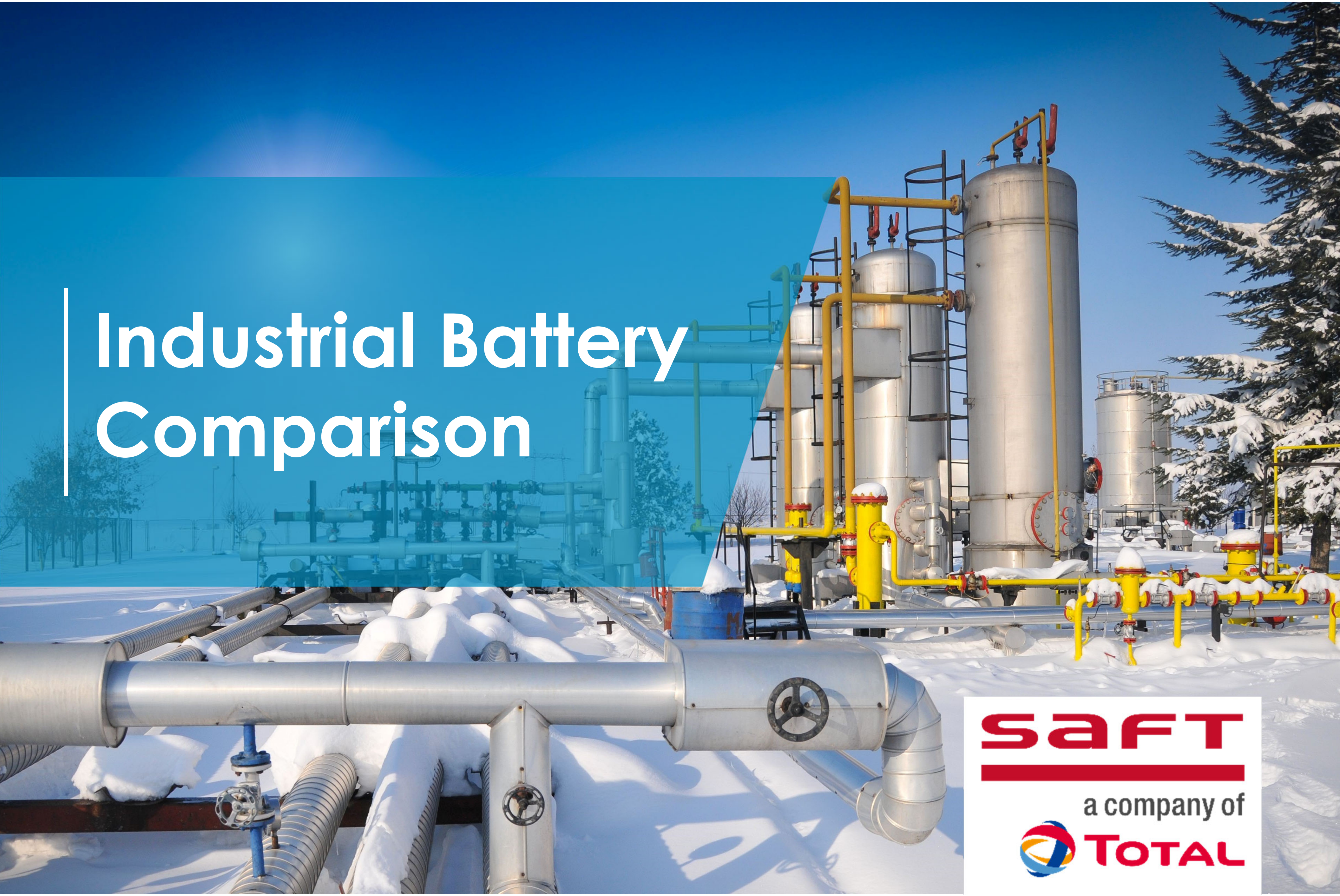
Industrial Battery Comparison



saft
a company of
TOTAL

Safety Precautions

- MSDS Sheets identify chemical hazards
- Use double insulated tools
- No smoking or open flames
- Avoid arcing near the battery
- Wear personal protective equipment
- Avoid wearing metal objects
- Ensure battery area ventilation is operable
- Neutralize static buildup

SAFT, now proud part of the TOTAL Group*

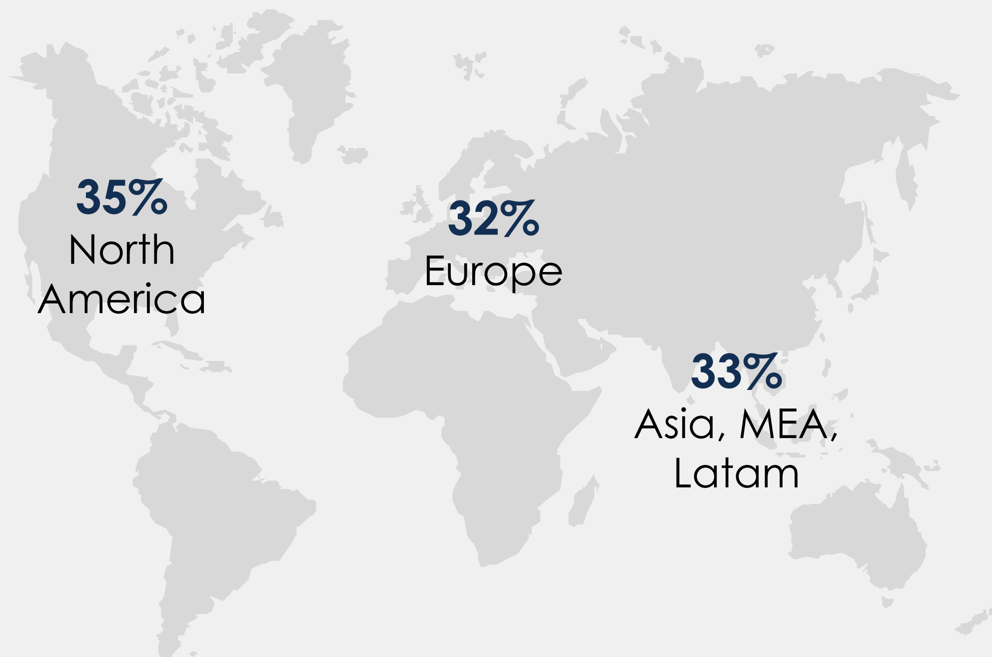
TOTAL

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	$921M*	9.7%	+4,100	+3,000
years of history	revenue FY 2017	invested in R&D	people	customers

*Using an exchange rate of 1.24

Leading Oil & Gas companies rely on Saft

International & National Oil and Gas Companies

1. Battery Basics
2. Battery History
3. Chemistries and Construction
4. Battery Comparison
5. Choosing the Right Technology

1 BATTERY BASICS

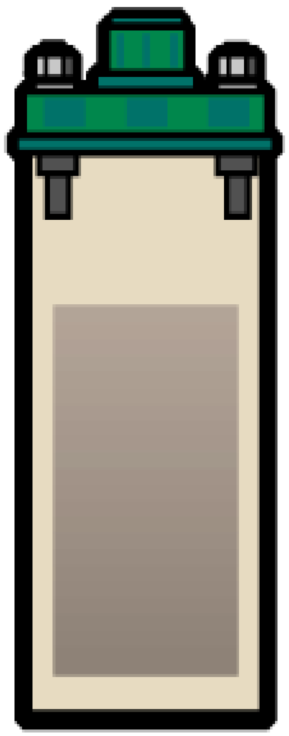
Battery Composition

A battery is an electrochemical energy storage device.

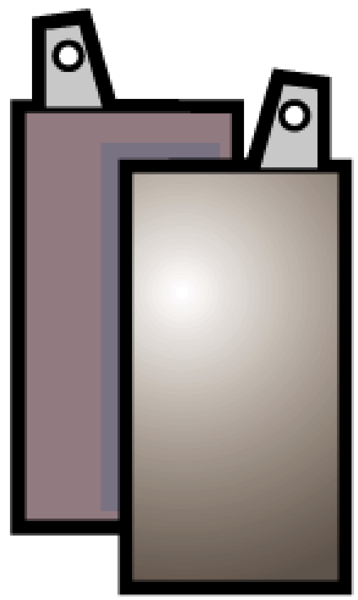
Energy Storage

Active Material

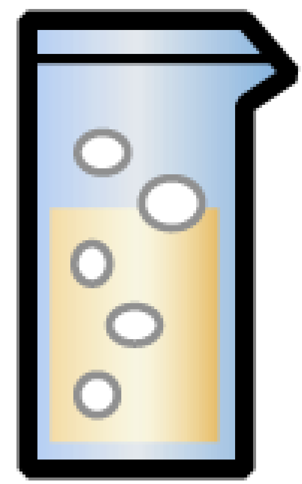
Electrolyte



=



+



Stationary Battery Cell Components

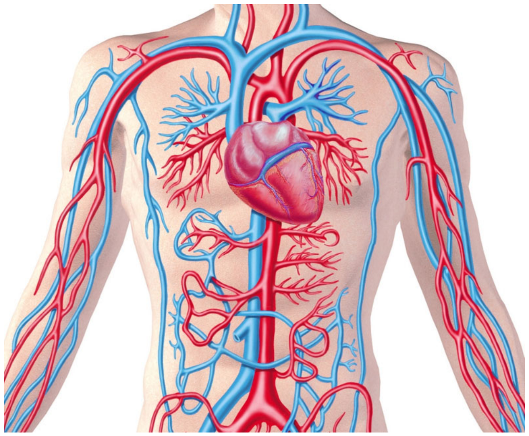
Substrate

Bones of the battery.
Physical structure inside the battery that houses the active materials. (May or may not be made of the same material as the active material)

Active Material

The muscles of the battery.
The material that does all the work storing and releasing energy.

Stationary Battery Cell Components



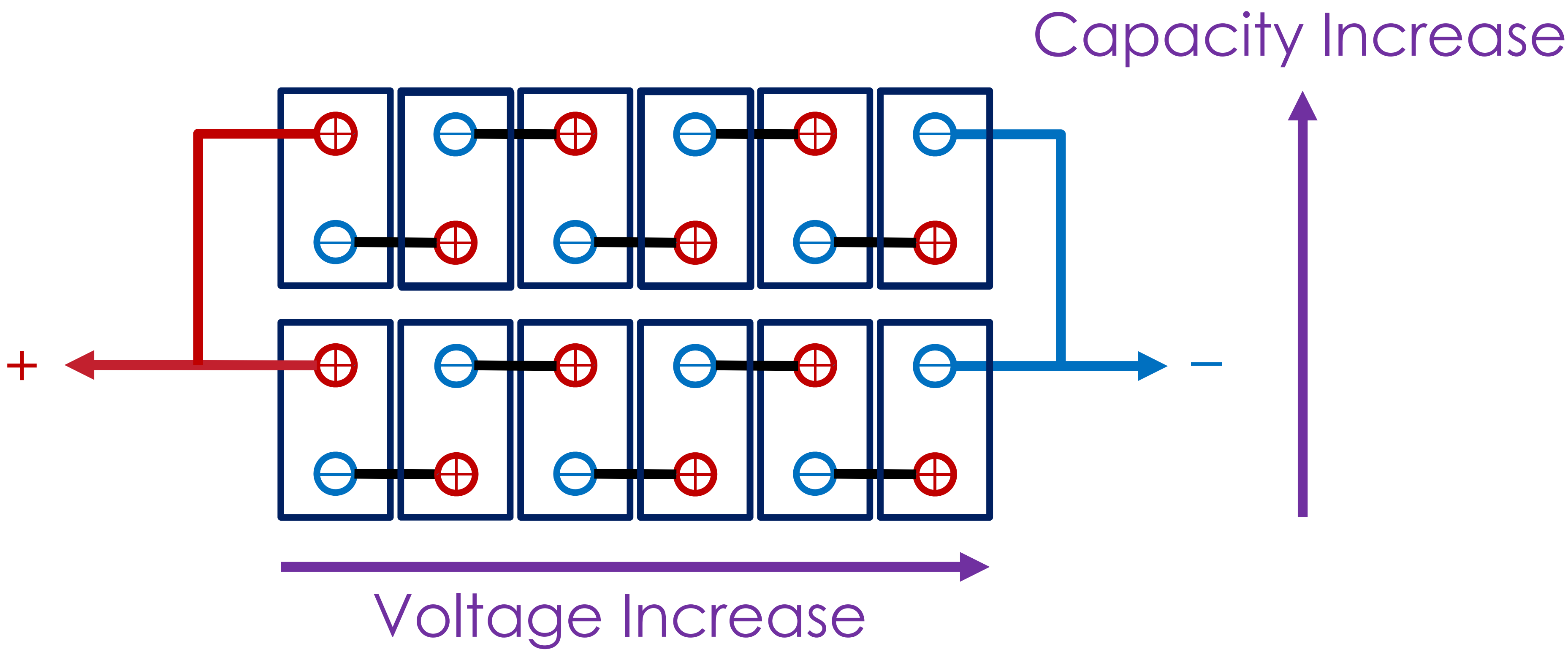
Electrolyte

The life blood of the battery.
Carries energy between the plates.
(May help with energy storage in some battery types)

Case (Jar)

Skin of the battery.
Keeps all the important bits inside!!

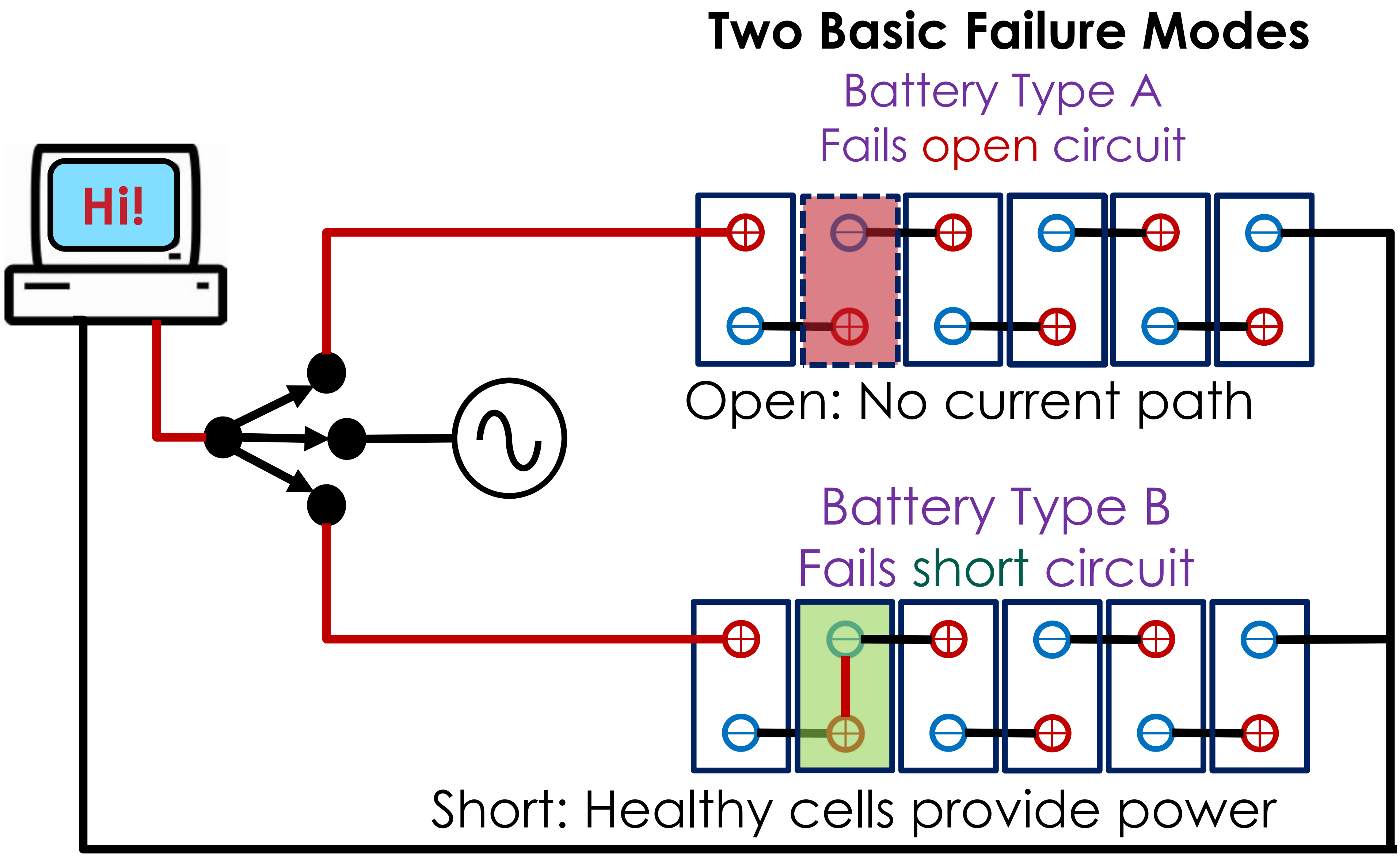
Battery System Configurations



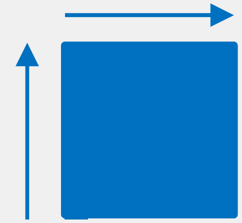
Cells in series increase voltage

Cells in parallel increase capacity

Battery Failure modes



Battery Terms



1 hour

1 amp

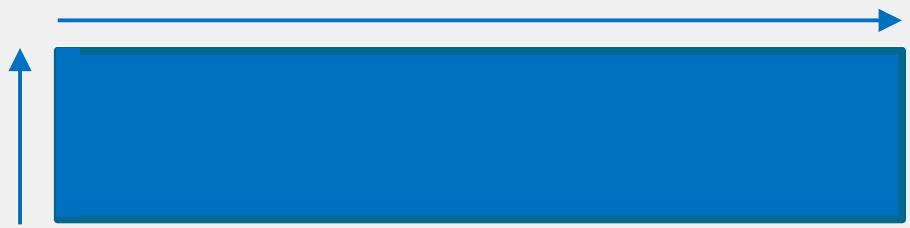
= 1 amp/hour

Ah – Ampere-hours

- Battery's rating of capacity

Rated capacity of a battery

- Continuous amps available for a set time period, to a certain end of discharge voltage, at a stated temperature
- Ni-Cd Example: 100Ah = 20A for 5 Hours down to 1.00 Volts/cell at 77°F



5 hours

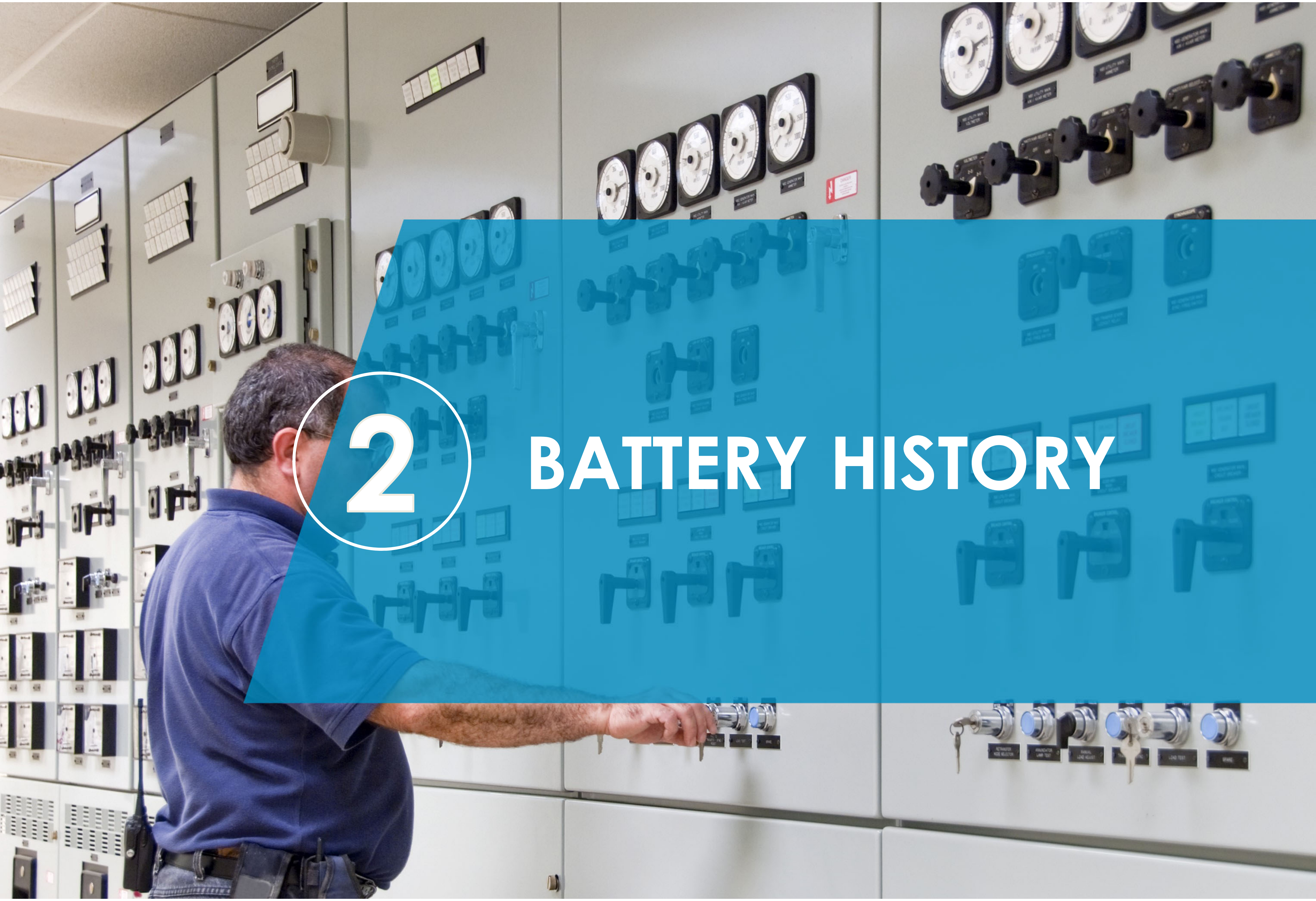
100 AH Ni-Cd Battery = 20 amps

Power = Instantaneous (V x I)

- Example: Switchgear Tripping current, instantaneous power requirement.

Energy = Power x Time

- Example: Continuous current loads for many hours.



2 BATTERY HISTORY

The Early Days of Batteries

Gaston Plante

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

Waldemar Jungner

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

1802 1836 1859 1868 1888 1899 1901 1932 1947 1960 1970 1990

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"

1802	1836	1859	1868	1888	1899	1901	1932	1947	1960	1970	1990

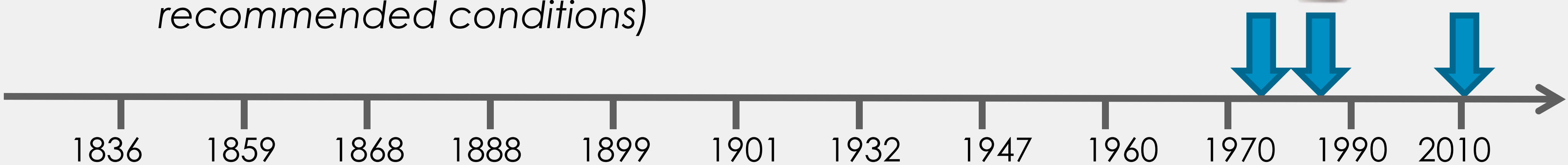
Battery Basics - History

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)*



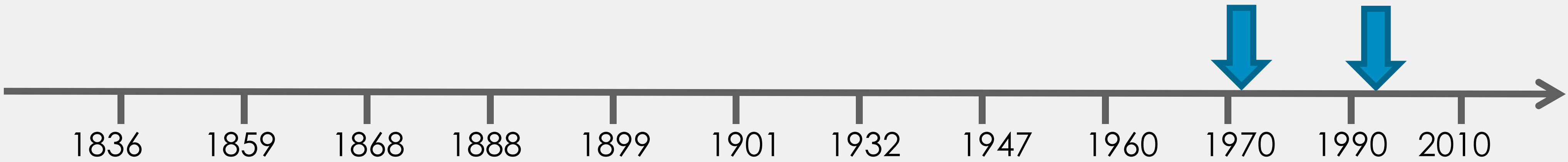
Battery Basics - History

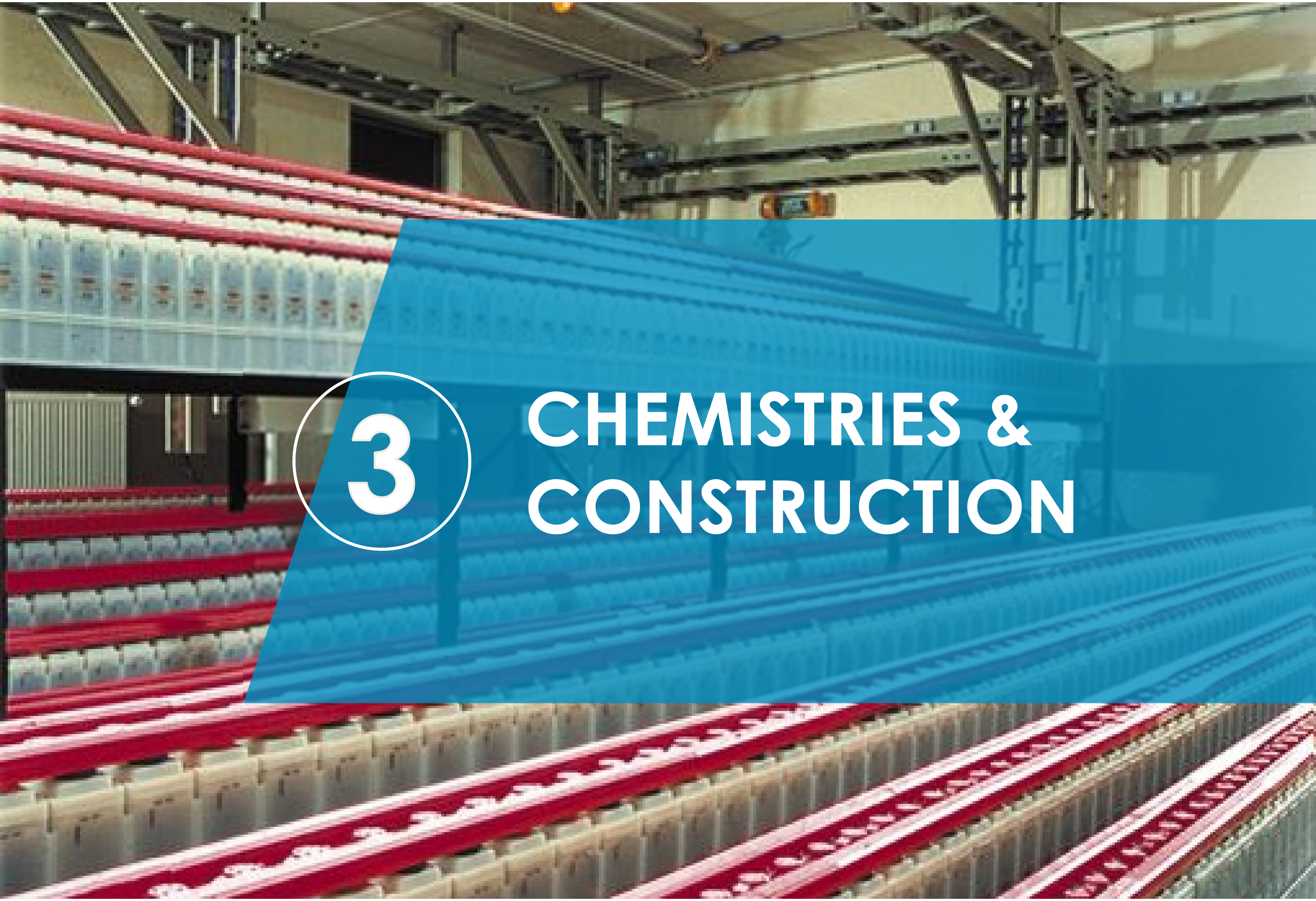
The future of batteries – Lithium-ion

- 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)

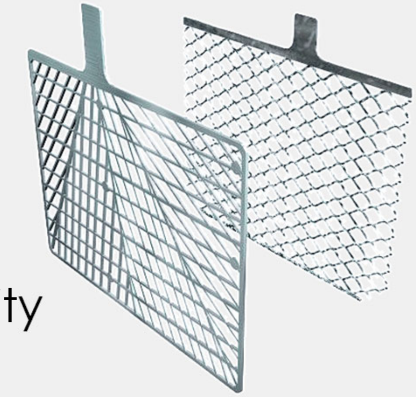
- 1992: Saft introduced its commercially available Li-ion cell





3 CHEMISTRIES & CONSTRUCTION

Lead-Acid Basics



- Plates –
  - Substrate: Pure lead or lead alloy grid
  - Positive Active Material: Lead oxide
  - Negative Active Material: Sponge lead
- Electrolyte - Sulfuric acid (H_2SO_4) 1.205 - 1.275 Specific Gravity and participates in the electrochemical storage reaction
- PH = ~2
- Nominal volts per cell ~2.0
- Inter-cell connection links - usually lead plated copper
- Different Grid Alloys – Selenium, Calcium, Antimony
- Failure mode: **OPEN CIRCUIT**
- Total Reaction

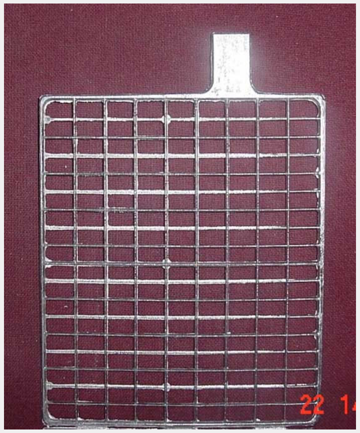
$$\overset{-}{Pb_{(metal)}} + \overset{+}{PbO_2} + 2H_2SO_4 \underset{\text{Charge}}{\overset{\text{Discharge}}{\rightleftharpoons}} 2PbSO_4 + 2H_2O$$

Flooded Lead-Acid Pasted Plate

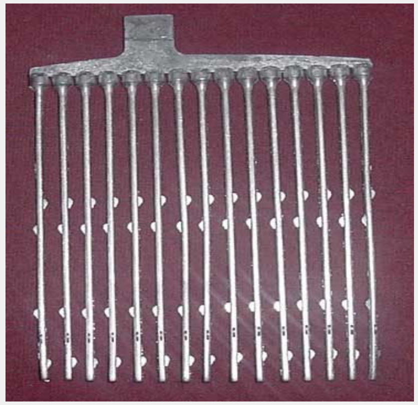
Basic Specification

- Jars - **S**tyrene **A**crylo**N**itrile (**SAN**) or **P**oly**C**arbonate (**PC**),
- **F**lame **R**etardant **-** ABS Lid-opaque, **PC** Jar-clear
- Construction: Plante, Manchester, Faure (Pasted Plate), Tubular
- Design Life - 20 years
- Service life - 12 – 15 yrs, depending on environment, design, application

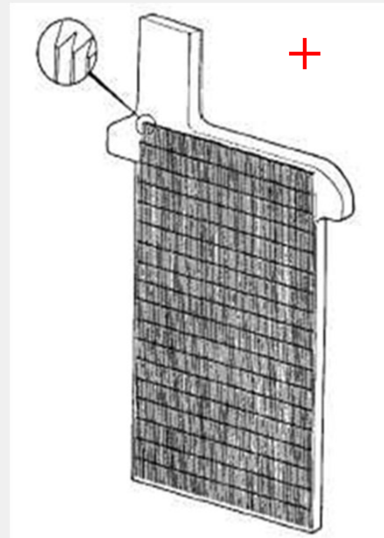
Pasted plates

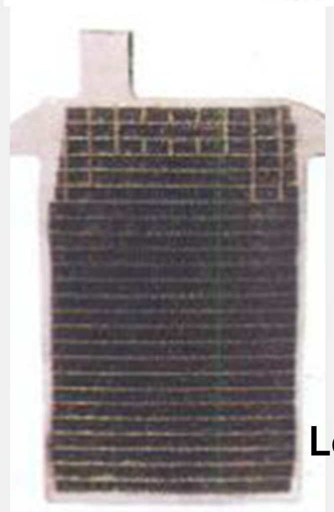


Tubular plates



Plante lead plate



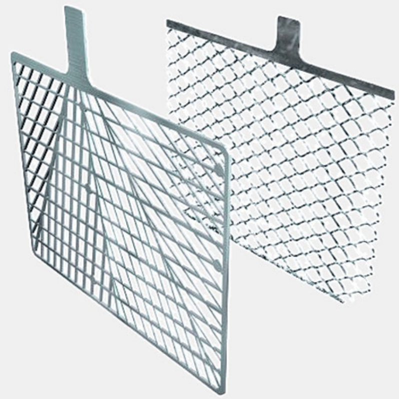


Lead grid

Negative plate

Valve Regulated Lead-Acid Batteries

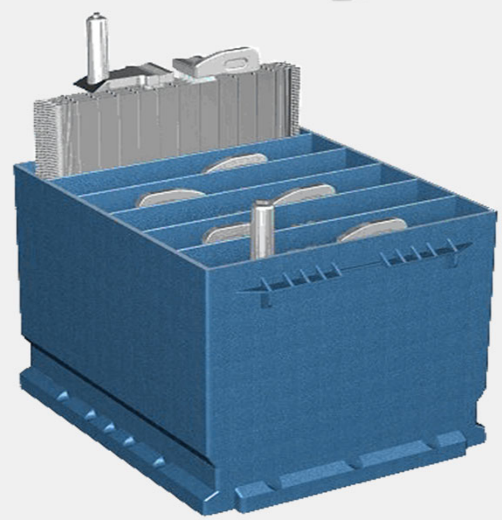
VRLA or Recombination Technology



- 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 due to low electrolyte content
  - 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
- Low initial cost

Disadvantages

- Multiple failure modes
  - Dry out
  - Thermal runaway
  - Negative strap corrosion
  - Sudden death… **OPEN CIRCUIT**
- Highly susceptible to ripple current
- Shorter life than vented cells
- Design Life:1-11 years
- Service Life: typically 3 – 7 years

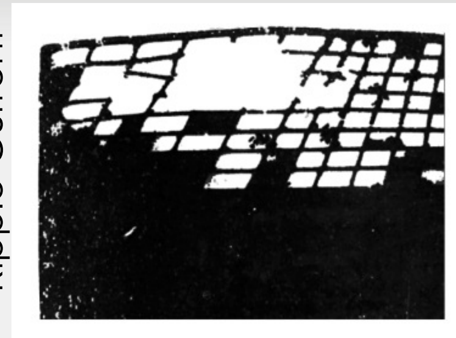
Typical Applications

- Telecommunications, UPS, Emergency Lighting

VRLA Battery Failure Modes: Summary

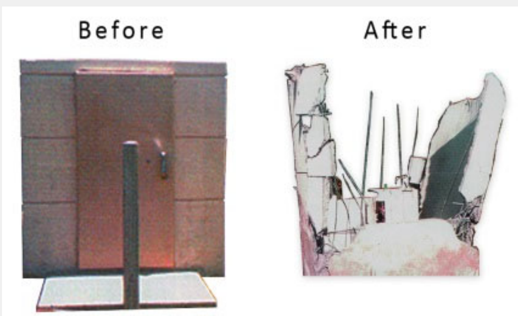
Thermal Runaway

Ripple Current



Storage

Sudden Death



Dry Out

High Temperature

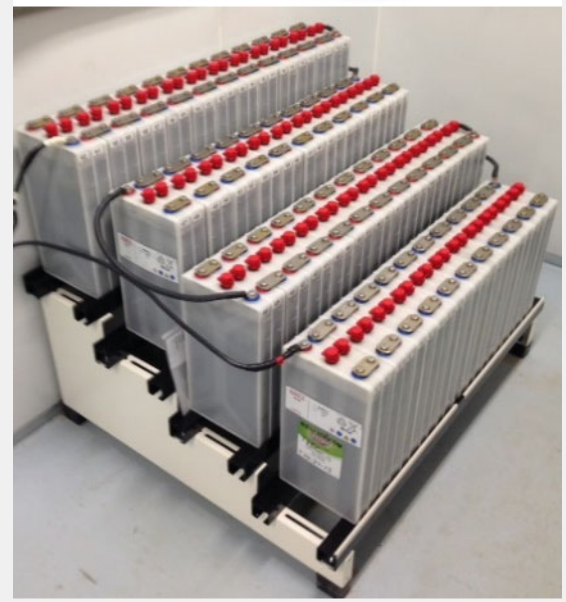
Corrosion

Sulfation

Nickel-Cadmium Basics

- Plates –
  - Substrate: Nickel-plated Steel
  - Positive Active Material: Nickel hydroxide
  - Negative Active Material: Cadmium
- Electrolyte = Potassium Hydroxide (KOH)
- PH = ~11
- Electrolyte is alkaline and **does not corrode the plates** or participate in the electrochemical reaction. It is actually a **preservative** of the plates.
- Nominal volts per cell ~1.2
- Failure Mode: **SHORT CIRCUIT**
- Different plate types: Pocket, Fiber, Sintered, Plastic Bonded (PBE)
- Total Reaction -

$$2\,NiOOH + 2H_2O + Cd \underset{\text{charge}}{\overset{\text{discharge}}{\rightleftarrows}} 2\,Ni(OH)_2 + Cd(OH)_2$$



Nickel Cadmium Features

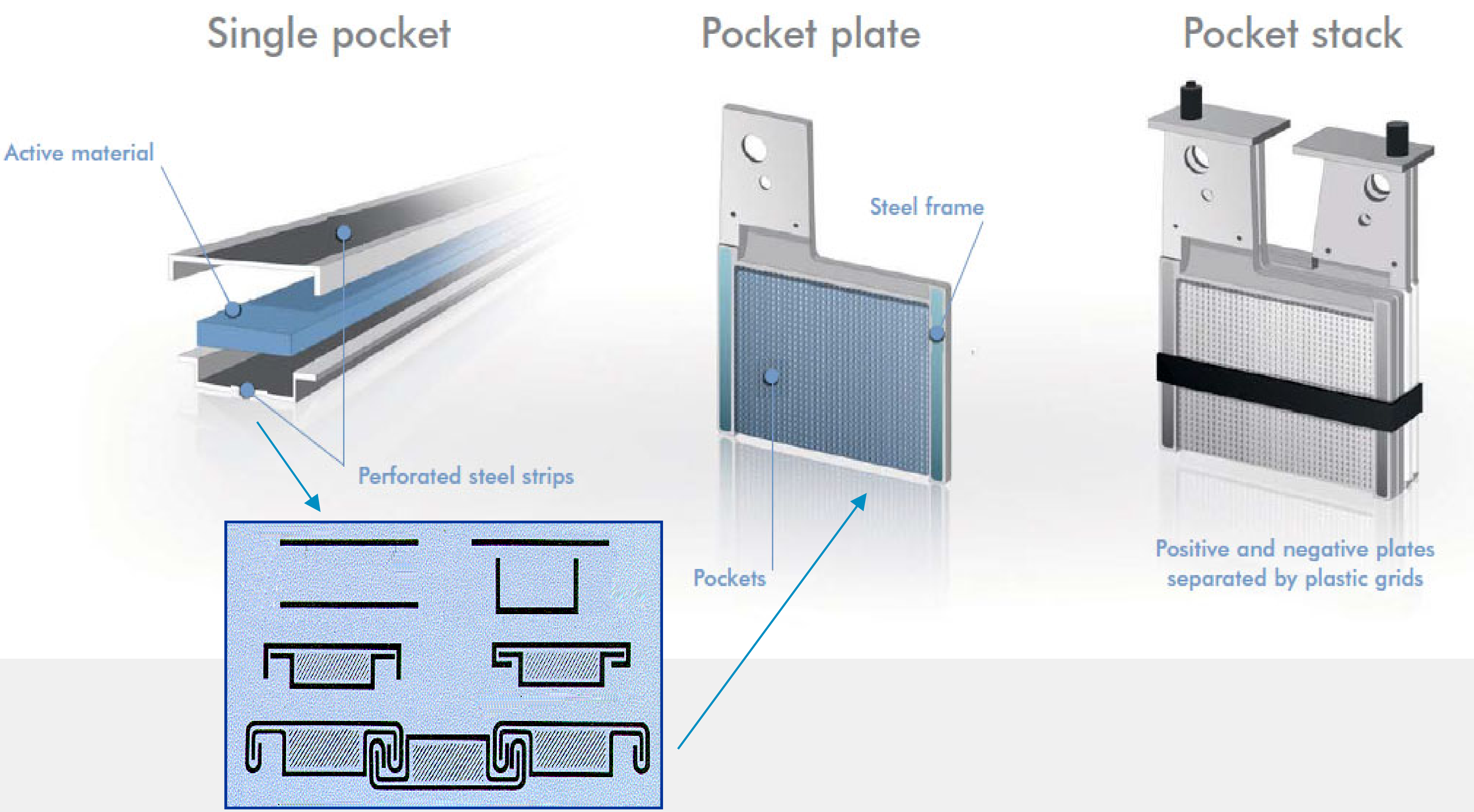
Advantages

- Most rugged battery type. All steel plate construction
- Resistant to: Electrical abuse, overcharging / over-discharging
- Physical abuse, extreme temperatures, shock & vibration
- Withstand temperature excursions from -40°C to +70°C
- Fast recharge with no adverse effects
- Impervious to ripple (a VRLA killer)
- 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

Nickel Cadmium Pocket Plate (traditional design)



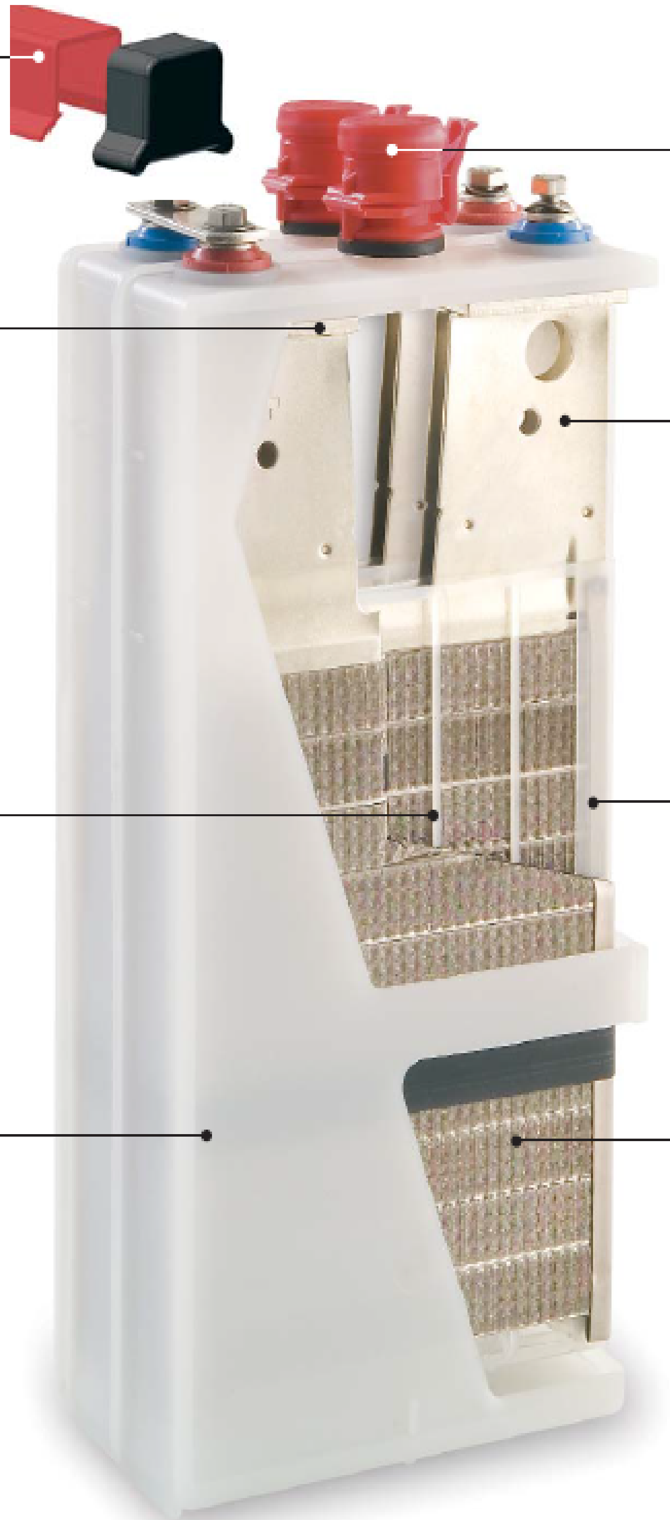
Protective cover
- *to prevent external short-circuits*
- *in line with EN 50272-2 (safety) with IP2 level*

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.

Maintenance Free (Recombinant) NiCd

Maintenance-free L and M types

- Qualified IEC 62259 for Ni-Cd with gas recombination (over 97%)
- Electrolyte is still liquid and abundant inside.

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

saft

High Performance NiCad Batteries (S/PBE)

Sintered plate (Positive Plate)

Plastic Bonded Electrode (Negative Plate)

Highest Performance NiCad

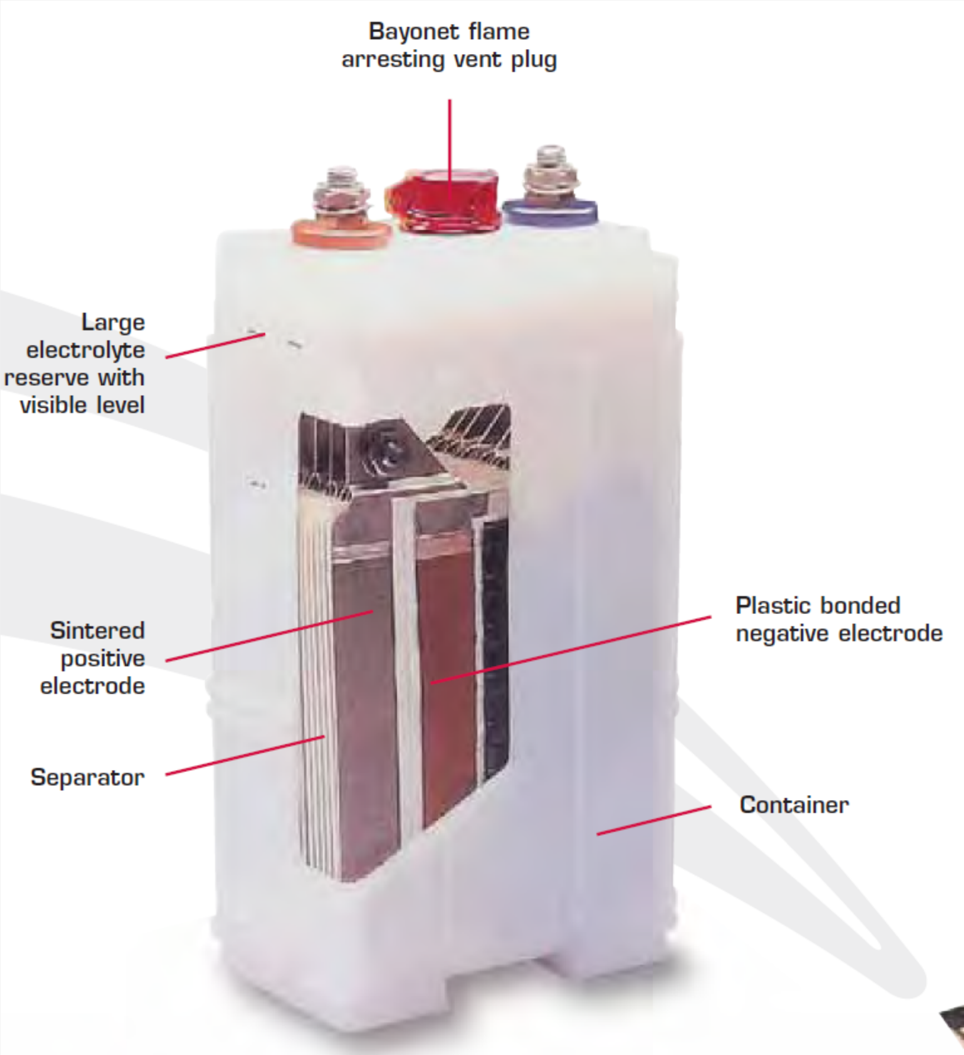
- High Energy Density
- High Power
- High charge acceptance at low voltage

Ideal for Engine Starting and Switchgear Applications

Low Maintenance

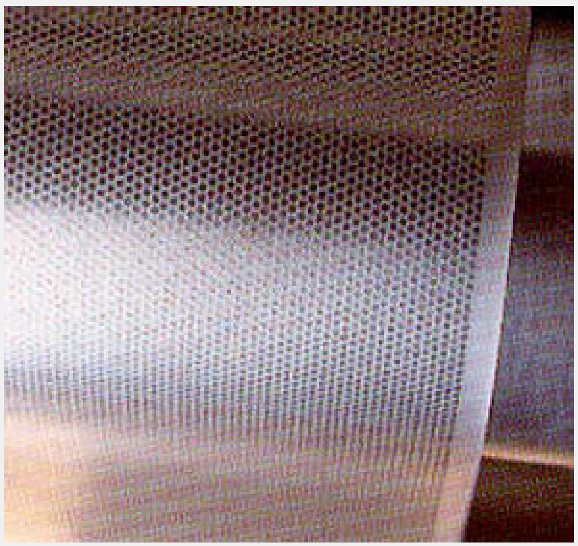
- 10 – 13 Year topping up interval

Single Cell / Compact Design



Sintered Plate Technology

Perforated & nickel plated steel strip

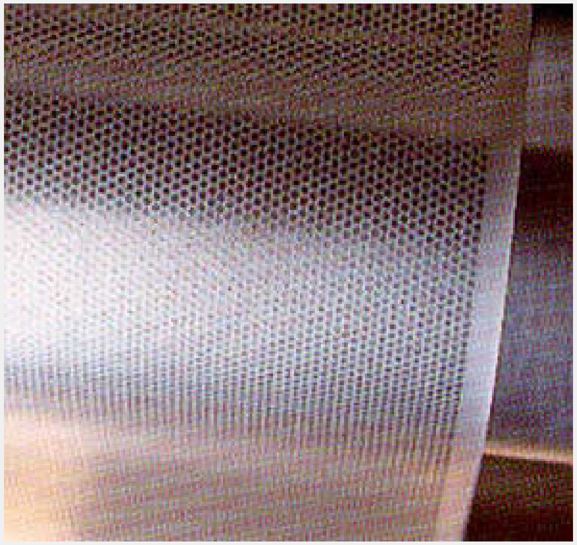


Electrochemical impregnation with active material

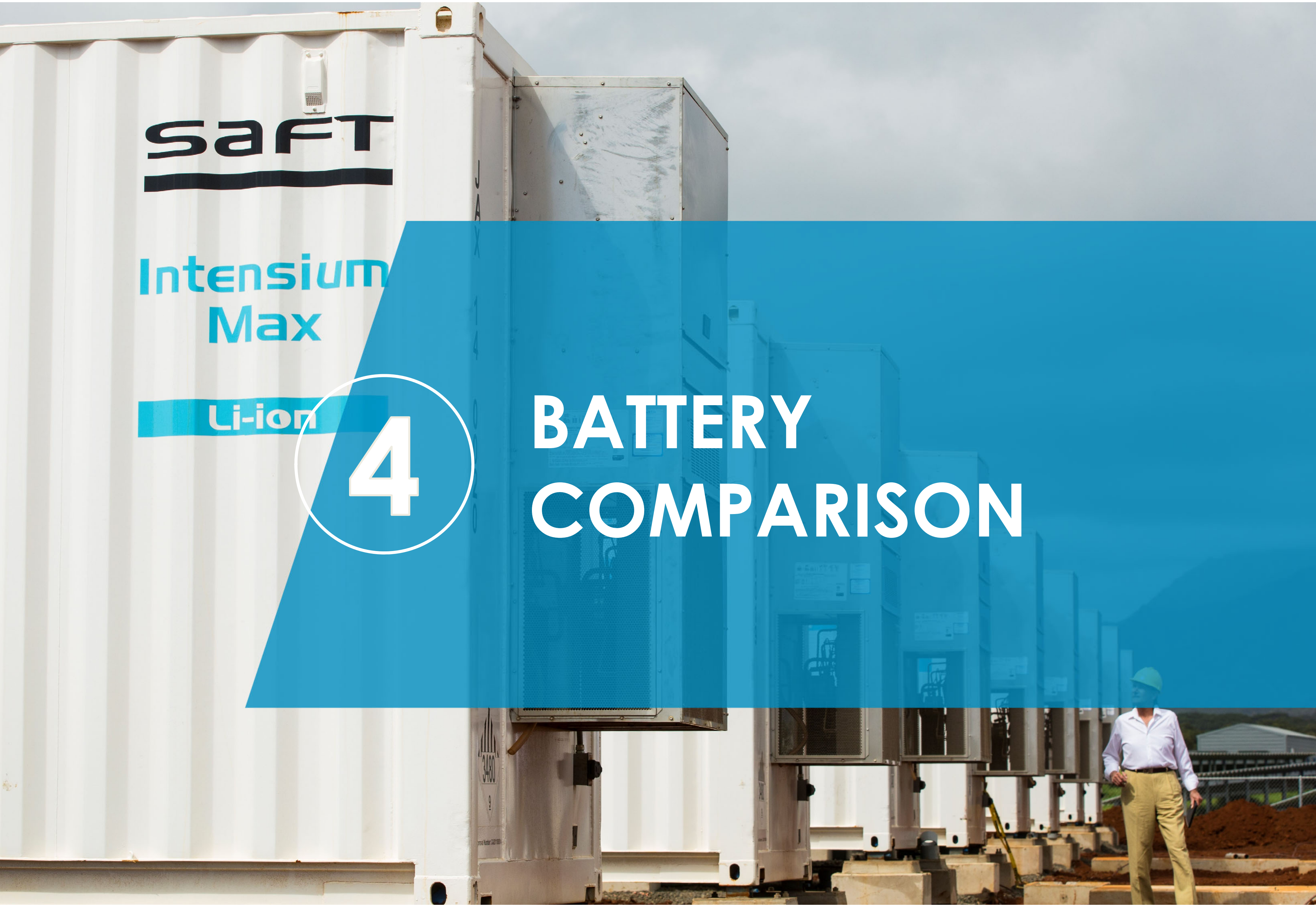
Nickel powder is sintered onto the strip to form a highly porous and conductive structure.

Plastic Bonded Plate Technology

Perforated & nickel plated steel strip



Pasting and drying of active material embedded into organic binder



4 BATTERY COMPARISON

Technology Physical Comparison

What to look for:

Technologies being compared

- Nickel-Cadmium Vs Flooded Lead-Acid (VLA)

Sizing Results

Comparison parameters

- Footprint
- Volume
- Total weight (battery + racking)
- Price

Sizing Parameters

Parameters	
Min. Voltage:	105 Vdc
Max. Voltage:	140 Vdc
Nom. Voltage:	125 Vdc
Design Margin:	1.15
Aging Factor:	1.25
Temperature (max):	30 °C
Temperature (min):	15 °C

Load Profile		
Step	Load	**Duration**
1:	5 A	8hr
2:	300 A	1 min*

**For Nickel-Cadmium the minimum performance step is 1 sec Vs. 1 min for Lead-Acid (Coup de Fouet).*
The "tripping load" can occur in under one second bursts.

Sizing Results

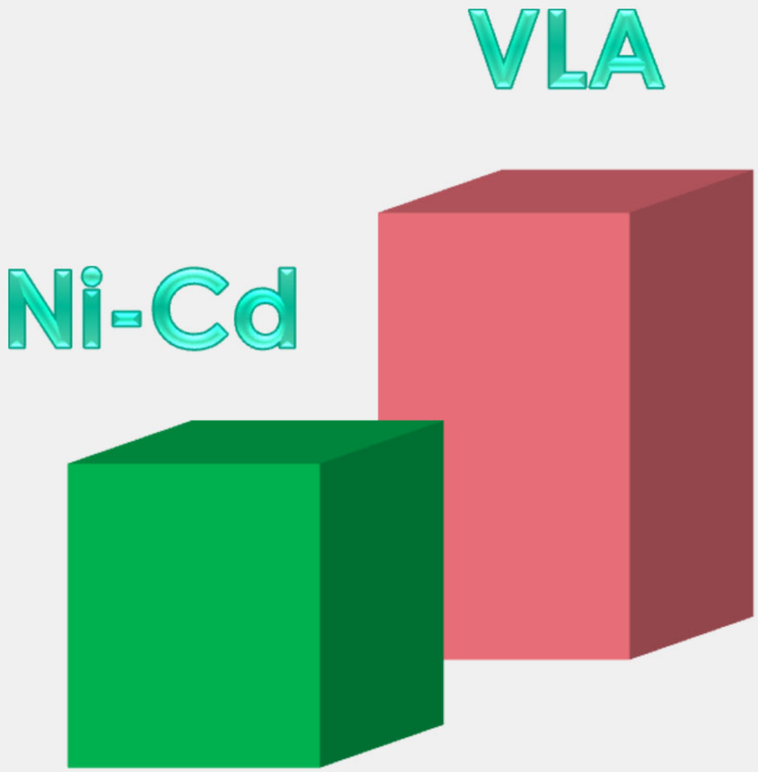
Nickel-Cadmium		Vented Lead-Acid	
Nominal Capacity:	130 Ah	Nominal Capacity:	350Ah
Total WxDxH	59" x 28" x 68"	Total WxDxH	83" x 28" x 71"
Total Weight:	~1,652 lbs	Total Weight:	~4,461 lbs
Installed Energy:	16.3 kWh	Installed Energy:	43.8 kWh

Footprint Comparison

Technology	W (in)	D (in)	Area (in^2)
Ni-Cd	59	28	1,652
VLA	83	28	2,324

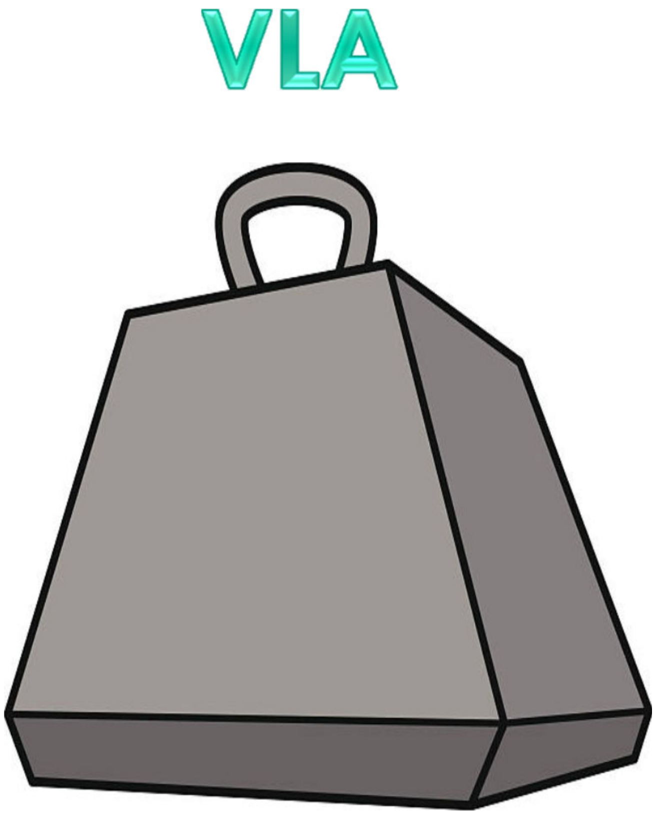
Volume Comparison

Technology	W (in)	D (in)	H (in)
Ni-Cd	59	28	68
VLA	83	28	71



Total Weight Comparison

Technology	Weight (lbs)
Ni-Cd	1,652
VLA	4,461



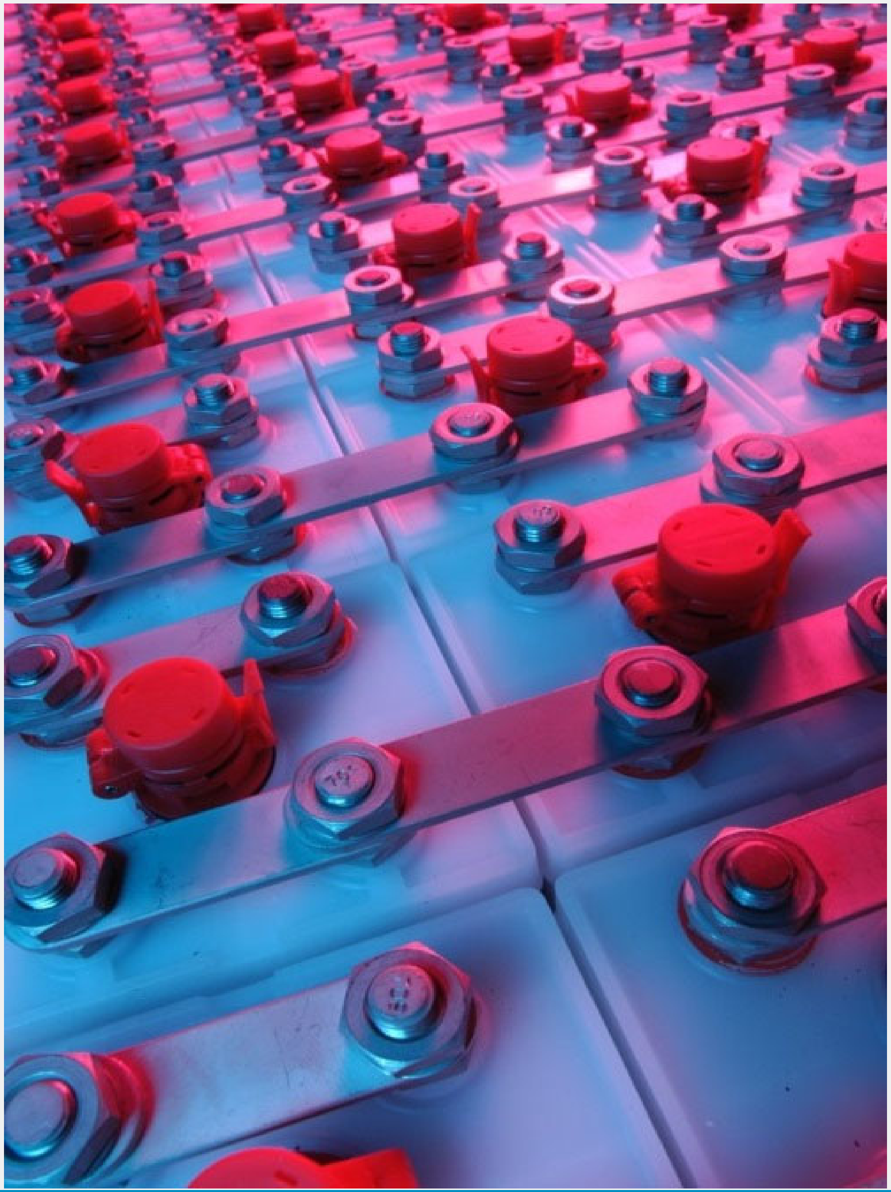
Price Comparison

Technology	Initial Price
Ni-Cd	$26k
VLA	$14k

5 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

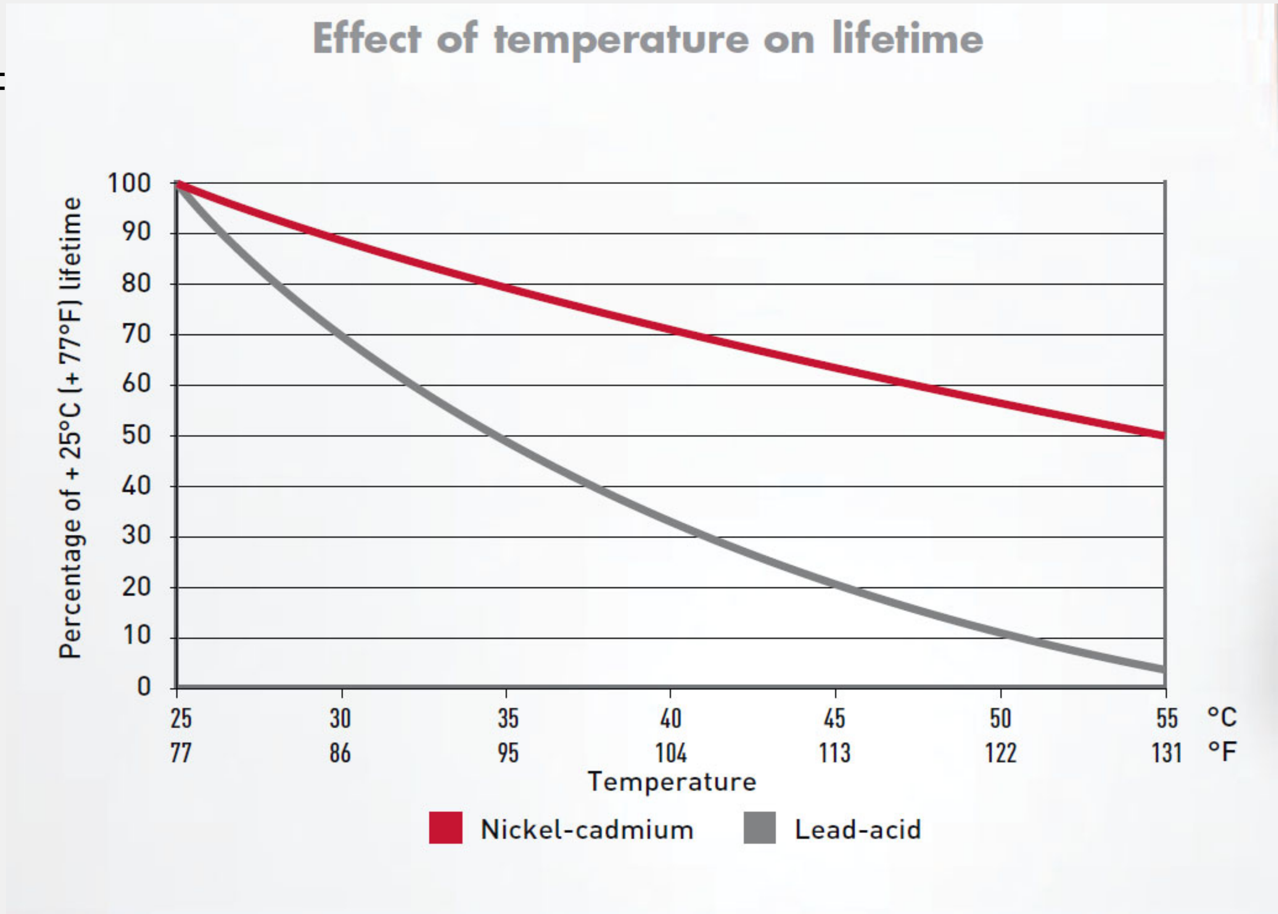
- Life is cut 50% for every 15°F over 77°F

Nickel Cadmium

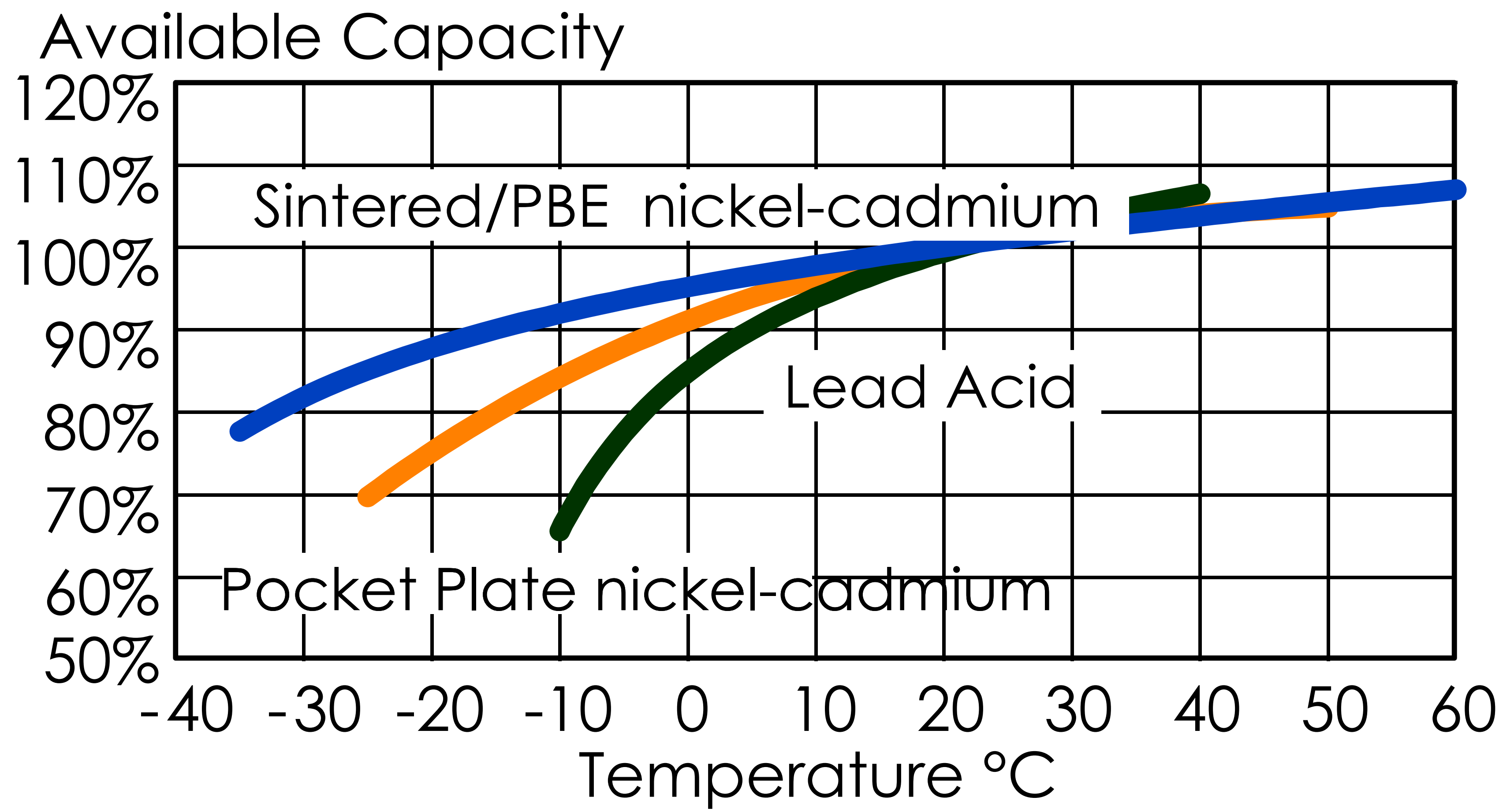
- Life is cut 20% for every 15°F over 77°F

Normal Service Life

- VRLA 3 - 10 years
- Flooded Lead 12 – 15 years
- Ni-Cd 25+ years

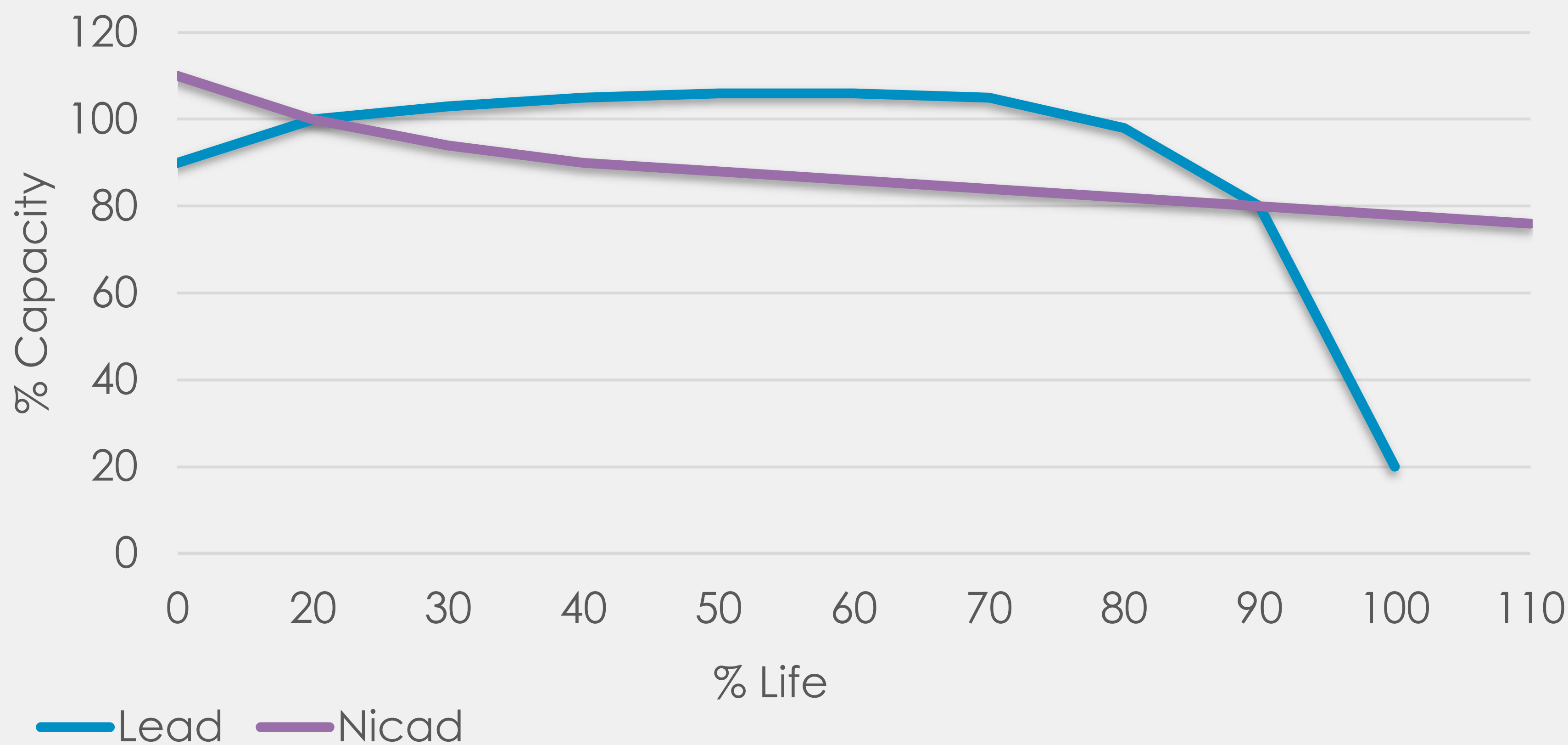


Low Temperature – Reduces Performance



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

Life Cycle Curve



- **Ni-Cd cells loose 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

Storage

How often do you hear, "The site is not ready."

- Once filled, Lead Acid needs refreshing charge every 3-6 months
- Nickel Cadmium Pocket Plate (SBLE/SBM/SBH) can be stored for 6 months to 1 year (filled and charged) or many years dry and discharged.
- Sintered Plastic Bonded Electrode (SPH) Cells can be stored discharged for many years.
- Uptimax are supplied filled and charged and can be stored for 2 years in this condition.
- ***Consider the battery's DATE CODE!***
- ***On-site commissioning is recommended for all batteries***

Cost of failure

- Battery cost in relation to protected equipment cost is negligible.
- **Loss of power could result in loss 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 lead-acid 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.**

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

Thank You . . . Questions??