Failure Modes for Flooded & VRLA Batteries

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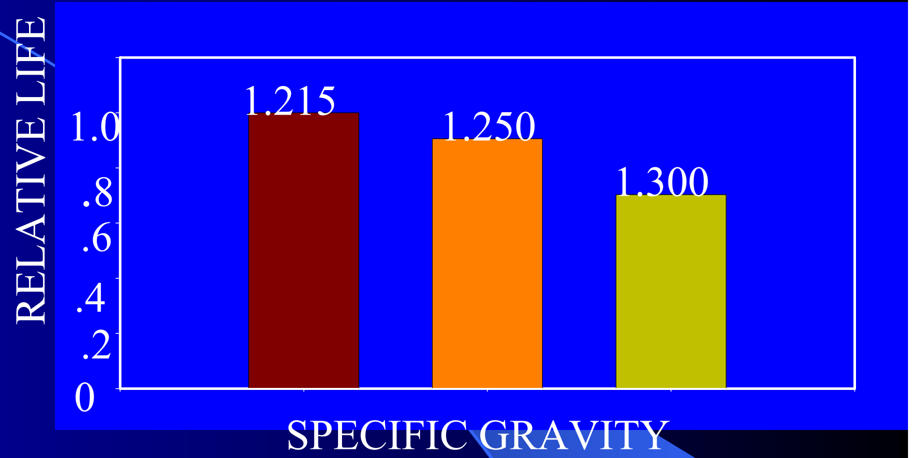
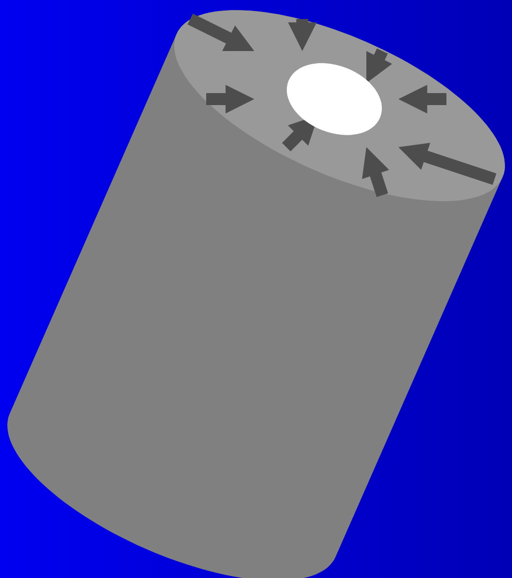
How do they fail?

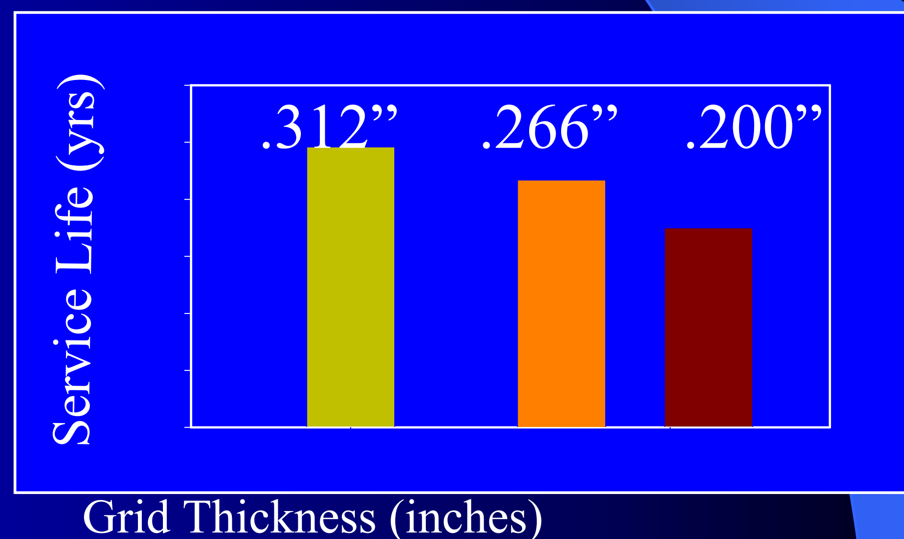
- Flooded modes of failure
  - Positive grid corrosion
  - Loss of active material
  - Internal shorts
  - Loss of electrolyte
  - Plate sulfation

How do they fail? - Flooded

- Positive grid corrosion
  - Takes place over time
  - No visible indication
  - Affected by grid design and acid strength

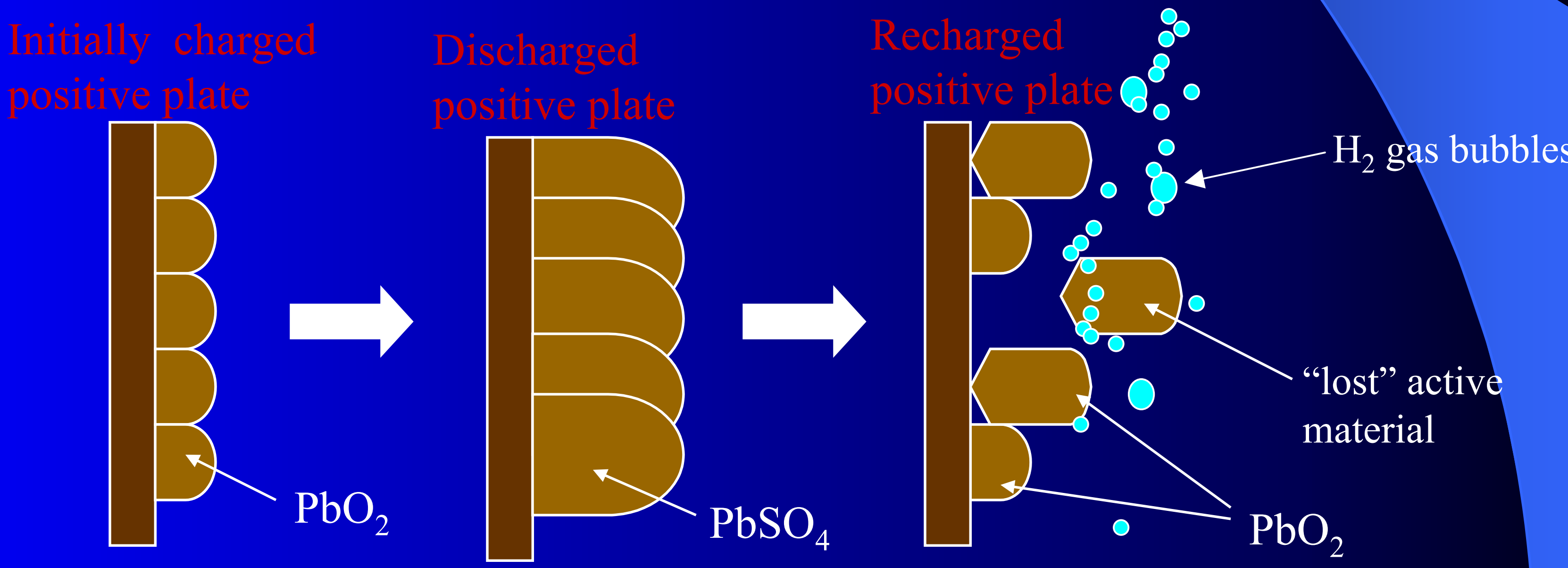






How do they fail? - Flooded

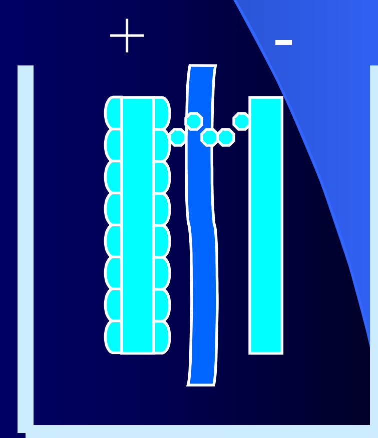
- Loss of active material
  - $PbSO_4$ is larger than PbO_2 - when recharged, the PbO_2 is sometimes reformed 'detached' from the plate - this 'lost' active material will no longer participate in the reaction and will result in lower capacity
  - $PbSO_4$ can also be 'washed' away from the plate surface by the gassing action during overcharge



How do they fail? - Flooded

- Internal shorts
  - Sediment short - ‘lost’ active materia
    that accumulates in the bottom of the
    jar - eventually touching both the
    positive and negative plates causing
    hard electrical short

  - Soft short - when dissolved lead sulfate is reformed back into lead during recharge - this lead path forms a high resistance electrical short that will slowly self-discharge a battery

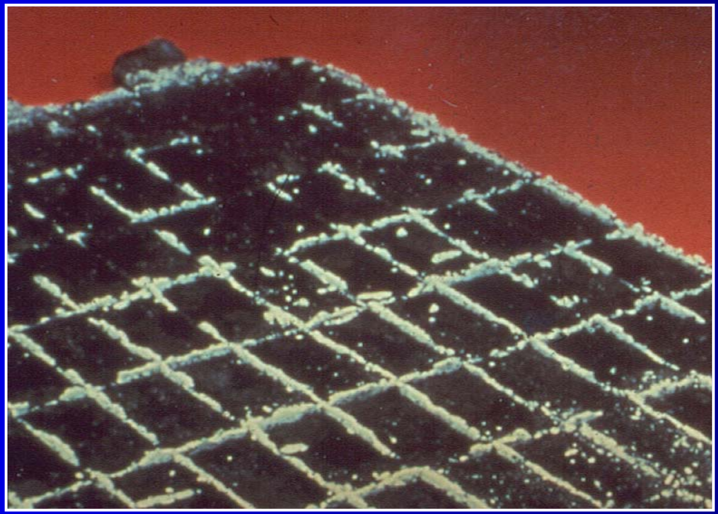


How do they fail? - Flooded

- Loss of electrolyte
  - Forgot to add water!
    - Maintenance error
  - Cracked jar
    - Accidental contact with cart
    - Jar will not fail on its own
- Exposed part of plate will react with air - resulting in capacity loss and eventual cell failure

How do they fail? - Flooded

- Plate sulfation
  - Prolonged discharged state
  - Not fully charged following the discharge



How do they fail? - Flooded

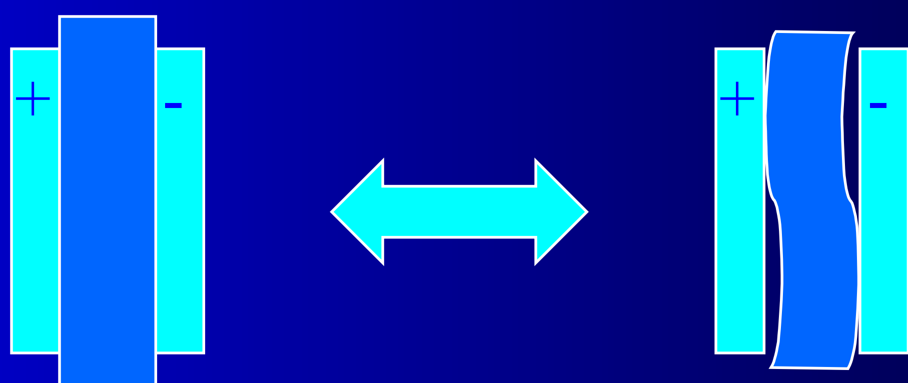
- Solutions
  - Positive grid corrosion
    - Correctly designed grid, alloy and acid concentration
  - Loss of active material
    - Choose right battery for the application
  - Internal shorts
    - Avoid low cutoff voltage discharges and frequent cycling
  - Plate sulfation
    - Recharge following discharge or prolonged shelf life

How do they fail?

- VRLA modes of failure
  - Loss of compression
  - Internal shorts
  - Thermal runaway
  - Dry out
  - Grid corrosion
  - Plate sulfation

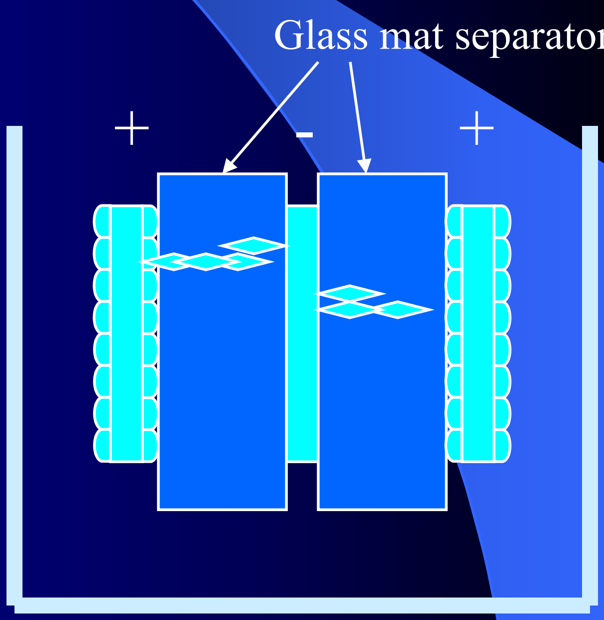
How do they fail? - VRLA

- Loss of element compression
  - VRLA batteries can not replace lost water
    - AGM separator becomes under-saturated and loses contact with plates
  - Excessive heat causes jar walls to bulge
    - Physical deformation causes separator and plates to lose compression



How do they fail? - VRLA

- Internal shorts
  - VRLA batteries are sensitive to low cutoff voltages
    - If discharged to very low voltages, acid concentration will drop to where lead will dissolve into electrolyte
    - During the recharge, dissolved lead will convert back to lead metal (dendrite) in the AGM
    - If converted dendrite grows through AGM, it causes shorts



How do they fail? - VRLA

- Thermal runaway
  - VRLA batteries are packed in tight and have less heat-sink to dissipate heat
  - Heat is natural byproduct of gas recombination
  - High ambient temperature will make situations worse, causing higher float current
  - At some point, the batteries will generate more heat than it can dissipate

How do they fail? - VRLA

- Solutions
  - Loss of compression
    - Use metal jackets and compression plates
  - Internal shorts & plate sulfation
    - Avoid low cutoff voltage discharges
    - Recharge immediately after discharge
  - Thermal runaway
    - Use temperature compensating chargers (reduces float voltage)
    - Use thermally controlled cabinets
    - Keep batteries away from external heat source

Summary

- ***Flooded***
  - Free electrolyte
  - Visual checks
  - Larger footprint
  - Need to maintain
  - More robust
  - High gassing
  - Need active ventilation
- ***VRLA***
  - No free electrolyte
  - Can not see internals
  - Space savings
  - Less maintenance
  - Sensitive to environment
  - Low gassing
  - No special ventilation

Battery Maintenance

Safety First

- Insulated Tools
- Eye Shield
- Protective Clothing
- Remove all Jewellery
- Appropriate Lifting Equipment
- Obey all Warnings!

Safety Precautions

- Only Authorized and Trained Personnel Familiar with Standby Battery Installation, Preparation, Charging and Maintenance should be Permitted Access to the Battery!
- Do Not Handle Cells During or After Boost Charge for 24 Hours

Maintenance

Results in optimum battery life

Equipment Needed

- Voltmeter
- Hydrometer
- Thermometer
- Digital Low Resistance Ohmmeter
- Insulated Tools
  - Torque Wrench
  - Plastic Wrench

Equipment Needed

- Thermostatically Controlled Hot Plate
- Baking Soda, Water, a Bucket, & Rags
- One Inch Paint Brush for NO-Oxide Grease
- Brass Bristle Brush
- Cell Lifting Strap/ Spreader Block
- NO SMOKING

Quarterly Maintenance

- Measure and Record Cell Float Voltage and Total Battery Voltage
- General Appearance and Cleanliness of Battery, Battery Rack and Battery Room
- Measure and Record Specific Gravity of Tenth cell; all Specific Gravities Annually
- Measure and Record all Battery Contact Resistance Values using D.L.R.O.

Quarterly Maintenance

- Electrolyte Levels
- Connections and Cables
- Cell Plates, etc.
- Cell Jars, Vents, Seals, etc.
- Racks and Rack Hardware
- Safety Equipment and Records
- Inspect and or Adjust Chargers and Alarms

Quarterly Maintenance

- Pilot Cell Temperature
- Record Findings Clearly and Date Entries
- Analyze Data

4th Quarter Annually

- Water All Cells
- Always use Distilled or De-ionized water
- Torque Battery Connections
- Equipment Housekeeping

Proper Hydrometer Use

- Avoid Spillage While Testing
- Squeeze Bulb First, Then Test
- Store Hydrometer in a Safe Location
- Avoid Use on Different Cell Types
- If Temperature is above or below Average add or deduct 0.001 for every 3ºF

Low Voltage Conditions

- Check – Panel Meter Is Correct / Charger Functioning
- Voltage at Battery
- Individual Cell Readings
- Low Voltage Readings Cause Accelerated Plate Corrosion

Low Voltage Conditions

- Discharge without Proper Recharge leads to Sulfation
- Remove Sulfation by Providing an Equalize Charge
- Failure to Recharge after Sulfation Leads to Hydration

Life Determining Factors

- Potential Failure Mechanisms
  - Positive Plate Growth
  - Positive Grid Corrosion
  - Cracked Jars
  - Seal Leaks
  - Terminal Post Corrosion
  - Sedimentation

Potential Damaging Conditions

- Constant High Temperature Operation Will Accelerate Chemical Activity
- Low Float Voltages Will Cause Sulfation and Reduced Battery Capacity
- Constant High Voltages will Accelerate Grid Corrosion and Reduce Battery Life
- Over-discharge may result in Hydration

Connection Integrity

- Critical to the Safe and Efficient Operation of any Battery
  - Cleanliness – Remove all Corrosion
  - Tightness – Re-Torque all Connections Yearly
  - Hardware – Replace Worn or Damaged

**Especially Important with Higher Voltage Batteries

Cleaning Cell Containers

- Wipe with Moist Cloth to remove Dust and Dirt
- Use Baking Soda & Water Solution on a rag for Electrolyte spills on cover
- Never use Solvents, Detergents, Glass Cleaners, Special Battery Cleaning Materials, Oils, Waxes or Polish. Could Lead to Cracks and Crazing and Eventually Leakage

Hydration

- Occurs when Battery is Completely Discharged
- Leads to Internal Short Circuits
- Hydration Damage is Permanent

Electrolyte Stratification

- Cell Electrolyte can be more concentrated at bottom of cell
- Methods for reducing Stratification
  - Equalize Charge to Stir Up the Electrolyte
  - Provide Sufficient Time for Chemical Diffusion
    - Several Weeks at Float Potential

Equipment Storage

- Storage Area
  - Indoors
  - Weatherproof
  - Cool / Dry
  - Avoids Freezing
  - Charging Facilities
- Storage Time and Guidelines
  - Lead Calcium (6 Months)
  - Lead Antimony (3 Months)

Temperature

- Effect of Temperature above 77 F
  - Increased Performance
  - Increased Internal Discharge
  - Lowers Cell Voltage for a Given Charge Current
  - Raises Charging Current for a Given Charge Voltage
  - Shortens Life
  - Increases Water Usage
  - Increases Maintenance Requirements

Lower than Normal Temperature has Opposite Effect

Pre Cell Installation Check

- Level Rack Assembly
- Torque All Braces, Rails and Frames
- Install Rail Covers
- Install Rear Siderails, (E.P. Racks Only)
- Do Not Install Rack Near Radiant Heat Source

Open Circuit Cell Voltages

Specific Gravity of Cell	Individual Cell Voltages
1.170	2.025
1.215	2.063
1.225	2.075
1.250	2.098
1.275	2.123
1.300	2.145

Arrangement of Cells

- Consult Cell Arrangement
- Observe Cell Polarities
- Load Bottom of Rack First, From the Middle
- Clean and Apply No Oxide Grease to Connectors and Posts by Lightly Brushing the Post and Connector.
- Remove Shipping caps and install Flame Arrestors
- Install Number Stickers and Caution Labels for Ease of Identification

Arrangement of Cells

- Never Lift Cells by the Posts
- Always Lift Cells From the Bottom of the Jar
- Water Level should be Between the "High" and "Low" Levels
- Never Add Water or Acid Until the Cells have been on Float Charge for One Week
- Space Cells ½" Apart
- Do Not Use Solvents as Lubrication.

Initial Charge Lead Antimony

Nominal Specific Gravity +0.010 / -0.005	Volts Per Cell Maximum	Time in Hours at Maximum cell Voltage
1.215	2.39	40
1.215	2.36	60
1.215	2.33	110
1.215	2.30	160
1.215	2.24	210

Initial Charge Lead-Calcium

Nominal Specific Gravity +0.010 / -0.005	**Volts Per Cell Maximum**	**Time in Hours at Maximum cell Voltage**
1.215	2.38	100
1.250	2.43	100
1.300	2.50	100

Float Voltage Lead Antimony

Nominal Specific Gravity	Recommended Float Voltage Per Cell
1.215 + 0.010 / - 0.005	2.15 - 2.18

Float Voltage Lead Calcium

Nominal Specific Gravity +0.010 / -0.005	Recommended Float Voltages VPC Min/Max	Allowable Float Voltage VPC Min/Max	Allowable Individual Cell Voltages VPC Min/Max
1.215*	2.19-2.20	2.17-2.22	2.12-2.27
1.215	2.21-2.22	2.20-2.23	2.12-2.29
1.250	2.25-2.26	2.22-2.27	2.15-2.32
1.215	2.21-2.22	2.20-2.25	2.13-2.30
1.300**	2.33-2.34	2.32-2.36	2.23-2.41

*Application to Telecom Only

**For Safety Related Nuclear Application Only

Equalize Charge

Lead Antimony Cells

Nominal Specific Gravity	Interval	Equalize Voltage Per Cell VPC
1.215	Every 3 Months	2.33 for 8-24 Hours

Equalize Charge

Lead Calcium Cells

Nominal Specific Gravity +0.010/-0.005	Equalize When Lowest Cell In String Reaches the VPC	Equalize Voltage Per Cell VPC
1.215	2.12	2.33-2.38
1.250	2.15	2.38-2.43
1.300	2.23	2.45-2.50

Battery Disposal

- Proper recycling of Lead Acid products is a Governmental Requirement and Simply Good Corporate Policy.
- Contact Your Local C&D Agent for Details concerning the Regulation in Your Area