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Energy Storage NEWS

Assessing the impact of updates to UL 1973 for stationary energy storage systems

WEBINAR | 29th September 2022

September 29, 2022

Assessing the impact of updates to UL 1973 for stationary energy storage systems

Scott Daniels and Michael Becker

This webinar is being recorded.

About the Speakers

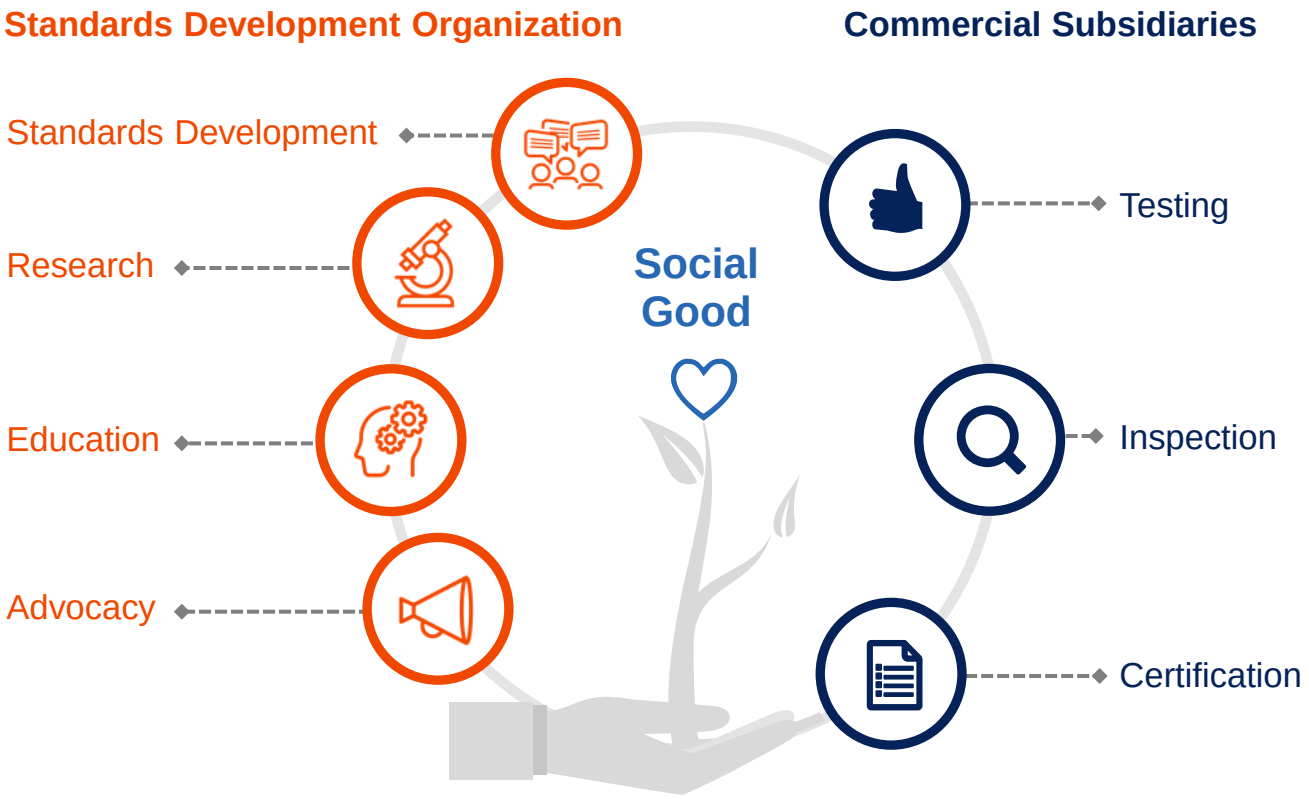
Scott Daniels As Head of Power and Energy Storage at CSA Group, Scott is an emerging technology and advanced energy resources professional with over 20 years of experience in the energy and clean technology sectors. A respected leader in power generation, distributed energy resources, and energy management, Scott has expertise in technology and business strategy focusing on energy, sustainability, technology commercialization, and investment strategy.

Michael Becker is a compliance and technical expert in the field of energy storage and systems engineering. He has extensive regulatory and new product development experience for battery systems targeted for energy storage, motive power, and back-up power applications. Michael has participated in the standards development process for applicable energy storage standards, such as UL 9540 and NFPA 855.

CSA Group At-a-Glance

Holding the future to a higher standard

CSA Group laboratories are Nationally Recognized Testing Laboratories (NRTL)



Commercializing technologies may require new standards or modifications of existing standards

Standards Development - Member Driven. Globally Relevant.

12	+10,000	+3,000	+1,000
Areas of focus	Dedicated members	Standards	Committees

Testing, Inspection and Certification

3	1,800	+2,550	36	+140
Business Units	**Employees**	**Accredited Certification Programs**	**Offices**	**Countries**

Solutions Portfolio

Delivering solutions that enable your business

Consumer Product Evaluation

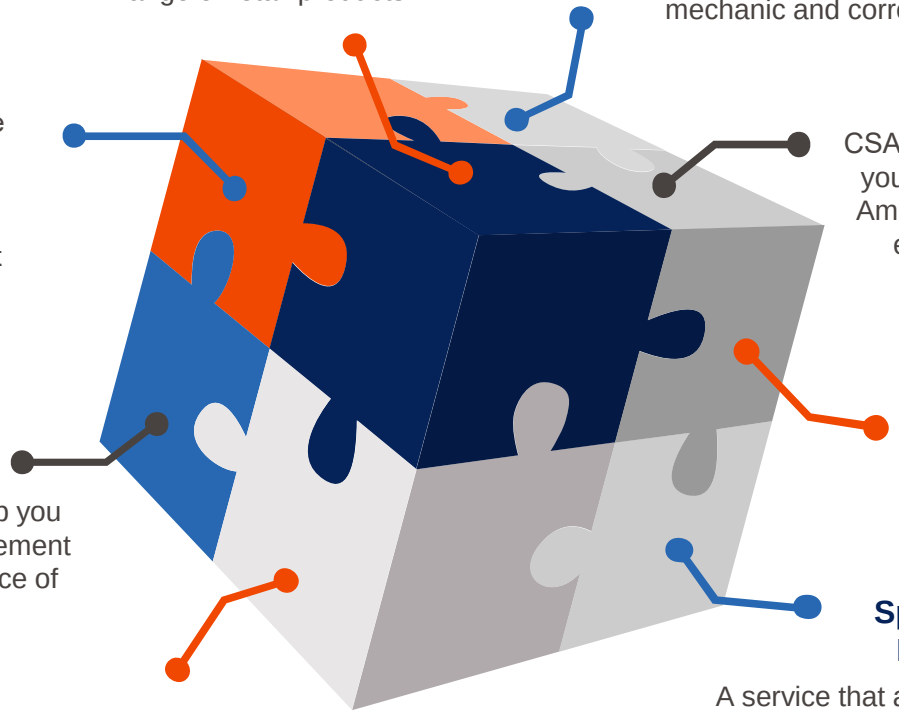
Offers third-party, independent verification, inspection and testing for a range of retail products

Environmental Testing

Helps customers to test their product under different environmental conditions such as climatic, mechanic and corrosive influences.

Certification

CSA Group will test your products' compliance with applicable safety, environmental, and operating performance standards for markets around the world. We can help you take full advantage of today's global economy and test against the approvals you need to enter new markets worldwide.



Energy Efficiency Verification

CSA Group's energy efficiency verification services allow you to demonstrate whether your products meet North American energy efficiency requirements. Our services encompass the complete set of energy efficiency standards, including ENERGY STAR®.

Electrical & Functional Safety

Offers customers valued peace of mind through fast and efficient safety and evaluation services, technical guidance and training.

Cybersecurity

We develop tailored solutions that help you identify potential issues, and then implement security measures to reduce the chance of malicious intrusions and attacks.

Special Inspection/ Field Evaluation

A service that allows a technical expert to assess your uncertified product against required safety and other applicable standards and codes.

Electromagnetic Compatibility (EMC) & Wireless

Testing to help you with various regulations and access to sell your electronics around the world.

Distributed Energy Resource Lab

New state of art laboratories located at the CSA Group US Headquarters site in Cleveland, OH

- New North American “Distributed Energy Resource Lab” 40k square-foot facility encompassing:
  - Certification
  - Electrical & Functional Safety
  - MW scale fire test lab
  - Environmental testing, Energy Efficiency Verification
  - Cybersecurity and communications
  - Performance testing & Reference Performance Testing
- Services for:
  - Power conversion systems including inverters & converters
  - Electric vehicle supply equipment (EVSE) including AC & DC EV chargers
  - Battery systems including portable power, eMobility, and stationary
- On-site employees include highly qualified technical experts, certifiers, and laboratory technicians
- Opening now!

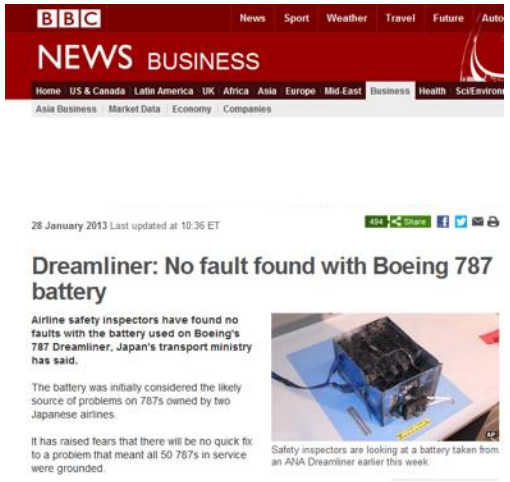
Application Metrics & Definitions – Battery Cell Focus

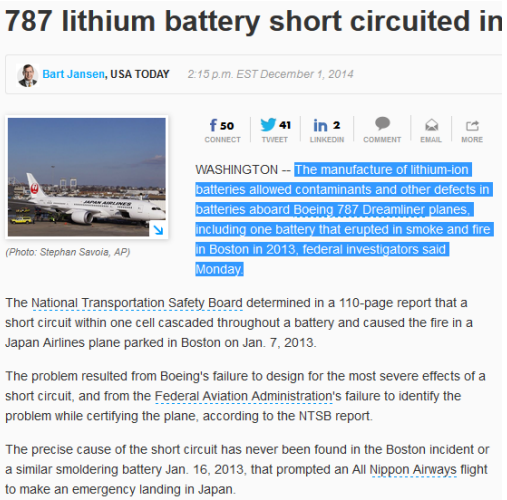
	Metric	Units	Definition	Notes	Energy Applications	Power Applications
Power & Energy Metrics	**Energy Density**	**Wh/L**	**Energy for a given volume**	**When volume is a concern**	**X**	
	Specific Energy	**Wh/kg**	**Energy for a given mass**	**When mass is a concern**	**X**	
	Power Density	**W/L**	**Power for a given volume**	**When volume is a concern**		**X**
	Specific Power	**W/kg**	**Power for a given mass**	**When mass is a concern**		**X**
	"Cost" - Power	**$/W**	**Cost of each Watt delivered from a cell**	**Power applications**		**X**
	"Cost" - Energy	**$/Wh**	**Cost of each Wh delivered from a cell**	**Energy applications**	**X**	
General Application Metrics	Roundtrip Efficiency	%	The total efficiency of both charging and discharging	Very important for Energy Peak Load Shift	--	--
	Elevated Temp	°C	Service/operational temperature	Elevated temp applications	--	--
	Cold Temp	°C	Service/operational temperature	Cold temp applcations	--	--
	Cycle Life	Cycles	Charge and Discharge Cycles before EOL* is reached	Temp, Rate, DOD etc..?	--	--
	Calendar Life	Years	How long can the cell be connected/on before EOL*	Temp Influence	--	--
	Safety	0-7	Per Standards. Example SAEJ2464	UL1973, UL9540A, SAEJ2464, etc.	--	--
	Self Discharge	% / Yr	Self discharge over time	How much does battery discharge when not in use?	--	--
Non-Application	Shelf Life	Years	How long can the cell sit on a shelf before EOL*	Temp Influence. Inventory Management		
	Disposal	$	The cost to recycle and/or dispose	True EOL replacement cost?		
	Manufacturability		How easy is it to manufacture	This is cell focused		
	Supply Robustness		Are materials readily available	This is cell focused: Cobalt etc. also # of cell suppliers		

Note: Roundtrip efficiency is typically important for energy applications that frequently cycle and can be important for power applications that frequently cycle

BOEING 787 Dreamliner Fire

Design Cycle Challenges





Incorrect Findings **Correct Findings**

Cell Cathode Chemistry: Lithium Cobalt Oxide

- Cathode is thermally unstable
- Very high energy density
- Used in portable consumer electronics
- Likely no “Ceramic Safety Layer”

National Transportation Safety Board Incident Report: NTSB/AIR -14/01; PB2014-108867

Complex and long design cycles pose significant challenges when selecting Li-ion cell technologies to satisfy critical application metrics

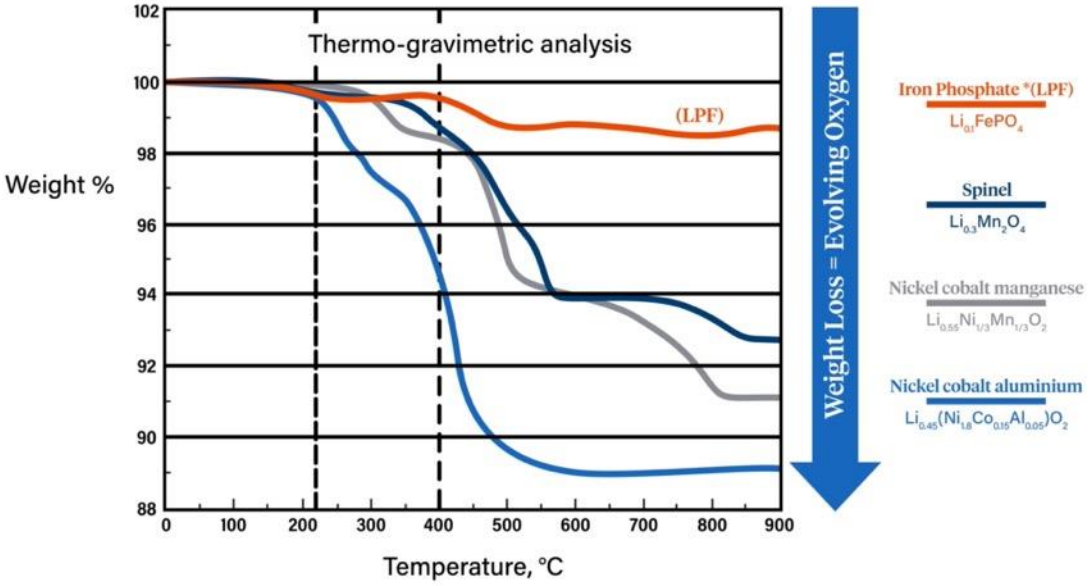
What Makes Li-ion Cathode Chemistry Safer?

Safer lithium-ion cathode chemistries hold on to their oxygen

- Battery cell fires are initially fueled by liquid electrolyte and atmospheric Oxygen (O_2)
- O_2 is a “Catalyst” & Oxide based Cathodes will release O_2 at elevated temperatures
- O_2 evolving from cathodes at elevated temperatures makes fire suppression extremely challenging
- Can not use conventional O_2 starvation fire suppression effectively since the battery cell fire is supplying its own catalyst

Thermo-Gravimetric Analysis (TGA) – A very sensitive small scale located in a heated sealed chamber that is used to measure small samples and their respective behavior to increasing temperature. For example, a small wet sponge will become light as the water evaporates when the temperature is elevated.

Lithium Iron Phosphate (LFP) is Thermally Stable



Application Metrics: APU Battery on Aircraft

Emergency backup power on large aircraft

- Limited space is a major concern
- Weight is a major concern
- Reliability and safety are major concerns
- Events are very infrequent
- Long duration application
- Maintenance is a concern

Metric	*Units*	Importance	Metric	*Units*	Importance
Energy Density	*Wh/L*	**High**	**Temperature**	*°C*	Low
Specific Energy	*Wh/kg*	**High**	**Cycle Life**	*Cycles*	Low
Power Density	*W/L*	Low	**Shelf Life**	*Years*	Low
Specific Power	*W/kg*	Low	**Calendar Life**	*Years*	**High**
Self Discharge	*% / Yr*	Low	**Safety**	*Per Standard*	**High**
"Cost" – Energy	*$/Wh or Wh/$*	**High**	**Round Trip Efficiency**	*% (>90%)*	Low
"Cost" – Power	*$/W or W/$*	Low	**Disposal**	*$*	**Med**

Application Metrics: Time of Use (TOU)

Peak load shift

- Cost is a major concern
- Limited space - racks and shipping container
- Reliability and safety are major concerns
- Cycling events are frequent with 20+ year perf. guarantees
- Long duration application
- Round trip efficiency is very important

Metric	*Units*	Importance	Metric	*Units*	Importance
Energy Density	*Wh/L*	**High**	**Temperature**	*°C*	Low
Specific Energy	*Wh/kg*	**Med**	**Cycle Life**	*Cycles*	**High**
Power Density	*W/L*	**Med**	**Shelf Life**	*Years*	Low
Specific Power	*W/kg*	Low	**Calendar Life**	*Years*	**High**
Self Discharge	*% / Yr*	**Med**	**Safety**	*Per Standard*	**High**
"Cost" – Energy	*$/Wh or Wh/$*	**High**	**Round Trip Efficiency**	*% (>90%)*	**High**
"Cost" – Power	*$/W or W/$*	Low	**Disposal**	*$*	**Med**

Voice of Application

Application Metrics: Portable Electronics

Smart phones and assessors

- Cost is very important
- Limited space is a major concern
- Reliability and safety are major concerns
- Cycling events are daily
- Long duration application
- Inventory churn is difficult to predict

Metric	*Units*	Importance	Metric	*Units*	Importance
Energy Density	*Wh/L*	**High**	**Temperature**	*°C*	**Med**
Specific Energy	*Wh/kg*	**Med**	**Cycle Life**	*Cycles*	**Med**
Power Density	*W/L*	**Med**	**Shelf Life**	*Years*	**Med**
Specific Power	*W/kg*	Low	**Calendar Life**	*Years*	Low
Self Discharge	*% / Yr*	**Med**	**Safety**	*Per Standard*	**High**
"Cost" – Energy	*$/Wh or Wh/$*	**High**	**Round Trip Efficiency**	*% (>90%)*	Low
"Cost" – Power	*$/W or W/$*	Low	**Disposal**	*$*	**Med**

Testing, Inspection, and Certification

Mission

Our commercial subsidiaries **provide expert testing, inspection, and certification** services that enable manufacturers to demonstrate that their products are in **compliance with applicable safety, environmental, and operating performance standards for markets around the world.**

UL 1973 Overview

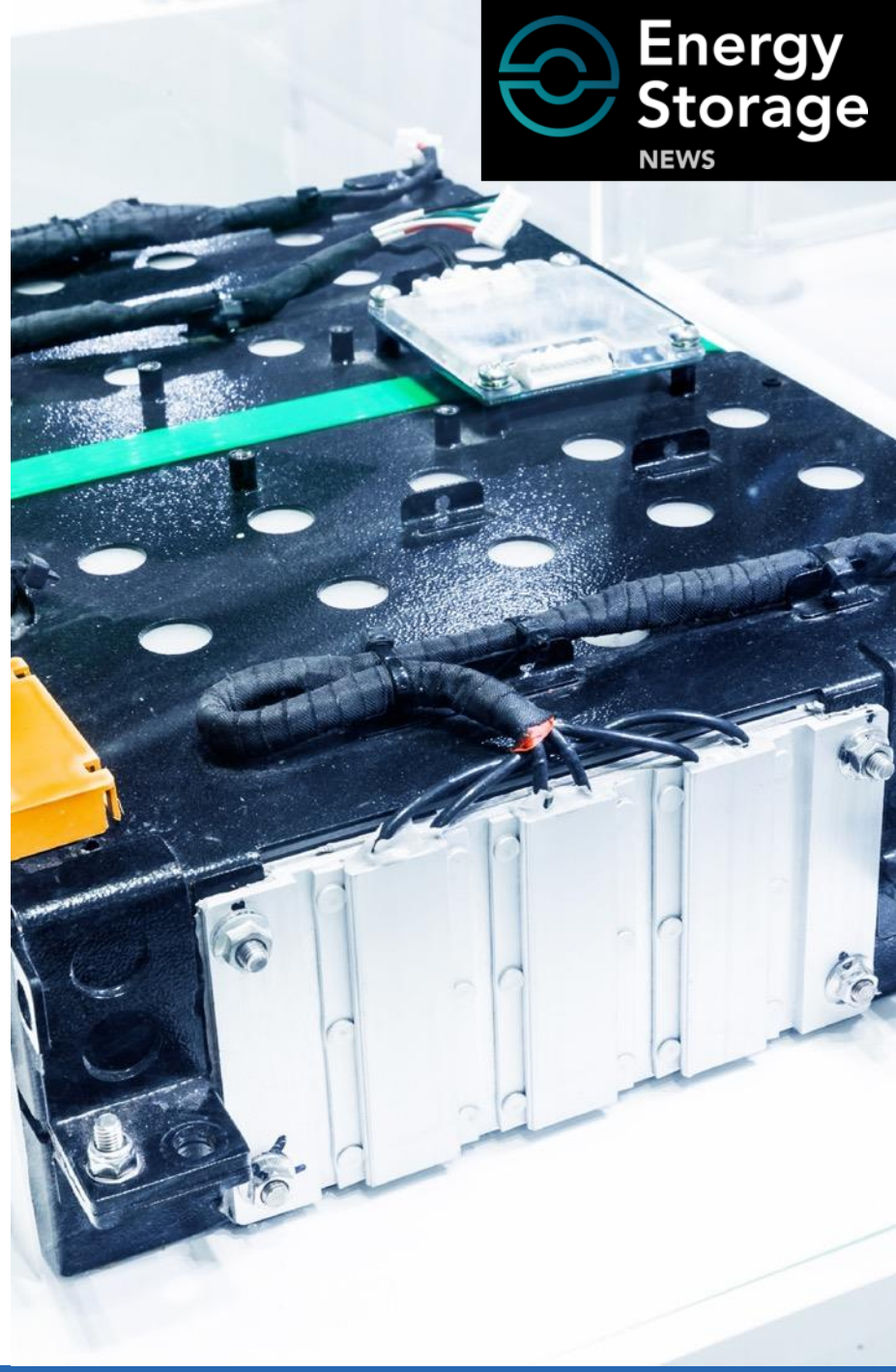
The scope of UL 1973 covers battery systems that are intended to be used in stationary energy storage systems.

It also includes battery systems used in Light Electric Rail (LER) and Vehicle Auxiliary Power (VAP) applications.

As a safety standard, UL 1973 does not cover performance or reliability considerations.

- For a typical stationary energy storage system, the scope of UL 1973 addresses requirements for the:
  - Cell
  - Module
  - Battery Rack up to Battery Management System (BMS)

The scope does not include power conversion equipment or other system level components. The full energy storage system is covered under UL 9540



UL 1973 Updates – Lithium-Ion Cell Requirements

- **UL 1973 2nd Edition**
  - Secondary lithium cells could comply with UL 1973 under one of the following criteria:
    - Compliance with UL 1642 in addition to the modifications under Exceptions No. 1-5 in 7.11.2.
    - Compliance with test program in Appendix E of UL 1973
- **UL 1973 3rd Edition**
  - Secondary lithium cells need to comply with the cell test program of Annex E
  - Lithium cell construction review required and documentation of cell components; needs to be designed to mitigate internal short circuit (criteria in 7.12.3)
- **What this means for ESS manufacturers**
  - Lithium cells certified to UL 1642 are not sufficient to meet UL 1973 requirements
  - Lithium cells are evaluated through a test program **AND** in-depth construction review into cell internal components

UL 1973 Updates – Repurposed Cells and Batteries

- **UL 1973 2nd Edition**
  - No specific requirements pertaining to repurposing of cells and batteries for use in stationary energy storage systems
- **UL 1973 3rd Edition**
  - Repurposed cells and batteries used in UL 1973 stationary energy storage systems need to have been processed in compliance with UL 1974
  - UL 1974 covers sorting and testing procedures for repurposed cells and batteries
  - A battery system built with EV batteries sorted using an approved process still needs to comply with UL 1973
- **What this means for ESS manufacturers**
  - If you are using repurposed cells or batteries to build a battery system, ensure they have been processed through a UL1974 approved procedure
  - End product battery system still needs to be evaluated to UL1973 requirements

UL 1973 Updates – Lead Acid and Ni-Cad Requirements

- **UL 1973 2nd Edition**
  - Minimal references to specific requirements for lead acid and Ni-Cad batteries; it was difficult to apply to lead acid monoblocs
- **UL 1973 3rd Edition**
  - Clarified requirements for lead acid and nickel cadmium batteries
  - Added Annex H “Alternative Approach for Evaluating Valve Regulated or Vented Lead Acid or Nickel Cadmium Batteries”
  - Creates a more focused test plan for these legacy technologies that can have simplified controls and may not use a Battery Management System (BMS)
- **What this means for ESS manufacturers**
  - Manufacturers of lead acid and Ni-Cad batteries can comply with UL 1973 without meeting all the requirements typical for a lithium-ion system
  - Stationary energy storage systems assembled on site using these technologies can still comply with UL 1973 and building fire code regulations

UL 1973 Updates – Vehicle Auxiliary Power Battery Requirements

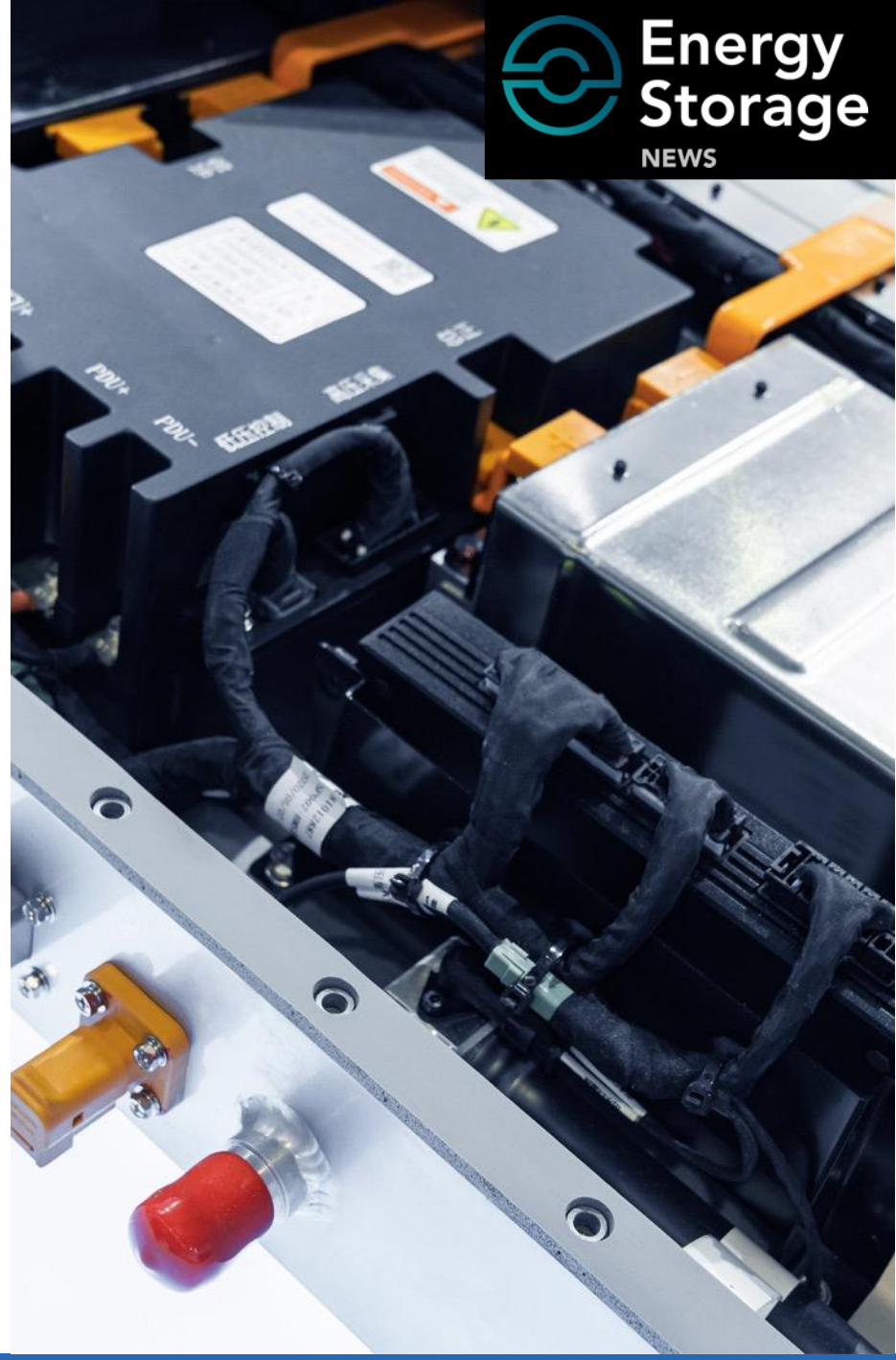
- **UL 1973 2nd Edition**
  - Most references were specific to Light Electric Rail (LER) applications; the only mention of Vehicle Auxiliary Power (VAP) was in the title of the Standard
  - Addressed mechanical testing for LER applications under Sections 25 thru 27
- **UL 1973 3rd Edition**
  - Clarified scope to apply to VAP applications; includes batteries used for recreational and other auxiliary vehicle power applications; does not provide traction power
  - VAP batteries must meet mechanical testing of UL 1973, including vibration, shock, and crush (UL 2271/UL 2580 also referenced)
- **What this means for ESS manufacturers**
  - Lithium-ion and other batteries used for VAP applications (RVs, truck refrigeration, etc.) need to comply with UL 1973 approved for use as VAP batteries

UL 1973 Updates – Clarifications for New Battery Technologies

- **UL 1973 2nd Edition**
  - Contains some guidance for applying requirements to alternate battery chemistries, including flow and sodium-beta batteries
- **UL 1973 3rd Edition**
  - Added guidance on requirements for several new chemistry types:
    - Sodium ion
    - Clarified testing on flow batteries in Annex C
    - Added Annex I “Test Program for Mechanically Rechargeable Metal-Air Batteries”
- **What this means for ESS manufacturers**
  - ESS manufacturers that utilize some of these newer or evolving battery technologies have clarified guidance in UL 1973

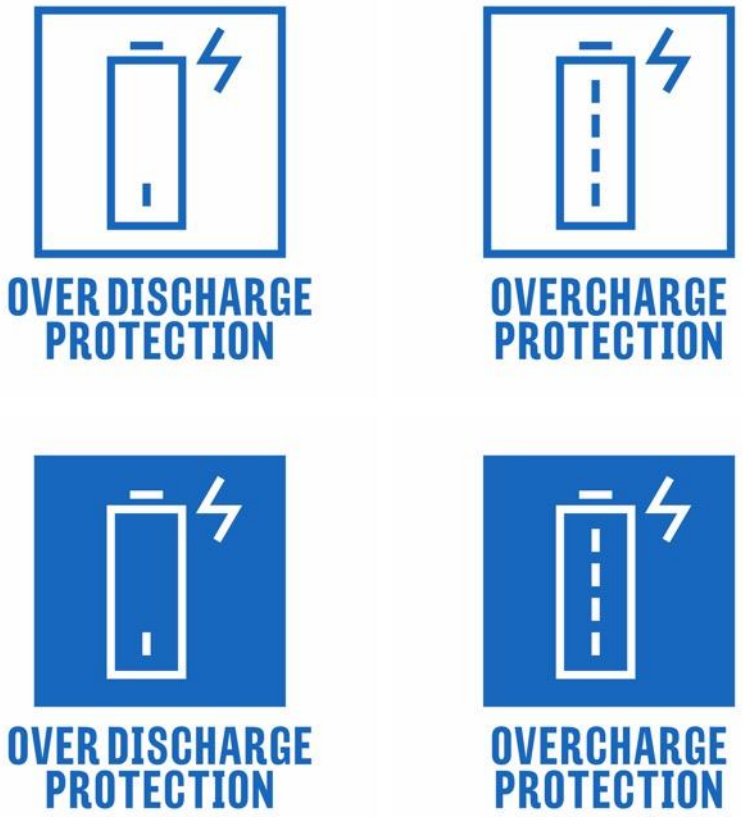
UL 1973 Updates – Functional Safety Requirements

- **UL 1973 2nd Edition**
  - Contained functional safety requirements under Clauses 7.7 and 7.8; was not clear if active protective device needed to meet functional safety requirements
  - Combined requirements for hardware and software requirements and did not specify level of protection (SIL/PL/ASIL)
- **UL 1973 3rd Edition**
  - Clarified that all active protective devices (ex. BMS) need to be evaluated to functional safety requirements
  - Unless safety analysis shows reduced risk, protective controls must meet minimum SIL 2, PL c, or ASIL C safety ratings
  - Hardware and software relied upon for safety separated based on standards requirements to UL 991/UL1998, UL 60730-1, or CSA C22.2 No. 0.8
- **What this means for ESS manufacturers**
  - Ensure that any protective controls, such as the BMS, meet the updated requirements for functional safety



UL 1973 Updates – Additional Electrical Tests

- **UL 1973 2nd Edition**
  - Overcharge testing of Section 15 mainly focused on an increased charging voltage but limited current to maximum charging rate
  - Over discharge testing of Section 17 was also based only on voltage limit with current limited to maximum discharging rate
  - Overload testing under short circuit test of Section 16 focused only on 85% of fuse rating instead of BMS protection limit
- **UL 1973 3rd Edition**
  - Added new High-Rate Charge test in Section 16; current supplied to battery during charge 20% above rating
  - Added new Overload Under Discharge test in Section 18; overload to be performed just below BMS protection limit and just above BMS protection limit but below fuse rating
- **What this means for ESS manufacturers**
  - To comply with UL 1973 3rd Edition, manufacturers will need to perform these additional tests



Questions?

Thank you.

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