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industrial battery innovation

ANDERSON'S
ELECTRONICS Inc.

Infobatt 2007

The Science of Using Catalysts in VRLA Cells

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Presentation Outline

- A history of problems with VRLA batteries
- An example of real batteries
- How a cell works with a catalyst
- “W” Site Case Study
- Conclusions

History of VRLA Design

- 1985: VRLA introduced by GNB.
- 1995 & 1996: VRLA problems published.
  - Feder: Study of 15,000 cells with drastically shortened life and unreliability.
  - Jones: Early failure modes discussed. Cells gassing too much to survive.
- 1997: Problem discovered
  - Jones & Feder discover negative plate self discharge problem and suggest catalyst solution.
- 1998: Problem quantified.
  - Feder: Study of 24,000 20-year cells with lifetimes from 2 to 7 years.
  - Jones: Conclusive catalyst data presented.
  - Catalyst commercially available.
- 2000: Microcat catalyst introduced.

Where are we today?

- Negative plate self discharge recognized as fundamental problem for VRLA.
- High temperatures understood to reduce VRLA life.
  - For every 10°C above 25°C life is cut in half.
- Catalysts are seen as one solution to the problem.
  - Many catalysts are in use across North America.

Overview of a Solution

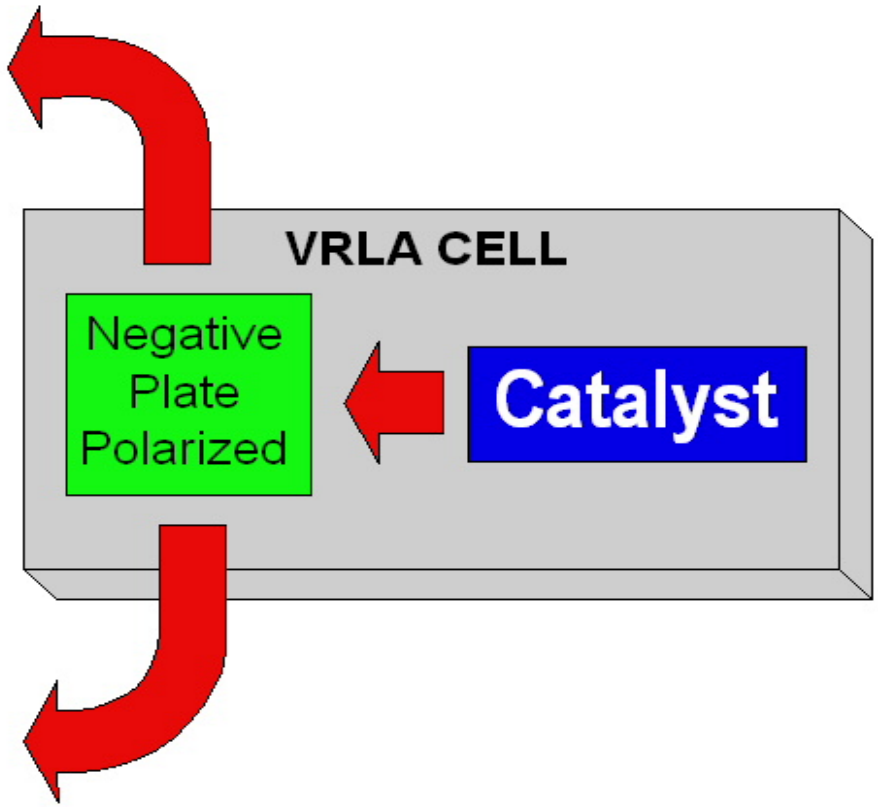
Effect

Reduced Float Current

Benefits

Increased Life
Minimized Water Loss
Maintain capacity
Minimize pos. plate corrosion
Reduced cell heating
Reduced thermal runaway risk
Energy savings

Especially good for high temperature applications



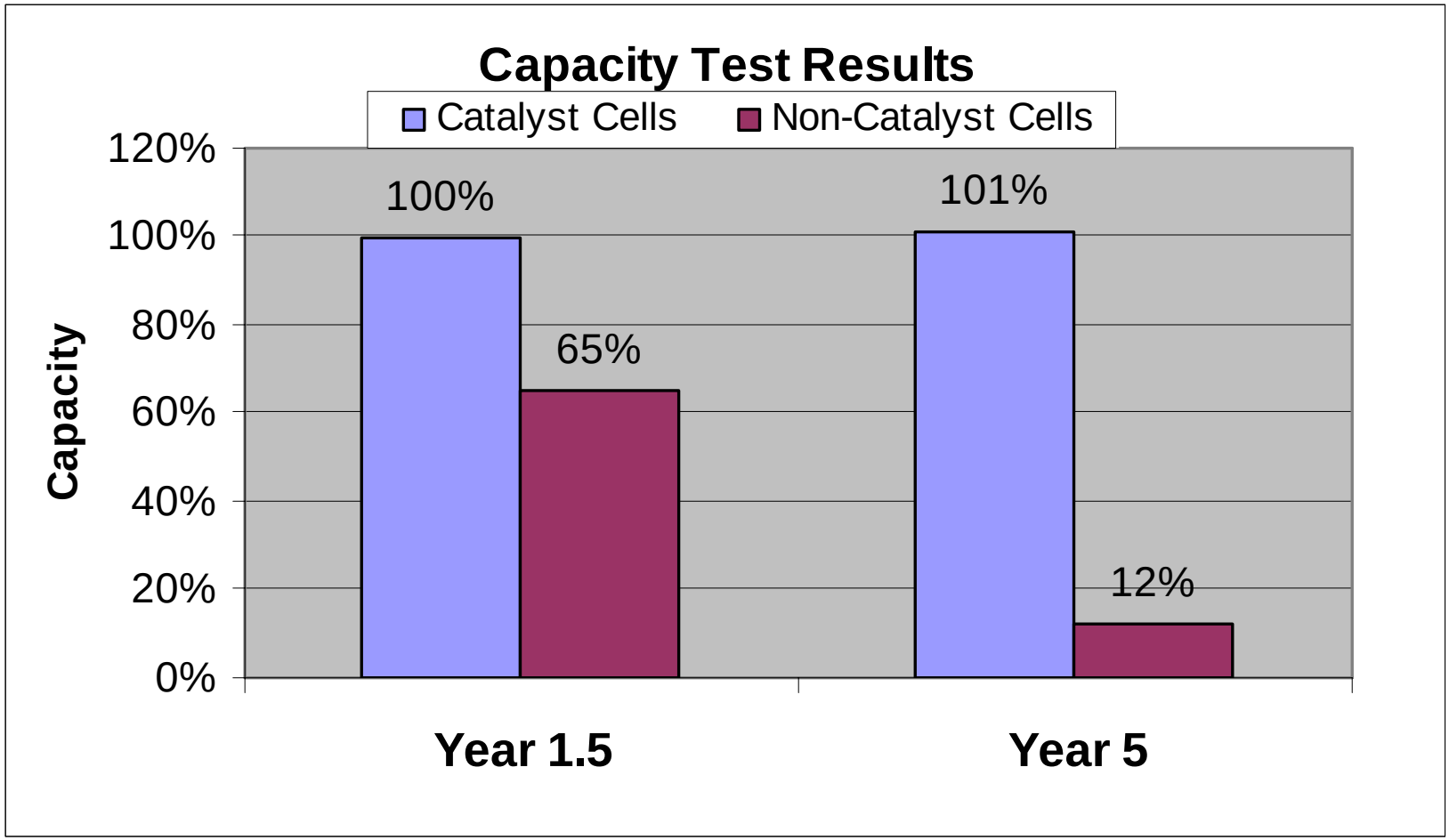
A Tale of Two Batteries

- A definitive test was needed.
- Test ran for 8.5 years in our lab.
- All cells at 90ºF (32ºC) and 2.27 VPC.
- 2 Groups of 6 cells each.
- High Quality 2 Volt VRLA AGM Cells.

A Tale of Two Batteries

- Parameters Frequently Measured:
  - Gas evolved.
  - Conductance
  - Capacity
  - Polarization
  - Float Current
- Cells never boost charged --- just float charged!

What did we find?
Capacity

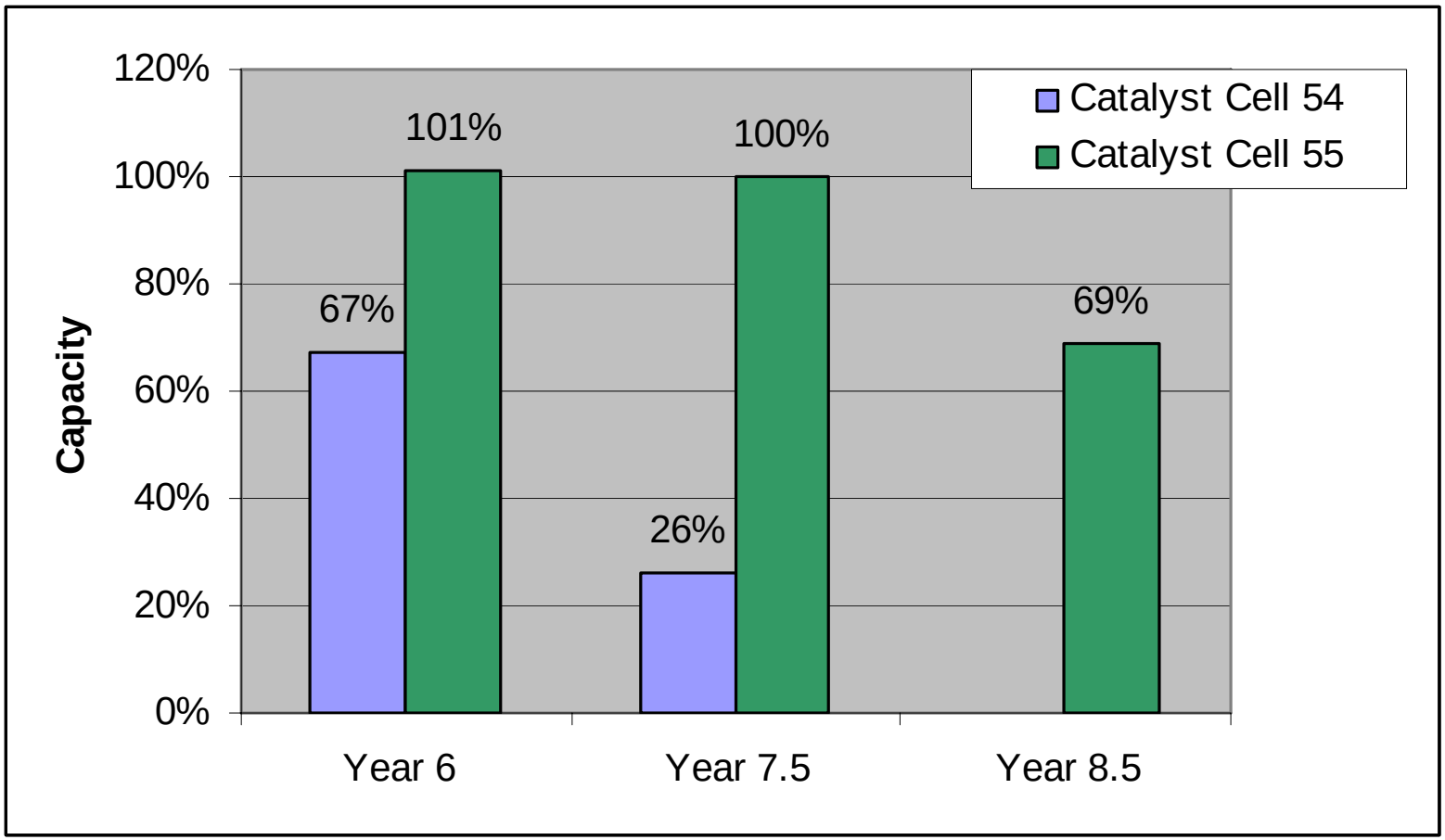


What did we find?
Cell Tear Down

- Tear down analysis of all but two catalyst cells conducted in years 4 & 5.
- Catalyst cells looked great.
- Non-Catalyst cells had:
  - Massive corrosion of negative grid.
  - Dry out.

What did we find?

Capacity Until End on 2 Remaining Cells

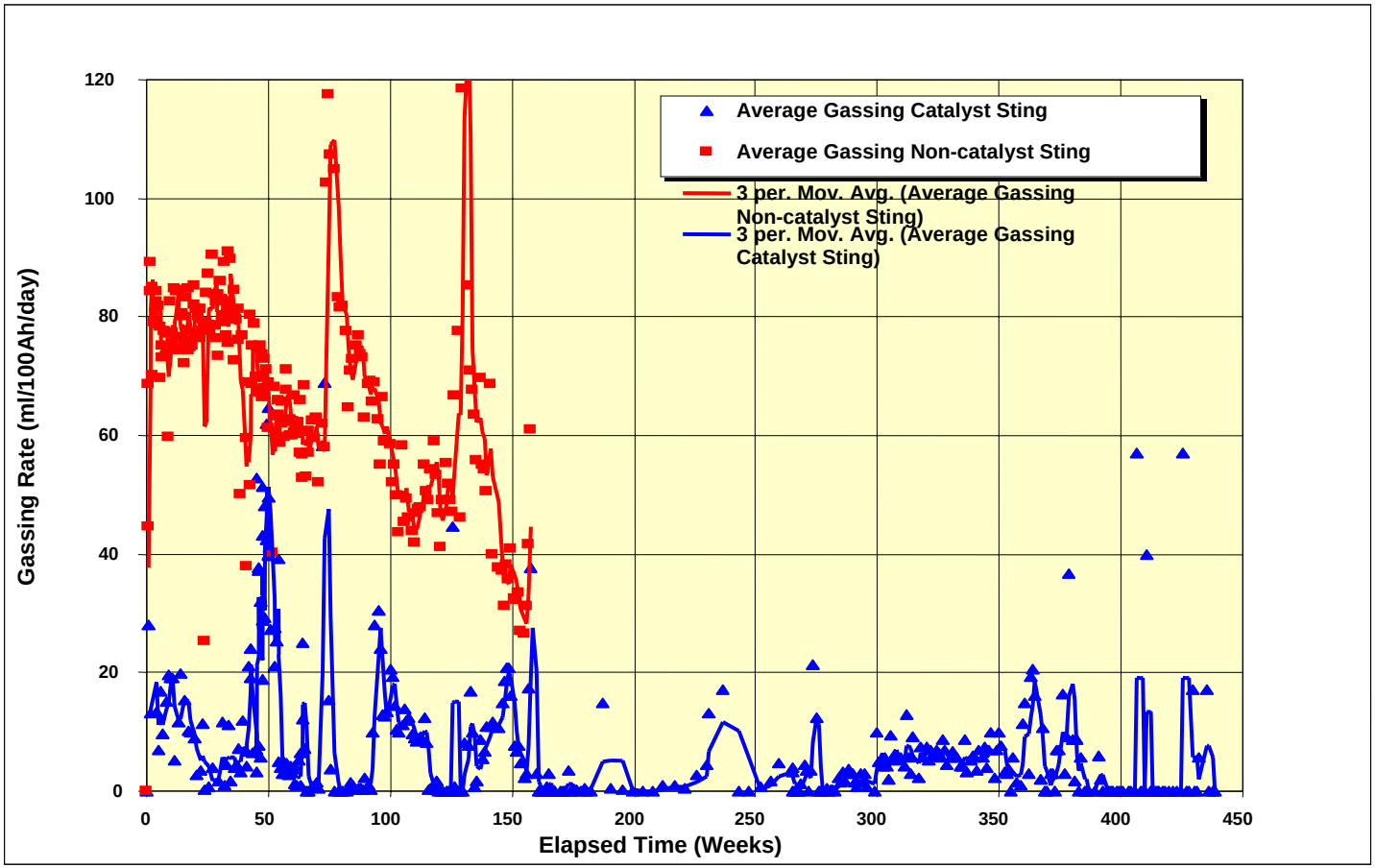


Note: 8.5 Years at 32°C is equivalent to 14 years at 25°C

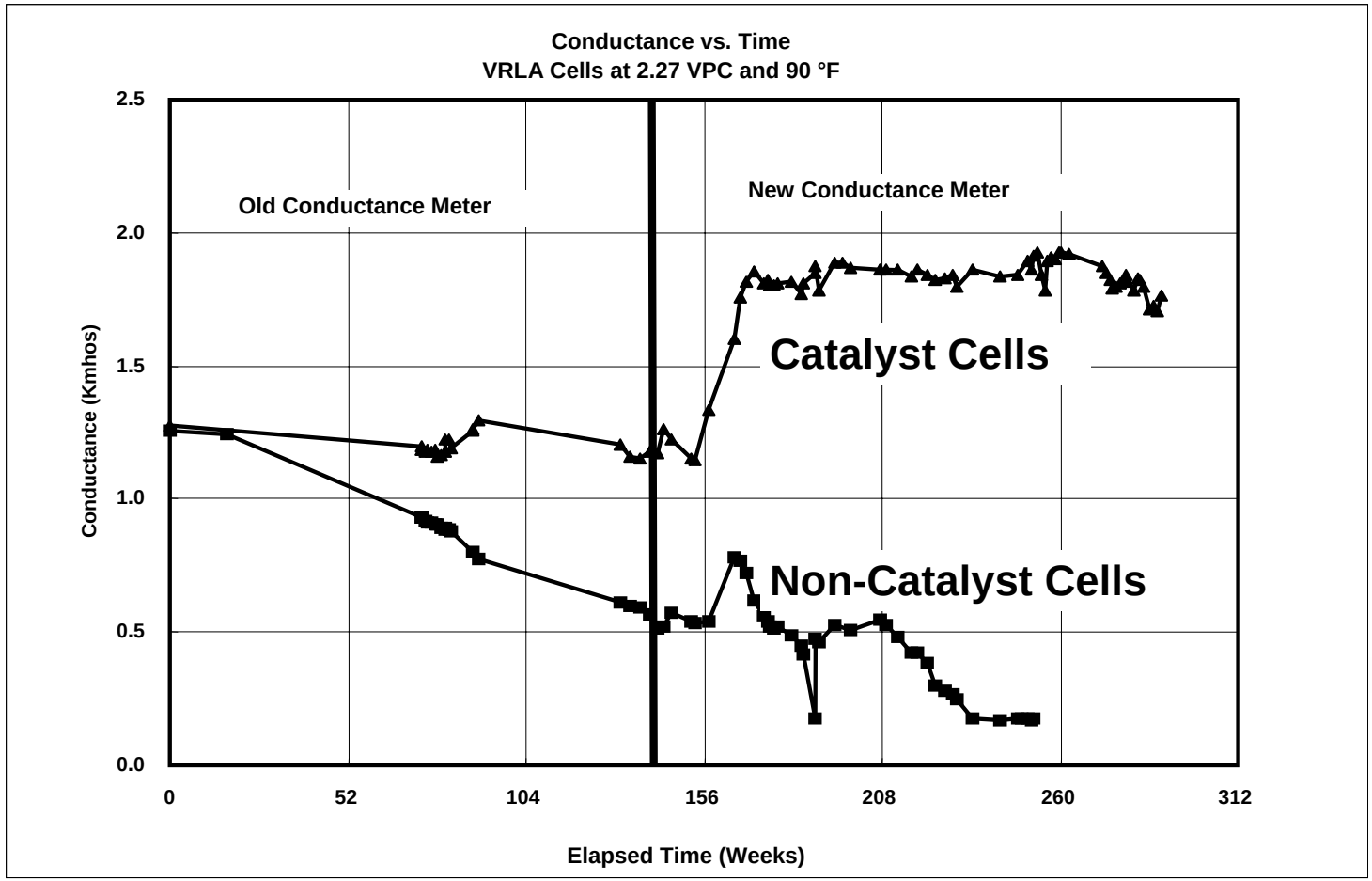
What did we find?
Cell Tear Down

- Year 7.5 one of two remaining catalyst cells fails.
  - Plates in excellent condition.
  - Failure was caused by positive strap corrosion.
  - Catalyst does not protect against this as it is a mechanical design issue.
    - Known defect of this design.
- Year 8.5 final catalyst cell fails.
  - Failure was caused by jar crack near positive post due to corrosion and growth of positive strap.
    - Known defect of this design.
  - This is equivalent to 14 years of life at 25°C.

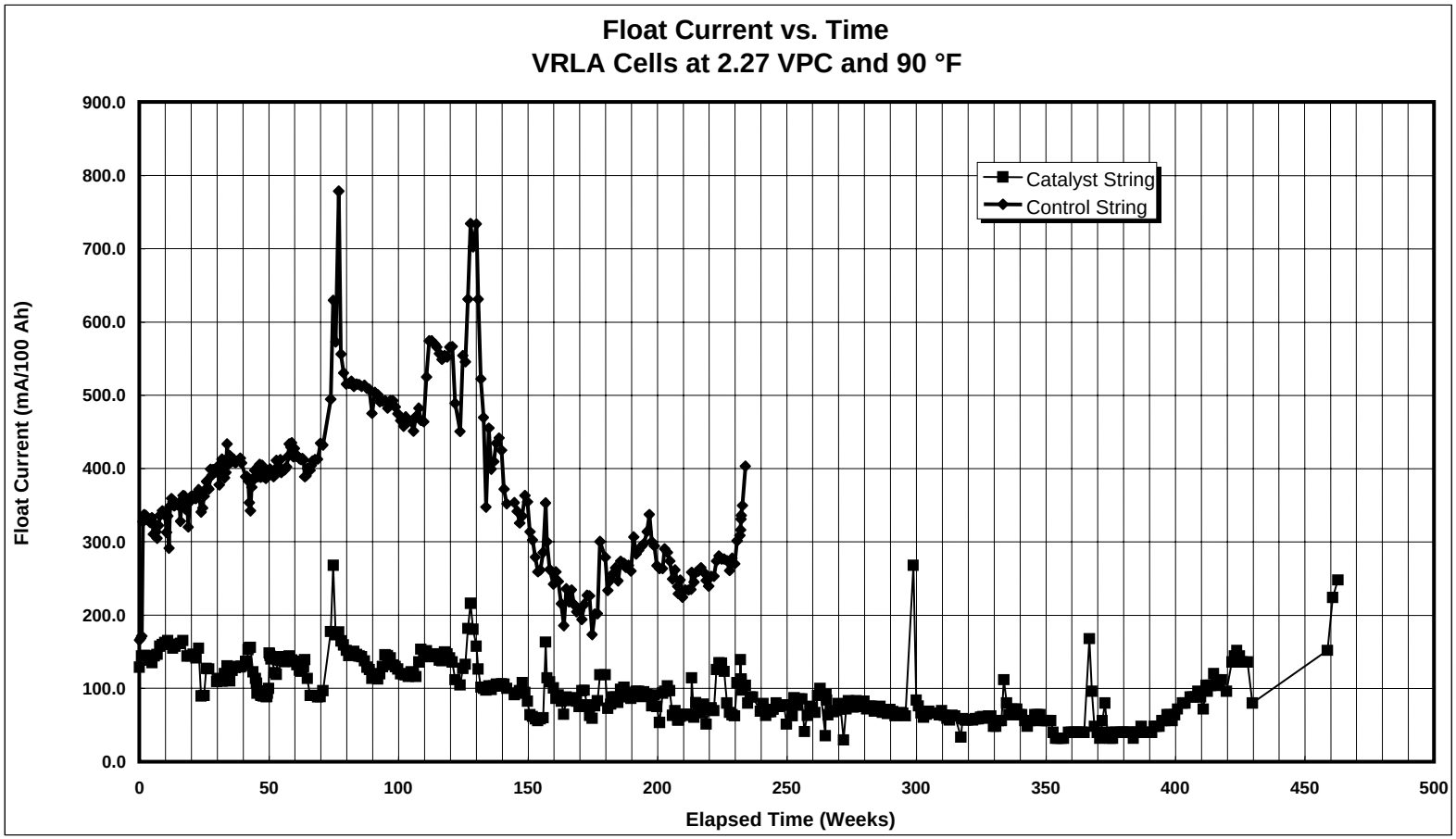
What did we find?
8.5 Years of Gas Evolution



What did we find?
Conductance



What did we find?
Float Current



Why is Float Current Important?

- A lowered float current is beneficial to the cell … but not just by adjusting the charger.
- Lowered float current reduces:
  - Positive plate corrosion.
  - Amount of gas generated by the cell (Water loss).
  - Cell dryout (better conductance).
  - Risk of thermal runaway.

What did we find? Polarization of Plates

	Non-Catalyst Cell	Catalyst Cell	Total Polarization
Neg.	0 mV	20 mV	120 mV
Pos.	120 mV	100 mV	120 mV

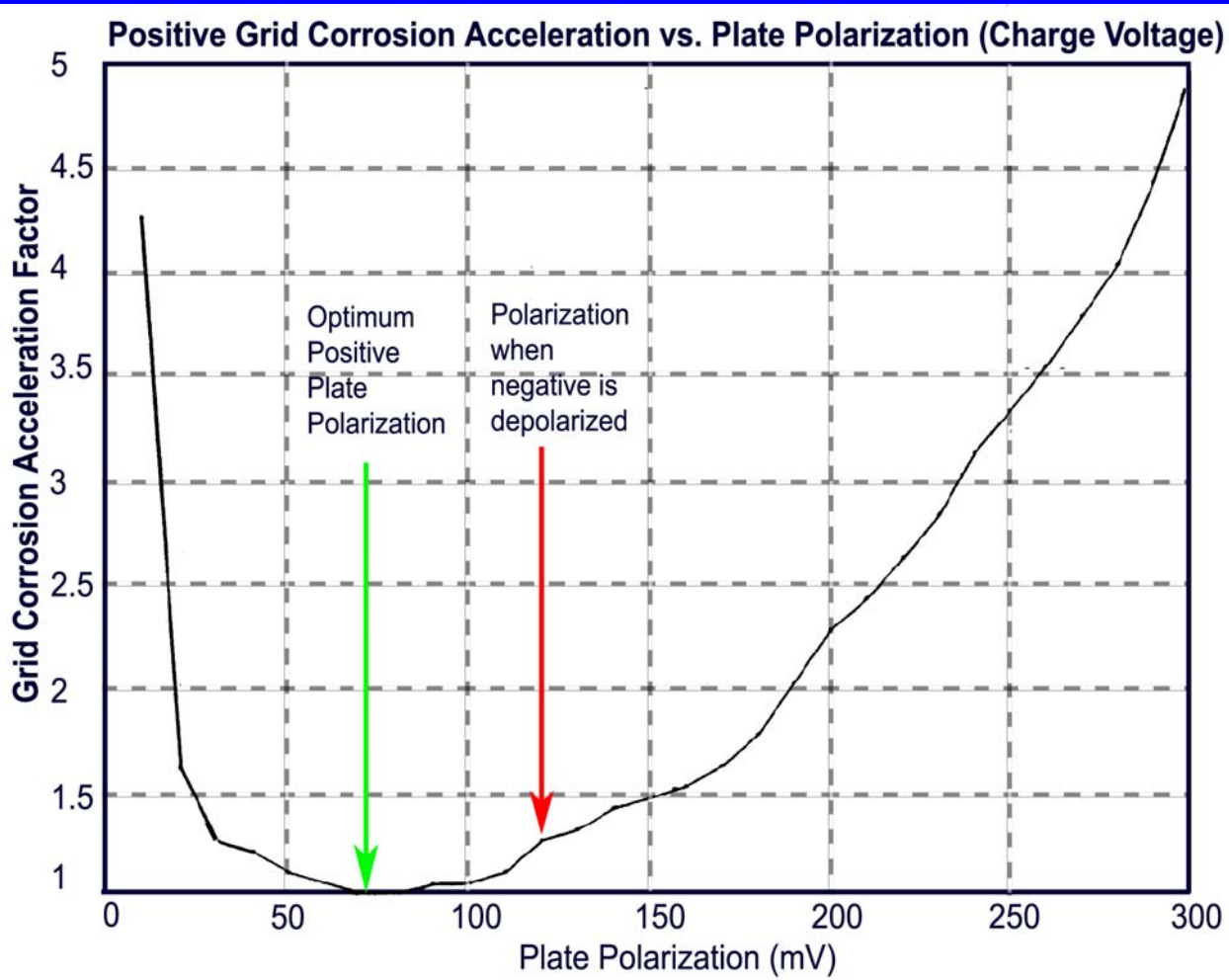
- Total Polarization is fixed by the battery design and charger settings.

Float Voltage	2.27 V	
Open circuit voltage	2.15 V	
Overvoltage	0.12 V	or 120 mV

Polarization Fundamentals

- Using a reference electrode we can determine how the overvoltage is split among the plates.
- Optimally, the positive plate receives the majority.
  - Too little and it won't charge properly
  - Too much and corrosion will be accelerated.
- Zero negative plate polarization is bad.

Lander Curve



Electrochemistry Basics

- Positive plate polarization, positive plate corrosion rate, and float current are all directly related.
- Lower positive plate polarization leads to lower float current.
- If negative plate is polarized it will automatically reduce the polarization on the positive plate.
  - This leads to lower cell float current.

What did we find?
Polarization of Plates

	Non-Catalyst Cell	Catalyst Cell	Total Polarization
Neg.	0 mV	20 mV	120 mV
Pos.	120 mV	100 mV	120 mV

- Non-catalyst cells: had higher float current because all of the overvoltage was on the positive.
- Catalyst cells: had lower float current because the overvoltage was distributed.

Take Home Point

- Keeping the negative plate polarized is the key to lowering the float current.

How does a catalyst help do this?

- Must start with some VRLA basics:
  - H_2 produced on the negative plate.
  - O_2 produced on the positive plate.
  - O_2, hydrogen ions and electrons recombine on the negative plate to form water.

How does a catalyst help do this?

  - When O_2 reaches negative plate it causes a reduction in the polarization.
  - While the cell is on float, a portion of the charge current will try to polarize the negative.
- There is a balancing act between the last two points

Putting it all together

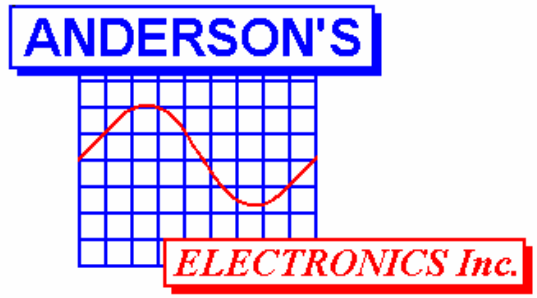
- By placing a catalyst into a VRLA cell:
  - A small amount of O_2 is prevented from reaching the negative plate.
  - The negative stays polarized.
  - The positive polarization is reduced.
  - The float current of the cell is lowered.

Out of the Lab

- But that was one lab test…

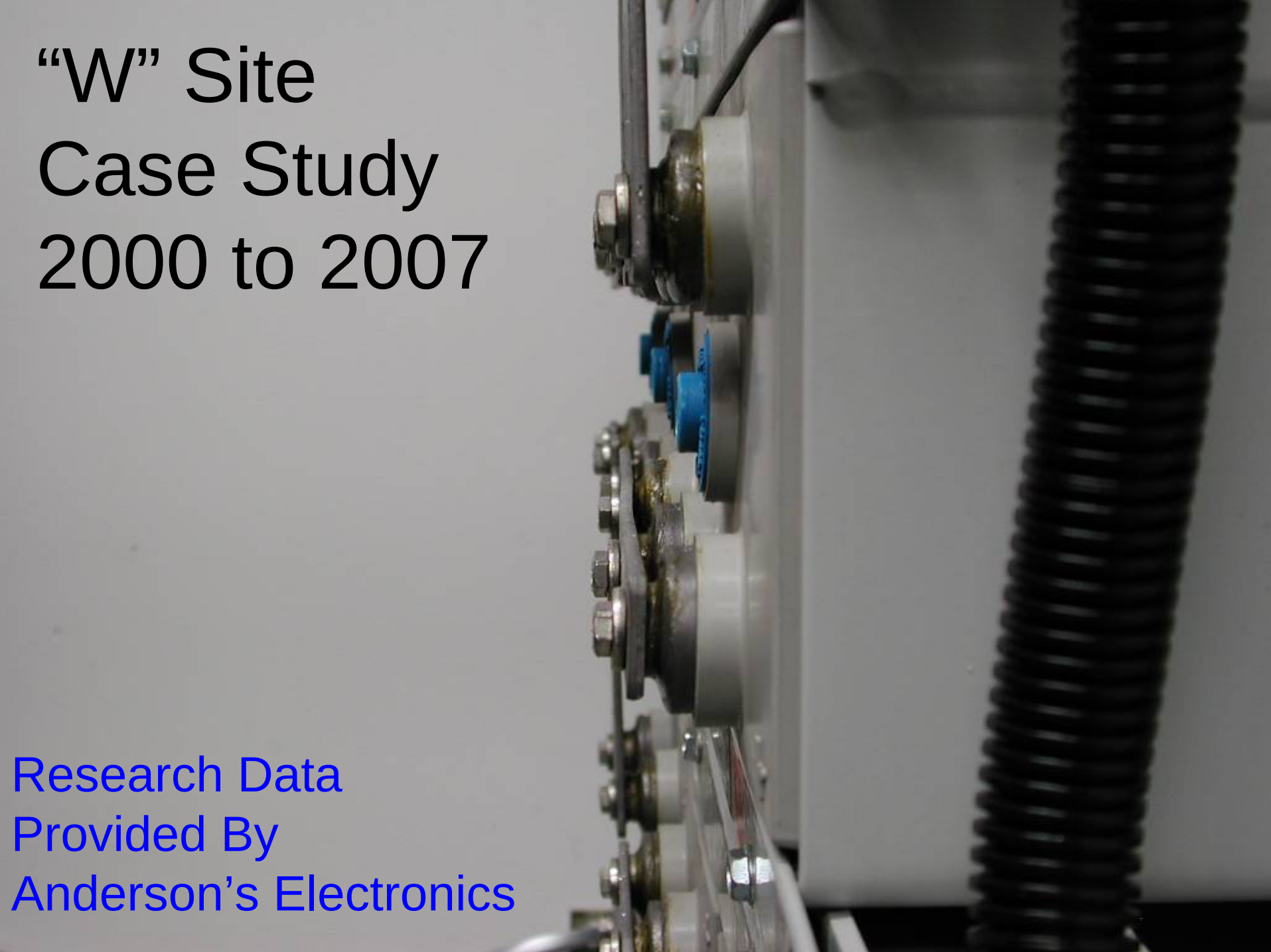
  …What about the real world?
- Anderson's Electronics has performed re-hydration and catalyst addition to over 18,000 cells in the field.
- The results have repeated the lab test findings.

Why Re-hydration Plus Catalyst Addition?



- The best time to install a catalyst is at the battery factory when the cell is new.
- If this is not done then the time clock on early failure starts.
- If the cell has been in the field a catalyst can be retrofitted, but the lost water should be replaced.

“W” Site
Case Study
2000 to 2007



Research Data
Provided By
Anderson’s Electronics

“W” Site Description

- 24 VRLA AGM cells installed by large Canadian Telco in 1993.
- All cells from same manufacturer and run under controlled conditions.
- Year 2000 -- Battery failed 3 hour capacity test in 9 minutes!
  - Slight bulging around positive posts confirm positive plate growth had started but not severe.
  - Water and catalysts added by Anderson’s to cells.
- Conductance, Internal Resistance and Capacity testing conducted yearly.

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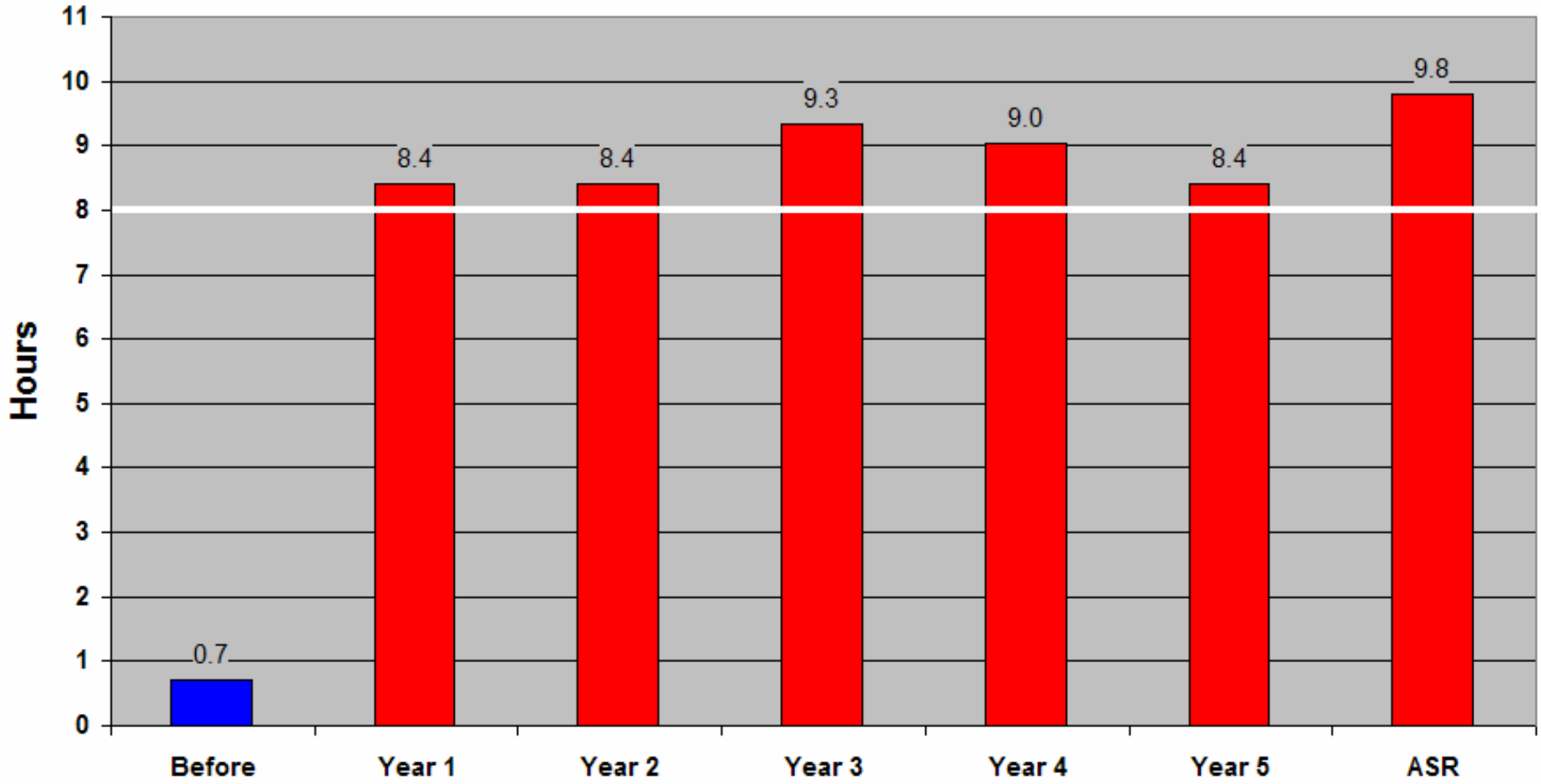
Site Runtime Projections @ 71 Amp Load
Before & After Catalyst / Re-hydration Procedure
900 Amp Hour Cells (1993)
(ASR) = After Second Re-hydration



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“W” Site History

- Six years after the procedure a single post seal leak formed and the owner removed the string from the site.
  - This is company policy even though battery still maintained capacity.
- Positive plate growth had advanced enough to form white rings around some positive posts.


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“W” Site History

- The string was relocated to Anderson’s test bay for reassembly and further testing.
- Anderson’s continued float charging the cells until Year 7 capacity test was due.

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Site Runtime Projections @ 71 Amp Load
Before & After Catalyst / Re-hydration Procedure
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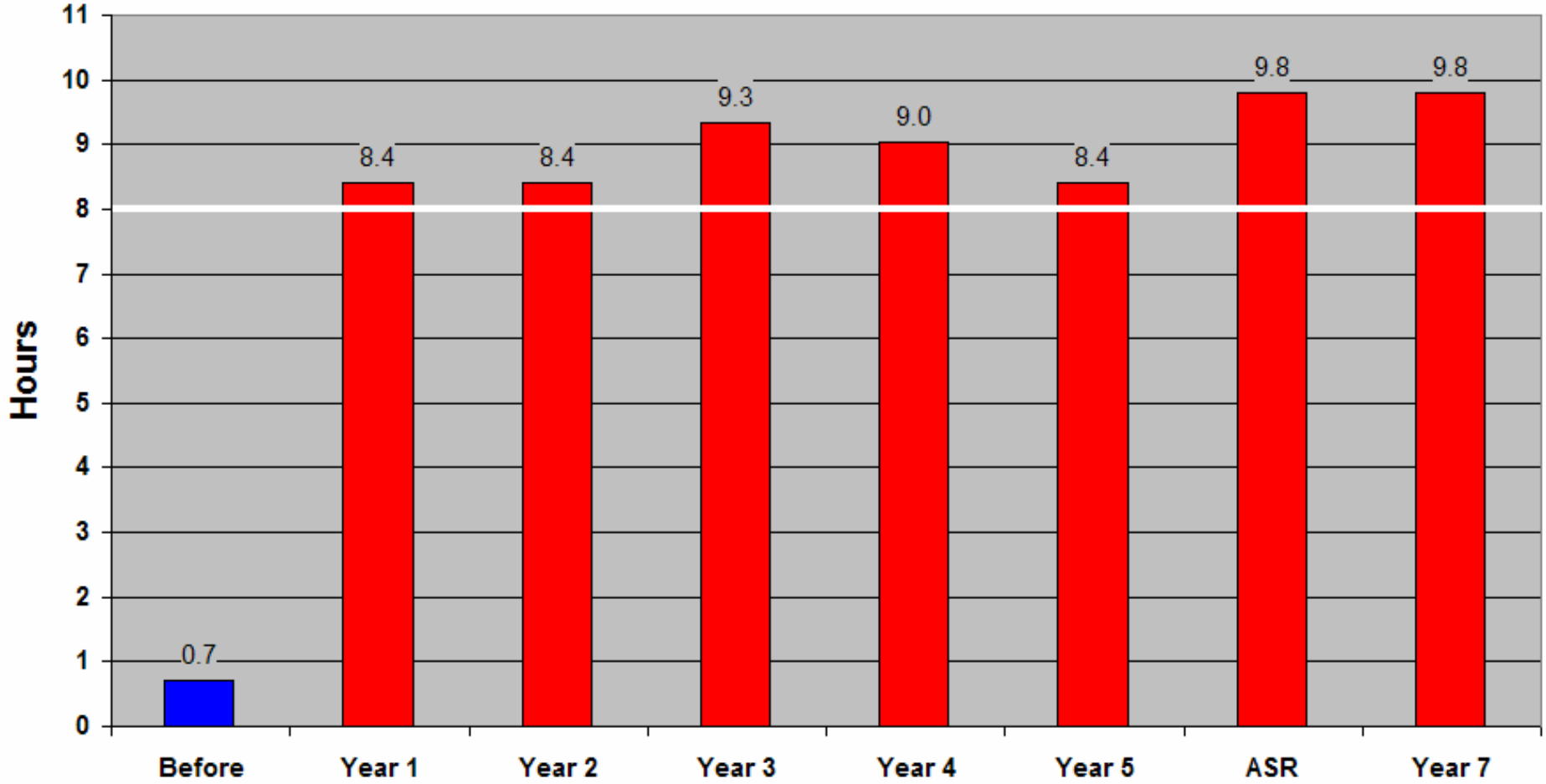

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What Happened?

- Water added to cells gave immediate improvement – improved ionic contact.
- Catalysts maintain the improvement because the root cause is addressed.
- Catalysts prevent negative plate from depolarizing, which lowers float current.
- Batteries remain in service longer.
- Water and Catalysts must be added together.

“W” Site Conclusions

- The battery was scheduled for replacement in 2000.
- It remained in service for another *six years*, protecting the site load while maintaining the minimum 8-hour reserve requirement.
  - Carried the load for 5 hours during blackout of 2003.
- Take home points:
  - Expensive replacement was deferred.
  - This battery was not dead – just discharged!

Lessons Learned

- Negative plate self discharge starts earlier than most people believe – within 12 to 18 months.
- It is important to install a catalyst as early as possible…
- …if not originally in cells then conduct re-hydration & catalyst addition before positive plate growth (or other failure modes) destroy the cells.

Economics

- A financial analysis of Anderson's work at over 1,359 sites (18,000 + cells) across Canada & USA revealed the following:
- For approximately every $1,000 invested in this process, $11,000 of battery replacement costs can be deferred for a minimum of 3 years.

Conclusion

- Negative plate self discharge shortens the life of VRLA cells.
- The use of a catalyst prevents some oxygen from reaching the negative plate keeping it polarized and the battery working.
- Lab and real world data shows better performance in cells with catalysts.
- Money and service interruptions can be saved through re-hydration & catalyst addition to in-service batteries.