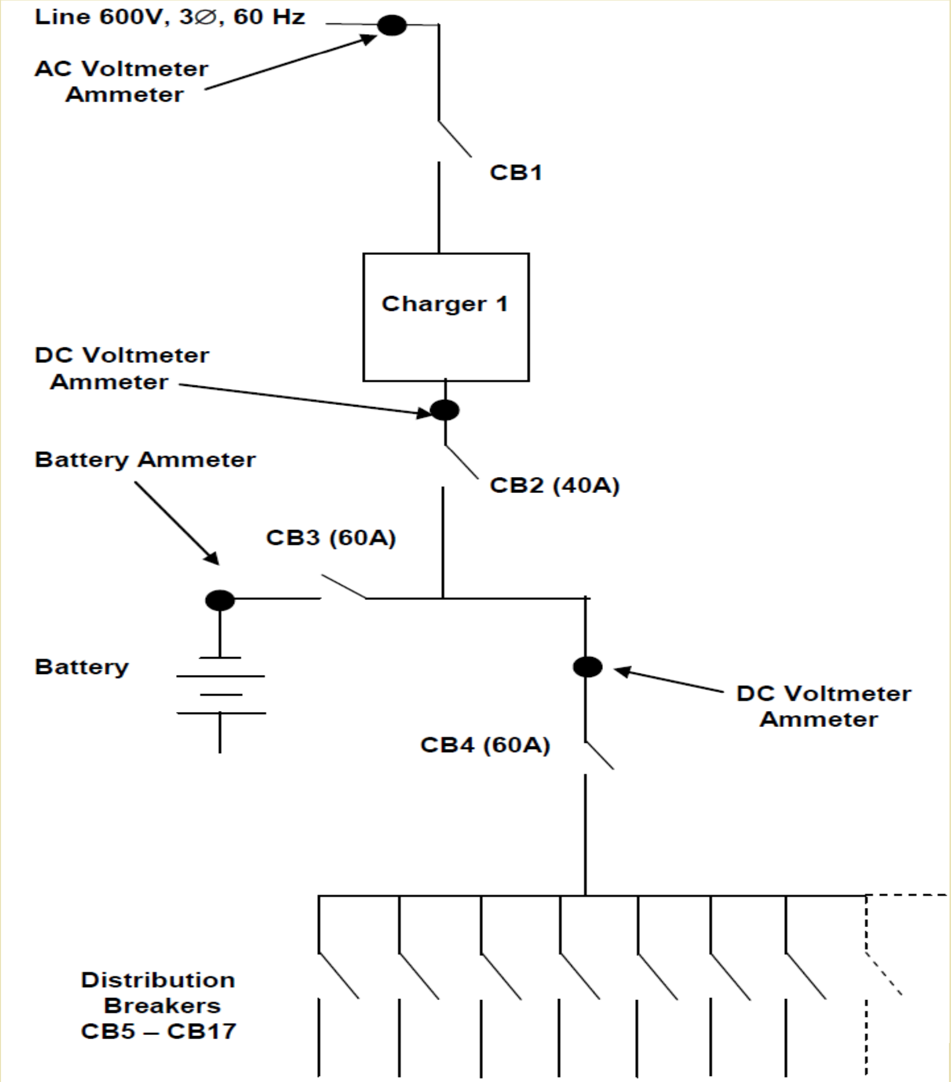
Battery & Charger Basics

Factors that will influence their selection

When a battery is not just a battery
And a charger is more than just a source of DC

What are we talking about?



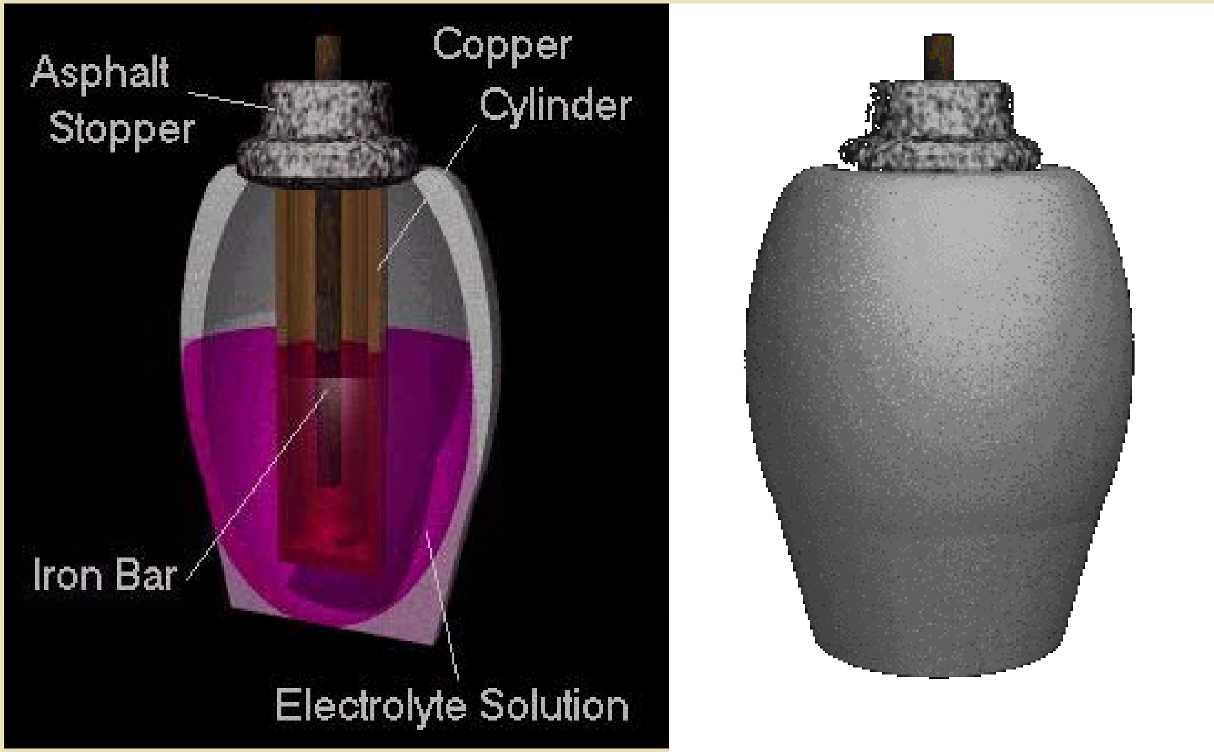
Loads:

- Meters
- Relays
- Lights
- Tripping coils
- Charging motors
- Lube pumps
- Inverter

Battery basics

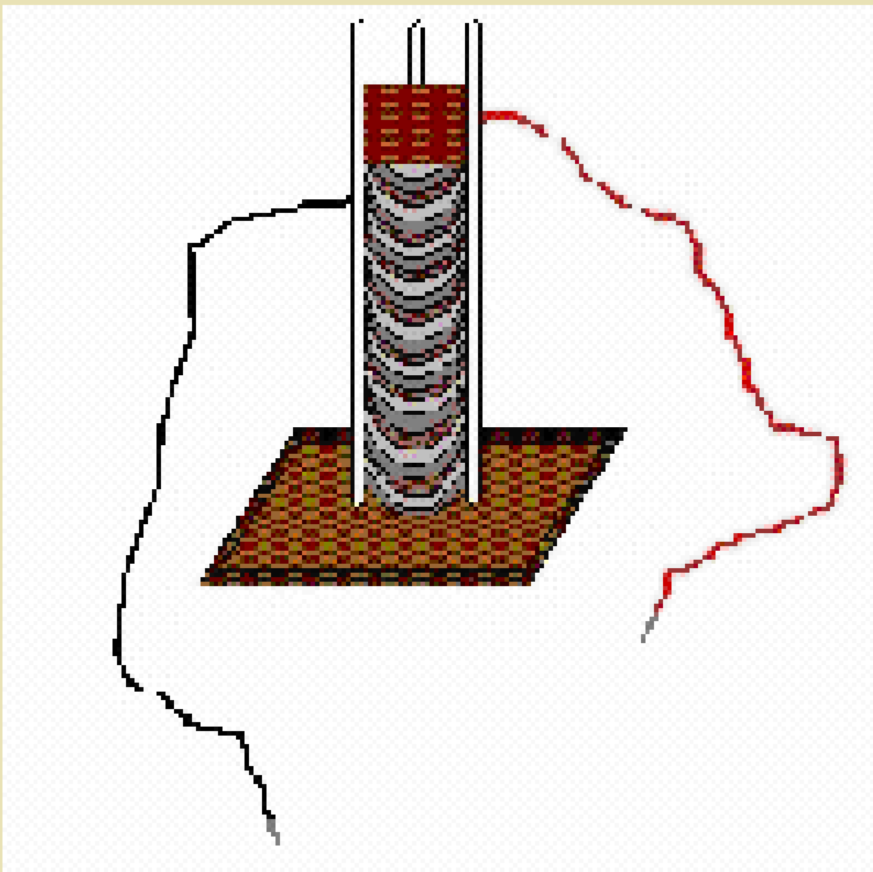
History

3rd Century AD: The BAGHDAD Battery 1.1Vdc



Battery basics
History

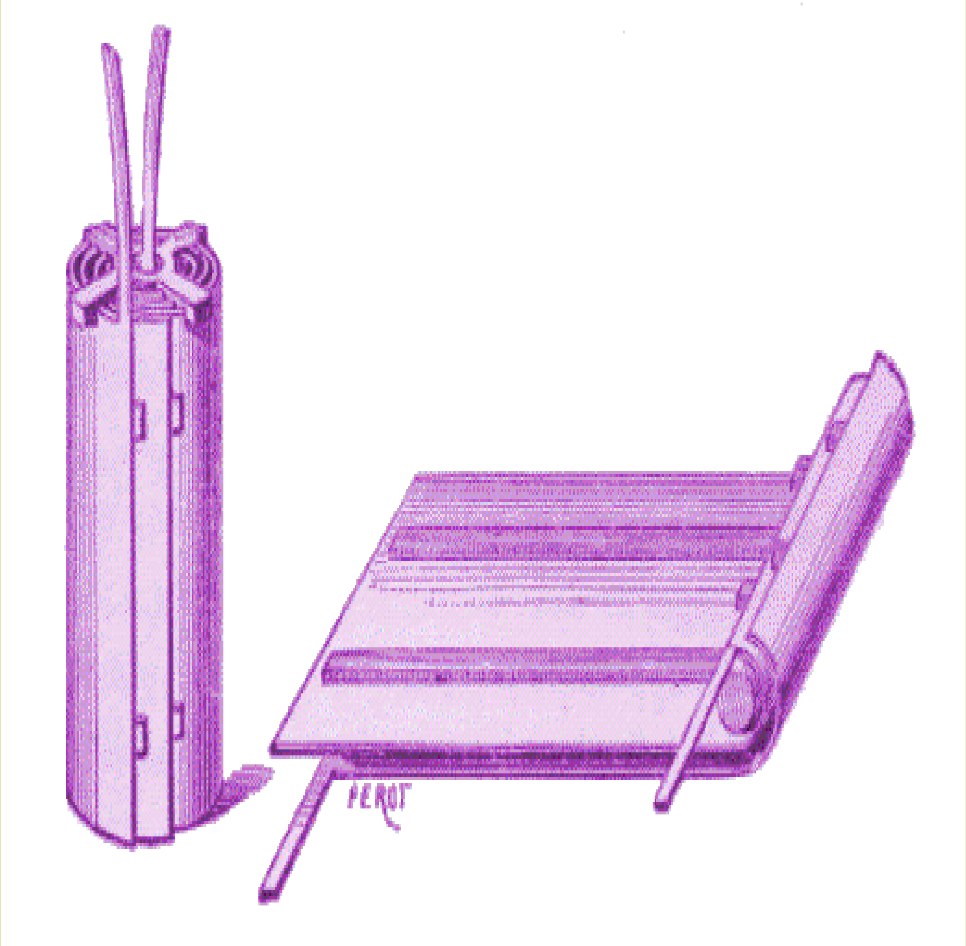
1800: Alessandro Volta Zinc-Silver in salty mix 1.1Vdc



Volta demonstrates his results to Napoleon

History

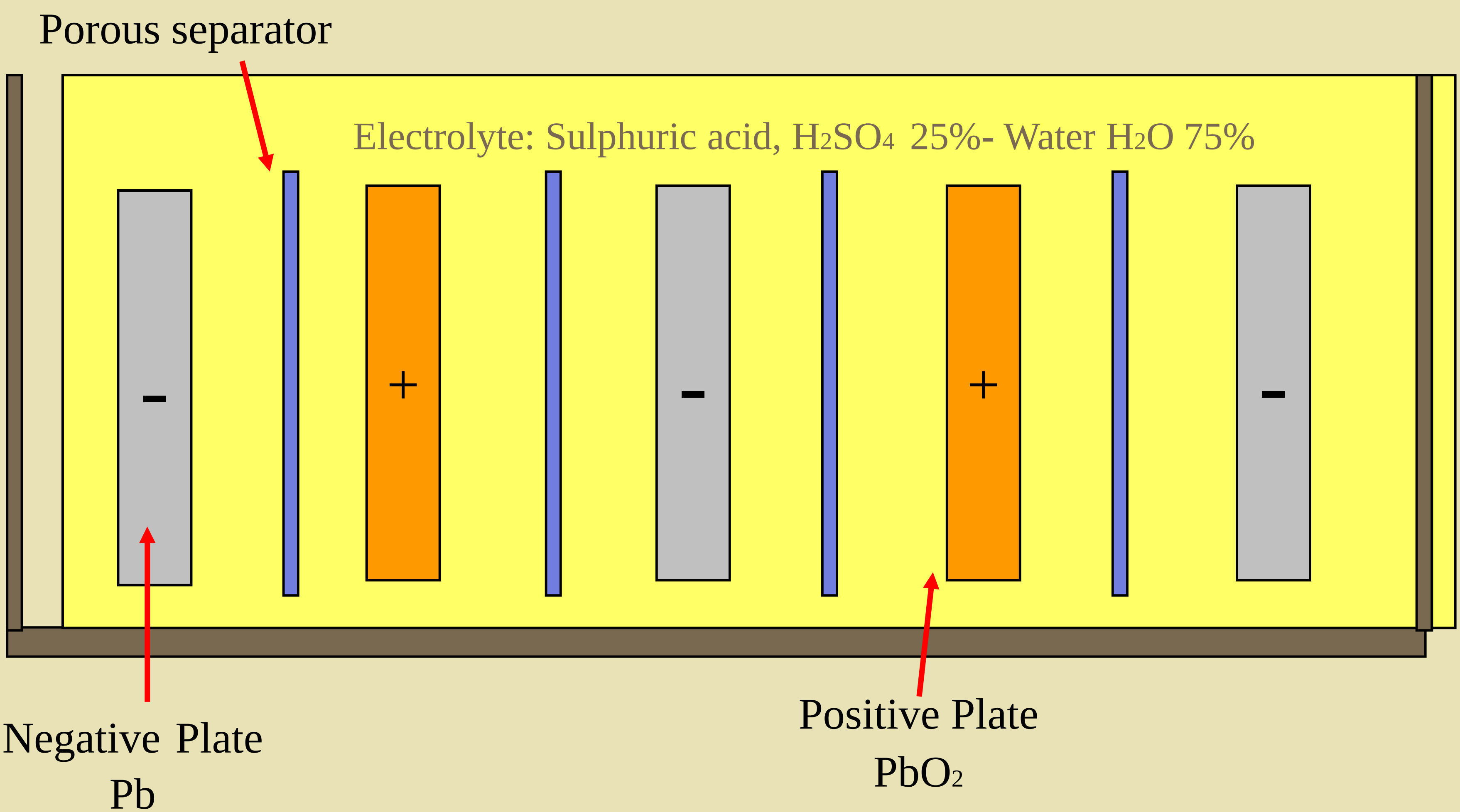
1859: **Gaston Planté**



The Lead-Acid battery
Two lead foils separated by a rubber sheet in sulphuric acid
(H2SO4)

Battery chemistry

Basic Lead Acid secondary cell *(rechargeable)*



Battery chemistry

Voltage

Open Circuit Voltage is in direct relationship with the concentration of sulphuric acid present in the cell

<u>Specific Gravity + 0.845</u>

=

<u>Open circuit voltage</u>

1.24 S.Gr.+0.845=2.085 Vdc/Cell
X 60 Cells= 125.1Vdc

Capacity

Capacity is in direct relationship with the cell's quantity of lead and the quantity of available sulphuric acid available to react with it.

Battery chemistry

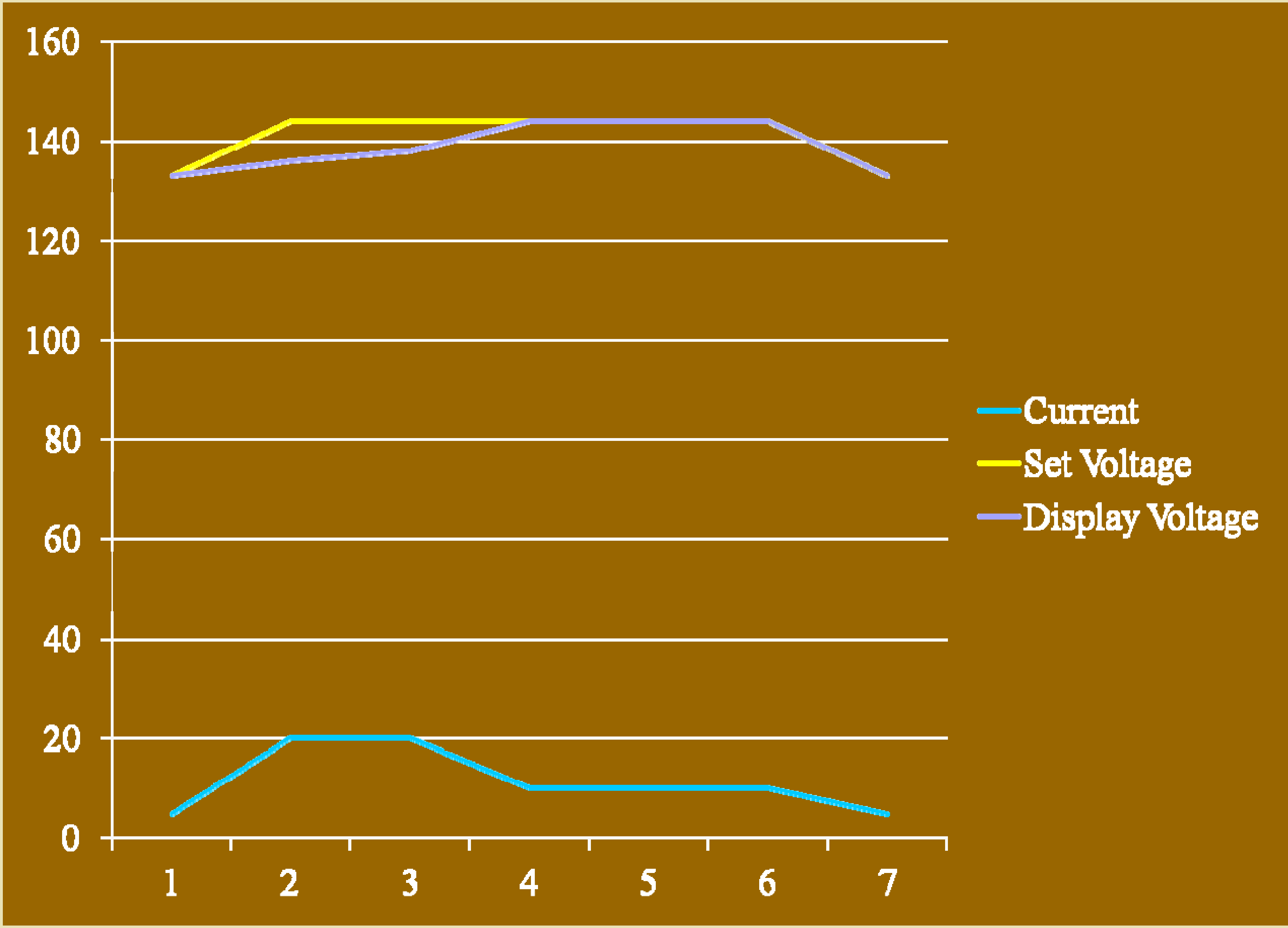
For the same quantity of lead

Higher specific gravity

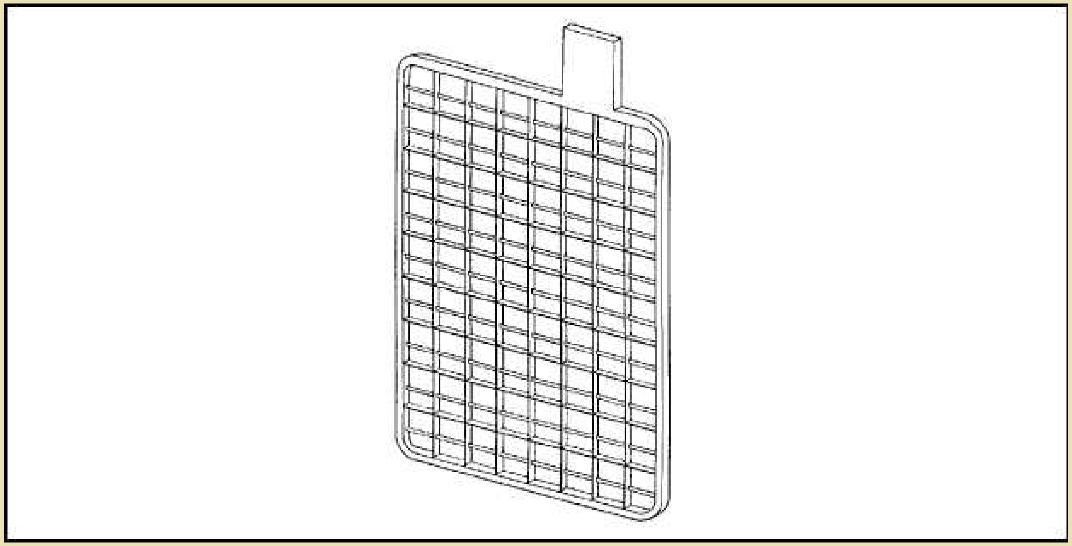
- **More Capacity**
- **Shorter life**
- Smaller footprint for the same Ah rating
- Better adapted to Higher & Shorter discharge rates
- **Less adaptable to “Floating” operation**

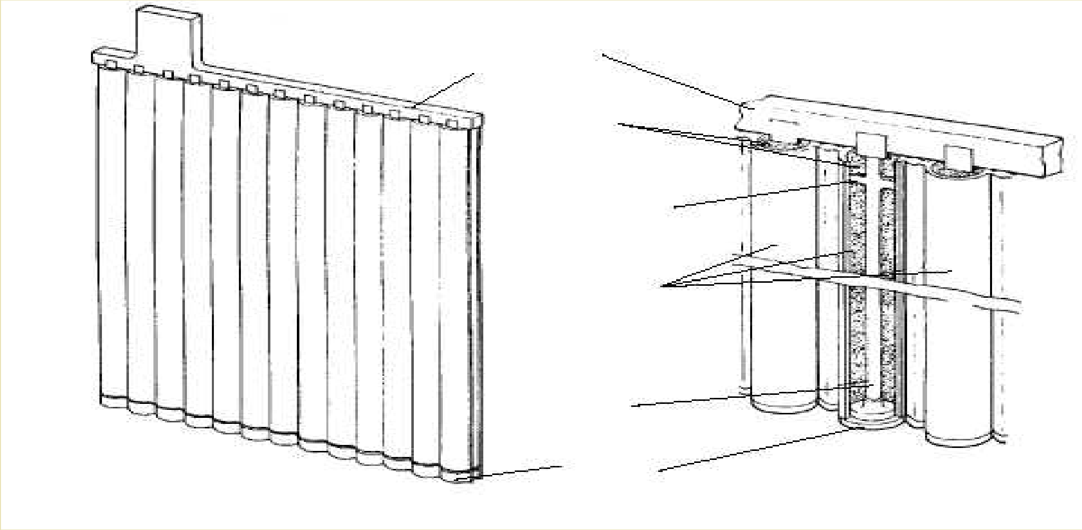
Lower specific gravity

- **Less capacity**
- **Longer life**
- Larger footprint for the same Ah rating
- Better adapted to Longer & Lower discharge rates
- **More adaptable to float operation**


160
140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
Current
Set Voltage
Display Voltage

Lead Acid Battery construction





- Flat Plate
  - Low cost
  - Excellent energy density
  - Good mechanical strength
  - Limited Life
  - Limited cycling capability
- Tubular Plate
  - Good energy density
  - Superior cycling capability
  - Longer life
  - Lower high-rate performance
  - Not the best suited for vibration
  - Inability to see the positive plate edges

Lead Acid Battery construction
2-Alloys

Lead Calcium

– Excellent stability of the float characteristics

– Requires minimal watering

– **Poor cycling *(capacity likely to exhibit a marked reduction in less than 50 cycles)***

– **Positive grid growth**

- ***Positive post seal problems***
- ***Loss of active material***

– **Subject to Passivation (Sudden Death). Requires regular testing**

Lead Selenium *(Low Antimony 1.6 % or less)*

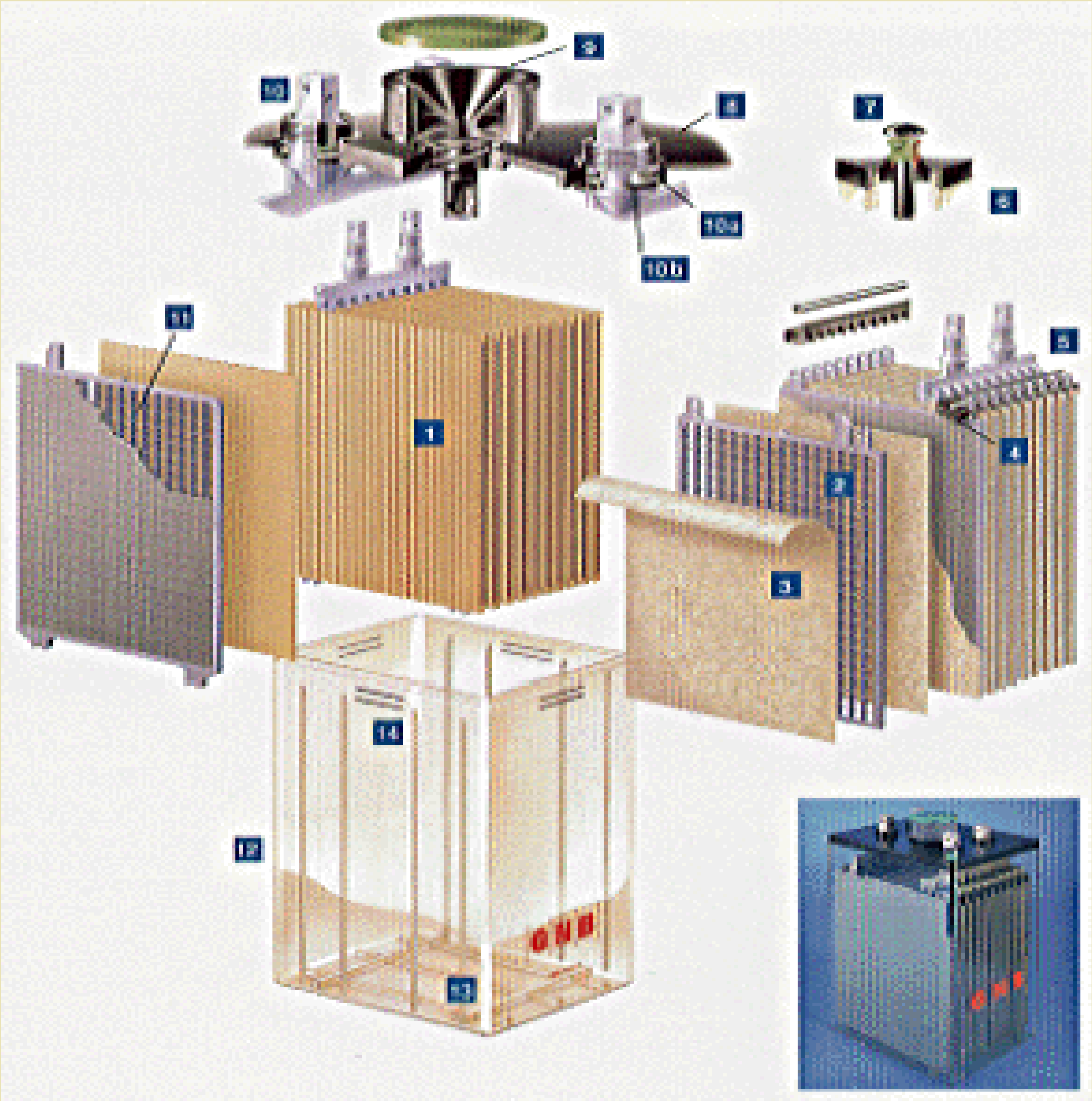
– Major reduction of the Antimonial poisoning

– Good float charge characteristics over the life of the Battery

– Good cycling *(800 to 1000 cycles typical)*

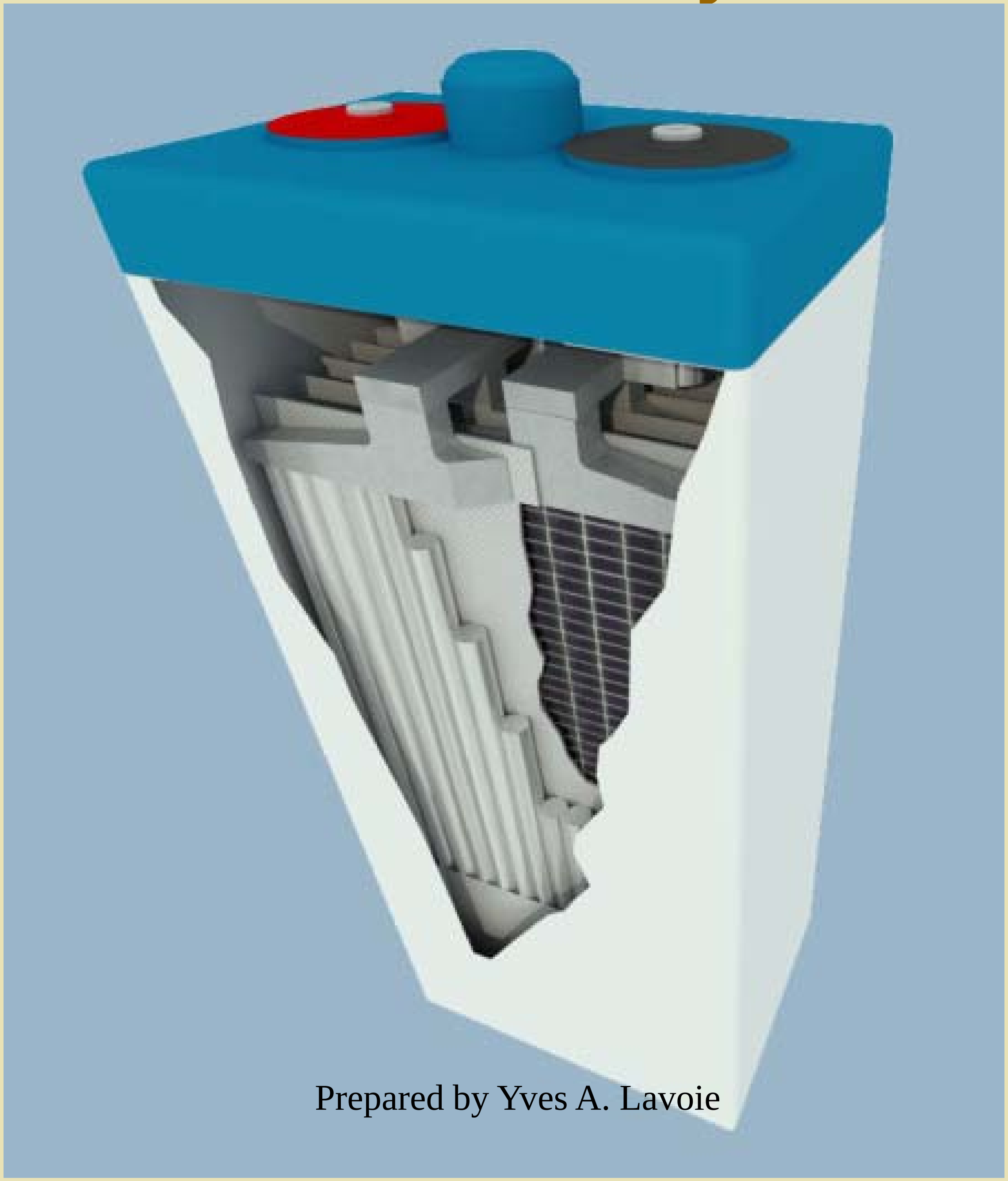
– ***Requires slightly more watering than Lead calcium batteries***

Vented Lead Acid Battery construction

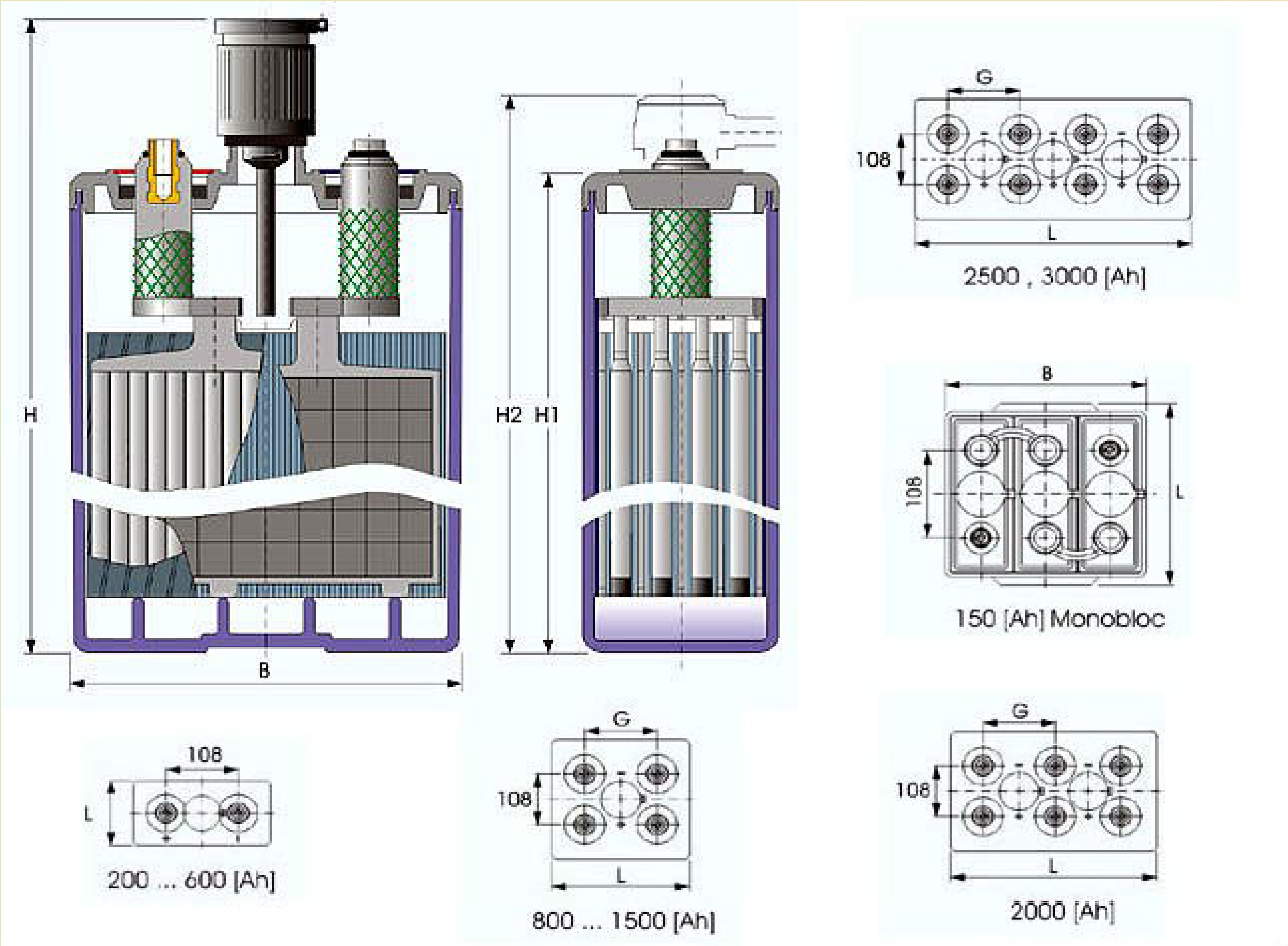


1. Micro porous separators
2. Positive plates
3. Glass Mat Retainer
4. Positive Plate support
5. Positive & Negative Bus Bars
6. Jar Cover Seal
7. Electrolyte Sampling Tube
8. Cover
9. Vent & filling tunnel
10. Post Seal
11. Negative Plate
12. Jar
13. Element support
14. Electrolyte level lines
15. Plate edge to wall Clearance

GEL Lead Acid Battery construction



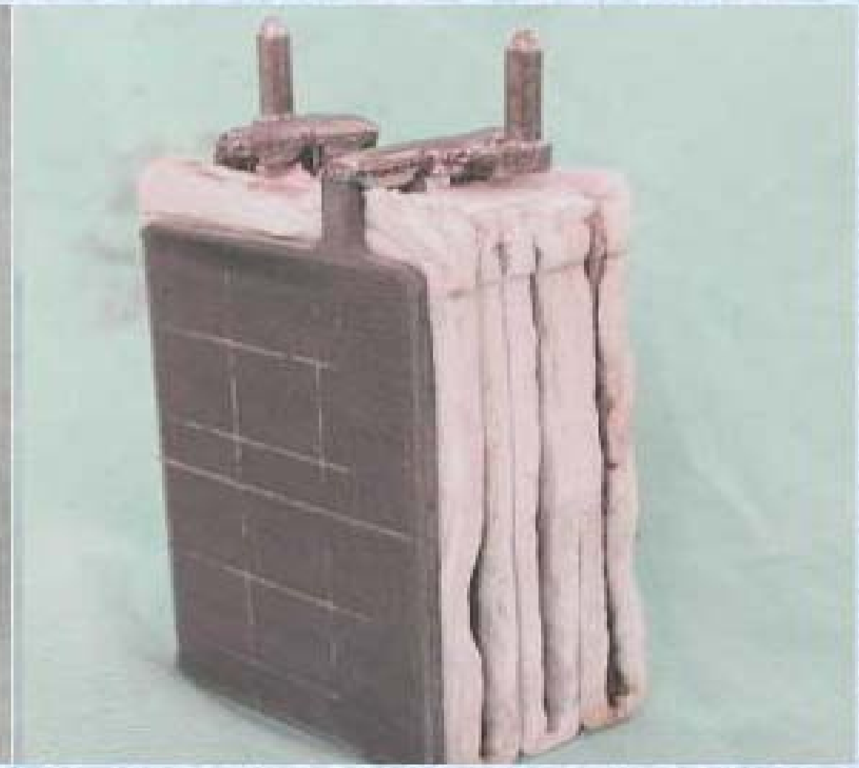
GEL Lead Acid Battery construction



AGM or Absorbed Electrolyte Lead Acid Battery construction

Plate group

Soldered plate group
(Element)



AGM or Absorbed Electrolyte Lead Acid Battery construction

AGM or Absorbed Electrolyte Lead Acid Battery construction

Lead Acid Battery construction
Absorbed Electrolyte (AGM)

Available in 5, 10 or 20 years warranty

Flat plate only

In a Substation application you can expect 20 % to 50% of service life.

In a UPS you can expect 10% to 40% of service life

Advantages:

- No water additions
- High energy density *(Small footprint)*
- Excellent High rate performance *(Good for short time backup)*
- Good cold weather performance *(Because of high S.gr.)*
- Excellent availability
- Low initial cost

Lead Acid Battery construction Absorbed Electrolyte

Disadvantages

- **Extremely sensitive to AC ripple *(causes micro-cycling)***
- **All inside cell connections exposed to Oxygen *(Negative bus corrosion)***
- **Open Cell failure more frequent than with any other Lead-Acid**
- **Mostly made with recycled "Non 100% pure lead".**
- **Subject to Negative plate Self Discharge *(Requires the use of Catalyst)***
- **Very sensitive to heat and dry out due to limited quantity or electrolyte.**
- **Having plates under mechanical pressure to insure perfect alignment and contact with the absorbed glass material increases inside stress.**
- **Subject to thermal run away**
- **Unpredictable due to Passivation *(Sudden death)***
- ***Very sensitive to deep discharge***
- ***Longer charging times preferable***
- ***No Tubular plates… Flat plates only***

Lead Acid Battery construction
Absorbed Electrolyte

Gelled Electrolyte

Available in 12, 15 and 18 years design life

Calcium alloy Flat plate Tubular plate

In substation application you
can expect 25 % to 100% of design life

In a UPS application you can expect 15% to 70%

- Negative plate corrosion.
- Unpredictable due to Passivation *(Sudden death)*
- *Longer charging times required*
- Temperature compensation required
- Sensitive to AC ripple
- Higher initial cost

Gelled Electrolyte

Advantages

- No water additions
- All inside cell connections are immersed in Electrolyte
- Mostly made with new lead *(Greatly reduces the risk of negative plate self discharge and the need for catalysts)*
- Good energy density
- Superior resilience to deep discharge
- Good cold weather performance
- Superior heat dissipation
- Less sensitive to heat and dry out
- Less subject to thermal runaway
- Less sensitive to deep discharges
- Excellent for solar application.

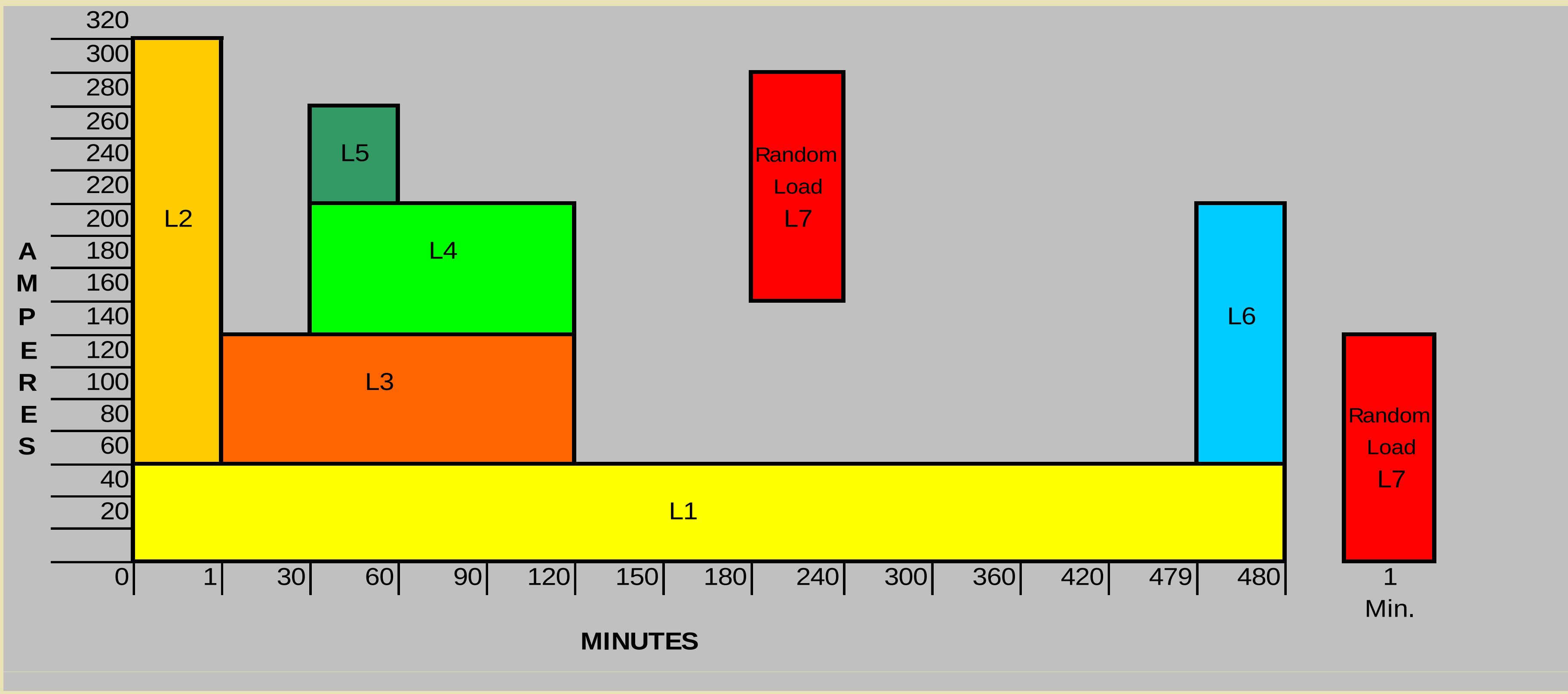
"After more than 18 months on float, production AGM cells continued to emit gas (ie: lose water) at rates too high to permit a 20 year life. The rates did not appear to be declining with time. Gel cells on the same test, but at a lower float voltage, had lower gas emission rates." INTELEC 1996 W.E.M. Jones, D.O. Feder: Behavior of VRLA Cells on long term float: Part 2

Vented vs. VRLA vs. Plate vs. Alloy
What the market has to offer:

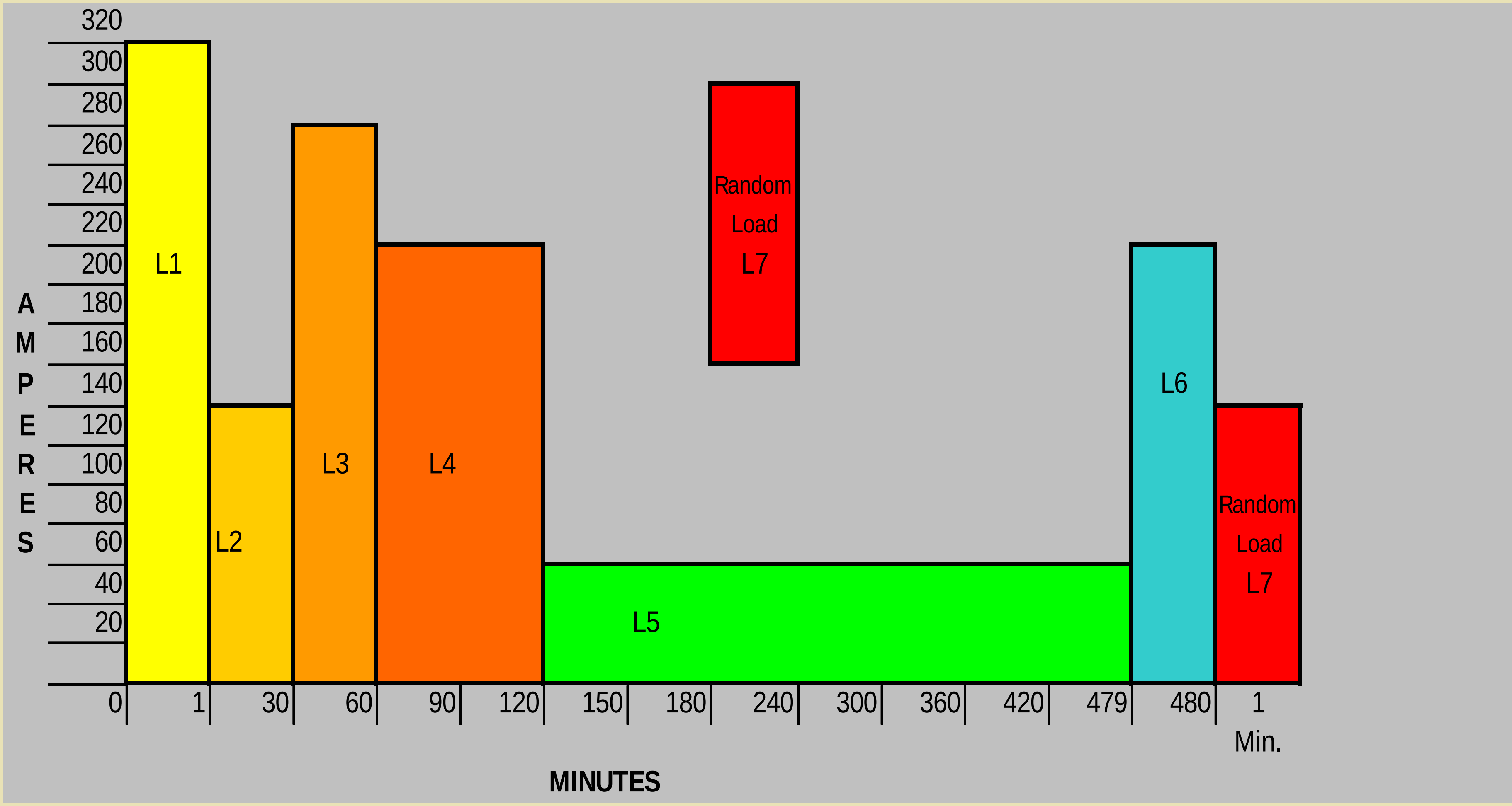
Plate composition	Pure Lead	Lead Calcium	Lead Selenium
Type of Battery			
Vented Lead Acid			
Plante	X		
Flat Plate (Grid plate)		X	X
Tubular Plate		X	X
Valve regulated Lead Acid (VRLA)			
Absorbed Electrolyte Cell (AGM)		X	
Flat Plate	X	X	
Tubular plate			
Gelled Electrolyte Cell		X	
Flat Plate		X	
Tubular plate		X	

Battery Sizing

Sizing and selection of lead-acid batteries should be performed according to ANSI/IEEE Std 485, *IEEE Recommended Practice for Sizing Large Lead Storage Batteries for Generating Stations and Substations.*



Battery Sizing



Battery Sizing

Other selection factors recommended by ANSI/IEEE Std 485 are the following:

1. Physical characteristics, such as size and weight of the cells, container material, vent caps, intercell connectors, and terminals.
2. Planned life of the installation and expected life of the cell design.
3. Frequency and depth of discharge
4. Ambient Temperature.
5. Maintenance requirements for the various cell designs
6. Seismic characteristics of the cell design.

Parameter # 1

Environment, 4 Factors:

A. Temperature
B. Layout
C. Ventilation
D. Regulatory
    A. Seismic
    B. Fire Protection

Temperature

- The ambient temperature that your batteries will be exposed to will affect their performance, longevity and reliability
- In North America the reference temperature is 25 ˚C (77 ˚F), Batteries built according to IEC Standards are rated at 20 ˚C (68 ˚F),
- If the operating temperatures in your battery room vary from the norm by +/- 3 ˚C you should add temperature compensation to your charger
- Batteries exposed to lower temperature will have lower performance and their sizing needs to be compensated
- Batteries exposed to higher temperatures will have a higher performance but a shorter life due to accelerated corrosion.
- The rule of thumb for decrease in life at higher temperatures is:
  - Lead-Acid 50% of life removed for every 10 ˚C
  - Nickel-Cadmium 20% of life removed for every 10 ˚C

Questions
Temperature

- Will the battery room be climate controlled?
- Should we climate control the room?
- Do we need to add temperature compensation to our charger?
- Should we examine other battery technologies.

Layout

2 Factors will influence your battery layout

- Battery Blocks or individual cells
  - Blocks have a smaller footprint but due to a smaller ratio of electrolyte to lead surface their life is generally 10 to 20% shorter with vented batteries, 20 to 30% with gel and around 50% for AGM
  - Individual cell monitoring may not always be possible
  - If a cell is defective you have to replace the whole block
- Number of tiers and steps in your battery rack
  - Racks that are narrow and high will expose batteries to temperature variations. These variation will cause some batteries to be undercharged wile others will be overcharged. Over time the imbalance is going to worsen and your system’s reliability and battery life will be jeopardized. If you have no choice, install a fan above the batteries.

Questions

Layout

- Are we going to use single cells or blocks?
- Will we sacrifice battery reliability and life to footprint ?

Ventilation

Do I need to ventilate or not?

- The Battery Technology
  - If we use vented batteries we will need to determine the quantity of hydrogen generated by the battery versus the number of air changes in the battery room
  - It is generally accepted knowledge that VRLA batteries, under normal circumstances do not require ventilation when installed in a regular room...
- High volt shutdown
  - If your charger was not specified with a ***Hi-Volt Shutdown*** we recommend that the room's air changes be verified against the possible Hydrogen and Oxygen generation of the battery if it is exposed to the voltage of a charger that would have lost regulation... +/- 162 Vdc

Questions
Ventilation

- Are we going to ventilate?
  - How much hydrogen will my battery generate under the worst case scenario?
  - Does the battery room have enough air changes to compensate
  - How do I ventilate
    - All the time
    - When the batter reaches a certain voltage (Charger activated)
    - Do I install a hydrogen detection device with a contactor to activate the fan
- I am installing VRLAs do I need to ventilate?
  - Worst case scenario...
  - Does my charger spec call for a charger equipped with high volt shutdown?

Parameter # 2

Load profile, 3 factors:

A. Loads

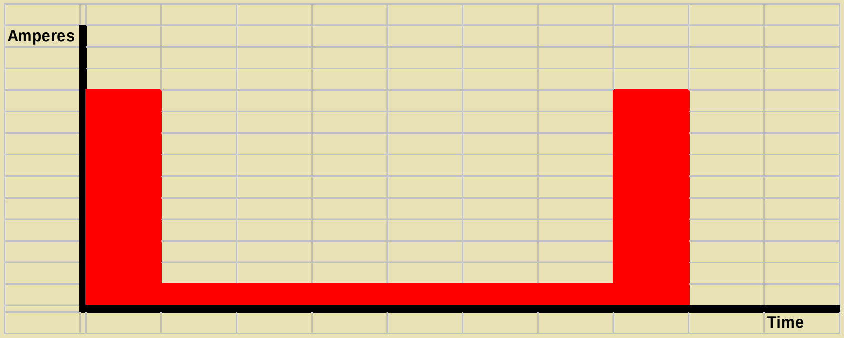
B. Backup time

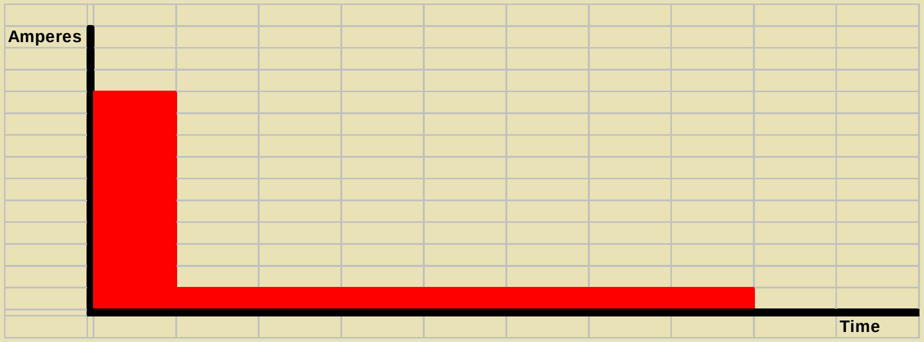
C. Voltage window

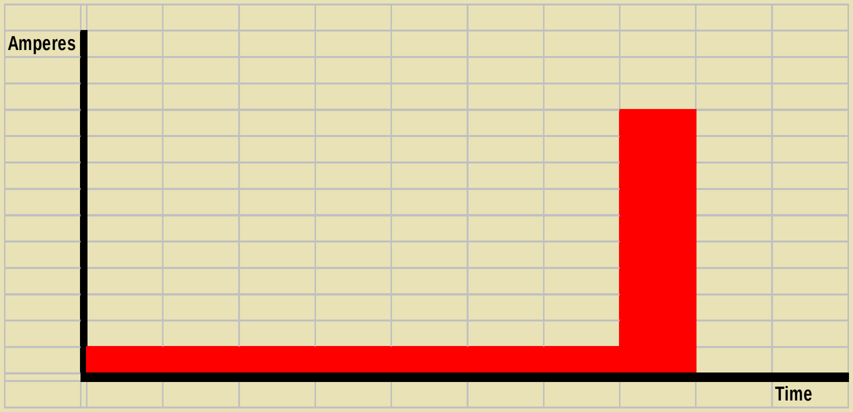
Loads

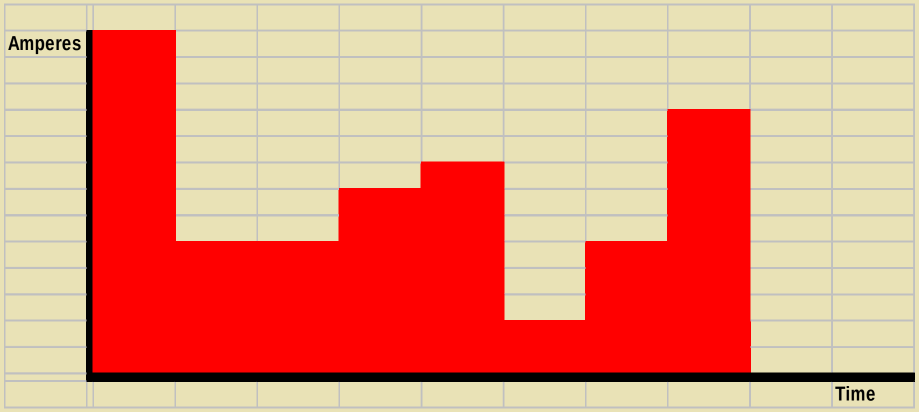
- There are different loads to be carried by the battery during a loss of AC.
  - Trip & Close solenoids + Spring charging motors
  - Meters + Protection relays + Lights
  - DCS / SCADA systems + telecom
  - Lube Pump
  - Inverter for AC loads
  - Others?
- Loads have to be structured in a coherent manner so that the battery can be sized

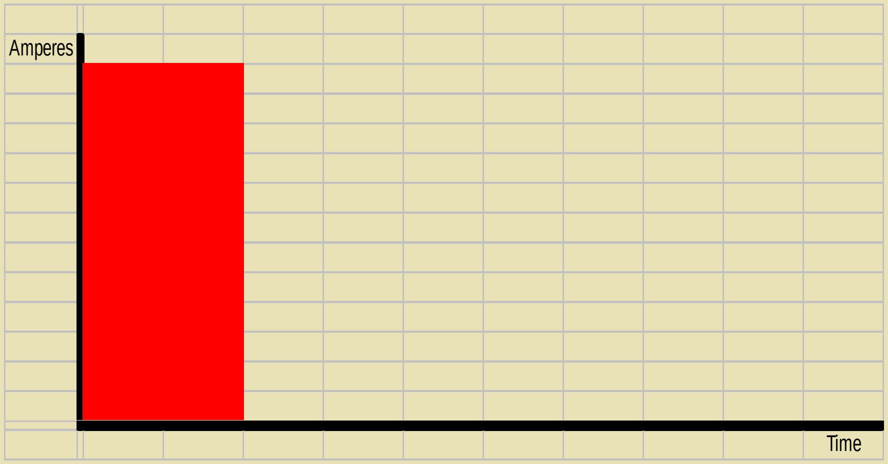
What is the structure of my load profile?











Questions

Loads

- What are my loads?
- What will be the structure of my load profile
- How often will the batteries be cycled

Backup time

5 factors will influence the required length of your backup time:

- The time required to stop a $$$ uninterruptable process
  - Aluminum smelter... Mine... Any high revenue generating process
- The time to repair a failed charger (Could lead to redundancy)
  - If spare chargers or spare parts are not available, your protection will last as long as your batteries.
- AC fail duration worst case scenario vs. alternate scenario
  - Historical data maybe useful...
- Availability of alternate AC sources
  - If you have a generator on site... Twin feeds from alternate sources...
- Legislation
  - In some regions 24 hours! For some applications the NRC is contemplating up to72 hours

Questions
Backup time

- Do I have an application related minimum?
- What is the worst case scenario for a charger repair?
- Is the cost of a battery with a longer backup time to high in comparison to redundant chargers?
- What is the longest blackout that I need to plan for?
- Do I have or want an alternate AC source (Standby generator or a second utility feed)?
- Are there regulatory parameters that I need to consider?

Voltage window

- The voltage window of each equipment will determine the highest voltage that my can be charged at:
  - V(max) (130 Vdc) / Equalize voltage per cell (1.47 Vdc) = maximum number of cells (88 Cells)
  - V(max) (140 Vdc) / Equalize voltage per cell (2.40 Vdc) = maximum number of cells (58 Cells)
  - V(max) (140 Vdc) / Equalize voltage per cell (2.33 Vdc) = maximum number of cells (60 Cells)

Question

- What is the operating voltage window of each equipment?

Parameter #3

Monitoring & Maintenance

To monitor and maintain or not...

To maintain or not?

- If you decide to monitor & maintain
  - Different batteries have different monitoring & maintenance needs
  - If qualified personnel is difficult to hire, think about training your current personnel . If hiring or training is not feasible, what about automation or even partial automation coupled with farming out the balance of the tasks.
- If you decide not to maintain **you will still need to monitor**
  - Over 100 years of experience has shown that **BATTERIES CAN AND WILL FAIL** sometimes less than 3 months after installation.
  - If a battery monitoring system is chosen who will analyse the data, who will respond to the alarms?
  - If you do not want to maintain or buy a monitoring system ensure that you specify a charger with the proper test and alarm features.
- Your choice of battery technology should be influenced by the decision you just took above

To maintain or not?

Vented

- Visual Inspection
  - Signs of corrosion or sulphation
  - Post growth or seal leaks
  - Cracked covers or jars
- Water replenishment
- Specific gravity readings
- Cell or block Voltage readings
- Cell or block Ohmic measurement
- Battery continuity test
- Verify torque measurements
- Connector & Post resistance
- Temperature measurement *(Battery or Ambient)*
- Battery capacity / Service test

VRLA

- Visual Inspection
  - Post growth or seal leaks
  - Cracked covers or jars
  - Bloated covers or jars
- Cell or block Voltage readings
- Cell or block Ohmic measurement
- Battery continuity test
- Verify torque measurements
- Connector & Post resistance
- Temperature measurement *(Battery or Ambient)*
- Battery capacity / Service test

QUESTION
To maintain or not?

- How will I take care of my batteries

Parameter # 4
Battery technology

- Choosing the right battery for my application

Choosing the right battery for my application

- Criticality of the application
- The environment my batteries will be in
- Load profile
- Maintenance environment
- Initial budget versus life-cycle cost

Choosing the right battery for my application

- Initial budget vs. Lifecycle cost
  1. $Automotive, Marine deep cycle. (Emergency patch for a week or two)
  2. $$$ 5 year design life AGM (1.5 to 2.5)
  3. $$$$ 10 year design life AGM (2 to 5)
  4. $$$$$ 20 year design life AGM (6 to 10)
  5. $$$$$ Flat plate Gel OGiV (Thin Plate) (10 to13)
  6. $$$$$ Tubular plate Gel OPzV (15 to 20)
  7. $$$$$$ Vented Flat plate Calcium (Thick plate) (12 to 20)
  8. $$$$$$ Vented Tubular plate Calcium (15 to 20)
  9. $$$$$$ Vented Flat plate Selenium Ogi (Thin plate) 15 to 20
  10. $$$$$$ Vented Tubular plate Selenium OPzS (15 to 25)
  11. $$$$$$$$$$$ Vented Planté (25+)
  12. $$$$$$$$$$$ Low maintenance Nickel cadmium (20+)
  13. $$$$$$$$$$ Vented Nickel cadmium (20+)
  14. $$$$$$$$$$$$$ Lithium Ion (20+)

QUESTIONs

Choosing the right battery for my application

- What is the right battery technology for my application

Parameter # 5

The dc power required by the application and the battery

- Basic alarms & functions & characteristics
  - AC Fail
  - Rectifier fail
    - Combination of Low Volt & Low current
  - High Volt dc
  - High Volt shutdown
    - To protect your investment
  - Low Volt dc
    - Your battery is discharging
    - Your battery has finished discharging
  - Low current dc
    - Your dc system is no longer feeding one of your circuits
  - Ground fault
  - Temperature compensation &High & Low Battery temperature alarm &Delta temperature alarm
    - So that your battery always receives the optimal float voltage
  - High ripple alarm
    - To know when it is time to replace the chargers filtering output capacitors
    - To insure that your batteries do not get micro-cycled

The dc power required by the application and the battery

- Other needs!
  - Event log with date & time stamp
    - Know everything that has occurred to your system
    - Better diagnostics
    - Protection for your battery warranty
  - Float current monitor
    - Float current increases as battery ages.
    - Premature rise in current coupled to a rise in temperature is an early warning of thermal run away
  - Digital Ampere/hour meter
    - Positive and negative current monitoring
    - Real time knowledge of battery state of charge
  - Battery continuity test
    - Can your battery deliver the high current needed to trip the breakers?
  - Battery Service test
    - Can your battery keep your loads operational as long as intended?

QUESTIONs

Charging needs of my battery & application

- Is a plain charger what I really need?
- How can I secure a safer system whithout breaking the bank?

CONCLUSIONS

- ASK THE RIGHT QUESTIONS = GET THE RIGHT ANSWERS = MAKING THE RIGHT CHOICE
- A CAREFULLY WRITTEN SPECIFICATION IS YOUR BEST PROTECTION AGAINST GREED

What are the costs associated to system failure?

1. Are lives at stake?
2. Are non interruptible processes involved?
3. Are major financial losses a possibility?
4. What risk level is acceptable?
5. What is the available budget and Is it in line with the risk level?

For more information

- IEEE standards, recommended practices and guides.
- Attend as many stationary battery events as possible: Infobatt, Battcon, Intelec.
- More than 15 years of papers archived on the Battcon website
- Become a member of the IEEE stationary battery committee: http://www.ewh.ieee.org/cmte/PES-SBC

Thank you!

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