

Industrial Batteries 101



SAFT





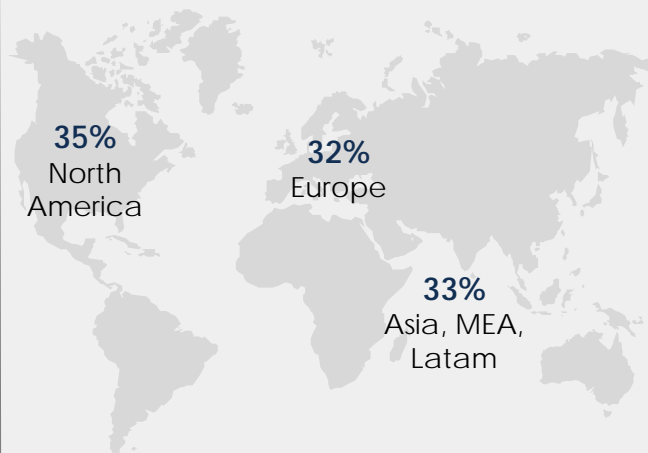
SAFT DEVELOPS AND MANUFACTURES ADVANCED-TECHNOLOGY BATTERY SOLUTIONS



FOR MULTIPLE APPLICATIONS

- **Diversified** base of industries
- **Broad portfolio of technologies** (Ni-based, Primary Lithium and Lithium-ion)
- **Leadership positions on 75-80%** of revenue base (Industrial Standby, Metering, Aviation, Rail, Defense, Satellites)

ON A GLOBAL SCALE



* SAFT is part of TOTAL new division, "Gas, Renewables & Power", since September 1st, 2016

~100
years of history

\$921M*
revenue FY 2017

9.7%
invested in R&D

+4,100
people

+3,000
customers

Leading Oil & Gas companies rely on Saft

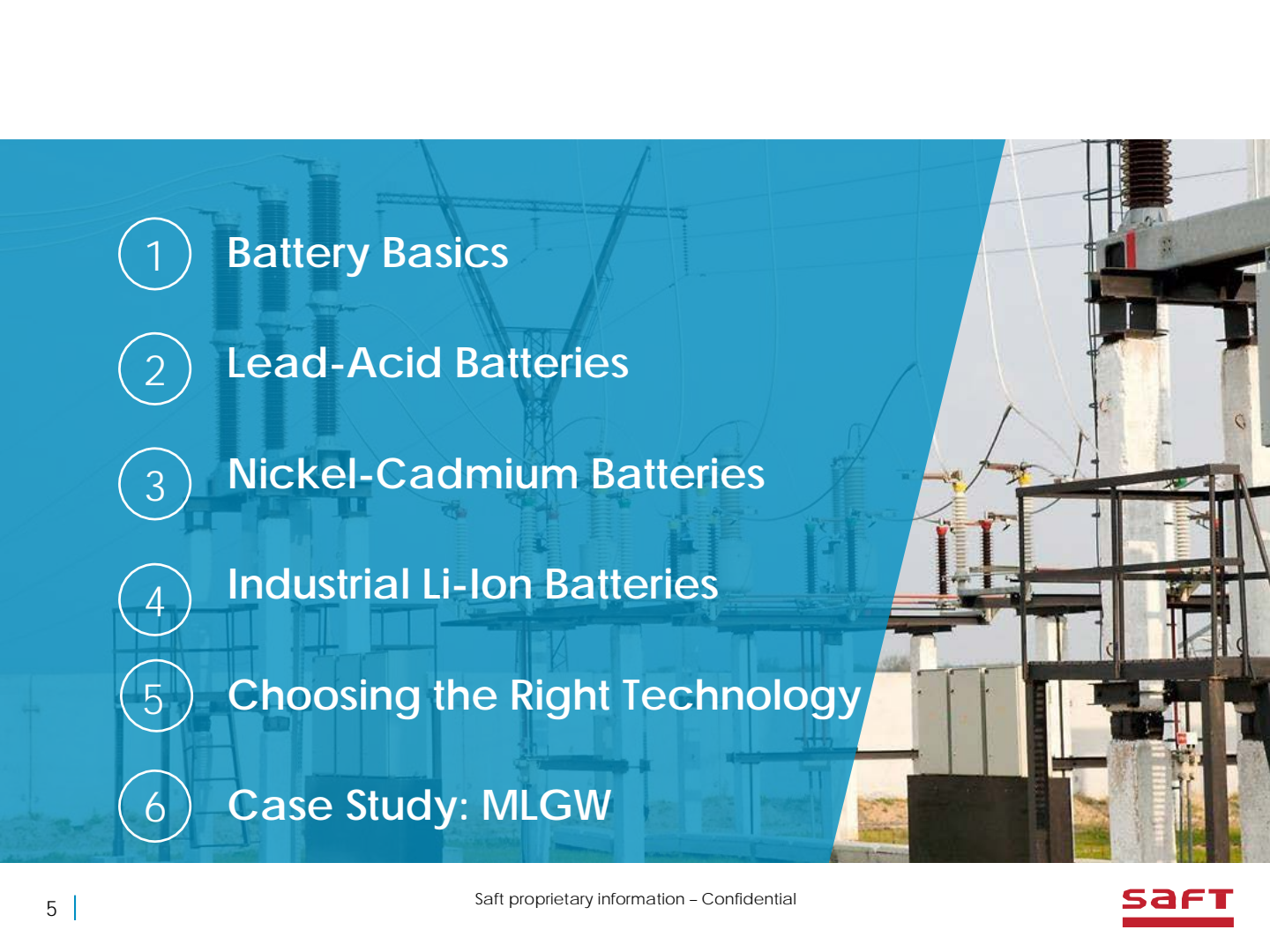
International & National Oil and Gas Companies



Leading Utility companies rely on Saft

International, National & Regional Utility Companies



- 
- 1 Battery Basics
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 - 4 Industrial Li-Ion Batteries
 - 5 Choosing the Right Technology
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BATTERY BASICS

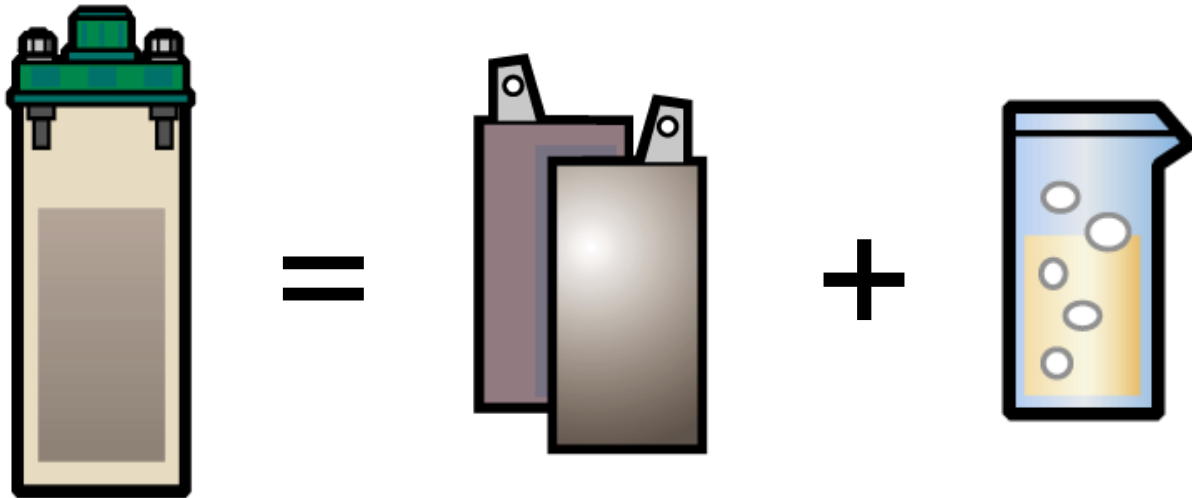
Battery Composition

A battery is an electrochemical energy storage device.

Energy Storage

Active Material

Electrolyte



Battery Terms

Ah – Ampere-hours

- Battery's rating of capacity
- 1 amp for 1 hour = 1Ah

Rated capacity of a battery

- Amps available at a fixed time, to a fixed end of discharge voltage, at a standard temperature
- Ni-Cd batteries rated capacity is measured at: (per IEC60623)
 - 5 hours, to 1.00Volts per cell (Volts/Cell) at 77°F, at fully charged state;
 - Example: 100Ah = 20A for 5 Hours
- Lead-Acid Batteries are rated at the 8hr rate to 1.75VPC @ 77F.

Power = Instantaneous (V x I)

- Example: Switchgear Tripping current, instantaneous power requirement.

Energy = Power x Time

- Example: Continuous current loads for many hours.

Battery Basics - Traditional Products

Electrolyte and Active Materials:

Lead-Acid

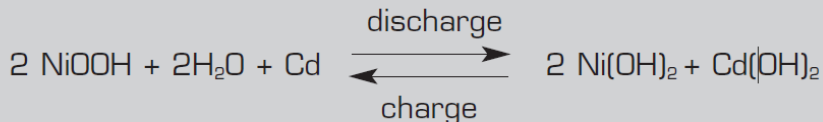
- Dilute Sulfuric Acid
 - pH = ~2
 - Nominal Cell Voltage = 2.0VDC

Equation 4
Total Reaction



Nickel-Cadmium

- Electrolyte: Potassium Hydroxide (KOH)
 - Takes no part in the chemical equation
 - pH = ~11
 - Nominal Cell Voltage = 1.2VDC
 - Electrolyte acts as preservative and means to transfer energy



Battery Basics - History

The Early Days of Batteries

Gaston Plante

- French Physician
- Invented the first rechargeable (secondary) lead-acid battery in **1859**



Waldemar Jungner

- Swedish Chemist
- Invented the first rechargeable nickel-cadmium battery in **1899**



SAFT History

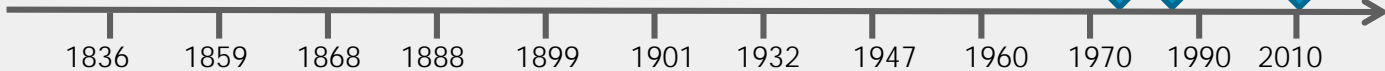
- Founded in 1918 by Victor Herald
- Originally **S**ociété des **A**ccumulateurs **F**ixes et de **T**raction (S.A.F.T.)
- Roughly translates to "Stationary and Traction Battery Company"



Battery Basics - History

Traditional Battery Improvements...

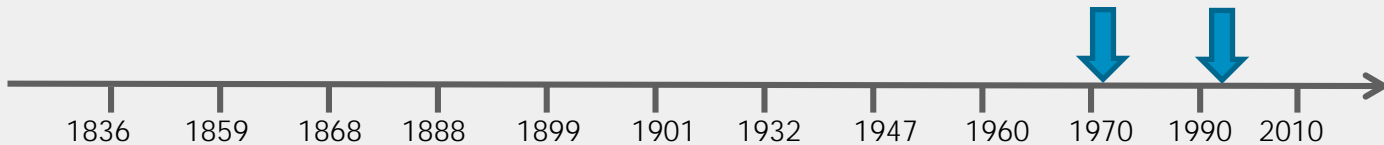
- 1970's: the development of valve regulated lead-acid batteries
- 1980's: Saft introduces "ultra low" maintenance nickel-cadmium batteries
- 2010: Saft introduces maintenance-free* nickel-cadmium batteries
 - *The term maintenance-free means the battery does not require water during it's entire service life (20+ years under Saft's recommended conditions)*



Battery Basics - History

The future of batteries – Lithium-ion

- 1976: Exxon researcher – Whittingham described lithium-ion concept in Science publication entitled “Electrical Energy Storage and Intercalation Chemistry”
- 1991: Sony introduced the first Li-ion cell (18650 format)
- 1992: Saft introduced its commercially available Li-ion cell





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LEAD-ACID BATTERIES

Flooded Lead-Acid Pasted Plate

Basic Specification

- Plates - Lead oxide enhanced positive, sponge lead negative
- Separator - Micro-porous fiber mat, sometimes pins
- Electrolyte - Sulfuric acid (H_2SO_4) 1.205 - 1.275 Specific Gravity
- Jars - **Styrene AcryloNitrile (SAN)** or **PolyCarbonate (PC)**,
- **Flame Retardant** - ABS Lid-opaque, **PC** Jar-clear
- Connection points - usually lead plated copper, can be tin or brass
- Life - from 5 - 20 years (typical 12 – 15 yrs), depending on environment, design, application
- Different Grid Alloys – Selenium, Calcium, Antimony



Valve Regulated Lead-Acid Batteries

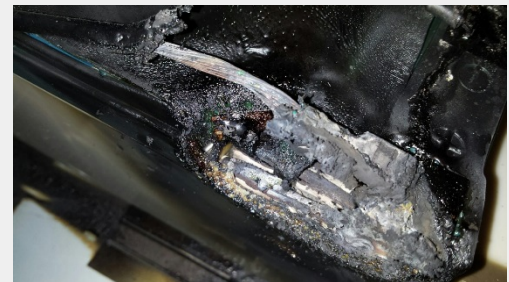
VRLA or Recombination Technology

- Immobilized electrolyte
 - Absorbed (AGM)
 - Fiberglass mat saturated with acid
 - Gel Cells
 - Silicon gel saturated with sulfuric acid
 - Gas path from positive to negative
- Positive internal pressure
- Recombination process is highly efficient
 - Charging energy is converted to heat
 - Thermal management is critical
- Grid corrosion results in hydrogen evolution
- Typically have FR (Flame Retardant) jars



VRLA (continued)

- Advantages
 - No water additions
 - High energy density
- Disadvantages
 - Unique failure modes
 - Dry out
 - Thermal runaway
 - Negative strap corrosion
 - Sudden death
 - Highly susceptible to ripple current
 - Shorter life than vented cells
 - Life 1-11 years (typically 3 – 5 years)
- Typical Applications
 - Telecommunications, UPS, Emergency Lighting





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NICKEL CADMIUM BATTERIES

What is a Nickel-Cadmium Battery?

- Nickel-Cadmium batteries use an alkaline electrolyte.
- The electrolyte is Potassium Hydroxide (KOH).
- Positive active material consists of nickel hydroxide and the Negative active material is cadmium.
- The plates do not react with the electrolyte. (unlike lead-acid batteries)
- Many Types: Pocket, Fiber, Sintered, Plastic Bonded, Foam, Recombinant



NiCad - Pocket Plate NiCad

Advantages

- Most Rugged Ni-Cd type,
- Resistant to: Electrical abuse, overcharging / discharging
- Physical abuse, extreme temperatures, shock & vibration
- Normal operating temperature range: - 20°C (-4°F) to +50°C (+122°F)
- Withstand temperature excursions from -40°C (-40°F) to +70°C (+158°F)
- Fast recharge
- Impervious to ripple
- Low maintenance
- Low total cost of ownership
- Design and service Life 25+ years

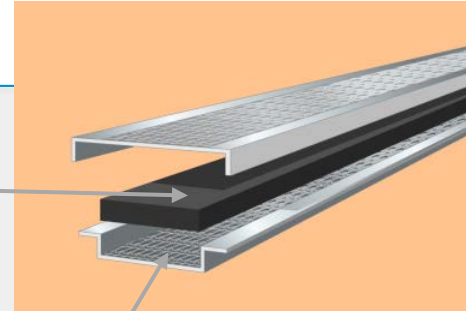
Disadvantages

- High initial cost compared with lead-acid
- Installed footprint can be larger than lead acid in some applications

NiCd Pocket Plate (traditional design)

Plate Construction

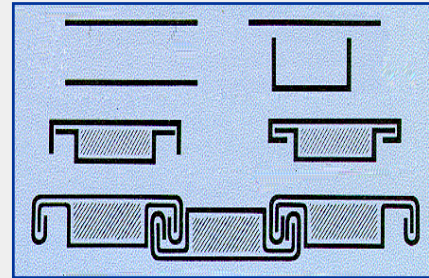
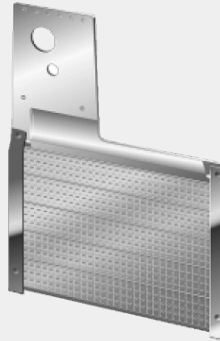
- Active material briquette held inside “pockets”
 - Nickel hydroxide, in positive plate
 - Cadmium hydroxide in negative plate
- Pockets are Saft’s patented double perforated steel strips
- Very Rugged
- Plates are welded to form groups



L, M, & H- Type Performances

- L = Long rate (Energy)
- M = Medium rate (mixed loads)
- H = High rate (Power)

Wide range of capacity steps



Protective cover

- to prevent external short-circuits
- in line with EN 50272-2 (safety) with IP2 level

Plate group bus

Connects the plate tabs with the terminal post. Plate tabs and terminal post are projection-welded to the plate group bus.

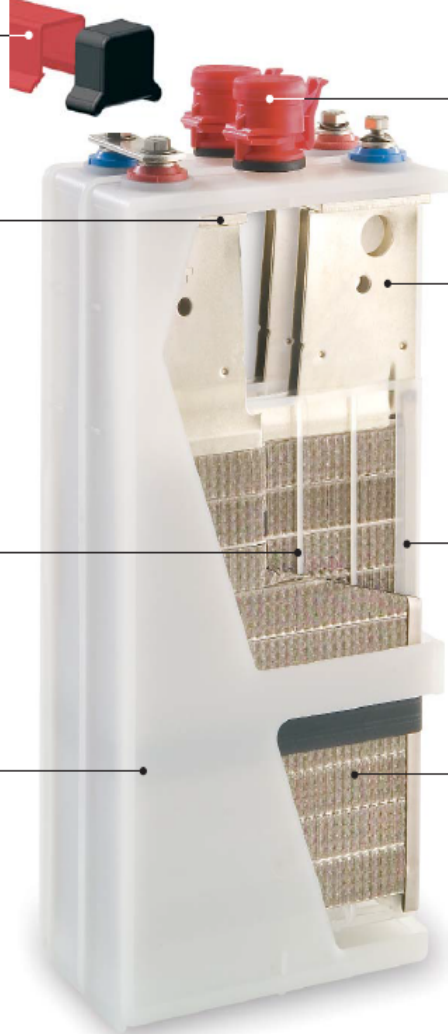
Separating grids

Separate the plates and insulate the plate frames from each other. The grids allow free circulation of electrolyte between the plates.

Cell container

Material: translucent polypropylene.

The cells are welded together to form rugged blocks of 1-6 cells depending on the cell size and type.



Flame-arresting vents
Material: polypropylene.

Plate tab
Spot-welded both to the plate side-frames and to the upper edge of the pocket plate.

Plate frame
Seals the plate pockets and serves as a current collector.

Plate
Horizontal pockets of double-perforated steel strips.

Saft cells fully comply and exceed the requirements of the IEC 60623 standard.

Low Maintenance Recombination NiCad

Maintenance-free L and M types

- Qualified IEC 62259 for Ni-Cd with gas recombination (over 90%)
- Electrolyte is still liquid and abundant inside.
- Wide capacity range
 - L type: 15 – 1700 Ah
 - M type: 8 – 1330 Ah

High tech maintenance-free concept

- Maintenance-free
 - No requirement to add any water throughout service life under recommended operations
 - Decrease the operational cost and reduce the maintenance manpower
 - Can be stored filled and charged up to 2 years



High Performance NiCad Batteries

Sintered plate (Positive Plate)

- Nickel powder sintered onto steel plate to create porous substrate
- Pure active materials electrochemically deposited

Plastic Bonded Electrode (Negative Plate)

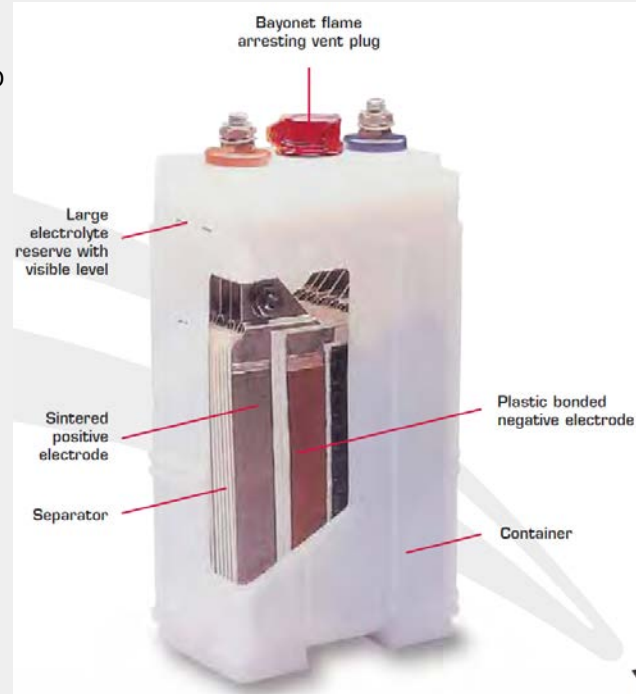
- Pure active material mixed with synthetic rubber
- Mixture coated onto steel plate

Highest Performance NiCad

Ideal for Engine Starting and Switchgear Applications

Low Maintenance, 10 – 13 Year topping up interval

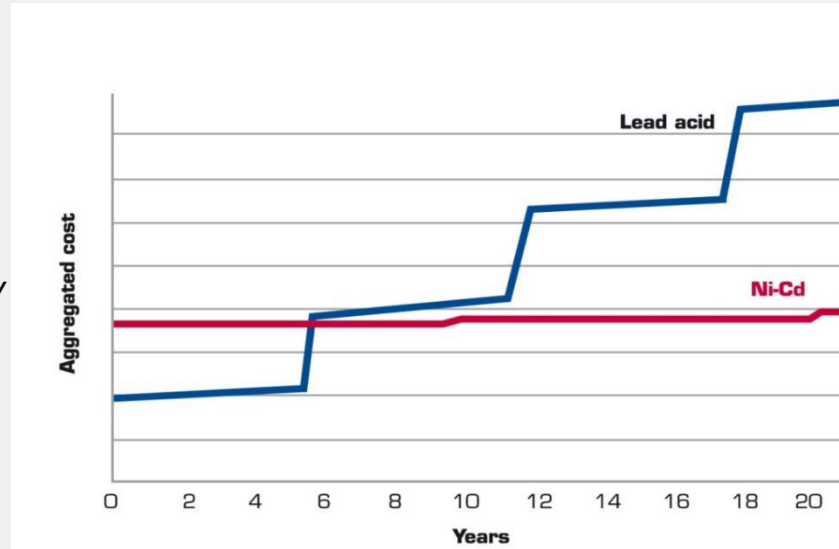
Single Cell Design / Compact Design



Nickel-cadmium technology

Built for endurance...

- Robust steel structure
- Simple electrochemistry
- No structural degradation
- All round reliability
- Return on investment in 5Y
- 20+ years service life
- = Low TCO !!



... a sound investment

saft

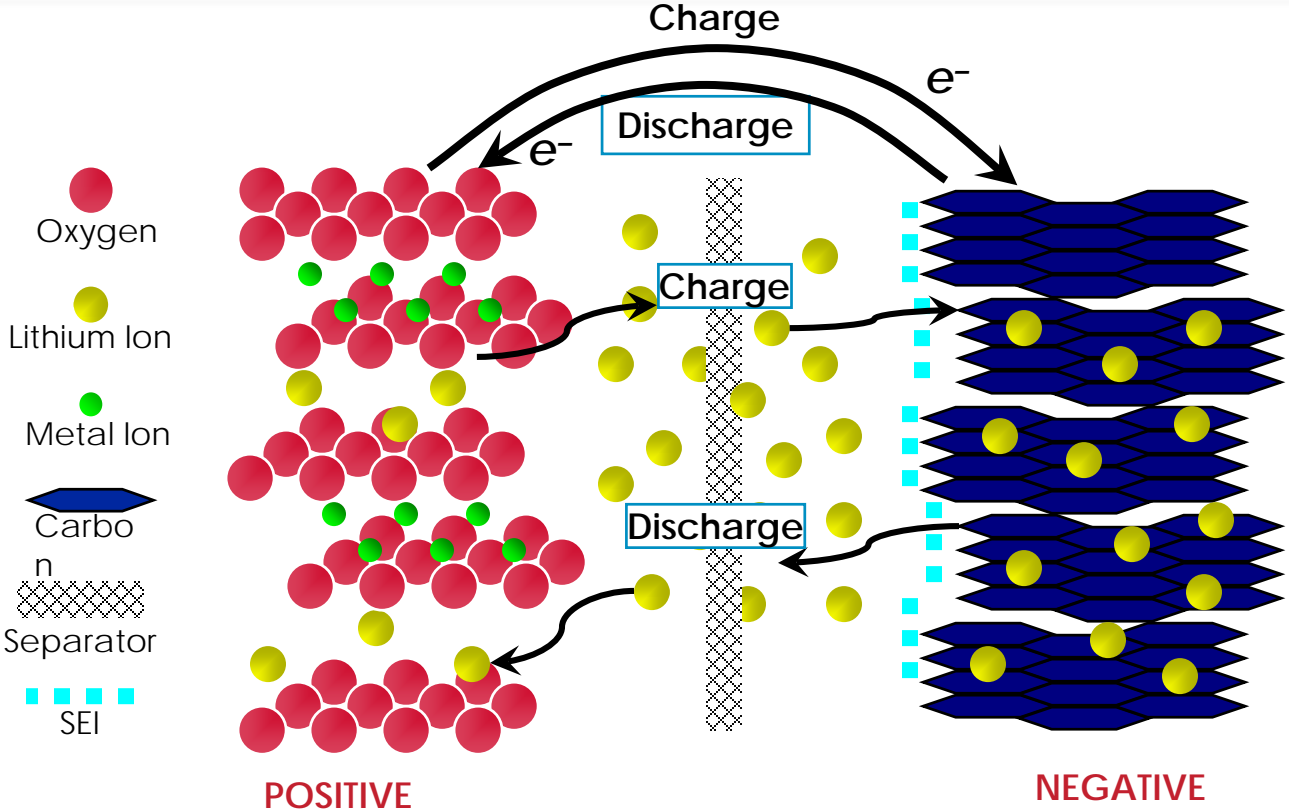
Intensium
Max

Li-ion

4

INDUSTRIAL LITHIUM-ION TECHNOLOGY

Intercalation & Reaction mechanism



Li-ion: Many Flavors

Currently Used Cathodes

- LiCoO_2 = LCO – Cell Phones, Tablets, Cameras
- LiNiCoAlO_2 = NCA – Industrial, EV's
- LiNiMnCoO_2 = NMC – E-bikes, Medical Devices, EV's
- LiMn_2O_4 = LMO – Power Tools, Medical Devices
- LiFePO_4 = LFP – Portable & Stationary, high load applications

Currently Used Anodes

- Graphite = Carbon (C)

Emerging anodes

- $\text{Li}_4\text{Ti}_5\text{O}_{12}$ = Lithium Titanate Oxide (LTO)
- Alloy anodes = Si and Sn based (Silicon and Tin)

Li-ion for Standby Applications

Technologies

- Ni Co Al (NCA) Lithiated oxide / Graphite
 - Improved Calendar Life, Cycle Life, Energy/Power Density
- Super Iron Phosphate – sLFP
 - Improved chemical stability, Flat Power Curve

Features

- Compact, sealed, maintenance -free
- Very high efficiency: >95%
- Long calendar and cycle life
- SoC indication: Essential for smart energy management
- Superior cell design and manufacturing process



Built in the USA. Saft - Jacksonville, FL - since 2011

Module Architecture

Cell Pack (cutaway)



SMU board: conducts information (V.A.T°) to BMM

Li-ion cylindrical cells: Saft Technology

Safety functions

Saft incorporates safety features at the cell, module, string and battery levels



Li-ion System Configurations

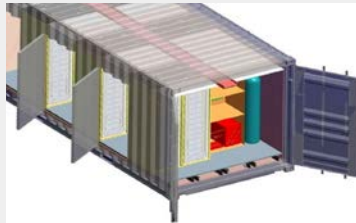
Racks



Cabinets



Containers



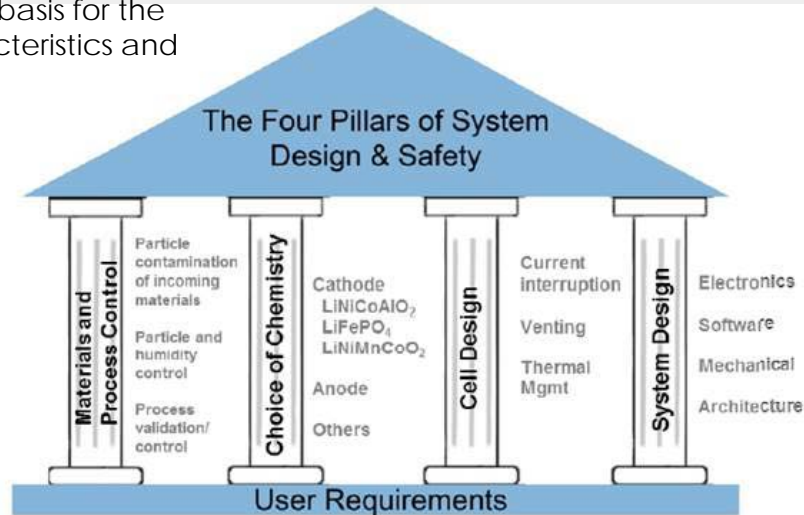
How to Evaluate Emerging Technologies

IEEE Std 1679-2010

- IEEE Recommended Practice for the Characterization and Evaluation of Emerging Energy Storage Technologies in Stationary Applications
- Recommended information for an objective evaluation of an emerging energy storage device or system for any stationary application
- The document provides a common basis for the expression of performance characteristics and the treatment of life-testing data

IEEE Std 1679.1 – draft format

- Evaluating Li-ion batteries



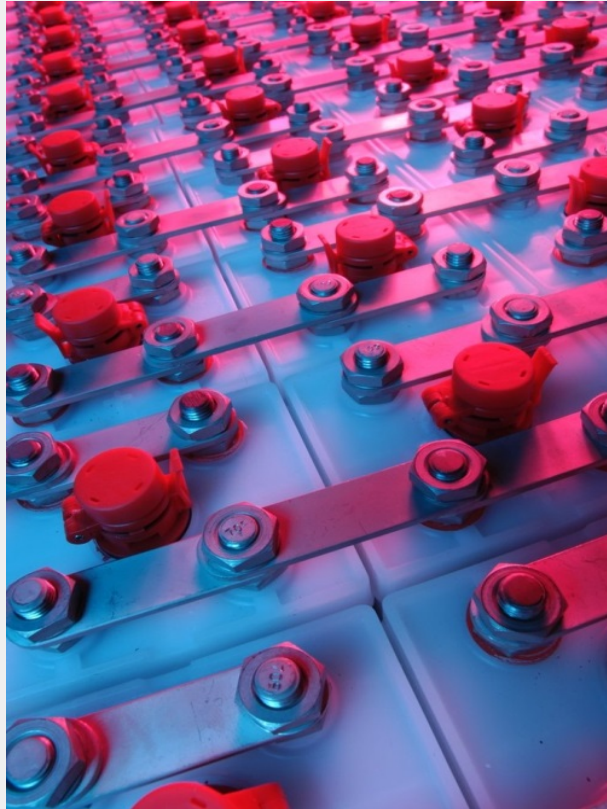


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CHOOSING THE RIGHT TECHNOLOGY

Considerations

- High Temperature
- Low Temperature
- Longer Life
- Low Maintenance
- Storage
- Space – Weight
- Vibration / Shock
- Cost of Failure



High Temperature – Shortens Life

Lead Acid

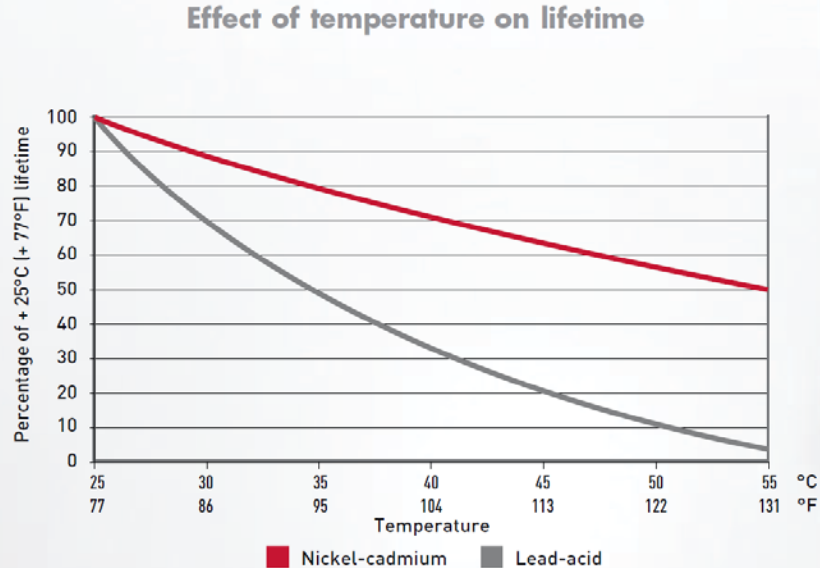
- Life is cut 50% for every 15°F over 77°F

Nickel Cadmium

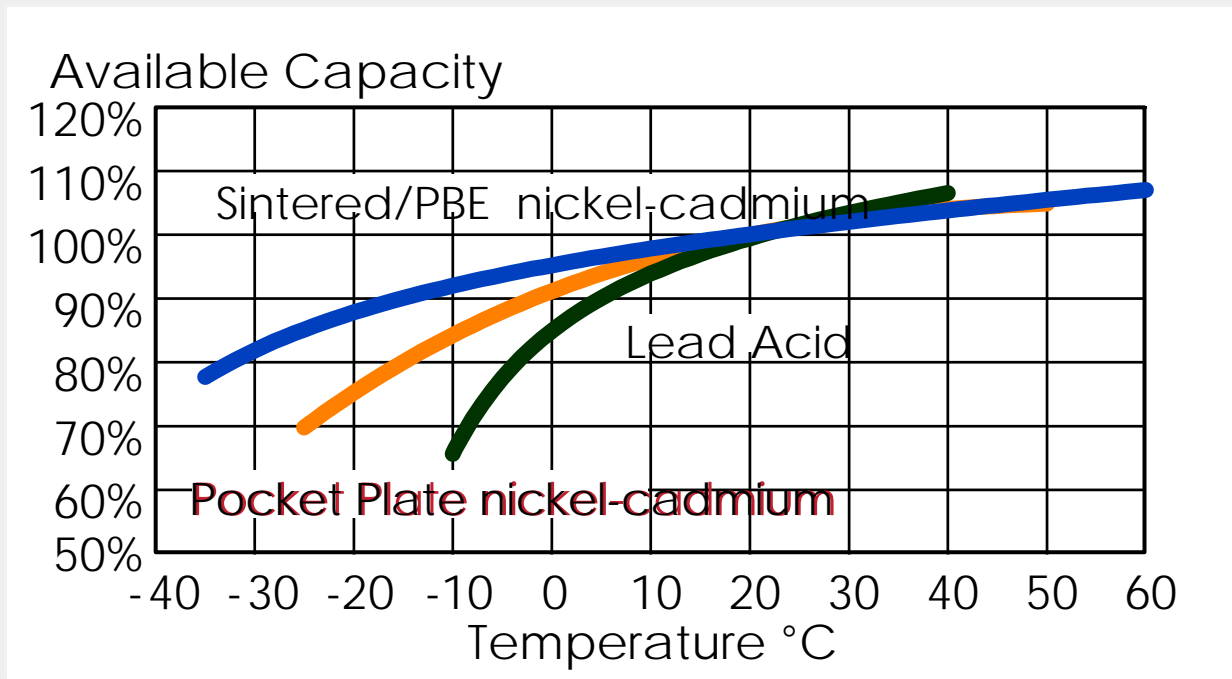
- Life is cut 20% for every 15°F over 77°F

Normal Service Life

- VRLA 3 - 10 years
- Flooded Lead 12 – 15 years
- NiCd 20 - 25+ years

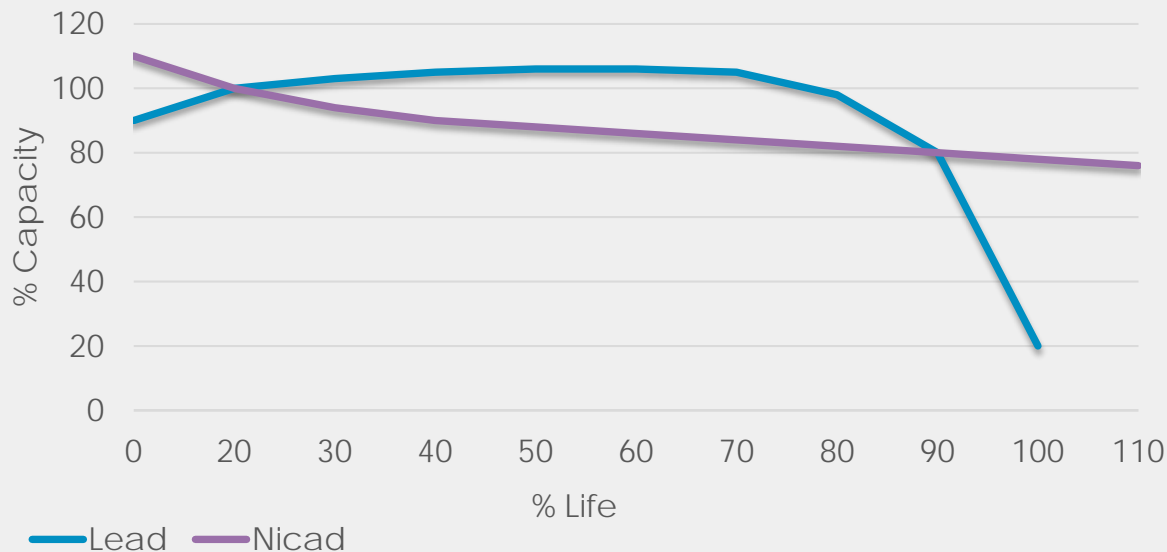


Low Temperature – Reduces Performance



Nickel cadmium can operate to - 50C, no danger of freezing. Lead Acid can Freeze

Life Cycle Curve



- Ni-Cd cells lose about 1% capacity per year of life, they can continue service after 25 years with no catastrophic failure and will not fail in open circuit.
- When lead acid cells fail, they fail abruptly
- Graph shows ideal environment, maintenance and operating parameters.

Maintenance

Why is it important?

- Secure and protect the battery investment
- Required for some applications (NERC/FERC)
- Predict failures
- Easy warranty claims

Must consider:

- Total cost of ownership
- Site location and accessibility

Maintenance Procedures	IEEE 450 Lead Acid	IEEE 1188 VRLA	IEEE 1106 Nickel Cadmium
Visual inspection	Monthly	Monthly	Quarterly
Pilot cell reading	Monthly	Monthly	Quarterly
Float voltage – battery	Monthly	Monthly	Quarterly
Float voltage – cells	Quarterly	Semi-annually	Semi-annually
Watering	3-6 Months	Never / replace	1.8 – 20 Years

Cost of failure

- Loss of power could result in cost of thousands to millions of dollars or even loss of life.
- Lead Batteries even when monitored and maintained can be unpredictable as to when they will fail. Lead cells usually fail as an open circuit. One cell failure will take out whole battery.
- Nickel Cadmium have very gradual capacity loss. Ni-Cd cells fail as a short circuit. The battery will still function with loss of several cells.



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CASE STUDY: MLGW

Case Study: Memphis Light Gas and Water



Customer Profile

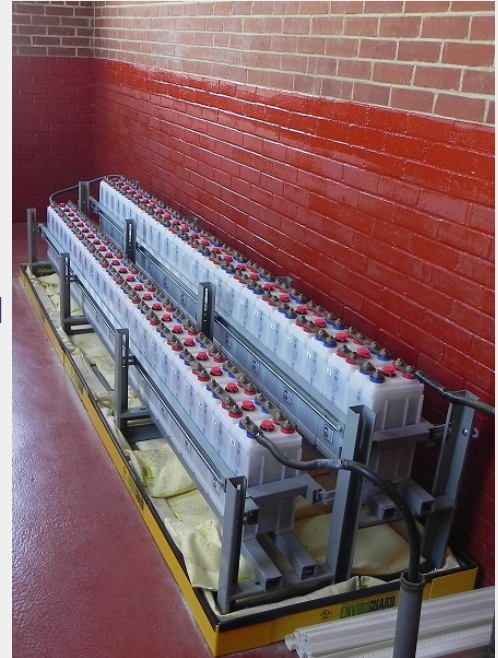
- Nation's largest three-service municipal utility
- Provide Electricity, Natural Gas, and Water service
- Serving Memphis and Shelby County, TN
- TVA's largest customer
- 421,000 customers
- 63 substations



Case Study: Memphis Light Gas and Water

Application

- Formerly used all lead-acid batteries for switchgear
- Main issue with lead acid was low reliability
- In 2010 they started replacing their lead-acid with NiCad as a way to improve reliability.
- In 2014 they decided to replace all lead acid switchgear control systems with NiCad.
- To date, they have replaced about half and have plans next year to ramp up to replace about 5-6 per year till complete.



Further References

- IEEE1106 – Recommended practice for Installation, Maintenance, Testing, and replacement of Vented Nickel-Cadmium Batteries
- IEEE1115- Recommended Practice for Sizing Nickel-Cadmium batteries for stationary applications
- IEEE 450 – Recommended practice for Maintenance, Testing and replacement of Vented Lead-Acid Batteries
- IEEE484 – Recommended practice for Installation of Vented Lead-Acid batteries
- IEEE485 – Recommended Practice for Sizing Lead-Acid batteries for stationary applications
- IEEE1188 - Recommended practice for Installation, Maintenance, Testing, and replacement of Valve Regulated Lead-Acid Batteries

Additional Saft Resources

Lunch and Learns

- Battery Sizing and Selection
- Advanced Nickel Cadmium Concepts
- Advanced Lithium-Ion Concepts
- Battery Chargers and other DC System Components

Guide Specifications for Consultants

Factory Battery Maintenance Training