POWERGENIX

Nickel-Zinc Batteries for Micro-Hybrid Vehicles

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August 23, 2012
Boston, USA

Contents

POWERGENIX

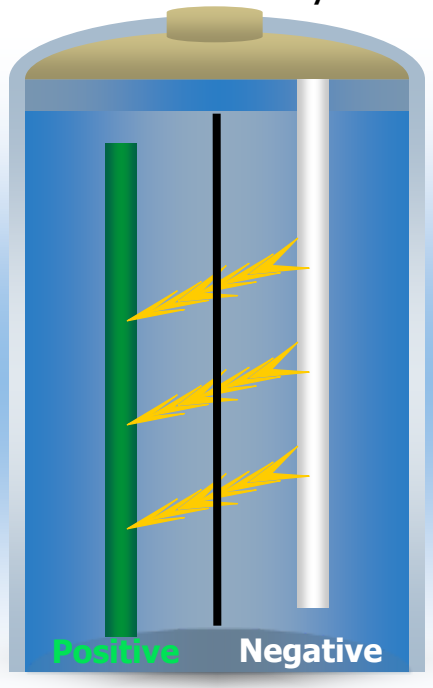
- Ni-Zn: A Differentiated Chemistry
- Superior Battery Solution for Huge Market
- Test Data Demonstrate Ni-Zn Performance

Ni-Zn: A 100 Year Problem Solved

POWERGENIX

Electrolyte Formula Stabilizes the Zinc Electrode

Material Science Advances Enable High Power Delivery and High Cycle Life



The Cell

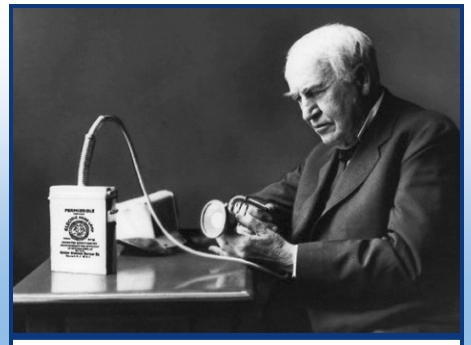
Our Technology Enables Manufacturing using **Existing** Ni-Cd and Ni-MH Production Equipment and Processes

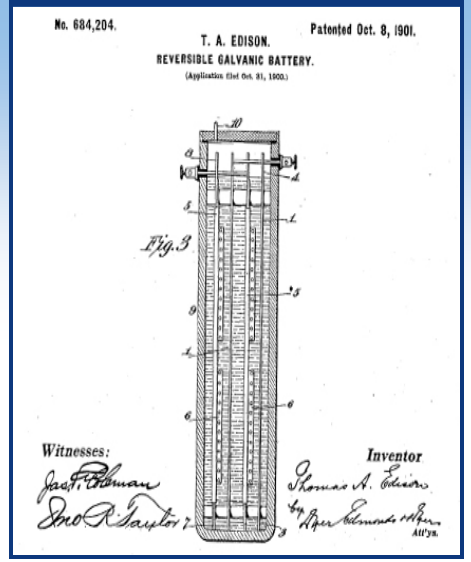
The Manufacturing

Ni-Zn: A 100 Year Problem Solved

POWERGENIX

From Edison





No. 684,204. Patented Oct. 8, 1901.

T. A. EDISON.

REVERSIBLE GALVANIC BATTERY.

(Application filed Oct. 31, 1900.)

Fig. 3

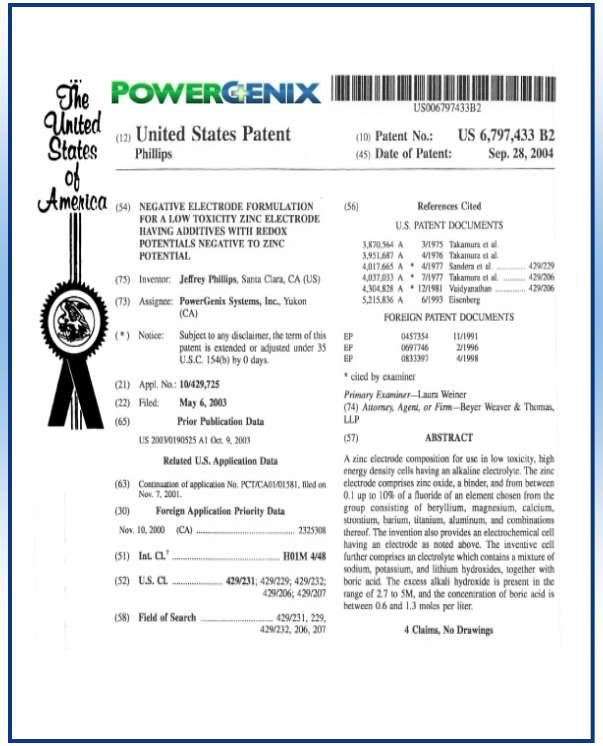
Witnesses: Jas. F. Bohman, Geo. R. Taylor

Inventor: Thomas A. Edison, by Dyer, Tompkins & Burton, Att'ys.

80 Patents Issued and Pending

- Electrolyte and Electrode Composition
- Charging Algorithms
- Cell Design
- Manufacturing Technology

To PowerGenix



The United States of America

POWERGENIX

US006797433B2

(12) United States Patent
Phillips

(10) Patent No.: US 6,797,433 B2
(45) Date of Patent: Sep. 28, 2004

(54) NEGATIVE ELECTRODE FORMULATION FOR A LOW TOXICITY ZINC ELECTRODE HAVING ADDITIVES WITH REDOX POTENTIALS NEGATIVE TO ZINC POTENTIAL

(75) Inventor: Jeffrey Phillips, Santa Clara, CA (US)

(73) Assignee: PowerGenix Systems, Inc., Yukon (CA)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: 10/429,725

(22) Filed: May 6, 2003

(65) Prior Publication Data

US 2003/0190525 A1 Oct. 9, 2003

Related U.S. Application Data

(63) Continuation of application No. PCT/CA01/01581, filed on Nov. 7, 2001.

(30) Foreign Application Priority Data

Nov. 10, 2000 (CA) 2325308

(51) Int. Cl.[7] H01M 4/48

(52) U.S. Cl. 429/231; 429/229; 429/232; 429/206; 429/207

(58) Field of Search 429/231, 229, 429/232, 206, 207

(56) References Cited

U.S. PATENT DOCUMENTS

3,870,564	A	3/1975	Takamura et al.	
3,951,687	A	4/1976	Takamura et al.	
4,017,665	A *	4/1977	Sandera et al	429/229
4,037,033	A *	7/1977	Takamura et al.	429/206
4,304,828	A *	12/1981	Vaidyanathan	429/206
5,215,836	A	6/1993	Eisenberg	

FOREIGN PATENT DOCUMENTS

EP	0457354	11/1991
EP	0697746	2/1996
EP	0833397	4/1998

* cited by examiner

Primary Examiner—Laura Weiner
(74) *Attorney, Agent, or Firm*—Beyer Weaver & Thomas, LLP

(57) ABSTRACT

A zinc electrode composition for use in low toxicity, high energy density cells having an alkaline electrolyte. The zinc electrode comprises zinc oxide, a binder, and from between 0.1 up to 10% of a fluoride of an element chosen from the group consisting of beryllium, magnesium, calcium, strontium, barium, titanium, aluminum, and combinations thereof. The invention also provides an electrochemical cell having an electrode as noted above. The inventive cell further comprises an electrolyte which contains a mixture of sodium, potassium, and lithium hydroxides, together with boric acid. The excess alkali hydroxide is present in the range of 2.7 to 5M, and the concentration of boric acid is between 0.6 and 1.3 moles per liter.

4 Claims, No Drawings

150 Years and Only 4 Proven Battery Chemistries ….We've Commercialized The 5th

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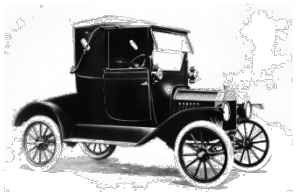

Lead Acid

Ni-Cad

Ni-MH

Li-Ion

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Ni-Zn

1860s **1960s** **1980s** **1990s** **2010s**

NiZn Benefits over NiMH and Li Ion Technologies

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vs. Ni-MH and Ni-Cd

NiZn:

- 25% smaller - 1.6v vs. 1.2v
- 30% lighter
- >25% more powerful: Lower cell impedance and fewer cells in series
- Lower $/KWh than Ni-MH
- Environmentally friendly:
  - *No* rare earth elements

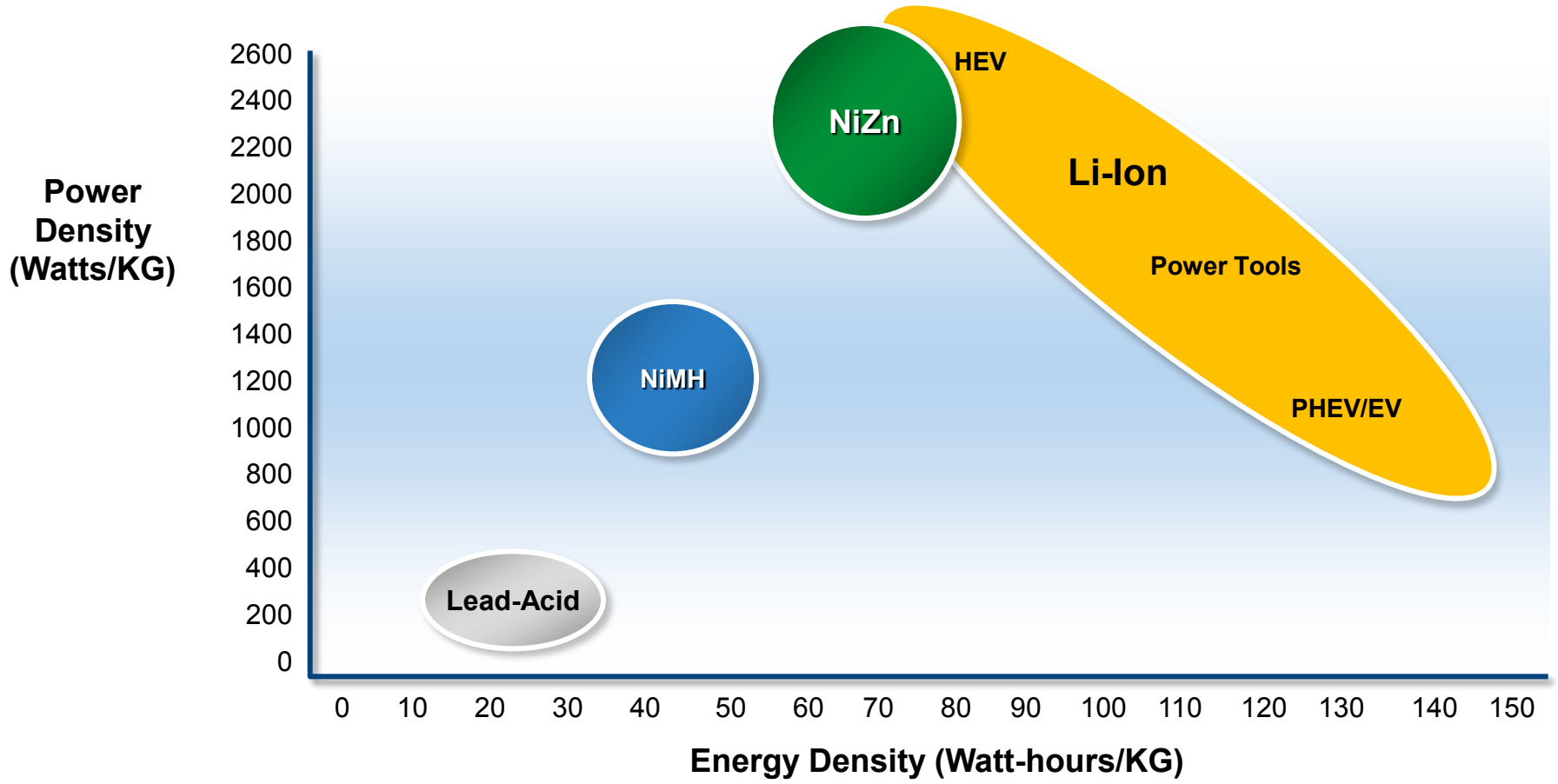
vs. Li-Ion

NiZn:

- Competitive power density
- Up to 50% lower cost in power applications
- Safe: NiZn has an aqueous (vs. organic) electrolyte

- Meets RoHS: No Cd, Pb, As, or Hg

Ni-Zn: Small and Light and Powerful



Sources: Ricardo Consulting, AABC, PowerGenix estimates

Ni-Zn: Safe High Power at Low Cost

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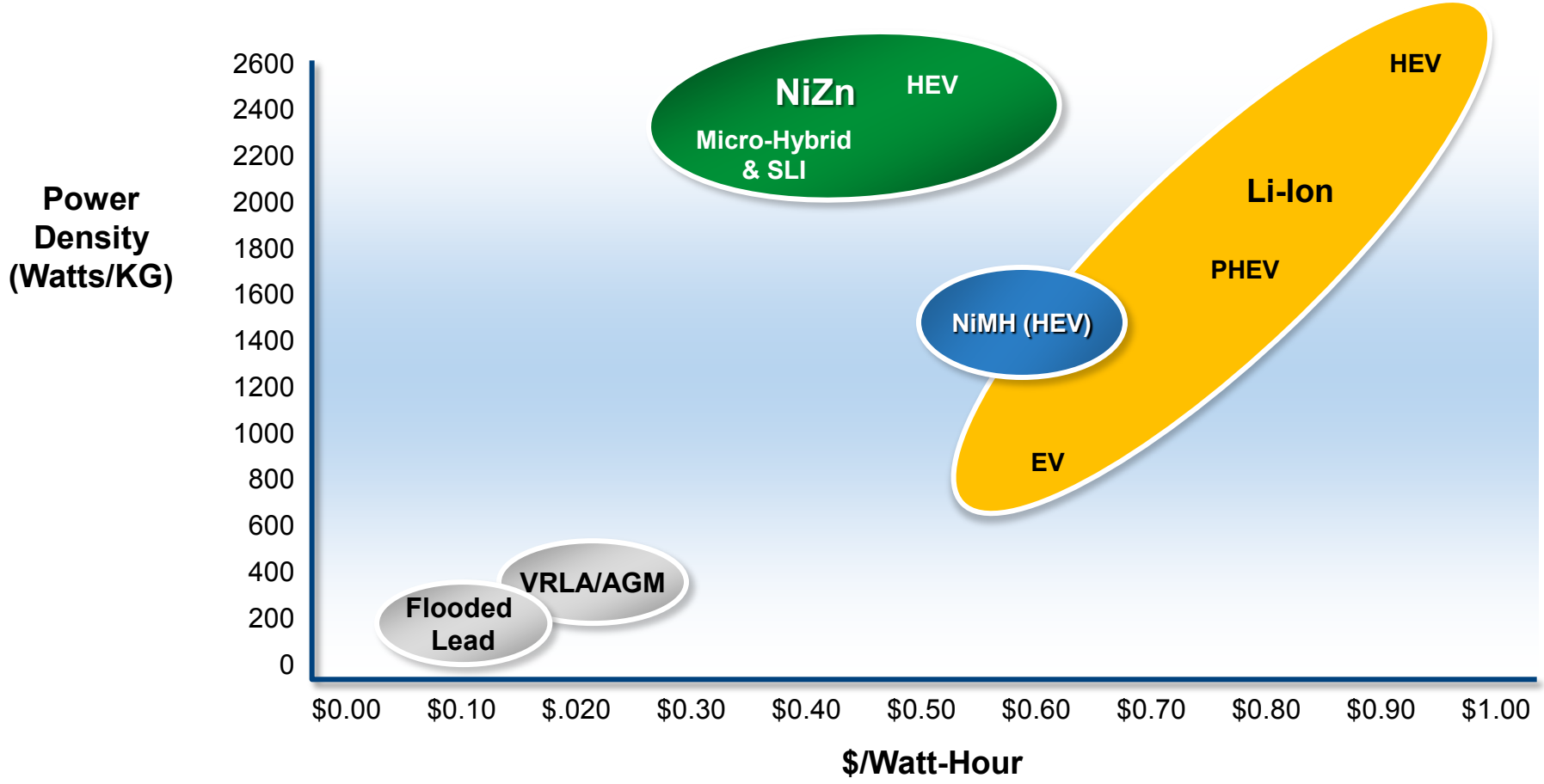

Sources: Ricardo Consulting, AABC, National Academy of Sciences, PowerGenix estimates

PowerGenix High Power Sweet Spot: Batteries for HEVs

POWERGENIX

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Li-Ion

VRLA (Lead)

NiMH

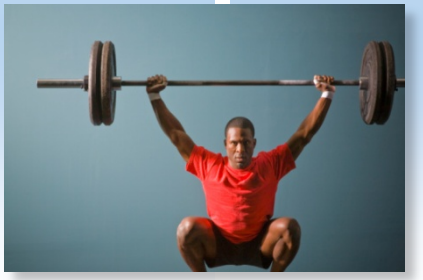
MICRO-HYBRID	MILD-FULL HYBRID	PLUG-IN HYBRID	ELECTRIC VEHICLE

THE REQUIREMENTS

A NATURAL FIT

POWER

ENERGY



BURSTS OF POWER

ENDURANCE

Ni-Zn Leads the Way in Recyclability

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Li-Ion

- 1/2 of Materials Unrecoverable
- Extensive Processing Required for Material Recovery

Ni-MH

- Nickel and Steel Converted to Stainless Steel
- Rare Earth Metals Lost as Slag

Ni-Zn

- **No** Lead or Rare Earth Metals
- All Zinc, Copper, Nickel Recaptured and Saleable on Commodity Market
- Comparable Recycling Performance to Lead-Acid

Sources: AltEnergyStocks.com

Licensing Monetizes Non-Core Segments

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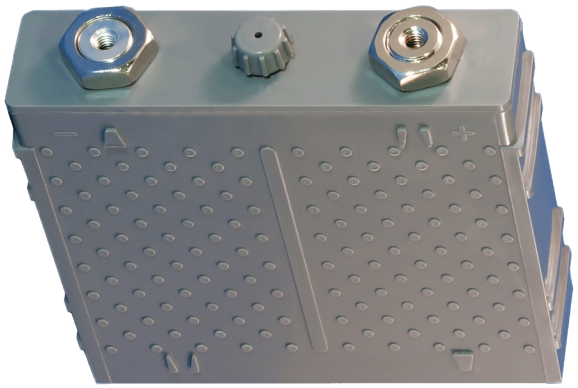
PRISMATIC PLATFORM



- Hybrid Electric Vehicles
- Stationary Storage
- Military

INDUSTRIAL CYLINDRICAL CELLS (AA/AAA, SC, D)

- Reserve Power/UPS
- Industrial/ Power Tools
- Consumer

Contents

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- ✓ A Differentiated Chemistry
- Superior Battery Solution for Huge Market
- Test Data Demonstrate NiZn Performance

The Micro-Hybrid Vehicle Characteristics

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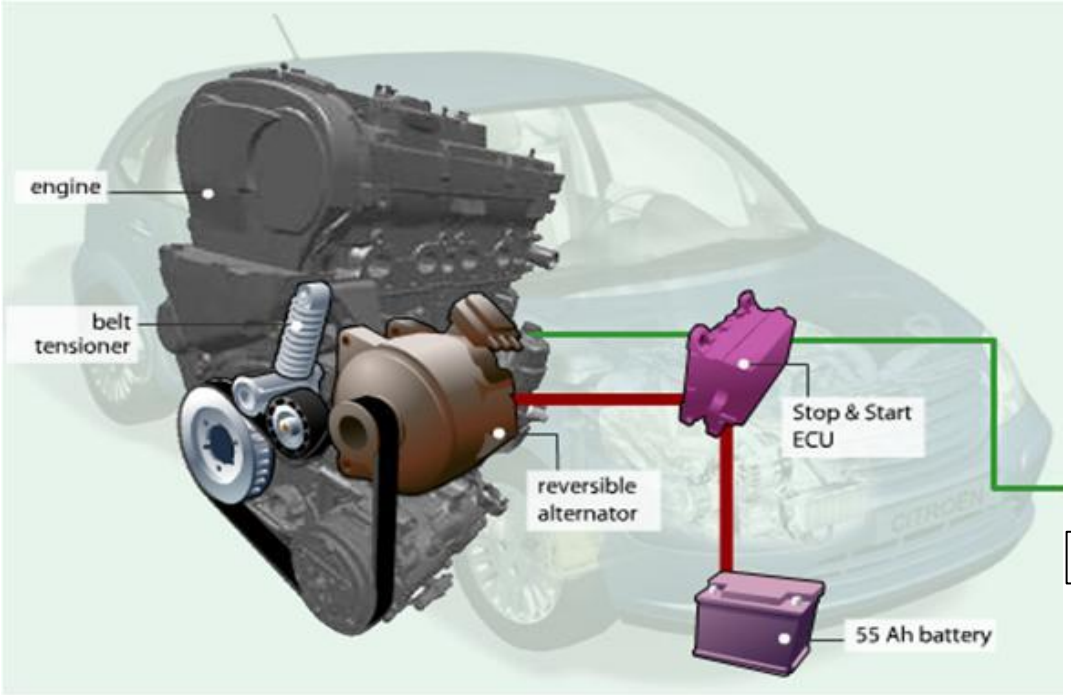

Vehicle ECU

- **Start-Stop is an automated engine on-off capability**
- **$150-$750 system cost with 3-10% fuel savings-up to 20% in heavy traffic**
- **Low cost implementation allows acceptable pay back time**

Graphics Source: PSA Peugeot-Citroen

Dramatic Market Growth in Start-Stop Segment

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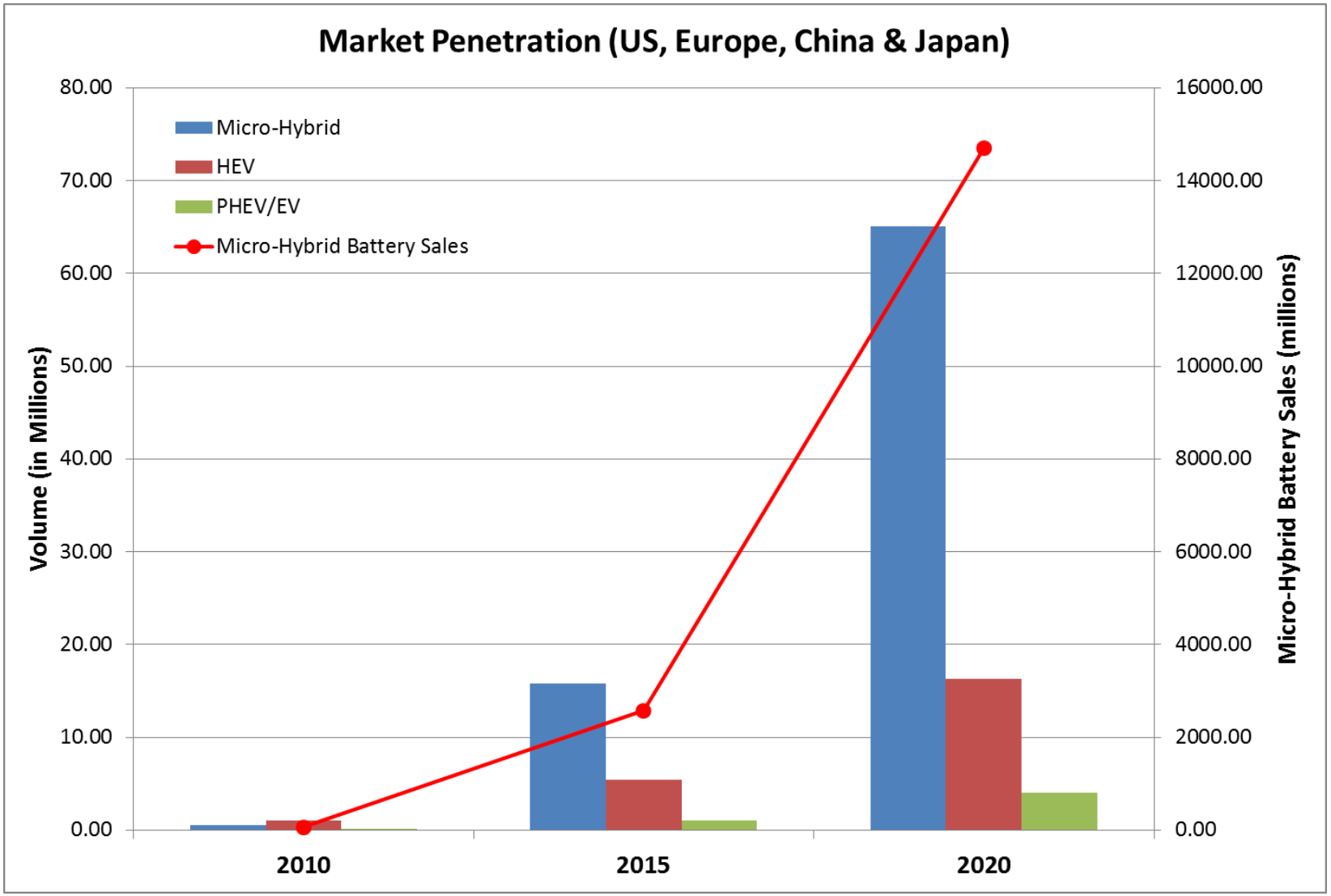

Sources: Ricardo Consulting, AABC, JD Power, Pacific Crest, industry sources, and PowerGenix Estimates

Simple Economics is Driving the Segment's Explosive Growth

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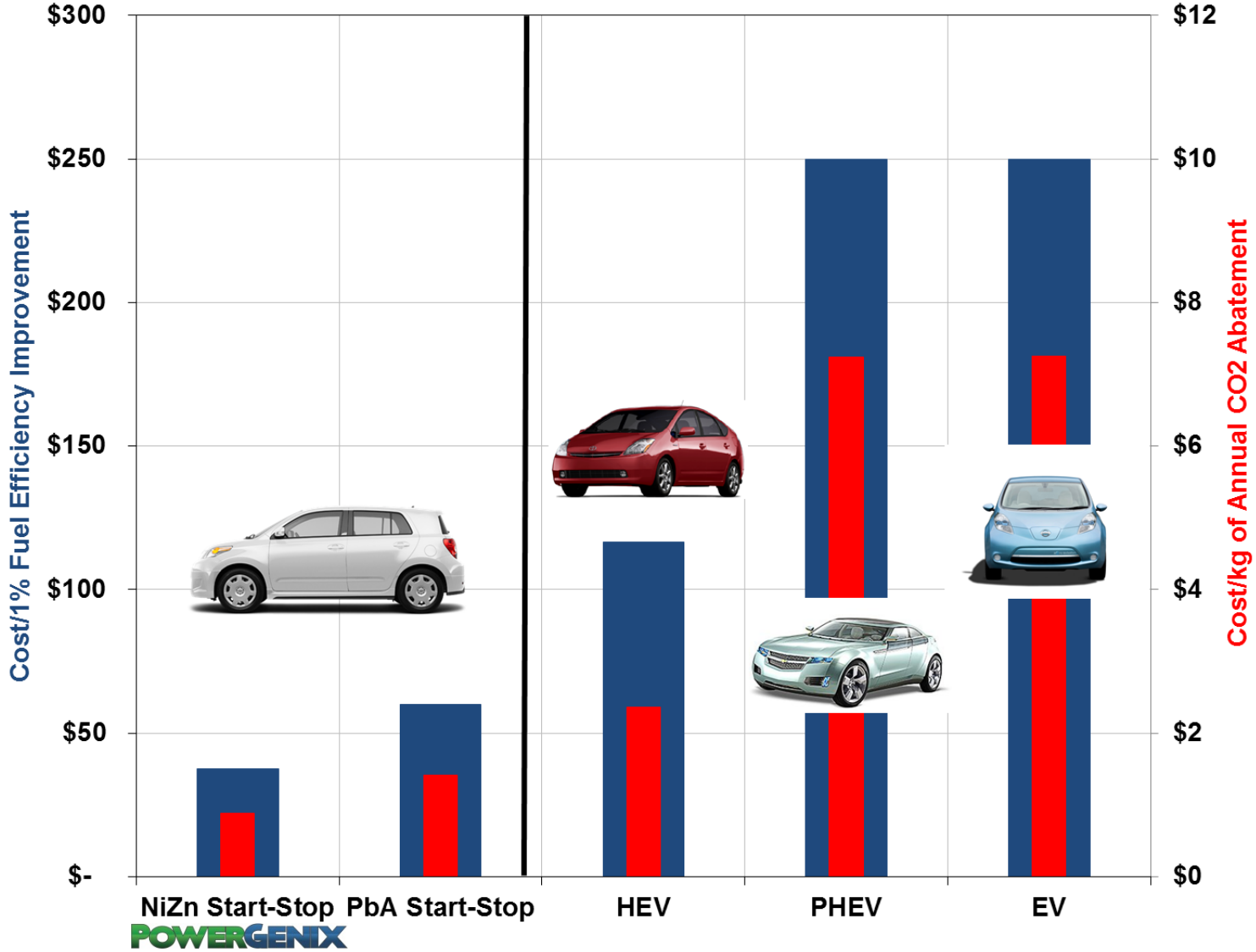

Sources: PowerGenix calculations based on data from Ricardo Consulting, AABC, Pacific Crest, and automotive OEM's

Ni-Zn's Advantages are Significant

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VRLA (Lead)

Ni-Zn

Half the Weight

Twice the MPG Gain

Twice the Life

Half the Total Cost

Why Ni-Zn

Ni-Zn vs. Lead-Acid for Micro-Hybrids: Dramatic Improvement in Weight and Performance

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VRLA (Lead)

Ni-Zn

Parameter	Lead-Acid	PGX NiZn
Form Factor	Prismatic	Prismatic
Nominal Voltage	12V	13.2V
Nominal Capacity	80 Ah	55 Ah
Pack Energy	960Wh	726Wh
Gravimetric Energy Density	35Wh/kg	**72 Wh/kg**
Gravimetric Power Density	400W/kg	**860W/kg**
Bare Pack Weight	27.5kg	**10.1 kg**
Service Life	2 Years	**5 Years**

Contents

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- ✓ A Differentiated Chemistry
- ✓ Superior Battery Solution for Huge Market
- ☐ Test Data Demonstrate Ni-Zn Performance

Key Battery Requirements for Micro-Hybrids

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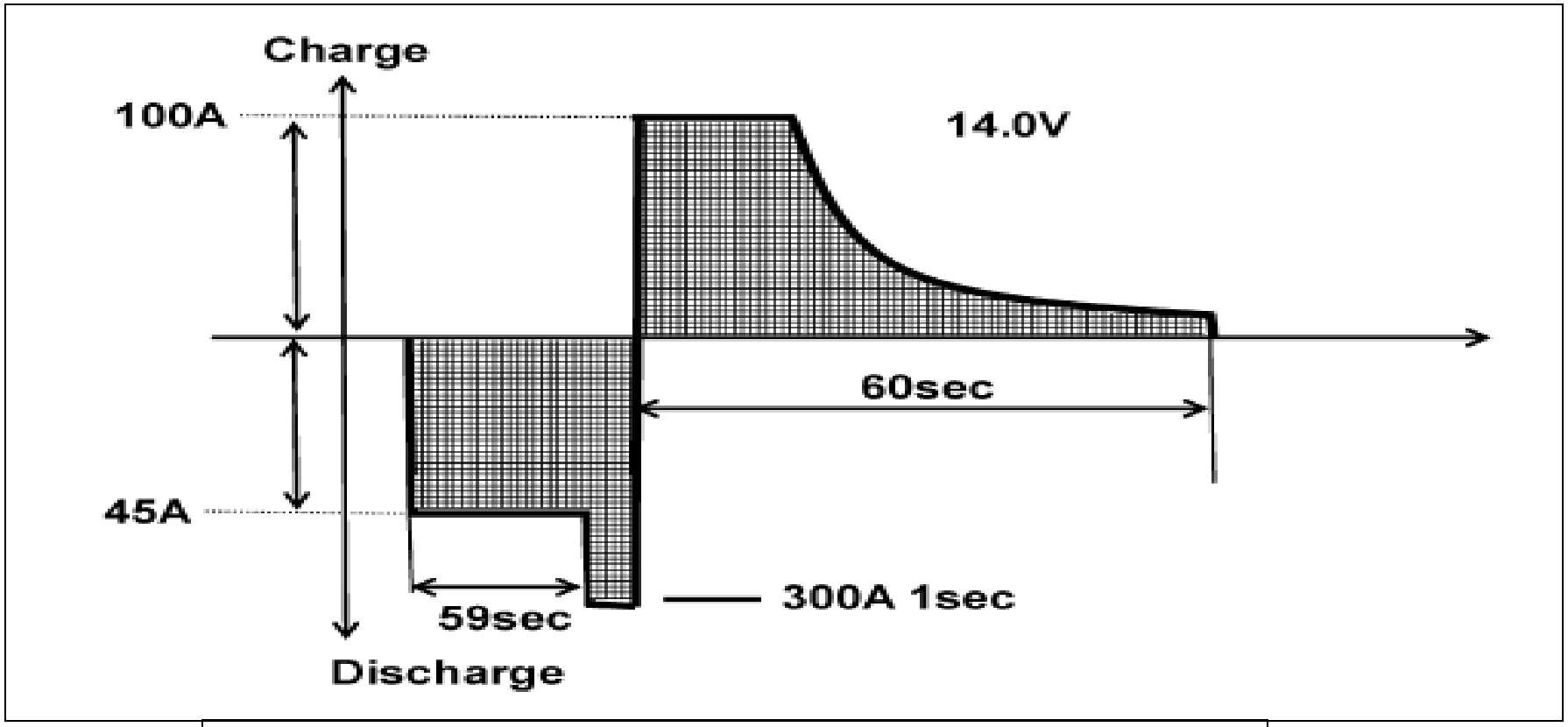
- **Sustained charge acceptance over service life**
  - **Maximum start-stop duty cycle and increased fuel efficiency**
  - **More demanding future requirements (regenerative braking)**
- **Operation at partial states of charge**
- **Voltage stability during engine start**
- **High & low temperature operation**
- **Small, lightweight, “one-box solution” with simple battery management**
- **Low purchase cost and total cost of ownership**

Japan (BAJ) Micro-Hybrid Standard: SBA-S-0101 test at 25℃

POWERGENIX

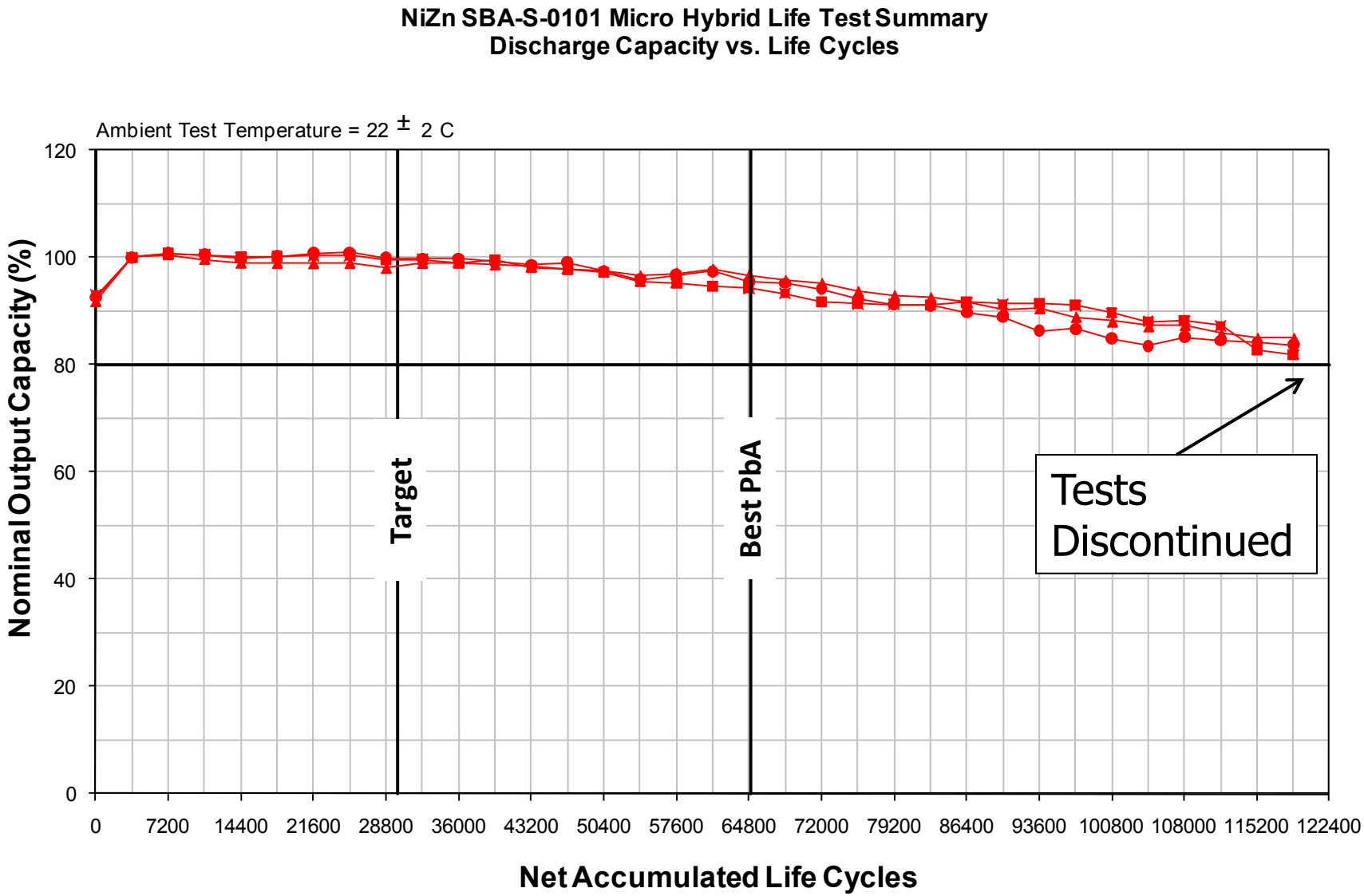


Idling-stop profile for cycle life test(SBA-S-0101)

Test method: Batteries are subjected repetitively to this profile for 3600 cycles, and are then placed on a 100% DOD charge/discharge cycle after a 48-hour rest

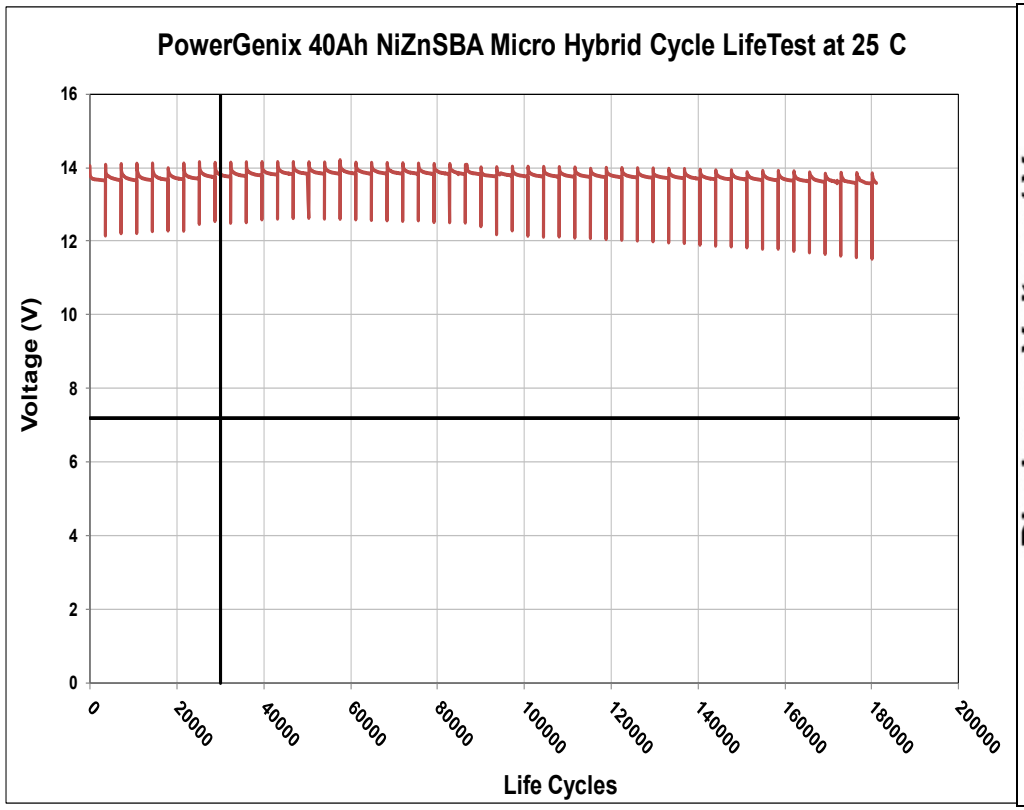
NiZn Micro Hybrid Cycle Life Performance: Cylindrical Cells

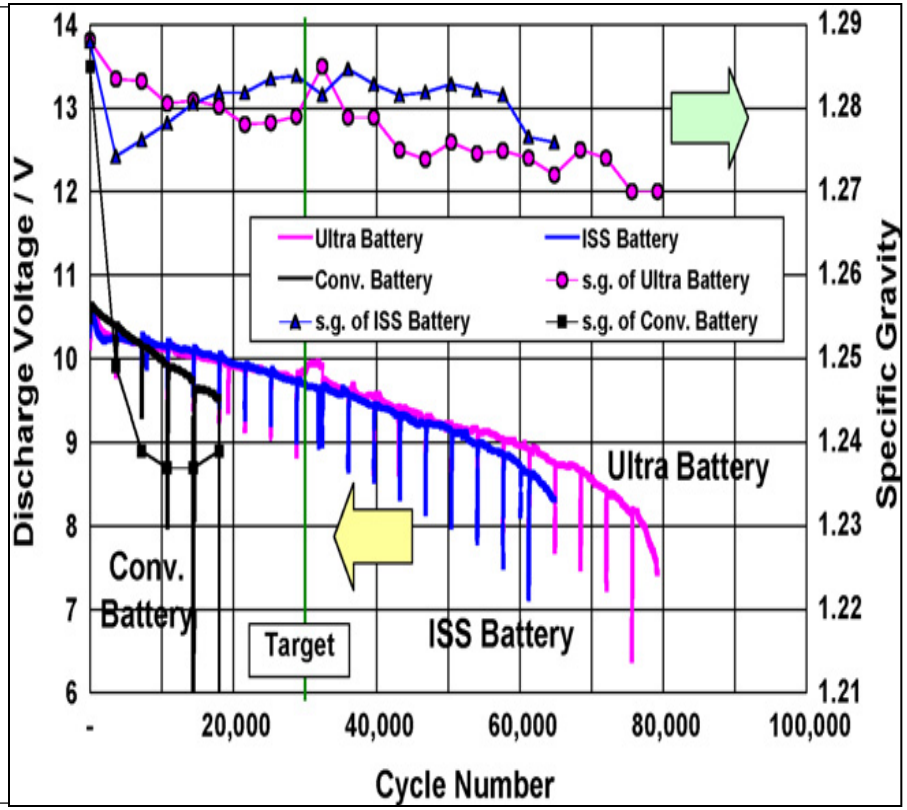
POWERGENIX



Superior NiZn Performance vs. PbA Under SBA-S-0101 Life Cycle

POWERGENIX



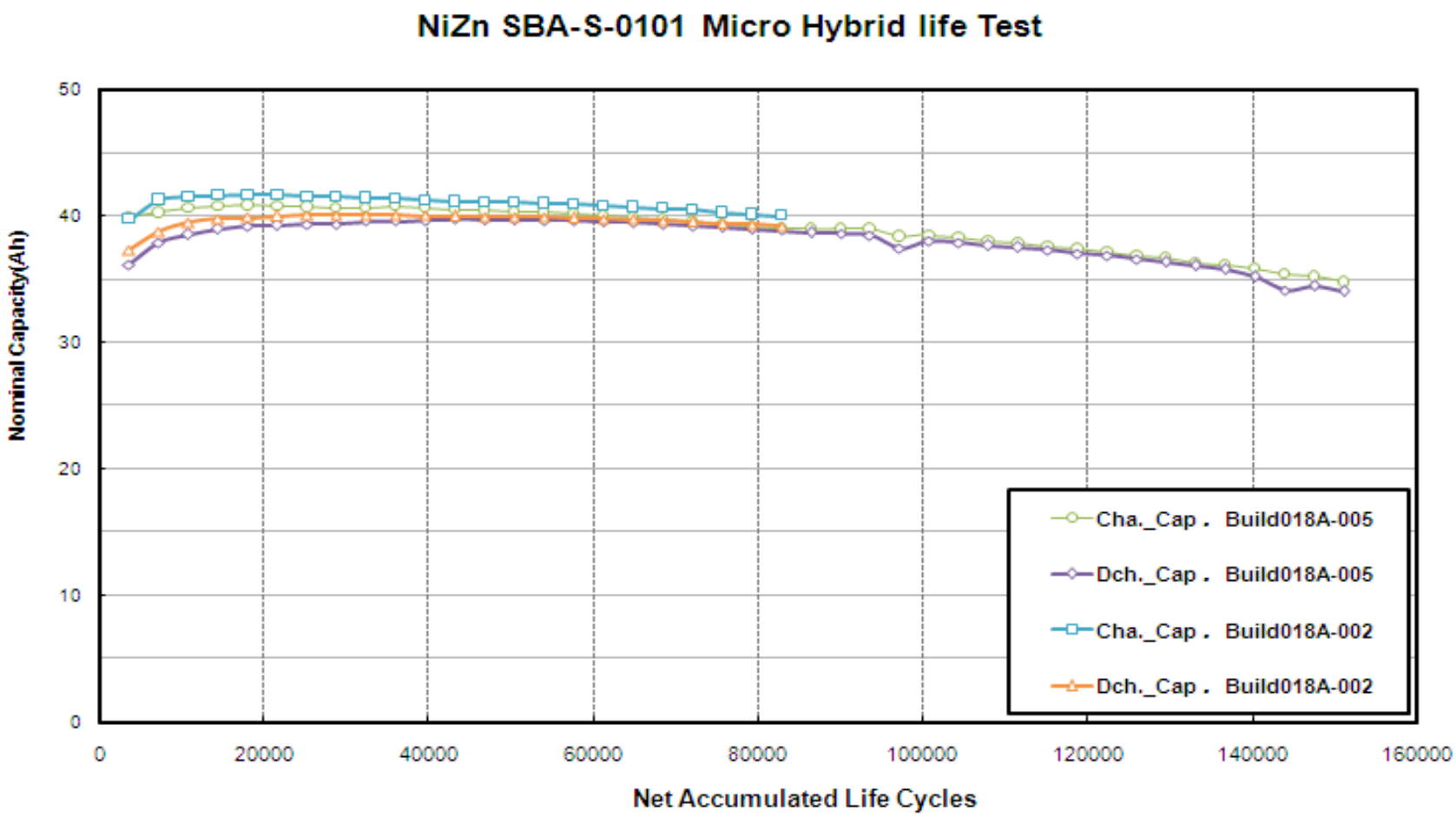


12V40Ah NiZn Packs **Lead Acid**

Source: *Further demonstration of the VRLA-type Ultra-Battery under medium-HEV duty and development of the flooded-type Ultra-Battery for micro-HEV applications* - Journal of Power Sources 195 (2010) 1241–1245.

The Stable Measured Capacity During the SBA Test

POWERGENIX



High Temperature Operation Remains Stable

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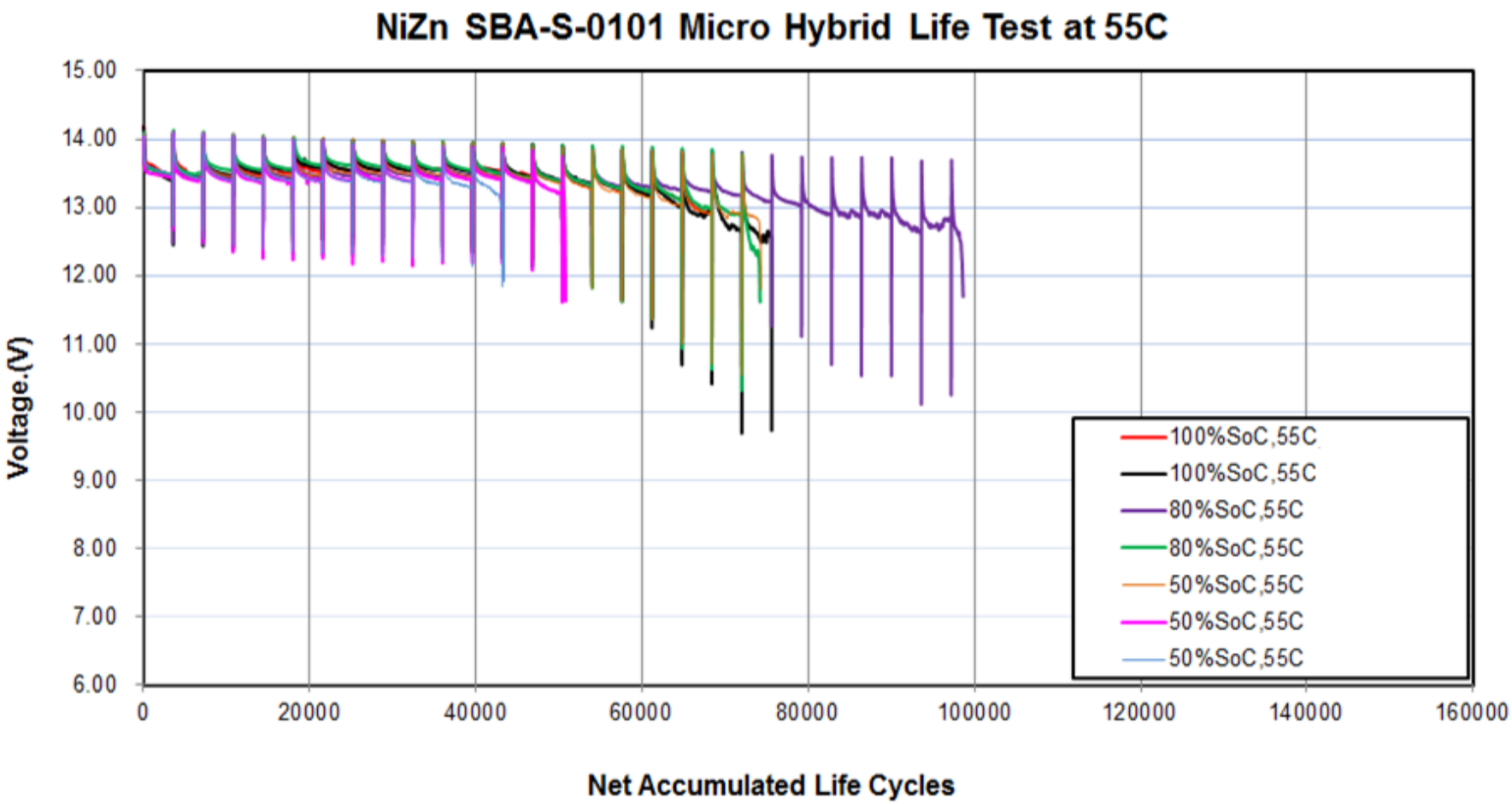
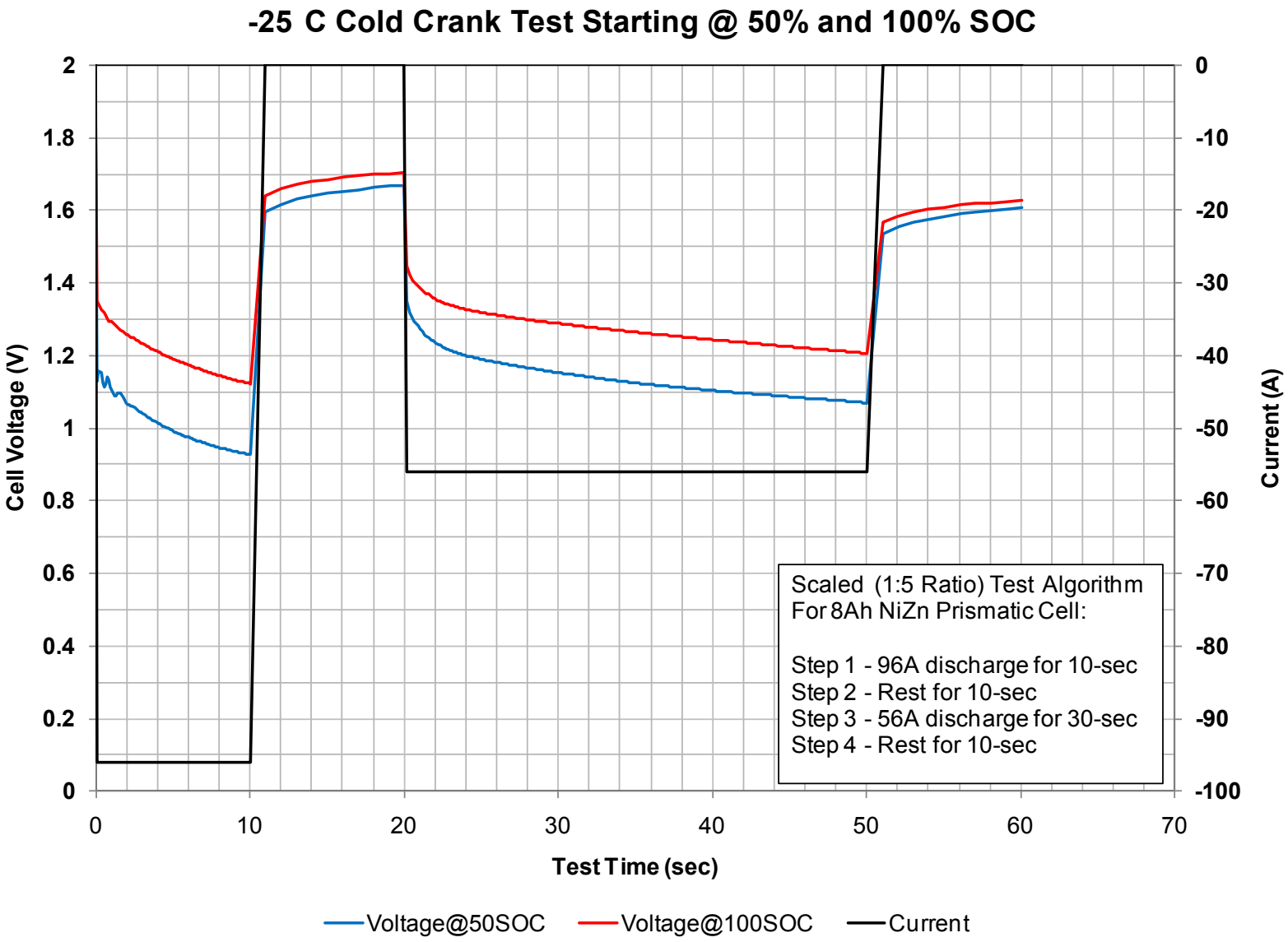


- **At 55°C the cells sustain 70,000 test cycles**
- **This represents around 6 years service life of continuous operation at 55oC**
- **The data implies under hood conditions are well tolerated by this chemistry**

Pass Cold Crank Test at 50% SOC and 100% SOC

POWERGENIX



Discharge Characterization at Various Rates

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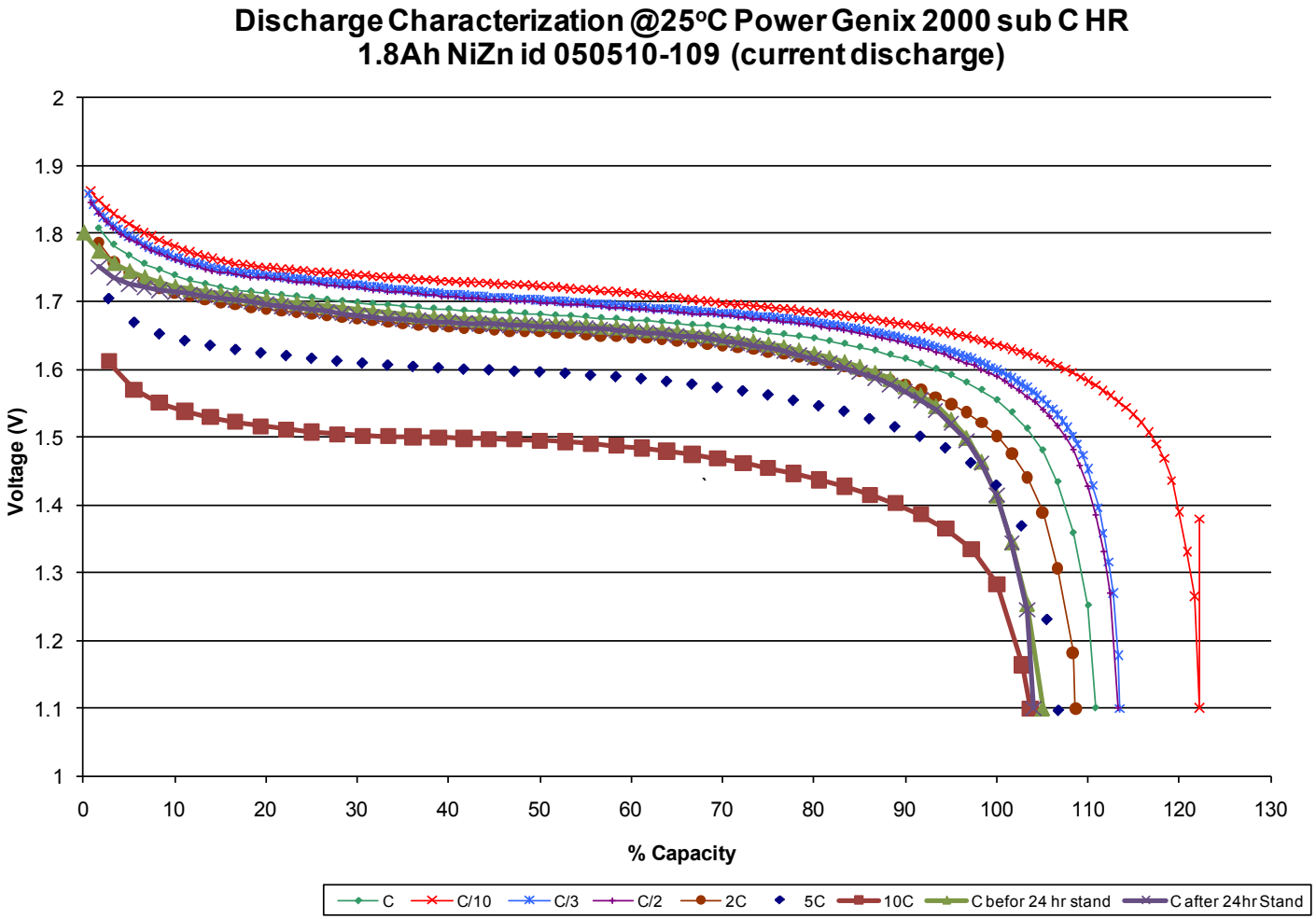

Source: US Army RDECOM-TARDEC

Cycle life at 80% DOD, at 30A @ RT

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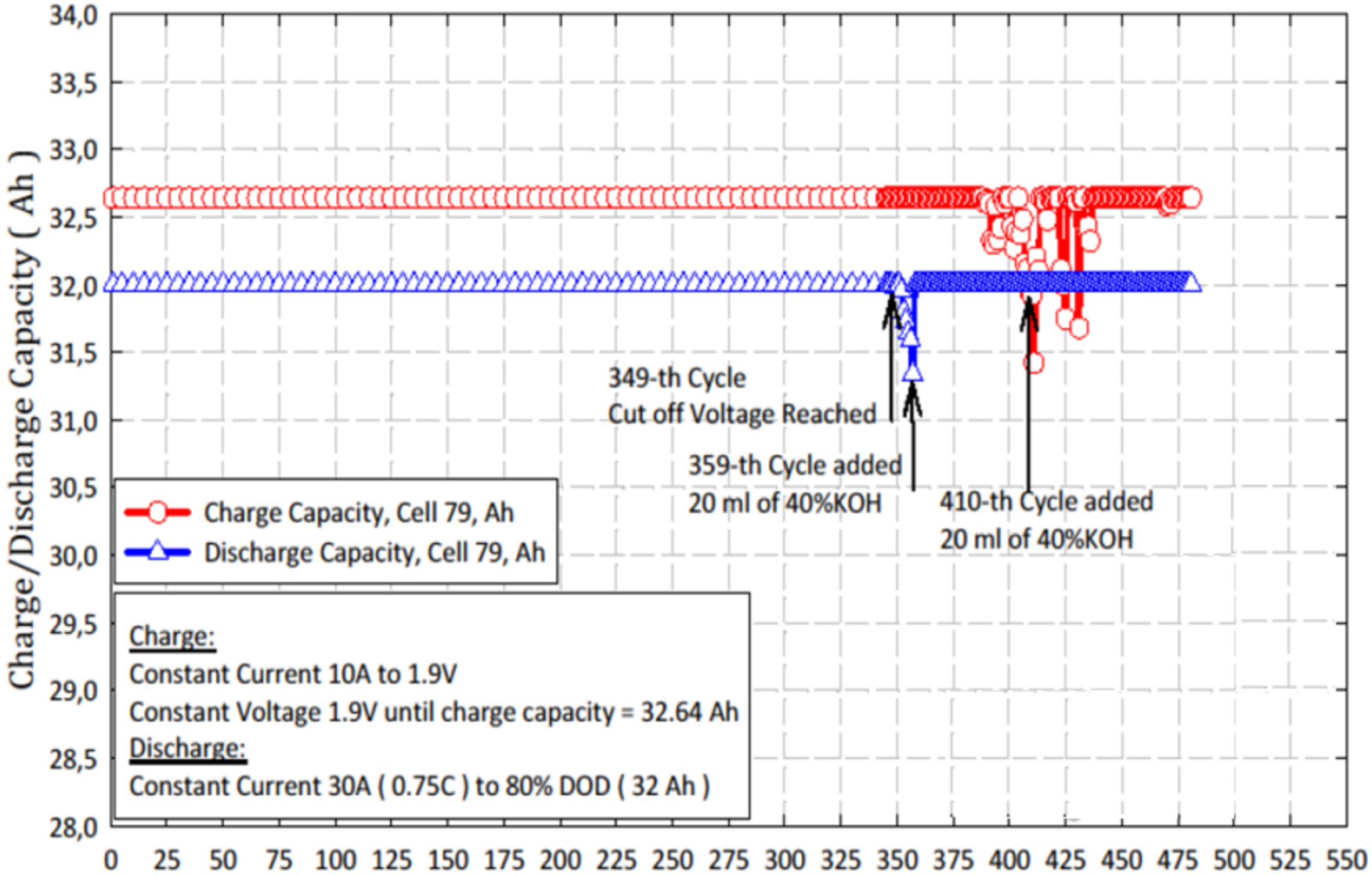
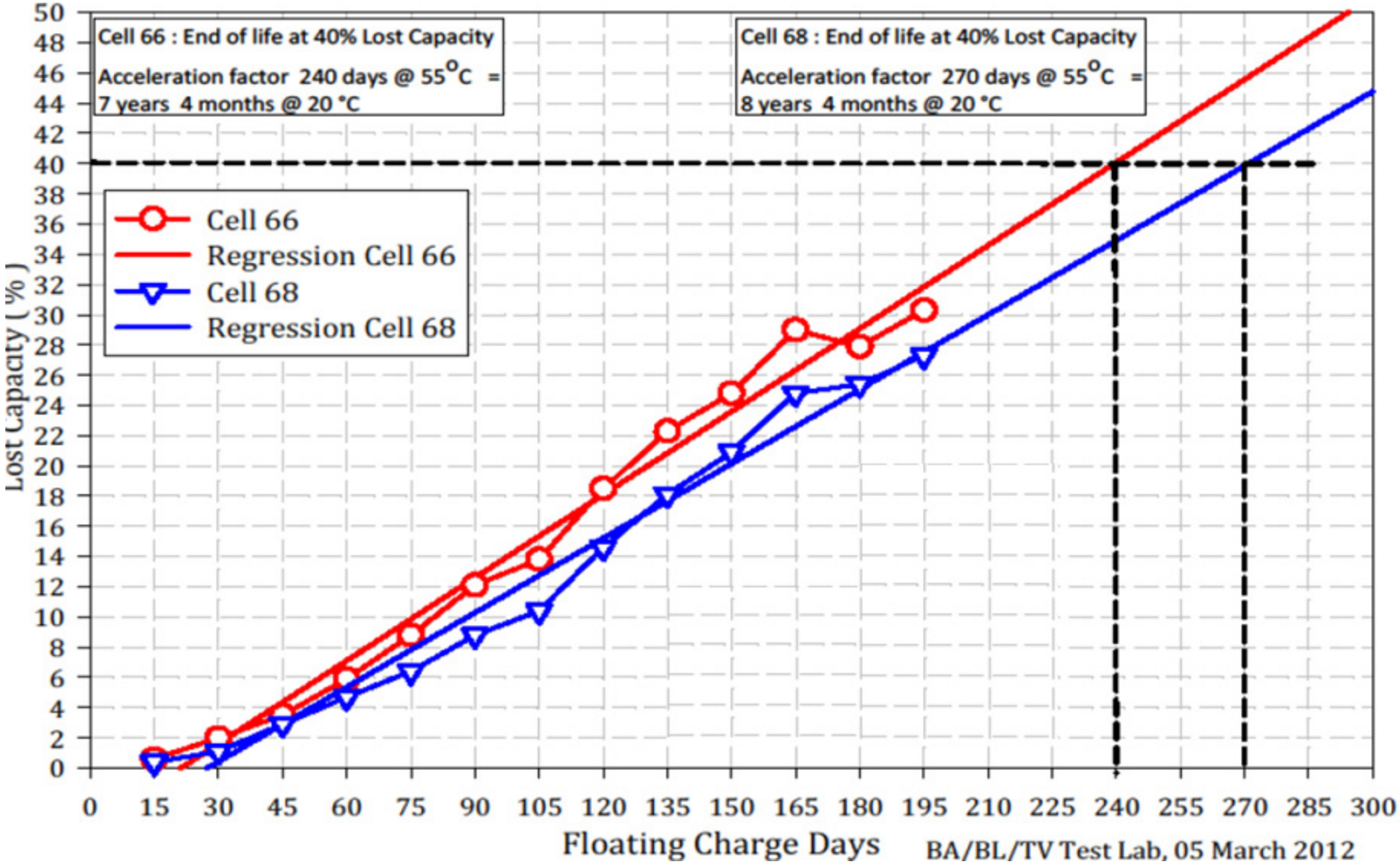


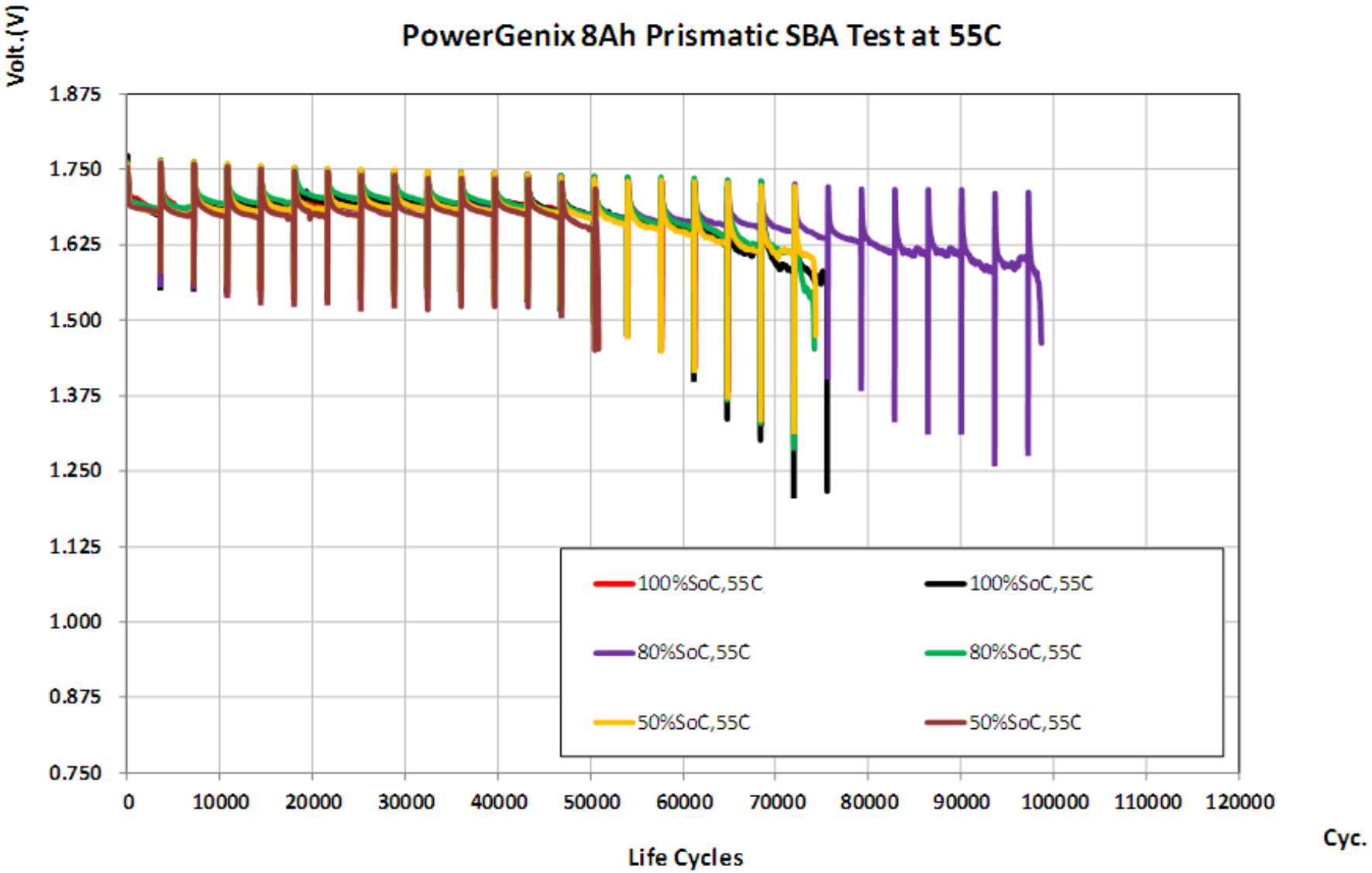
Cells 66 and 68-Floating Charge at Constant Voltage 1.85V&55 Degrees

POWERGENIX



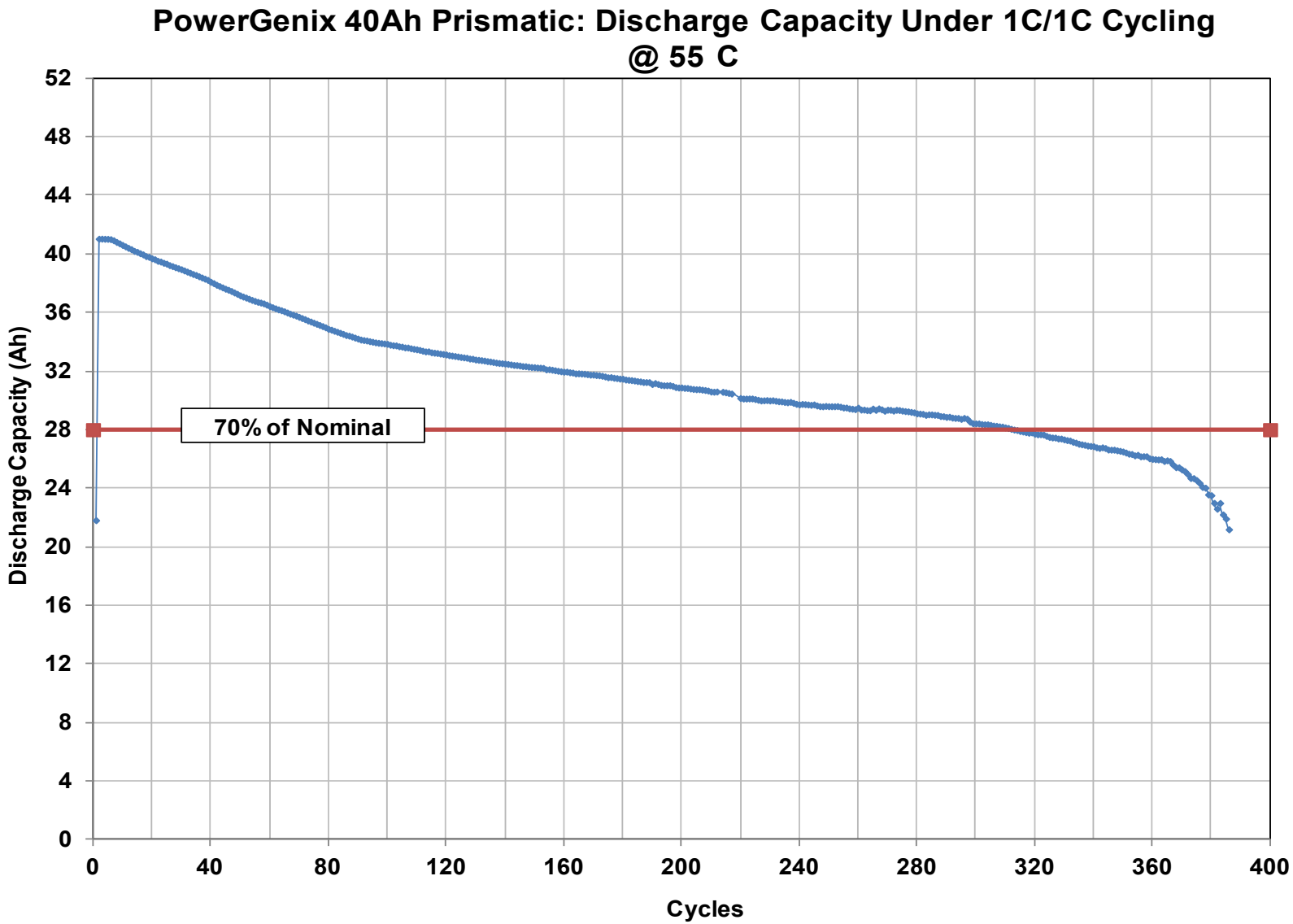
Exceptional High Temperature Performance Under SBA-S-0101 Cycle Life @ 55° C

POWERGENIX



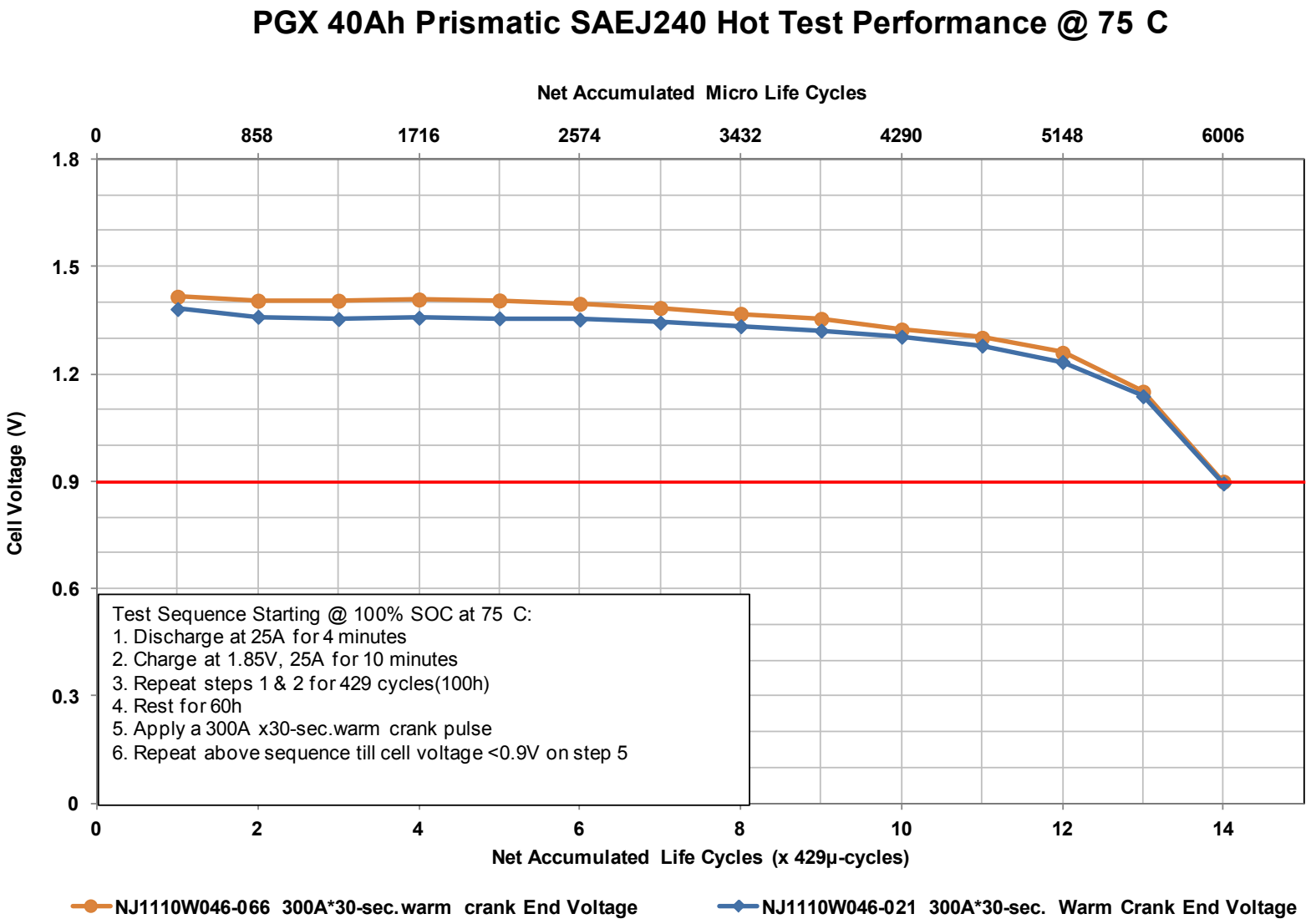
Exceptional High Temperature Performance Under 1C/1C 100% DOD Cycle Life @ 55° C

POWERGENIX



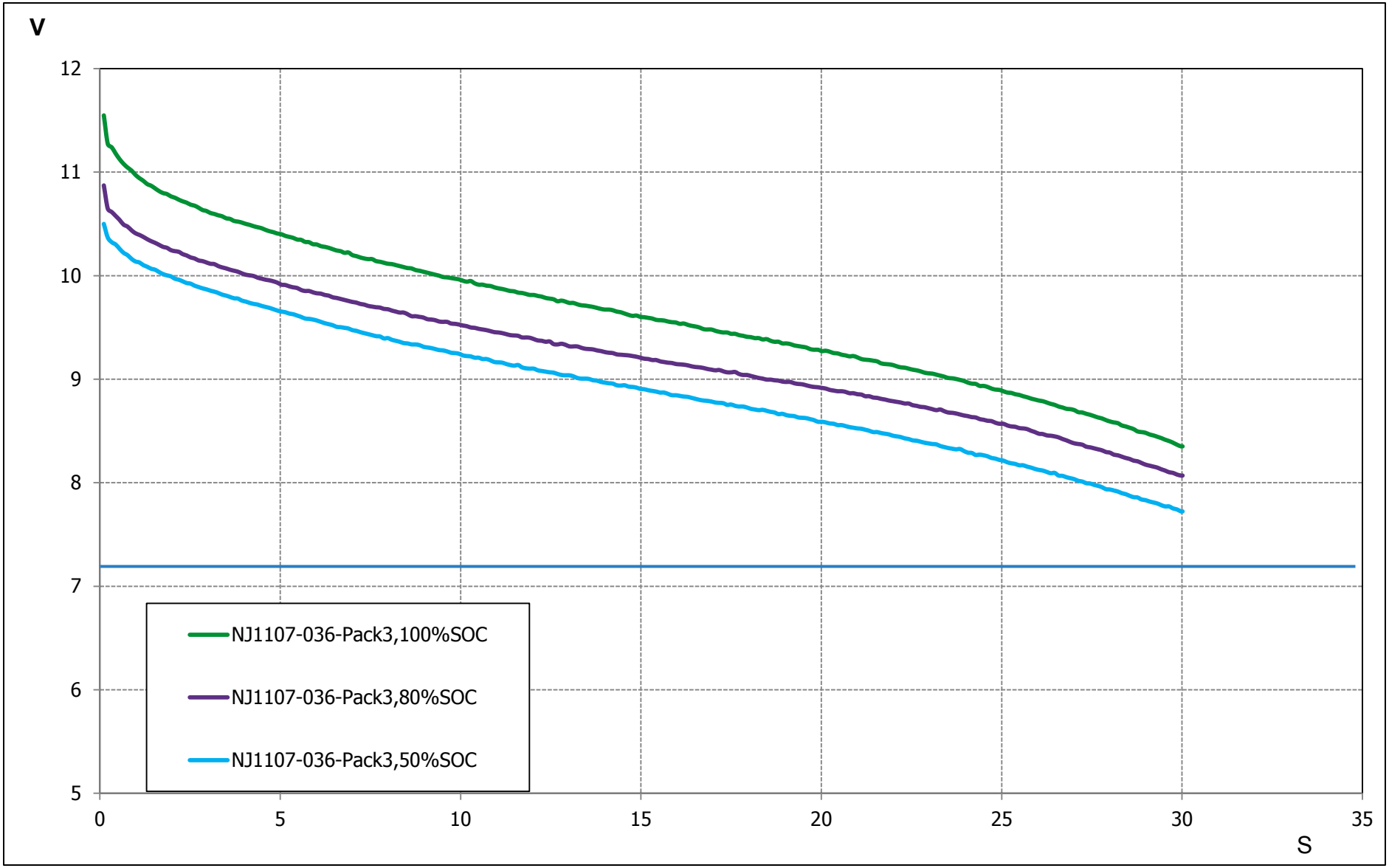
Superior NiZn High Temperature Performance Under SAE J240 Hot Test

POWERGENIX



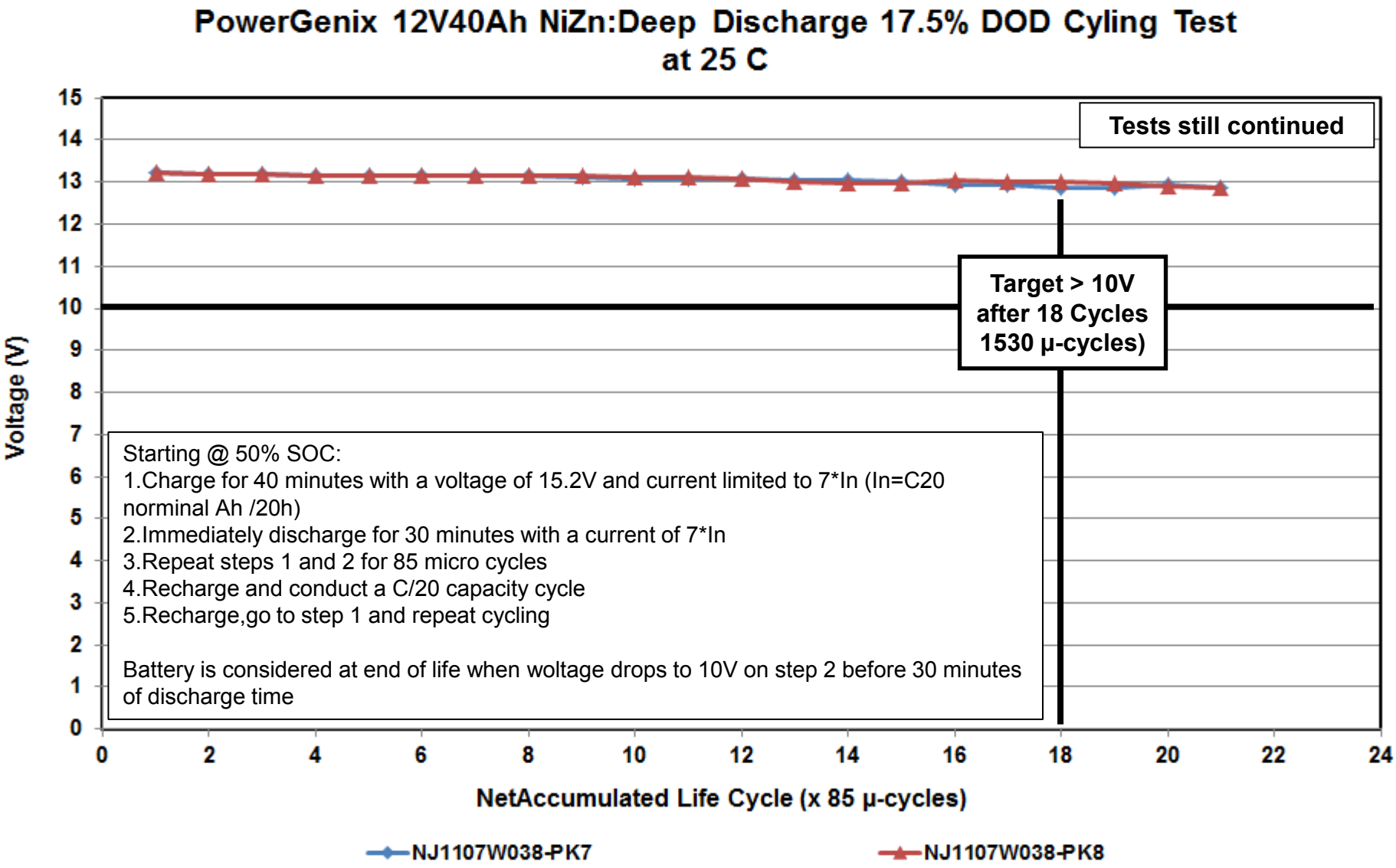
Exceeds 300A x 30-sec. JIS D5301 Cold Crank Test Requirements @ -18℃

POWERGENIX



Excellent Cycle Life Performance Under 17.5% DOD Test

POWERGENIX



Starting @ 50% SOC:
1.Charge for 40 minutes with a voltage of 15.2V and current limited to 7*In (In=C20 norminal Ah /20h)
2.Immediately discharge for 30 minutes with a current of 7*In
3.Repeat steps 1 and 2 for 85 micro cycles
4.Recharge and conduct a C/20 capacity cycle
5.Recharge,go to step 1 and repeat cycling

Battery is considered at end of life when woltage drops to 10V on step 2 before 30 minutes of discharge time

Life Test for Automotive Storage Batteries

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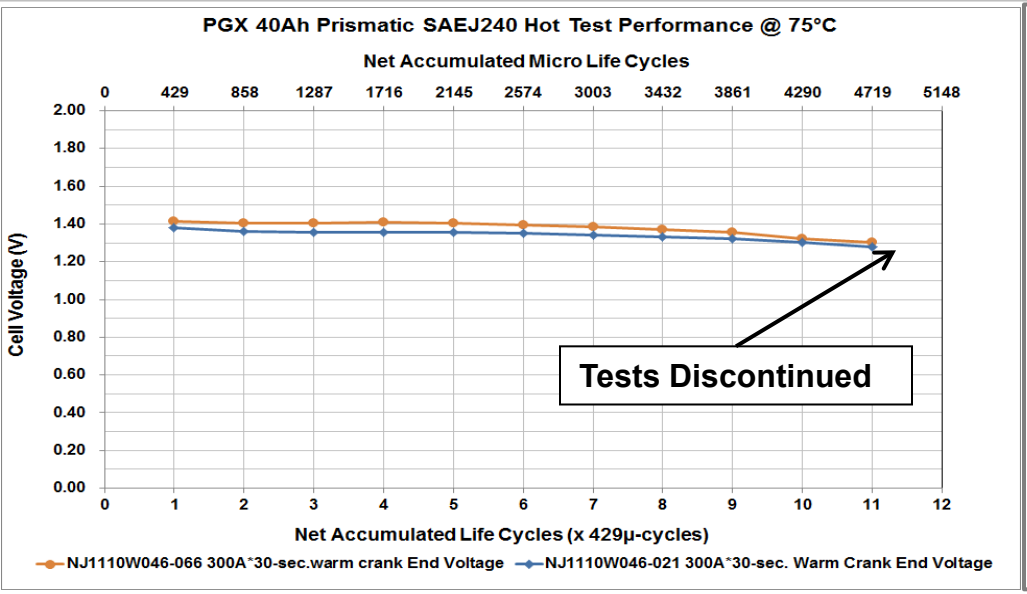

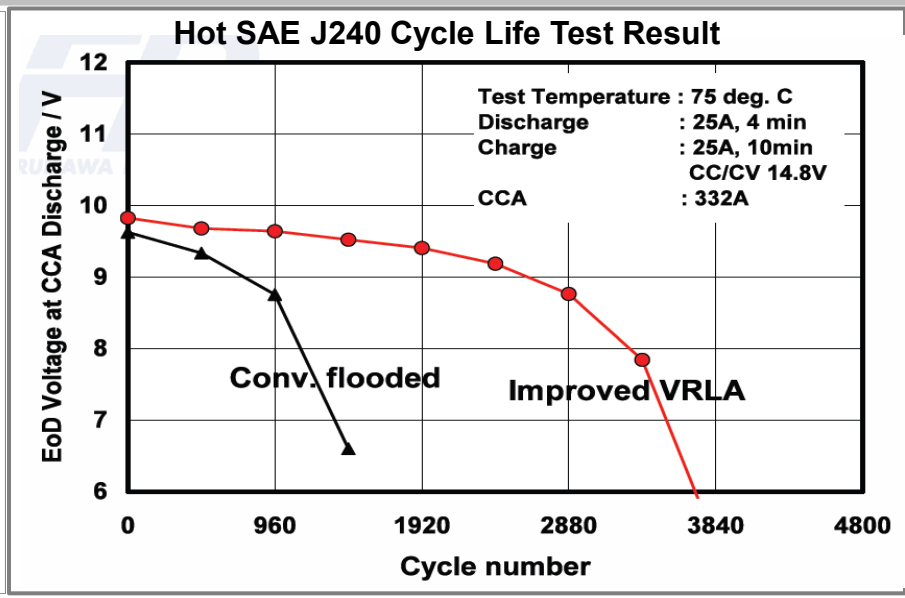

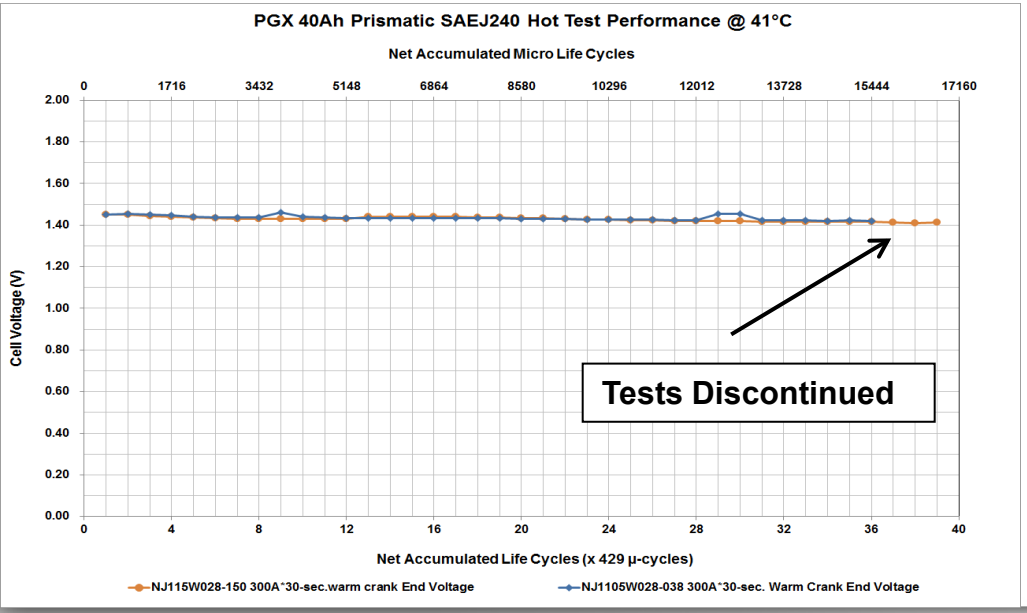

Test Sequence Starting @ 100% SOC

1. Discharge at 25A for 4 minutes
2. Charge at 1.85V, 25A for 10 minutes
3. Repeat steps 1 & 2 for 429 cycles9(100h)
4. Rest for 60h
5. Apply a 300A x30-sec.warm crank pulse
6. Repeat above sequence till cell voltage <0.9V on step 5

Meets EN 50342 Cold Crank Requirements

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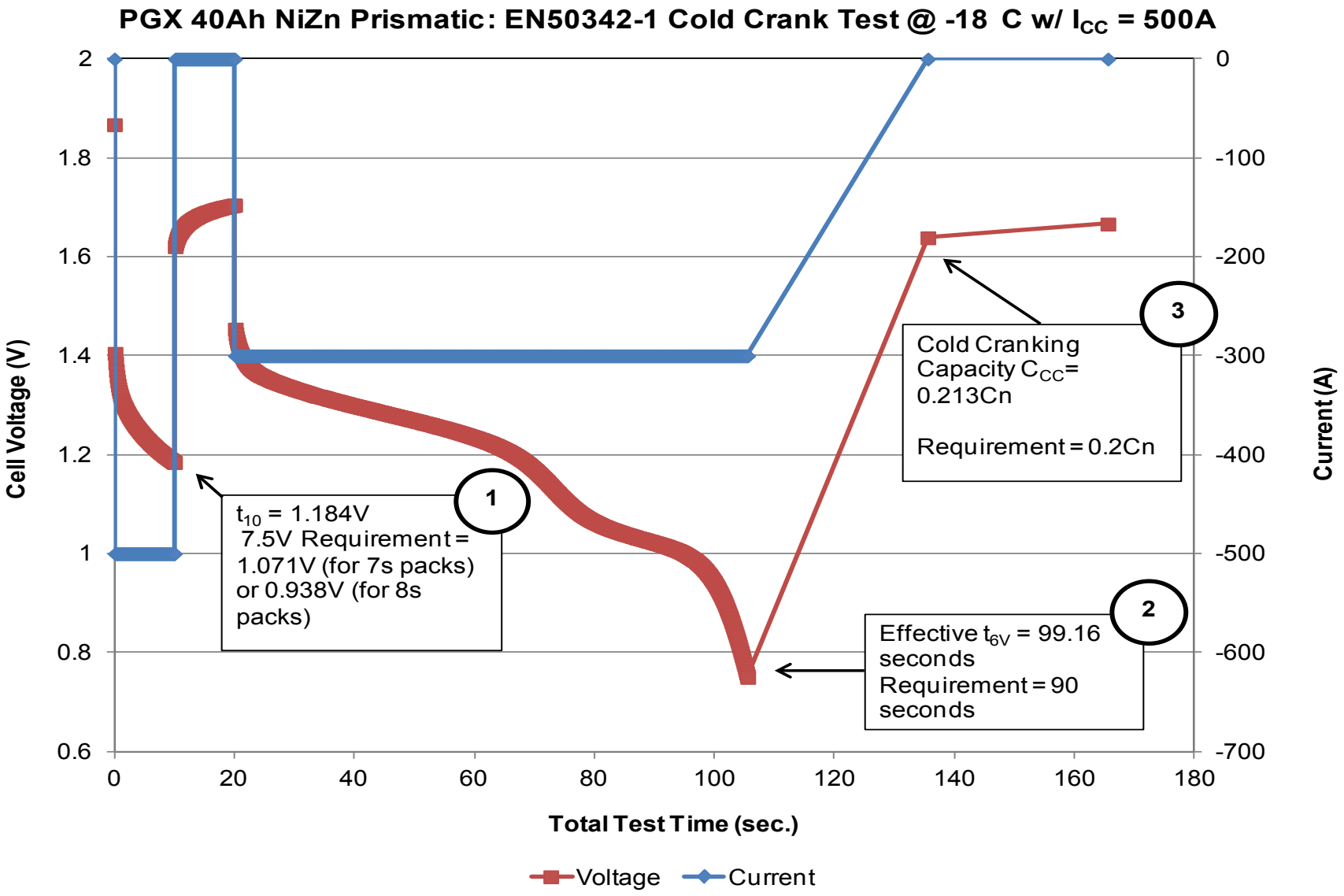

Lower Self Discharge vs. Premium Pure Lead AGM Batteries

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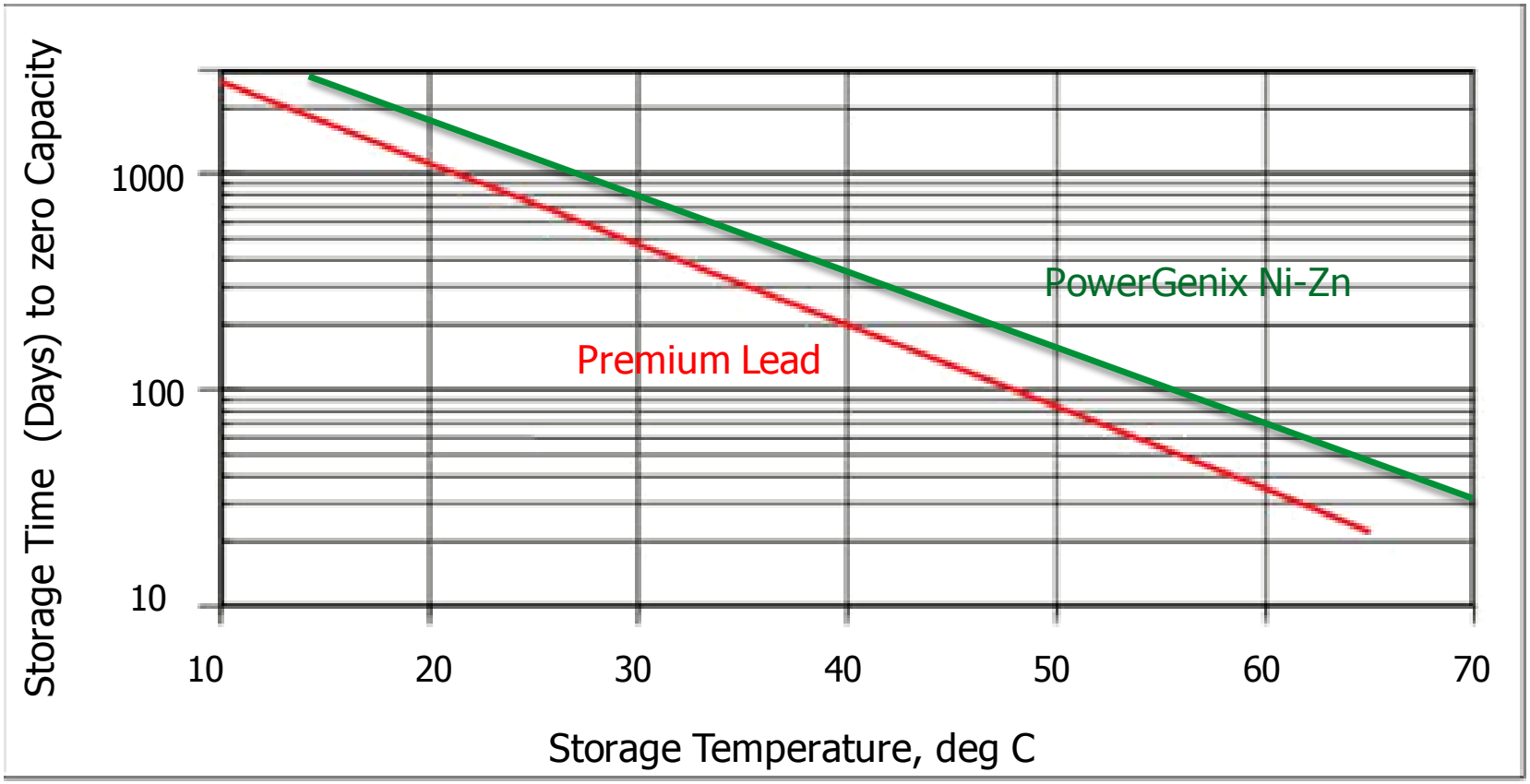
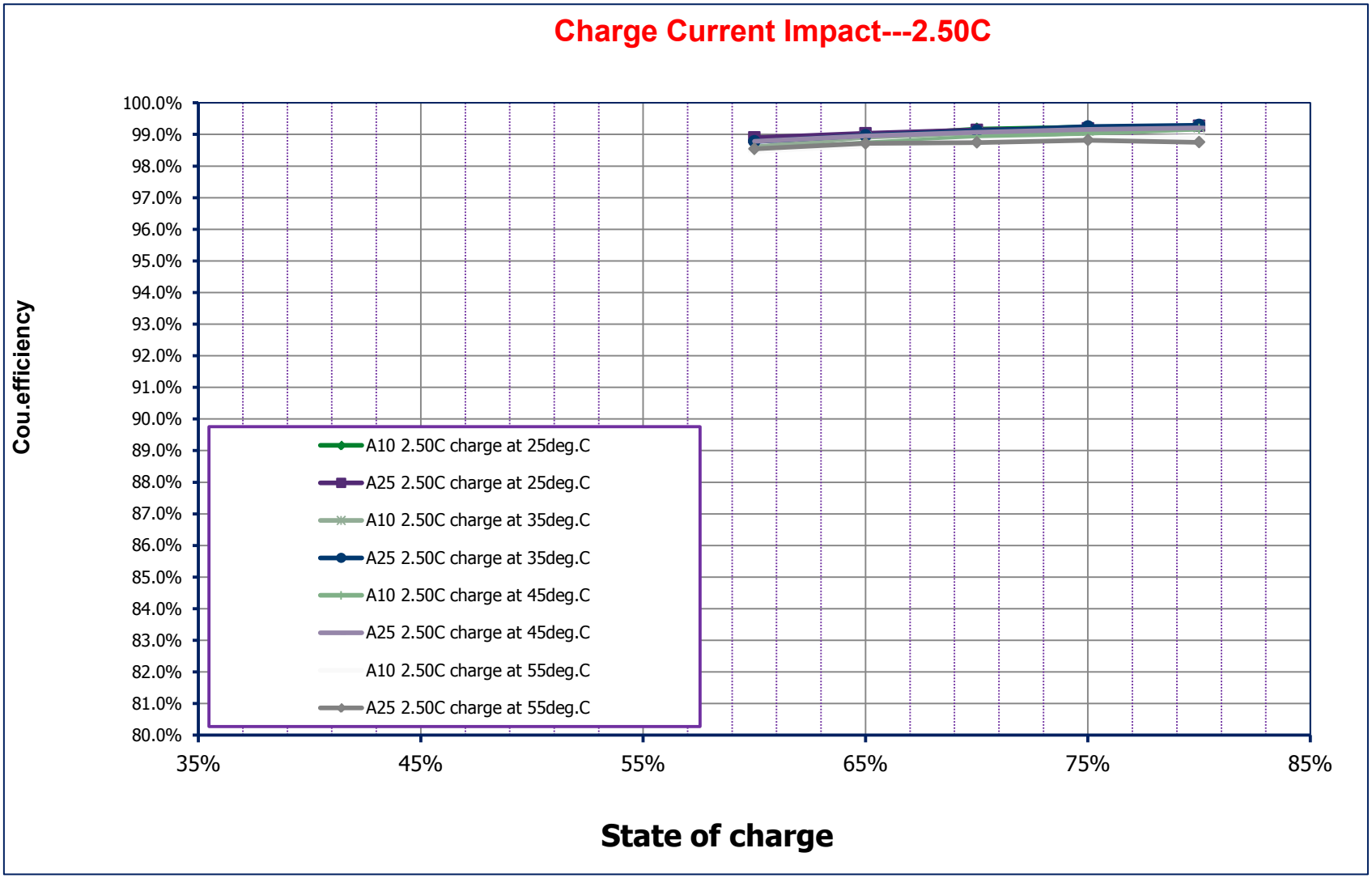


>98% Charge Acceptance at 100A Constant Current Across Large SOC & Temperature Range

POWERGENIX



NiZn Charge Acceptance Characterization – Different Charge Rates

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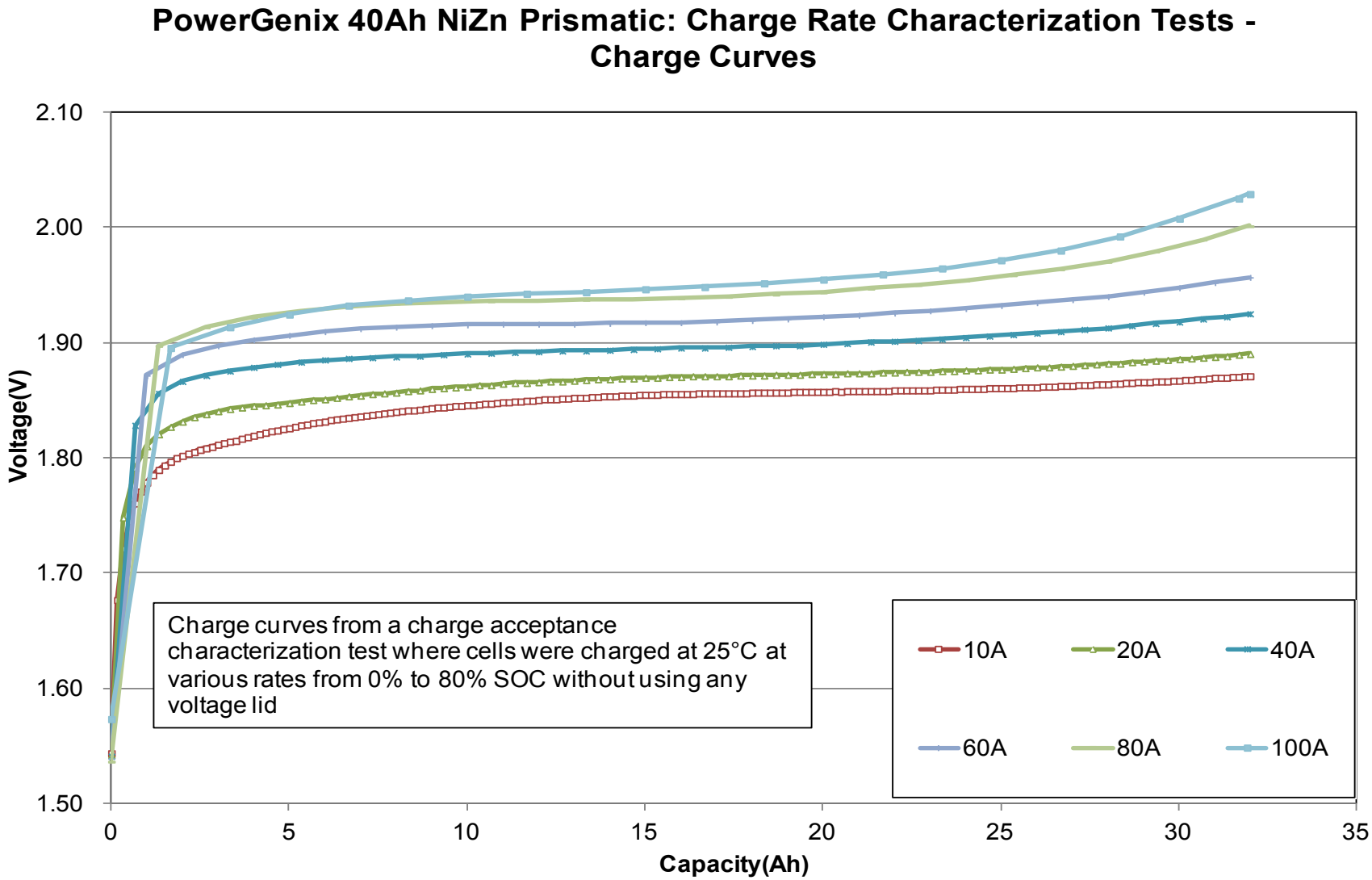
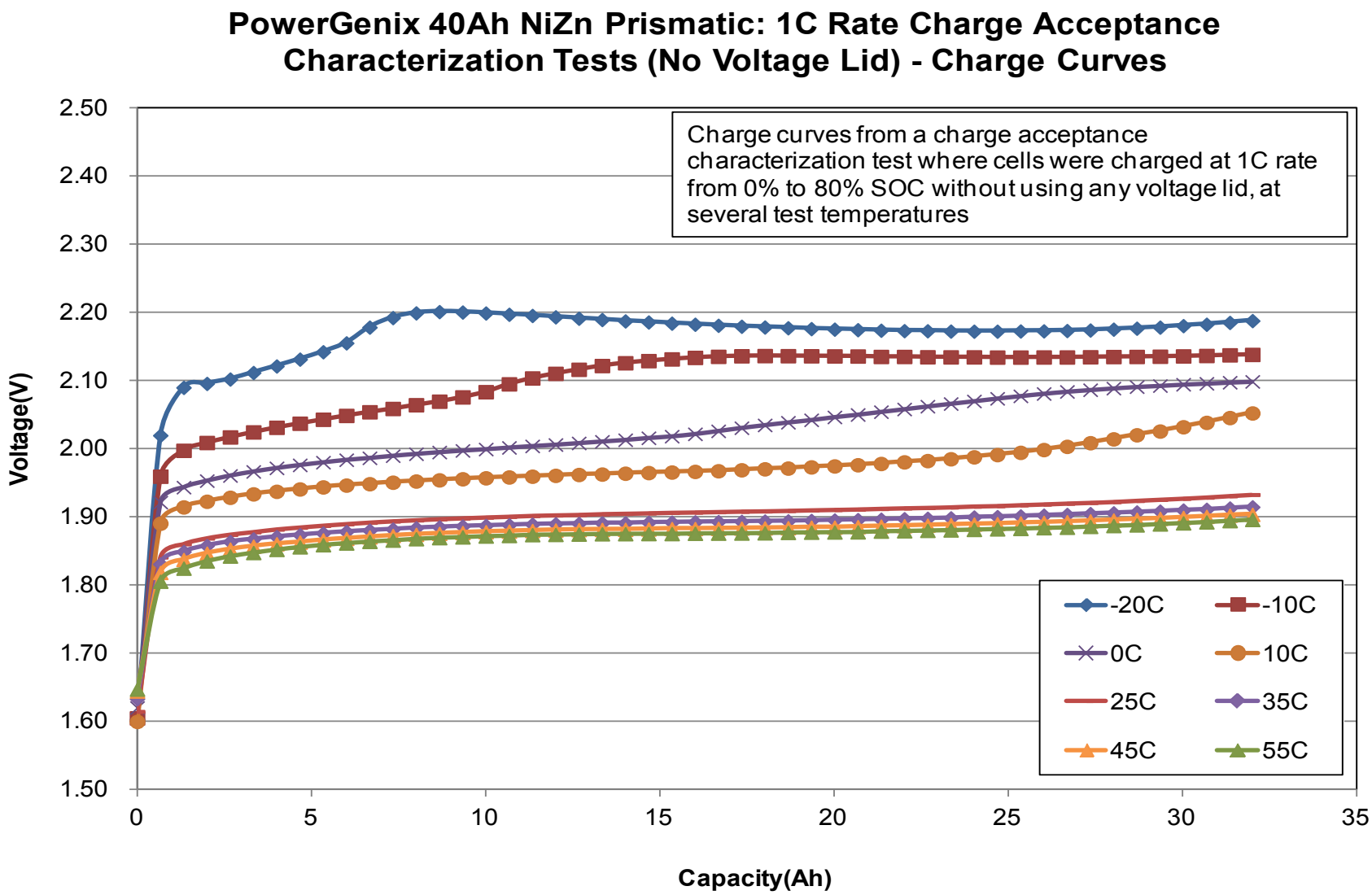


NiZn Charge Acceptance Characterization – Different Test Temperatures

POWERGENIX



Abuse Test Results

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Test Procedure	Test Conditions	NiZn EUCAR Hazard Level	Test Result
Over Charge	24 Hour Over-Charge @ 100A Constant Current	2	Pass
Over Discharge	300A Constant Current Discharge For 1 Hour or -5V	2	Pass
External Short Circuit	< 5mΩ External Hard Short in < 1-sec @ 100% SOC	2	Pass
Thermal Stability	5°C Heat Increments After Every 30 Minutes @ 100% SOC	3 (Stable up to 152°C skin temperature)	Pass
Nail Penetration	Starting @ 100% SOC	2 / 3 (externally induced rupture)	Pass
Crush	Starting @ 100% SOC	2 / 3 (externally induced rupture)	Pass

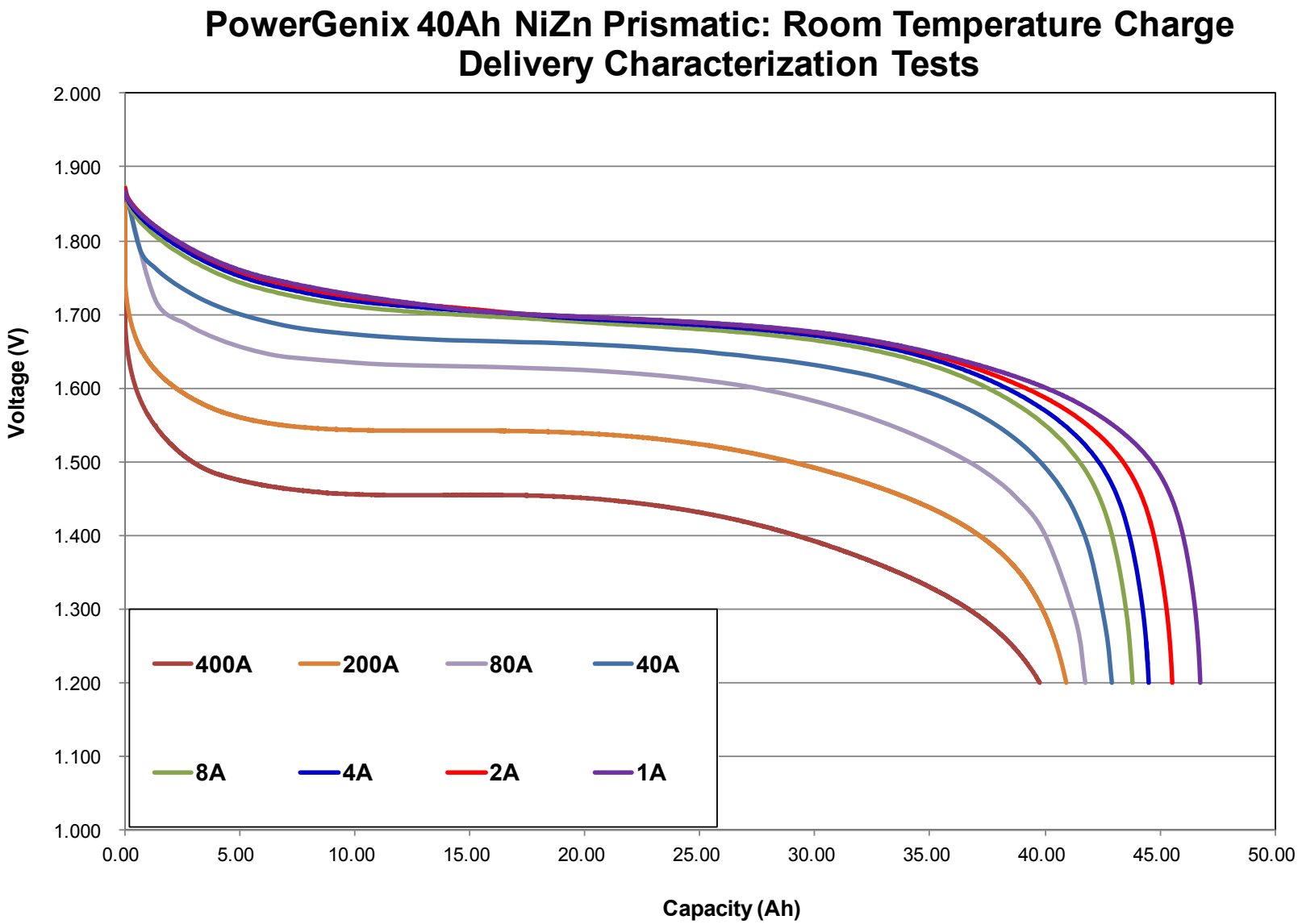
EUCAR Hazard Level Descriptions

2 = No leakage/venting/fire/flame/rupture/explosion/exothermic reaction/thermal runaway. Cell irreversibly damaged

3= No venting/fire/flame/rupture/explosion. Weight loss < 50% of electrolyte weight

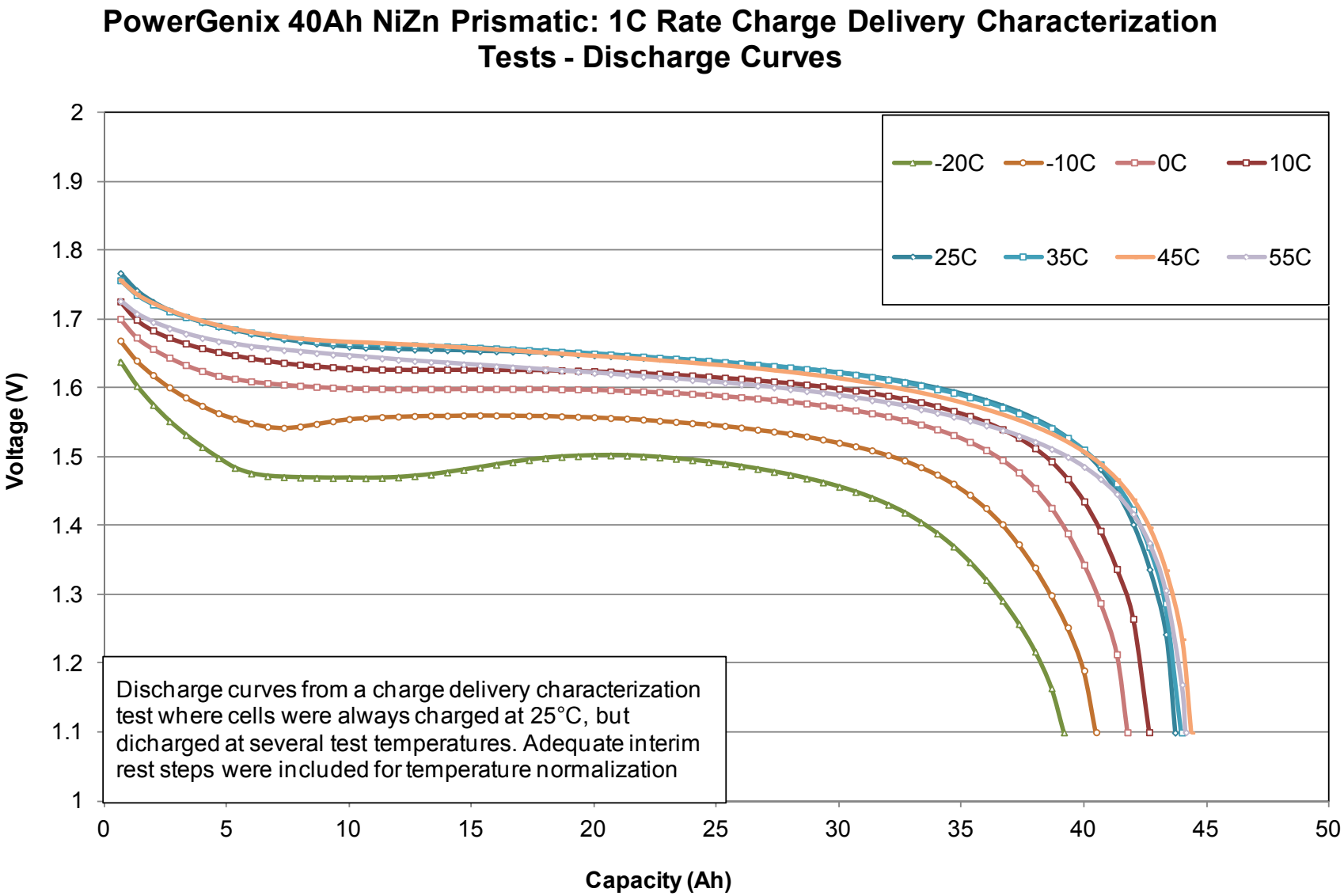
Test Specification: SAE J2464 and FreedomCAR EESS Abuse Test Manual for HEV Applications, where applicable

NiZn Discharge Rate Characterization



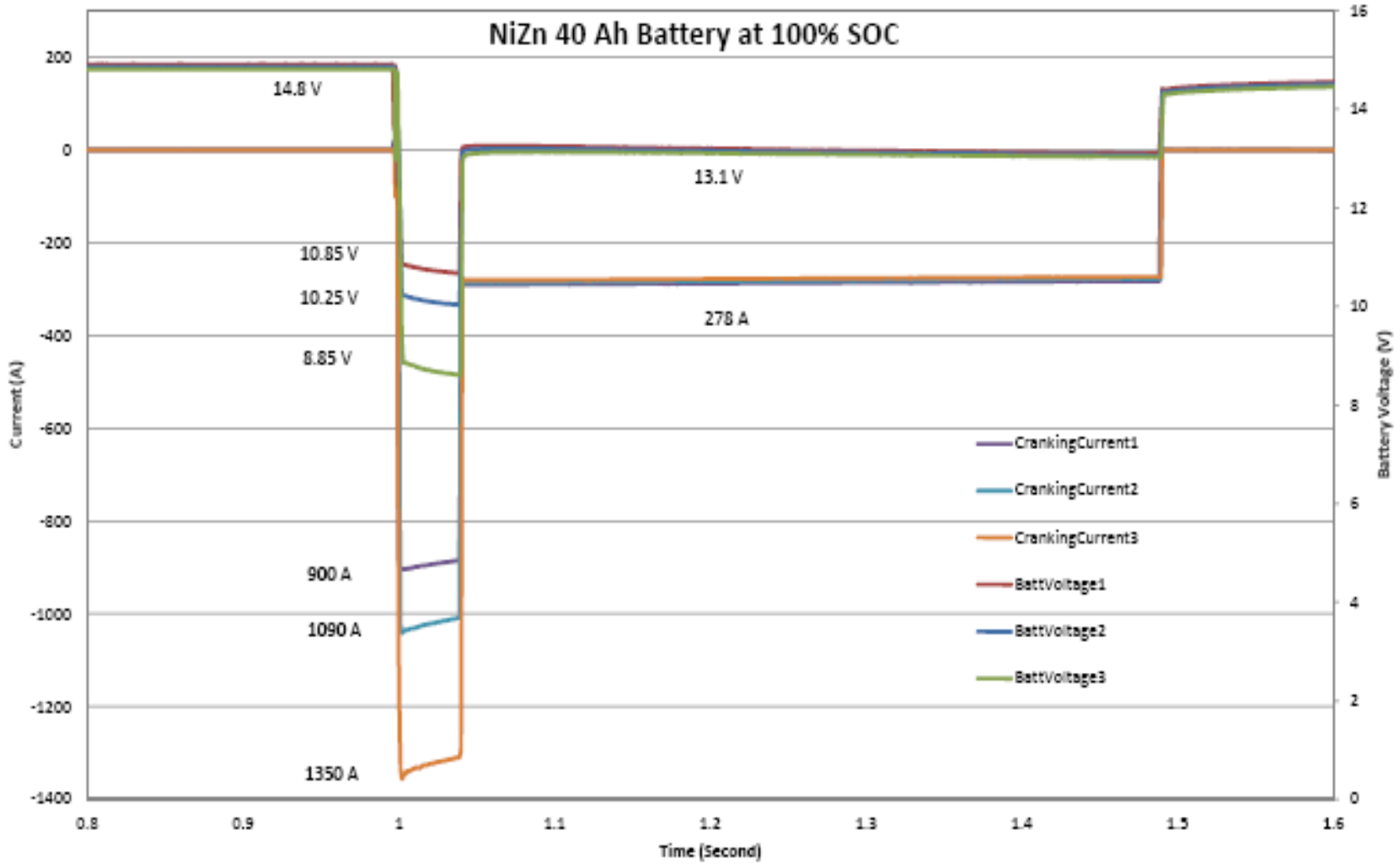
NiZn Discharge Characterization – Different Test Temperatures

POWERGENIX



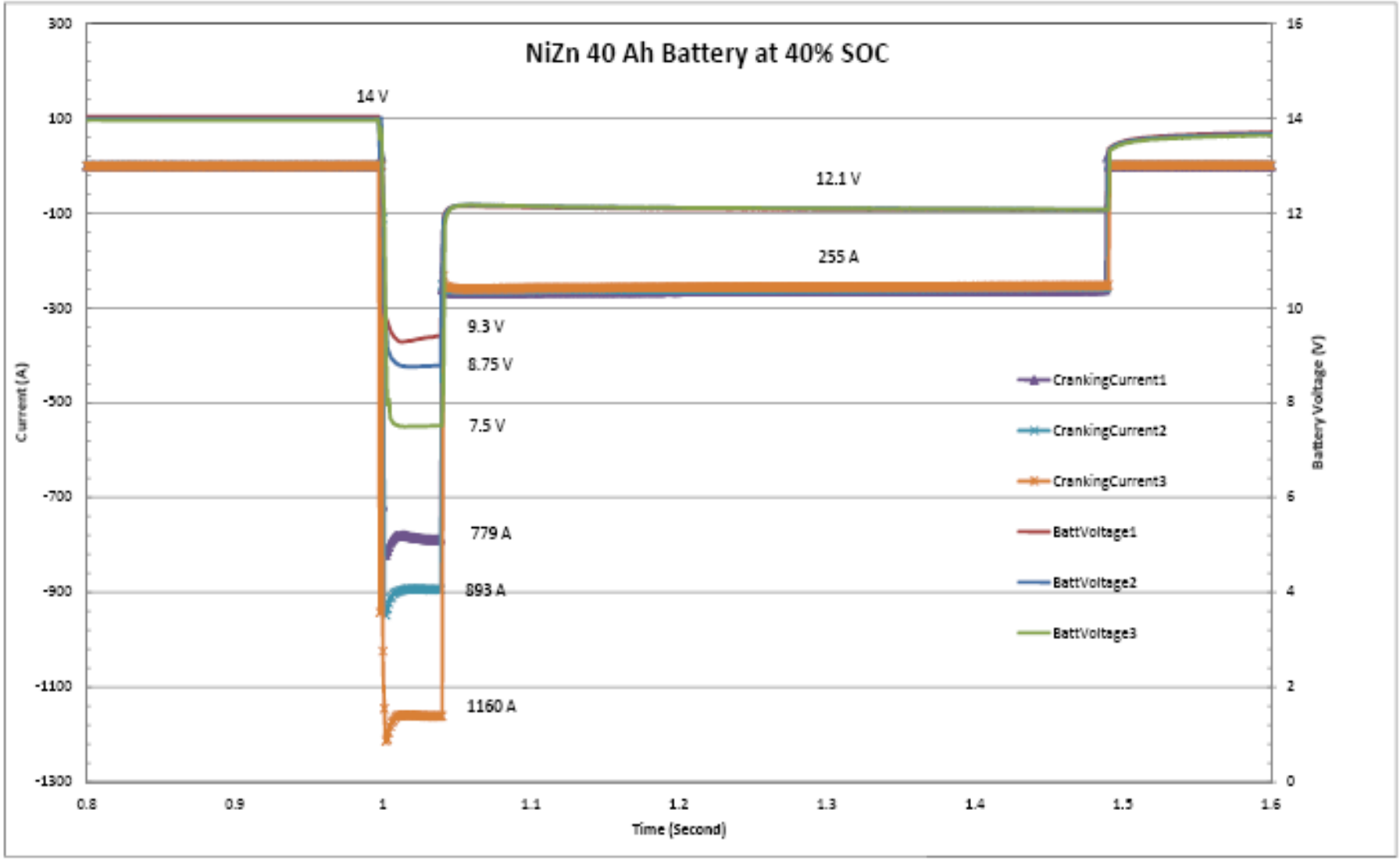
Excellent Cranking Performance @ 100% SOC in A V8 Pickup Truck

POWERGENIX



Excellent Cranking Performance @ 40% SOC in A V8 Pickup Truck

POWERGENIX



NiZn Outperforms in Every Key for Micro-Hybrids

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Technology	NiZn	Pb-Acid (AGM)	Li-ion	Ultra-caps
Cost	Best	Good	Poor	Worst
Service Life	Excellent	Worst	Excellent	Fair
MPG Improvement	Best	Worst	Fair	Fair
Weight	Best	Poor	Fair	Worst
System Complexity	Low	Low	Poor	Worst
Safety	Best	Good	Fair	Fair

Contents

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- A Differentiated Chemistry
- Superior Battery Solution for Huge Market
- Test Data Demonstrate NiZn Performance

Summary

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Ni-Zn: An energy storage solution that meets performance and cost requirements of current and future micro-hybrid systems

- Powergenix Ni-Zn batteries provide simple solution to current micro-hybrid dynamic charge acceptance, voltage stability, and service life problems
- Looking forward PowerGenix Ni-Zn can meet more demanding next-generation micro-hybrid system requirements, improving total vehicle fuel economy by 15%
- The system has low cost of ownership and is highly recyclable
- PowerGenix is currently sampling 40Ah product to automotive OEMs in Europe, North America, and Asia

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- With over 80 patents, PowerGenix offers a high performance, reliable, and low cost Ni-Zn solution for demanding automotive demanding
- NiZn is a low cost, one battery, under the hood solution for start-stop systems
  - With 3X the cycle life of Pb AGM and >95% sustained dynamic charge acceptance, NiZn supports next generation start/stop
  - 65% lighter than Pb AGM with >2X energy and power density
  - Five year service life with minimal performance degradation
  - Extremely safe, environmentally friendly and >90% recyclable
- PowerGenix has demonstrated high volume of Ni-Zn cells. A world class factory with a capacity of 200,000 kWh will be commissioned and ready for qualification by auto-OEMs by the end of 2012

PowerGenix: Ideally Structured for Success

POWERGENIX

PGX: THE BEST OF BOTH WORLDS

THE STRUCTURE

China

- IP Generation
- Product Engineering
- 80 Employees

U.S.

- Business Development
- Finance and Admin
- 8 Employees

THE PAY-OFF

- Optimal Cost Structure and Proximity to Supply Chain
- Cost-Competitive Engineering Resources
- Advantaged Access to Attractive Chinese Markets

- Access to North American Markets
- Technology Access
- Access to U.S. Capital Markets