



C&D TECHNOLOGIES
Power Solutions

Developments in 20-yr VRLA Technology

Content

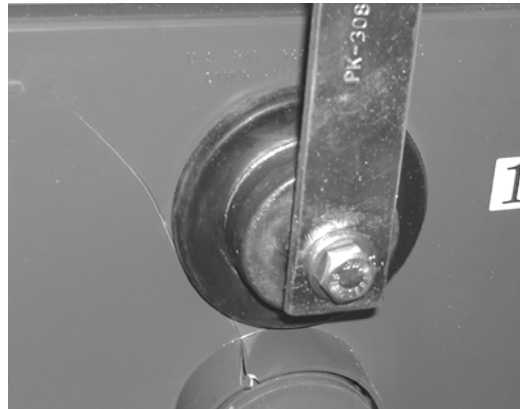
- **Background & history**
- **VRLA issues**
- **Key differences (VRLA vs. Flooded)**
- **Latest advances in VRLA technology**
- **Test results**
- **Conclusions**

Background & history

- **In the mid-80's VRLA technology was adapted from cylindrical cells to flat pasted plate rectangular cells and mono-blocks**
- **Resulted in development of larger, higher capacity cells (20-year design life) - after general acceptance of flat plate cells in the small UPS market (10-year design life)**
- **Touted as a maintenance-free alternative to flooded batteries**

Background & history – VRLA issues

- **After introduction – found unexpected short life and new failure modes**
 - Uncontrolled grid growth, resulting in cover and jar cracking
 - Heat distorted plastic parts
 - Ground faulting due to cracked jars/cover
 - Premature capacity loss
 - Poor cycling



Key VRLA issues

- **Reliability issues**
 - Sudden & unpredictable failure
 - Shorter field life than flooded
 - Charge acceptance issue
 - Wide variations in performance
 - Wide float voltage range
 - Increasing float current with age
 - Few indications of impending problems
 - Little to no visual clues until failure
 - Some failures can be catastrophic in nature

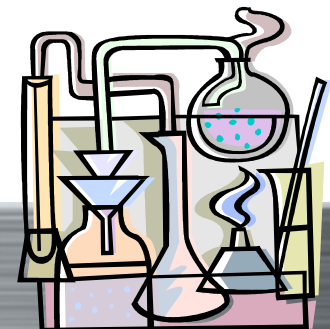


VRLA issues

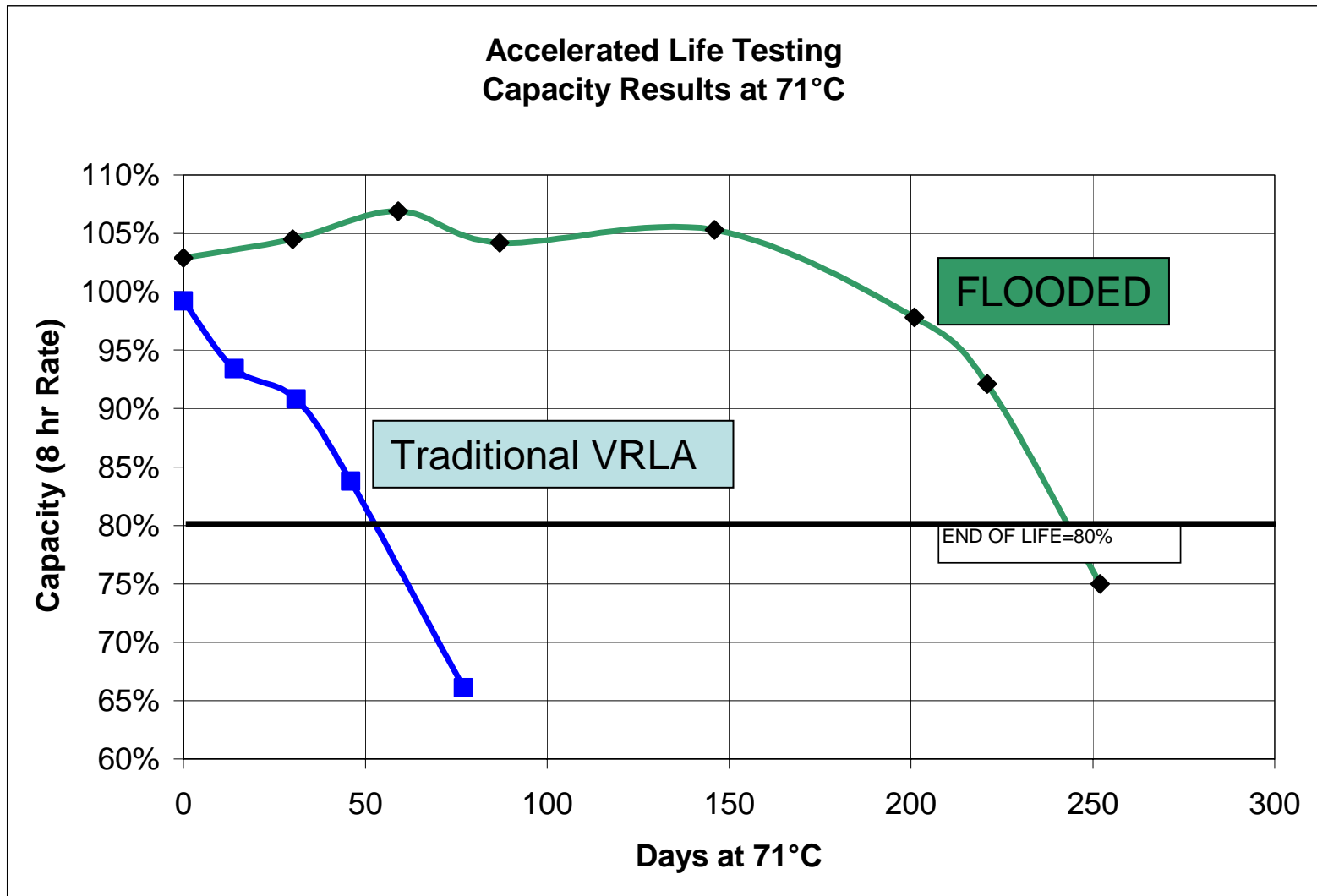
- **These issues led to poor customer acceptance of VRLA as a flooded battery substitute**
- **Started the use of alternate technology in high temp environments**

VRLA advantages

- **However, VRLA batteries offer advantages over flooded cells**
 - Energy density
 - Low maintenance costs
 - Very low hydrogen emission
- **Thus finding a reliable, long service life VRLA batteries became a priority**
- **Set off a frantic R&D in lead acid battery industry**



VRLA vs. Flooded

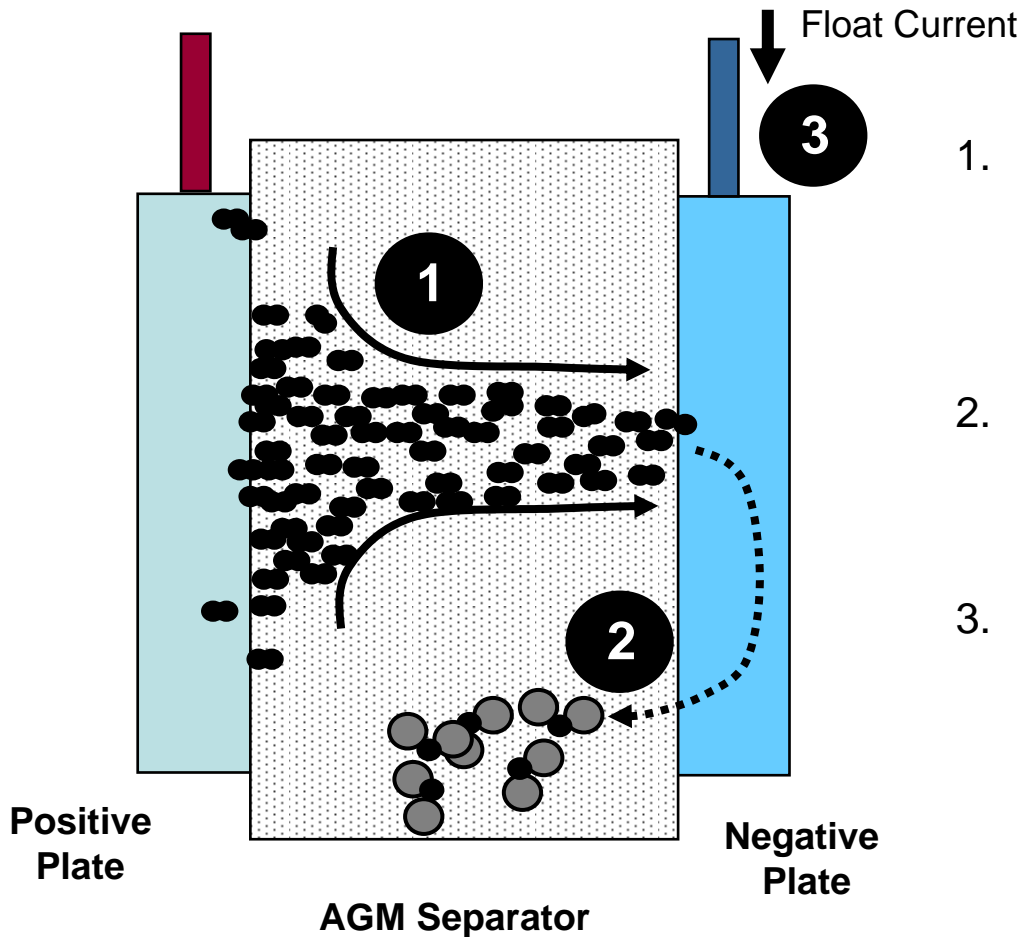


Key difference – float behavior

- **Structurally, flooded cells and VRLA are similar**
 - Lead alloys, plate thicknesses, active materials
- **Key differences**
 - Acid concentration (~10% higher, 1.215 vs. 1.300)
 - Limited acid volume
 - Separator material
 - Higher compression
 - H₂ and O₂ recombination efficiency and process
 - *Float behavior – plate charging and current acceptance*

Recombination - VRLA

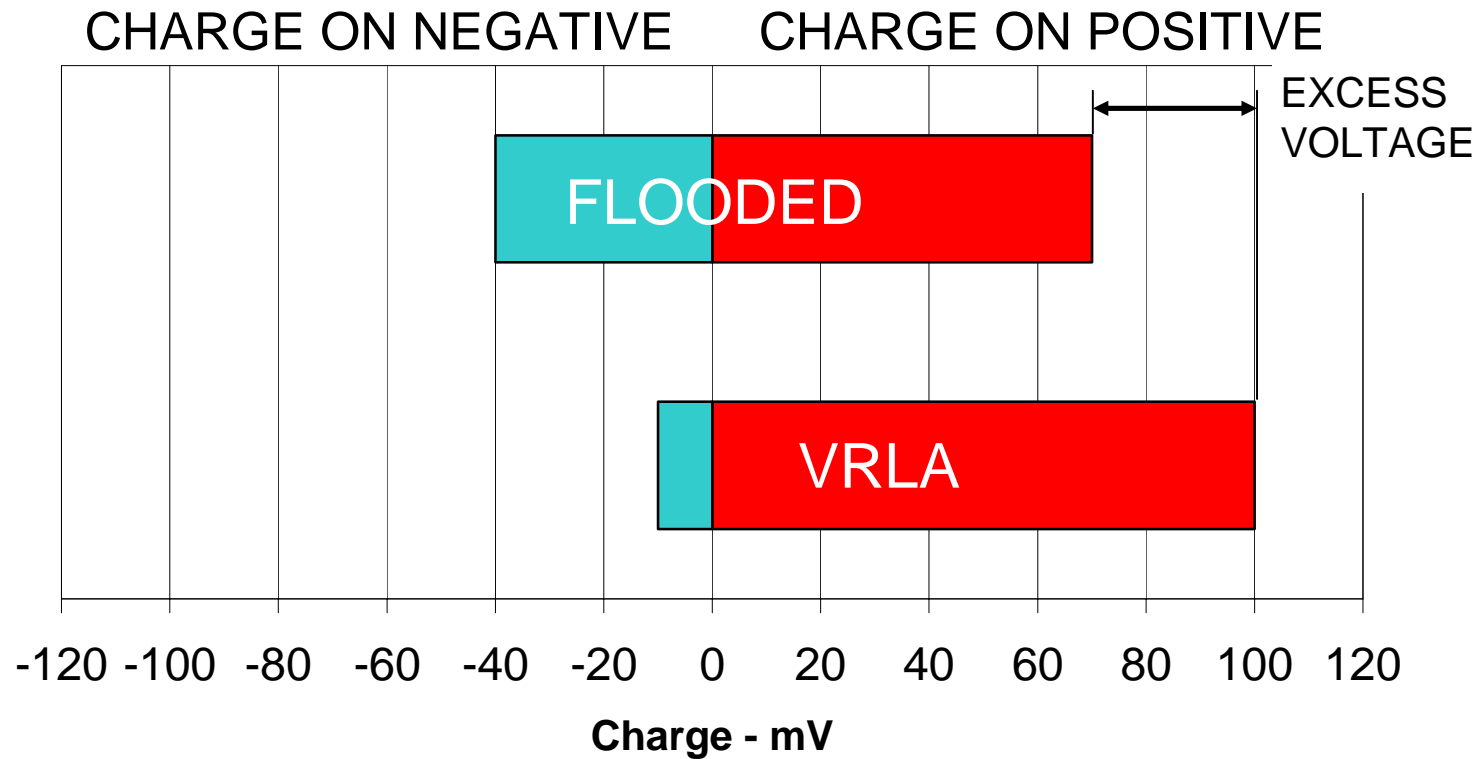
Recombination Process in a Traditional VRLA Battery



1. Oxygen, which is generated on charge, migrates through pores of the Absorbed Glass Separator to the Negative Plate
2. At the negative plate, the Oxygen recombines back into water
3. This discharges the negative plate, and the float current must be increased to counteract this discharge reaction

VRLA vs. Flooded – charge voltage distribution

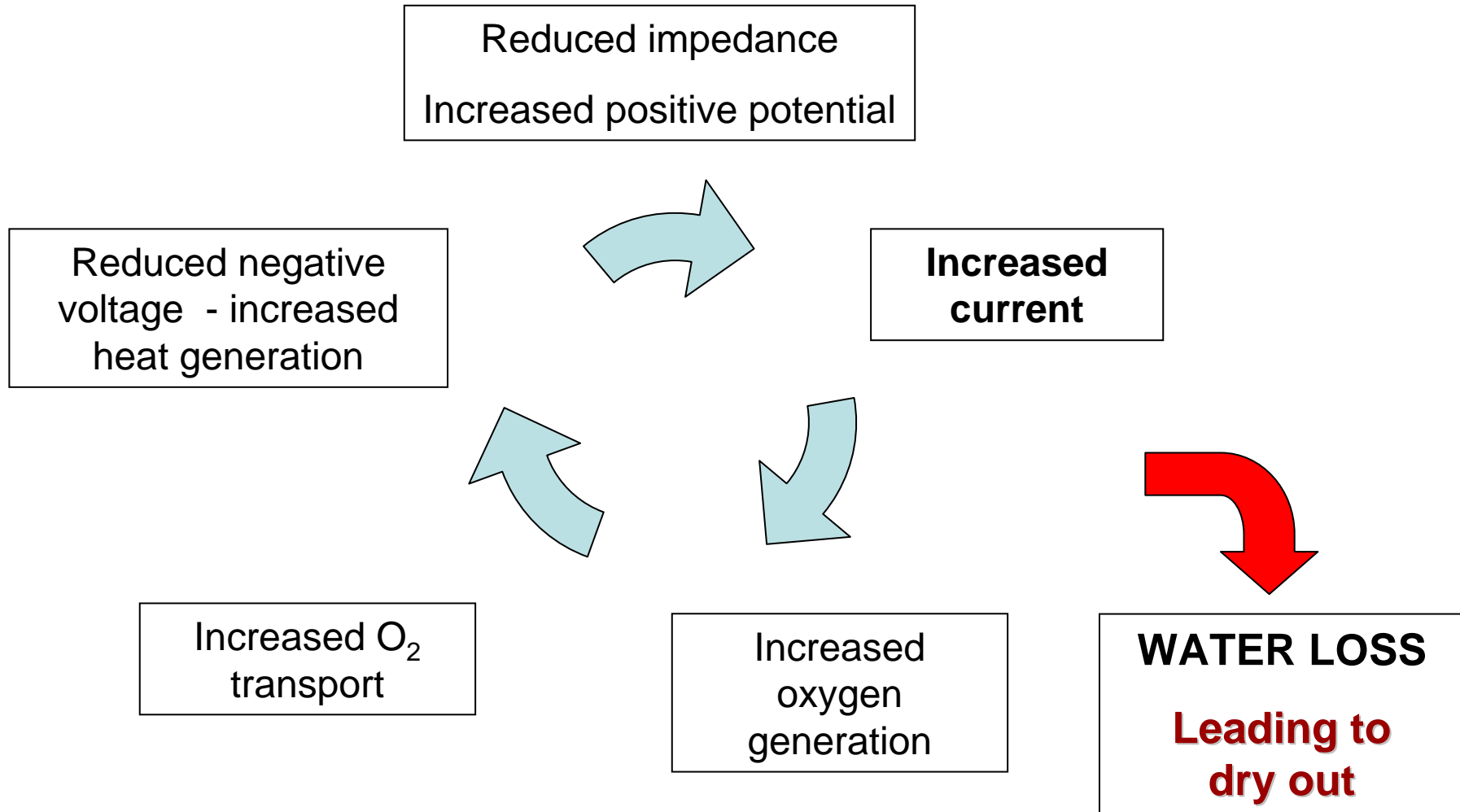
Charge Voltage Distribution Flooded vs. VRLA



Effects of excess positive voltage

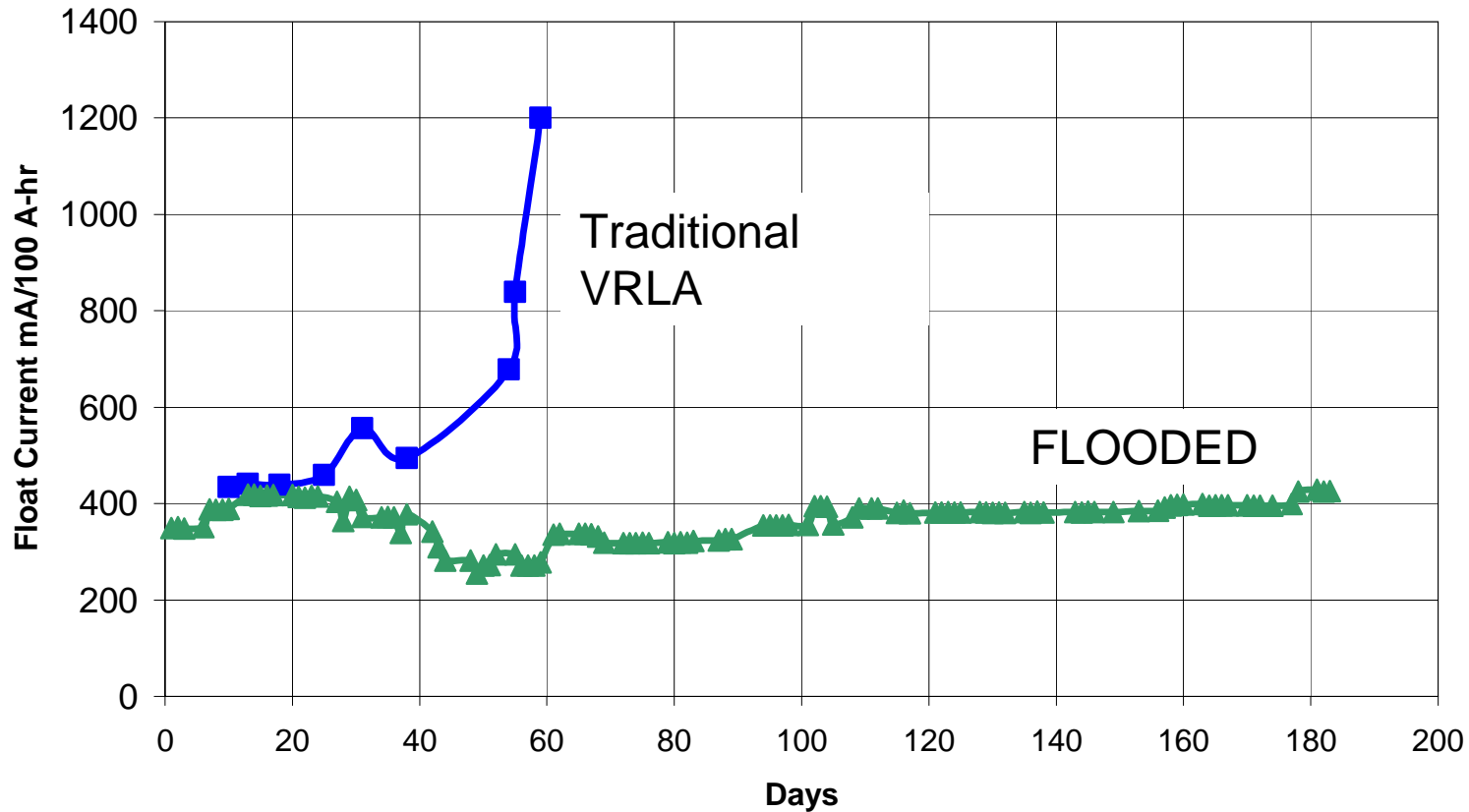
- **Higher positive potentials have the same effects in VRLA & flooded lead acid batteries**
 - Higher charge current
 - Higher gassing rates
 - Higher corrosion rates
- **However, the effects in VRLA batteries are compounded by limited acid volume and the oxygen cycle – resulting in excessive heat generation leading to dry outs**
 - Reducing charge voltage is not an option
 - Negative plate and strap discharge will result

VRLA feedback loop



VRLA vs. Flooded - float current

Accelerated Life Testing Float Current at 71°C



Float current

- **String float voltage is set at the charger**
- **However, float current is NOT setting of the charger**
- **Float current is the result of the design and process optimization**
- **Batteries from different manufacturers will have different float currents**

Improving VRLA

- **Increasing robustness**

- Making the construction of plates and cells tougher to resist stress
 - Thicker plates
 - Corrosion resistant grid alloys
 - Tougher plastics / external support for compression
 - Controlled plate growth
- Providing extra sites for oxygen reaction (catalyst)

- **Managing charge voltage**

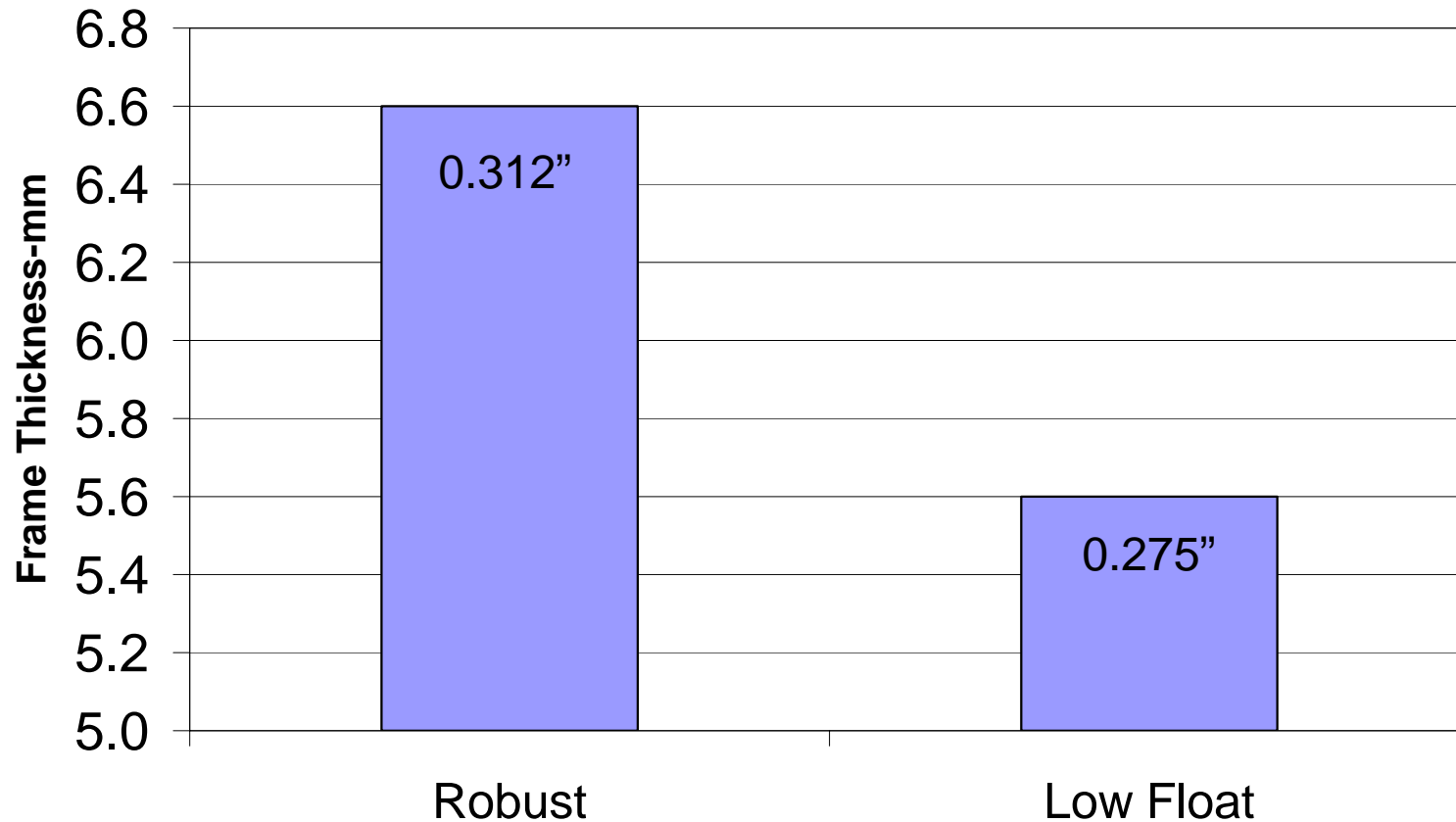
- Changing the active material design to reduce positive over-voltage and reduce float current

Testing approaches

- **Identified two product versions**
 - Robust (thick plate) version
 - Low float current (active material) version
- **Chose high temperature, accelerated life test for comparison**
 - Fast results
 - 3rd party verification possible – Telcordia standard

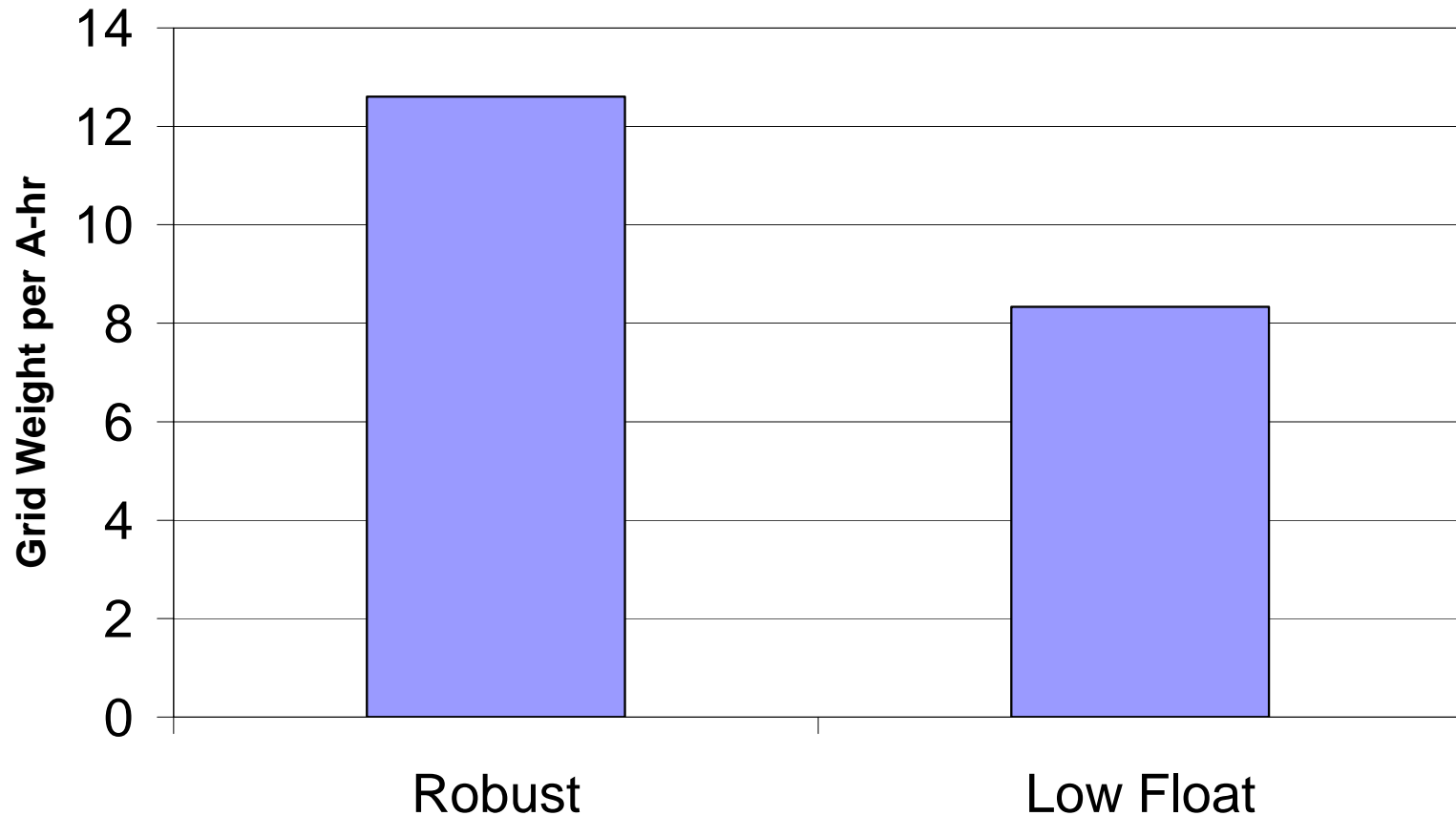
Test sample comparison

Grid Thickness Comparison

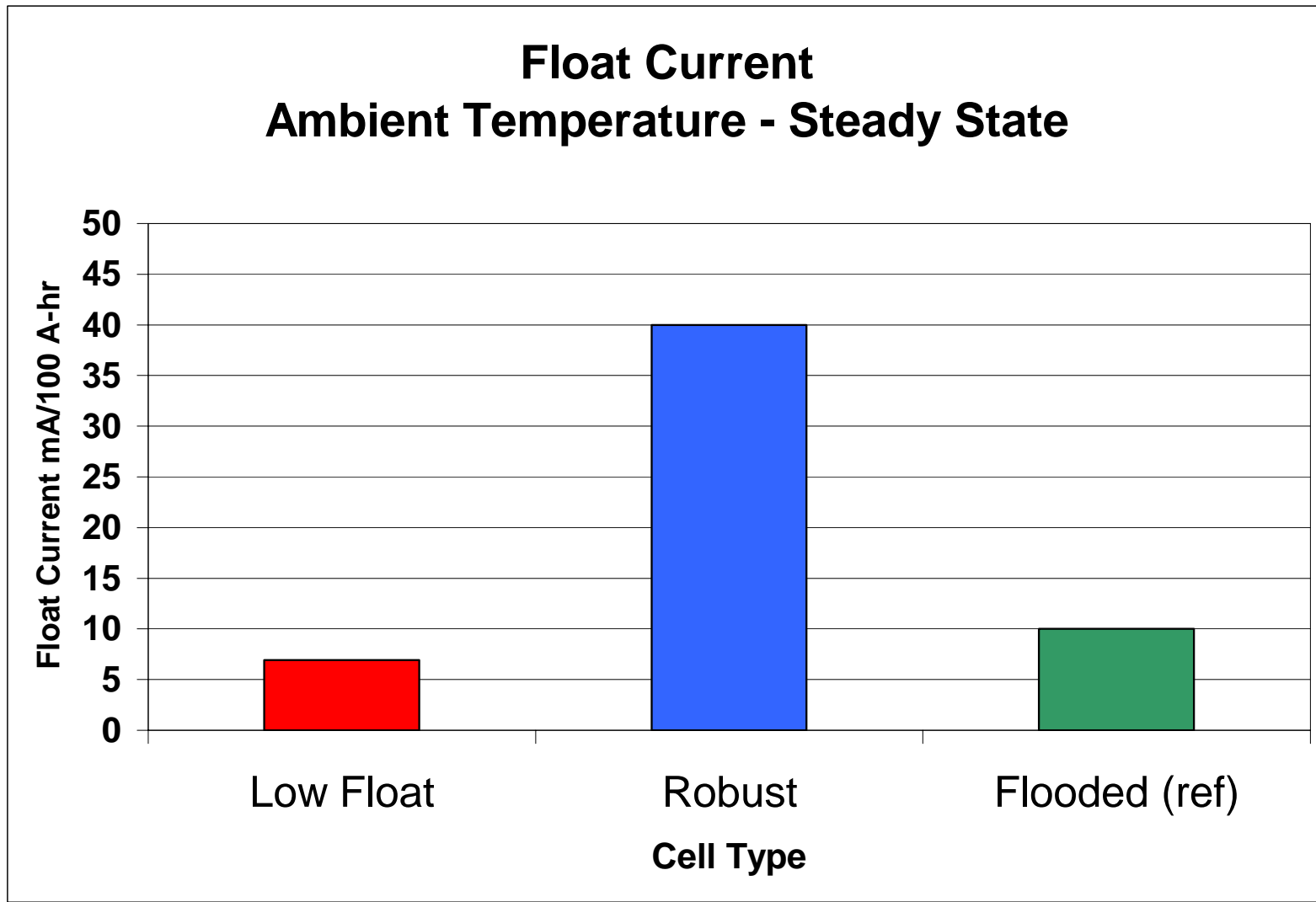


Test sample comparison

Grid Weight Comparison



Float current comparison



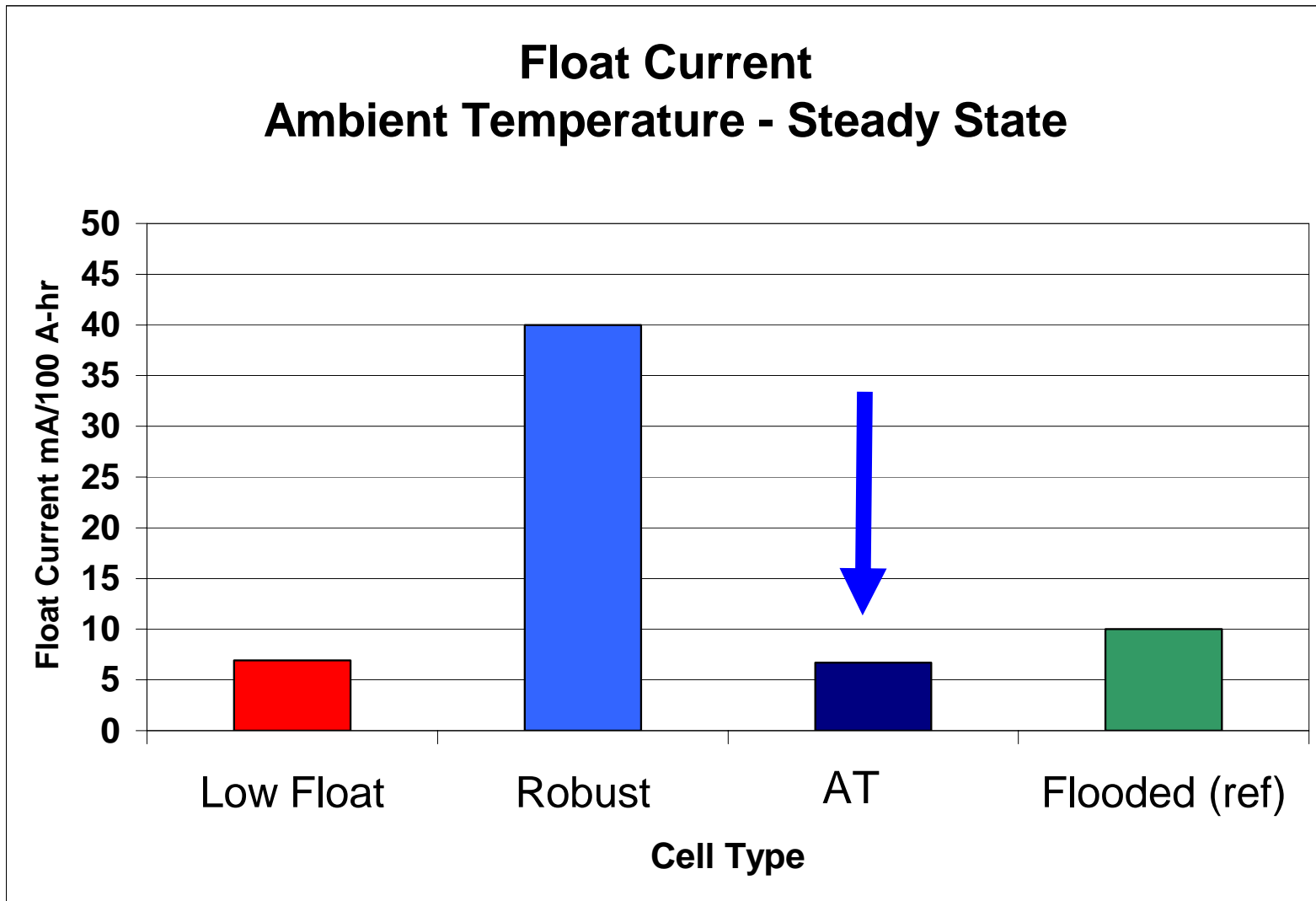
Test results comparison

- **Time to 80% capacity**
 - Robust version: ~55 days
 - Low float current version: ~130 days
- **Conclusion**
 - Robust design can only slightly delay failures due to high positive voltage and high float current
 - Need to combine the robust design with low float current model
 - Catalyst was not tested

Reaction to test results

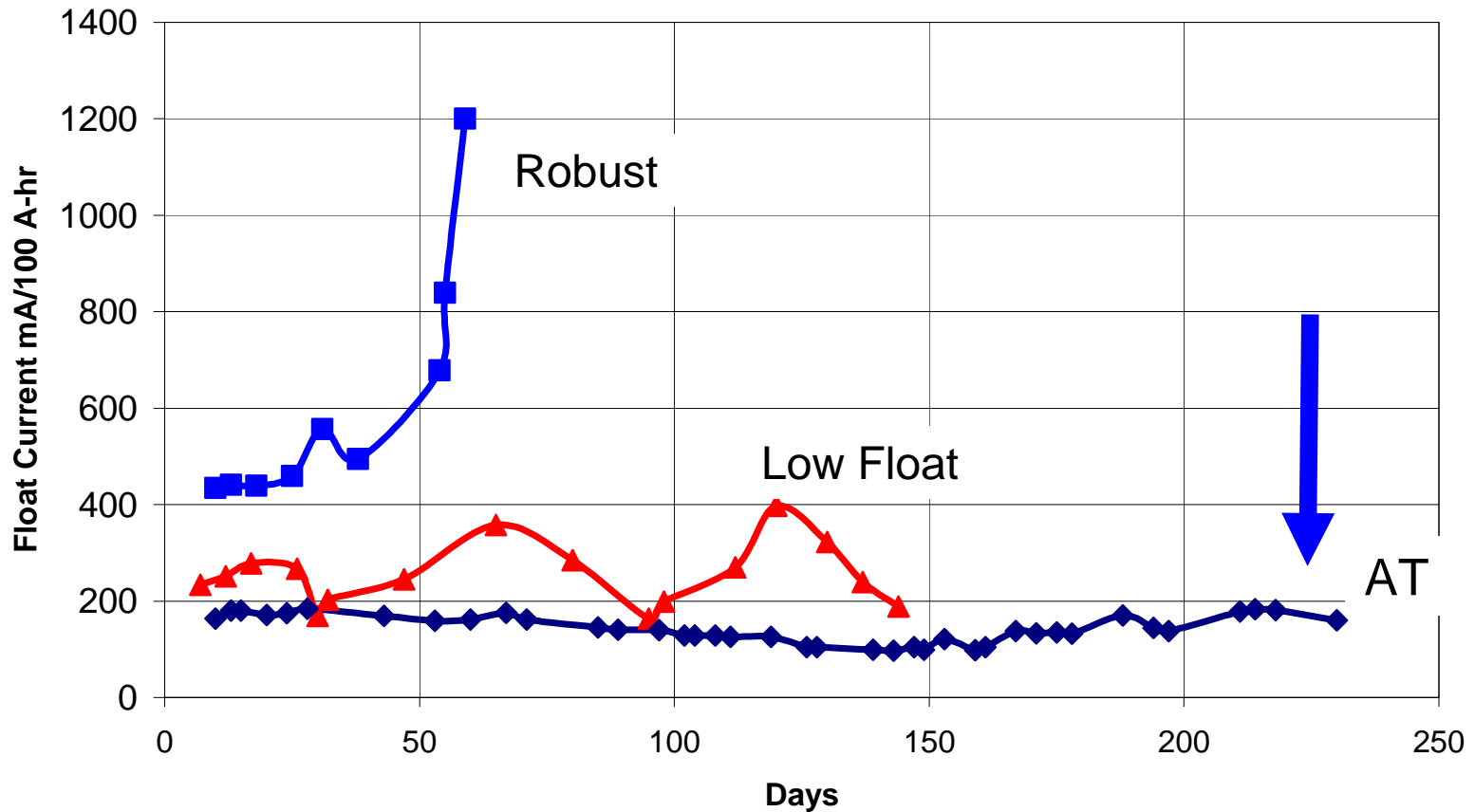
- **Can robust design increase the life of a low float current VRLA design?**
- **Plan**
 - **Build next generation cells by transferring low float current active material to robust cell structure – will call this Advanced Technology (AT)**
 - **Use improved jar and cover material**
 - **Test under similar conditions**
 - **Determine failure modes**

New test results

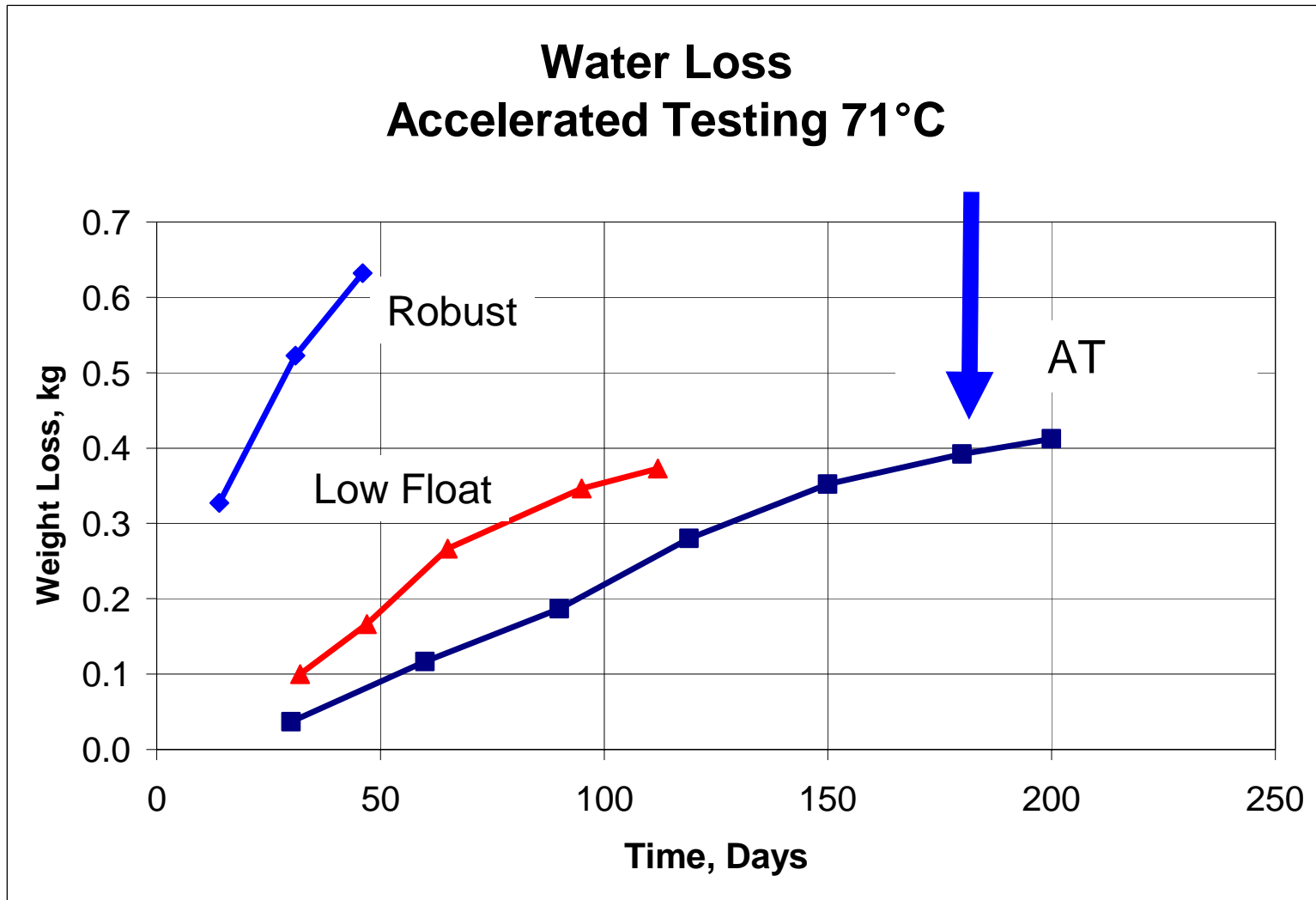


Float current comparison

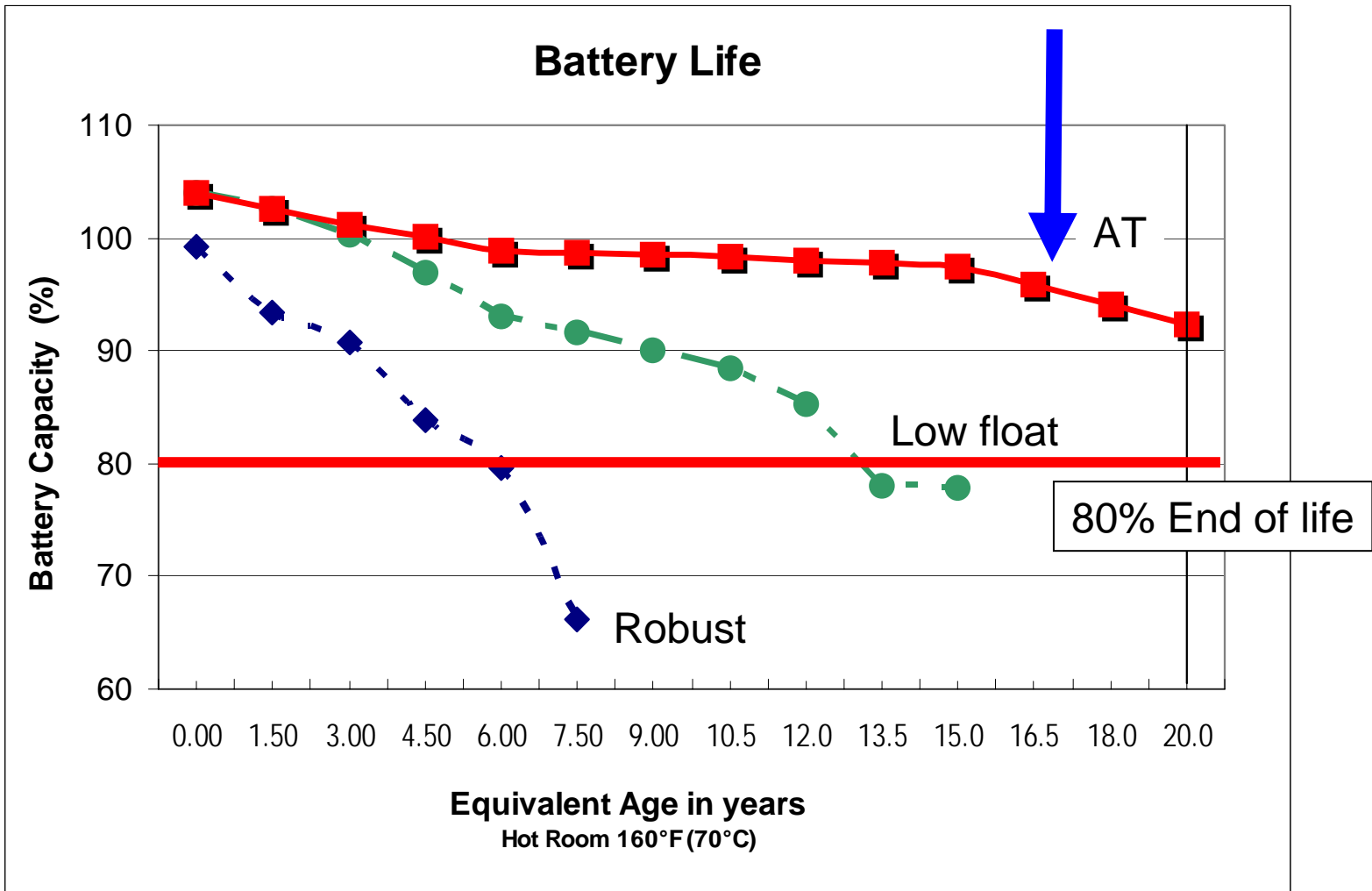
Accelerated Life Testing
Float Current at 71°C



Water loss comparison – as a result of improved jar and cover material



Capacity comparison



Test results analysis

- **Failure mode analysis**
 - **Robust version: Grid growth caused by dry out**
 - **Low float version: Grid Corrosion**
 - **Advanced Technology (AT): test continuing**
 - **Degree of grid corrosion level at 200 days was roughly half of failure value – actually measured through teardowns**
 - **Actual test time now beyond 300 days**

Conclusions

- **Voltage distribution across positive and negative plates in VRLA cells is the key to long product life**
 - **Must be achieved through design**
- **Combination of robust design and low float process will extend battery life**

Continuing work

- **Expanding accelerated testing to other temperatures**
- **Tracking behavior (current, impedance, etc) through the end of life**
- **Extending technology to other products and applications**