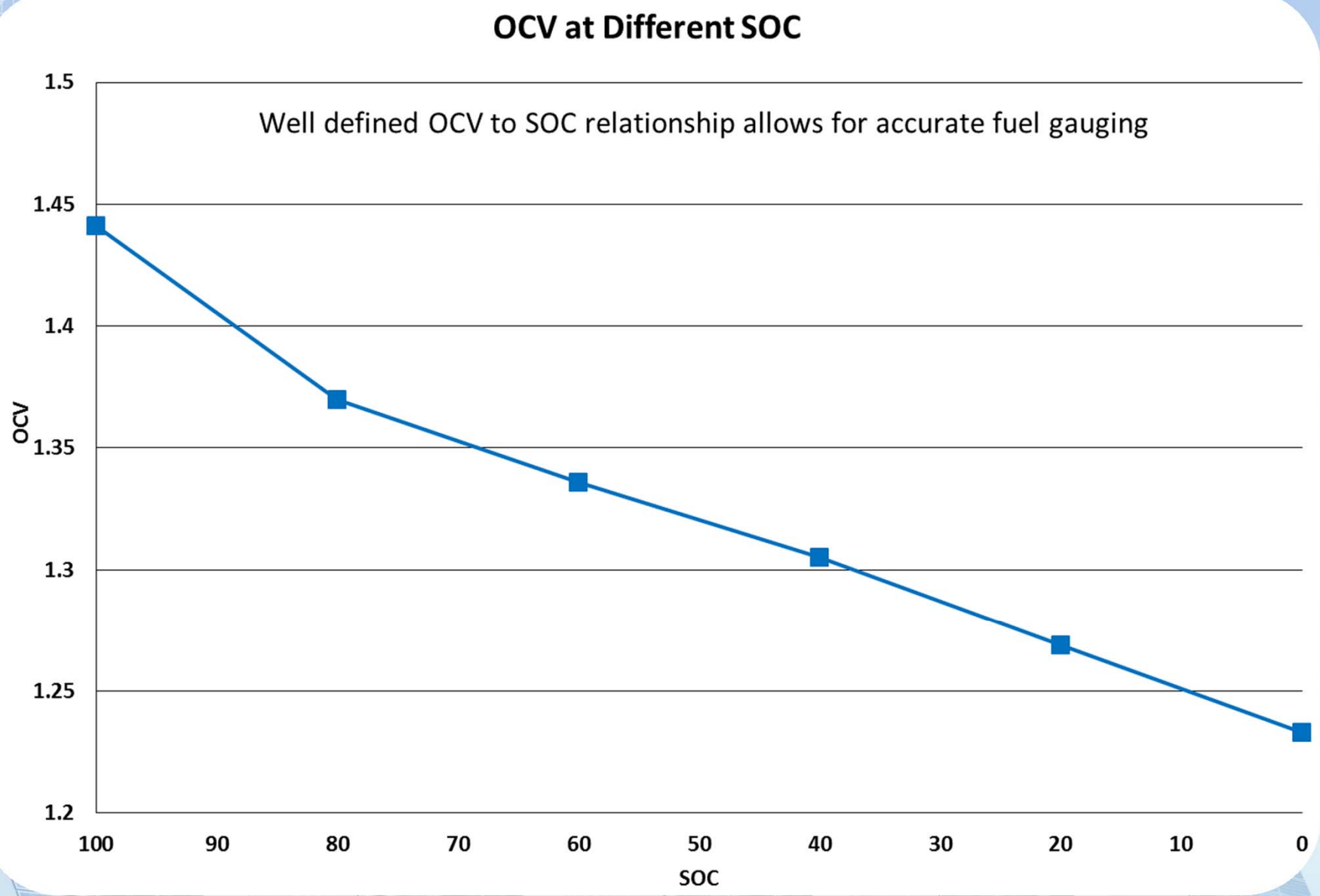


Encell Displays Superior Life



OCV at Different SOC

Open Current Voltage at Different SOC %



ENCELL technology

"At $400 per kWH, an energy storage solution is interesting. At $200, it will become a big thing" – Utility Industry Executive

Competitive Analysis

Energy Storage Battery Comparisons

ENCELL technology

Encell NiFe is Cost Competitive and Functionally Superior

	Encell NiFe	Pb-Acid	Li-Ion
Energy (WH/kg)	48	40	200
Power (W/kg)	288	180	1400
DoD (%)	80	50	90
Cycles	5,000+	1,000	3,000
WH Efficiency (%)	70	65	90
Low Temperature (deg C)	-10	0	-10
High Temperature (deg C)	60	40	40
Charge Rate (C)	C	C/5	2C
Discharge Rate (C)	6C	C/3	4C
Flammability	No	No	Yes
Abuse Tolerance	H	M	L
Battery Price ($/kWh)	$200	$100	$500
Effective Price ($/kWh)	$346	$200	$556
Lifetime (cents/kWh/cycle)	< 7	20.0	18.5

Appendix – Additional Reference and Details

- Ni-Fe in the 1970's
- Ni-Fe Chemistry
- Ni-Fe Advantages
- Ni-Fe in Action

Ni-Fe in the 1970's

Ni-Fe R&D during the oil crisis

- A resurgence in electric vehicles was initiated by the energy crisis in the 1970's
- 3 major development programs were started to relaunch the Edison NiFe automotive battery, since it was seen as the best technology for automotive application:

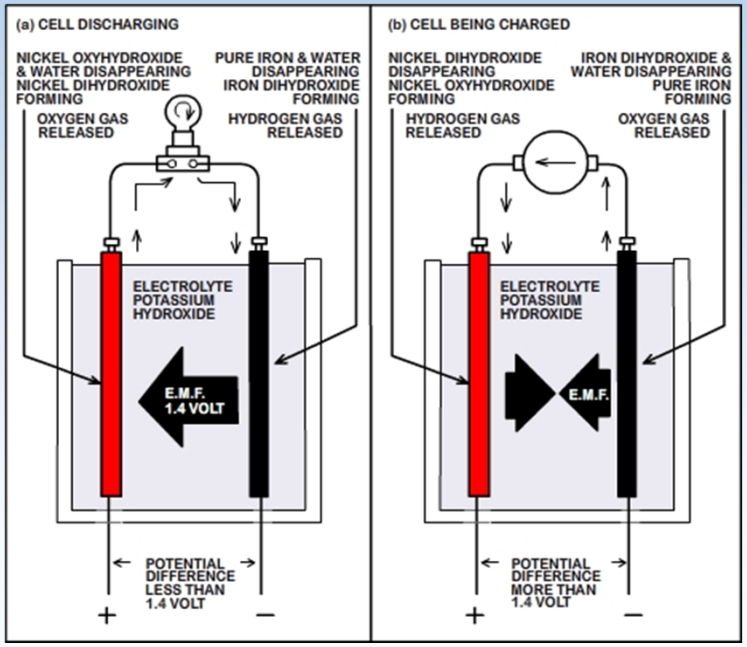
	Technology	Advantages
– Eagle Picher and SAB NIFE : (Bankrupt/abandoned technology)	Sintered Electrodes Solid Separator	Improved Power and Efficiency (Chrysler's TEvan in 80's)
– Sanyo and Panasonic: (Shut down/abandoned technology)	Coated Electrodes Felt Polymer Separator	Improved Cost and Quality
– Saft and Varta: (Now – Changhong in China)	Electrode Additives Better Current Collectors	Improved Energy density and Charge Retention

- Each program ran about 10 years and spent about $10MM and shut down when the energy crisis ended.

Ni-Fe Chemistry

Historical Highlights:

- > than 100 years Shelf Life w/100% performance
- > than 1,000 full, 80% depth of discharge cycles
- 65% energy efficiency
- Green (nonflammable, no acid, nontoxic metals)
- Most Abuse-tolerant (10X overcharge and reversal)



Electrode Reactions:

Cathode: $2\ NiOOH + 2\ H_2O + 2\ e^- \leftrightarrow 2\ Ni(OH)_2 + 2\ OH^-$

Anode: $Fe + 2\ OH^- \leftrightarrow Fe(OH)_2 + 2\ e^-$

(Discharging is read left to right, charging is from right to left.)

Ni-Fe Batteries

Ni-Fe Advantages

- **BATTERY LIFE** - Longest cycle life battery chemistry known. No known failure mode of the active material. Edison batteries are functioning at initial capacity after 100 years.
- **OPERATING RANGE** - High temperature performance much better than NiMH, LiIon, NiCd, Lead Acid, and NiZn. Excellent performance at 80^{o} C.
- **ROBUSTNESS** - Most robust to abuse of all battery chemistries. Tolerates extreme overcharge, deep discharge, extreme reversals, short circuits with no degradation. Electrode dimensional stability, no swelling for mechanical stress
- **EFFICIENCY** - Has potential to be the highest rate since the reaction kinetics are among the fastest.
- **EXCELLENT SAFETY** - Safest: does not have a known thermal runaway, explosion, or burning failure mode. Also environmentally friendly since it does not use acid, or dangerous metals. Battery can be short circuited for handling (after full discharge) and stored fully discharged
- **COST** – Cost equal to or below Lead Acid

Ni-Fe in Action

Cycle Life and Reactivation: +

- NiFe batteries have exceptionally long life with little capacity fade. NiFe batteries can be returned to full capacity by a reactivation cycle if capacity fade occurs.

Deep Depth of Discharge : +

- NiFe batteries can operate without degradation over the entire SOC range: 0 – 100%.
- Uniquely, battery can be left at 0% SOC and then recharged for full performance.

Capacity recovery: OK

- Encell batteries do not lose capacity when discharged at high rates – the voltage drops due to the diffusion resistance in the battery. When the discharge stops at the voltage limit, the voltage will recover and can be discharged again

H2 Out-gassing: -

- H2 out-gassing occurs during charge and overcharge.
- Batteries are topped-off with water; so maintenance required (as all flooded batteries)
- Encell is engineering a sealed NiFe battery that does not need refilling (like a VRLA).

Fast Charge/Fast Discharge Rates: +

- Capable of sustained 2C charging and 6C discharging and burst 10C charging and 20C discharging– Significantly better than lead-acid batteries

Efficiency (Input / output Energy): OK

- Demonstrated 70% energy efficiency, matching Lead Acid.
- Development cells with over 85% energy efficiency with scale-up underway.