UL 1973 APPENDIX H: A NEW SAFETY APPROACH TO TRADITIONAL LEAD ACID AND NICKEL CADMIUM STATIONARY BATTERY SYSTEMS

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Abstract

Lead acid (LA) and nickel cadmium (Ni-Cd) batteries have been used in stationary standby applications for many years with minimal incidents. Previously, the individual LA or Ni-Cd batteries may have been certified to UL 1989 but often they were not. They would have followed the NEC Article 480 for the installation along with the fire and building codes requirements for ventilation and spill containment. With the introduction of grid connected energy storage systems (ESS) for support of renewable energy and other applications, there has been an increase in the use for less traditional chemistries for ESS including lithium-ion batteries and more exotic types such as flow batteries. In addition, the codes have been adapting to adequately address ESS and have included some rather strict criteria for ESS installation including strict limits on size and separation distances that have not been required in the past for traditional LA and Ni-Cd stationary standby applications. In addition, the codes have expanded the scope of ESS to include standby applications with additional criteria applied to LA and Ni-Cd that were not applied previously. This includes the aforementioned strict size and separation distance limits for LA and Ni-Cd stationary battery installations. Exceptions to these limitations can be granted with large scale fire testing of UL 9540A with AHJ approval of the installation. Also, the ESS or similar stationary system incorporating battery energy storage has to be listed to UL 9540.

This new criteria for LA and Ni-Cd batteries presents a dilemma, as these systems are typically open racks of cells or batteries in an installation. There is no "system" to be tested before they are installed. Although there were some concessions in the codes for LA and Ni-Cd for limited applications, some of those developing the fire and installation codes believe that LA and Ni-Cd chemistries should be treated in an equivalent manner.

The LA and Ni-Cd industry approached UL about developing criteria for their batteries that could be accepted in the codes. The criteria should help to enhance the LA and Ni-Cd battery safety, and should be an approach that makes sense for the technology. The task group, established by the IEEE Battery Codes & Standards group representing LA and Ni-Cd manufacturers and other stakeholders, and UL developed a safety evaluation program together that resulted in a proposed new Appendix H to UL 1973. Using this Annex, individual cells and monobloc batteries can be certified to ensure that they can be installed safely in the field without further concern. Included is a test method that is being proposed for UL 9540A to address LA and Ni-Cd batteries.

Revisions to UL 9540 Appendix D are being proposed to align with the Appendix H of UL 1973.
This presentation will provide an overview of the changing regulatory environment for LA and Ni-Cd stationary storage batteries and the UL 1973 Appendix H criteria to not only provide a realistic path for evaluation of these systems for the current regulatory environment, but also to improve their safety.

Introduction

Lead Acid and Nickel Cadmium batteries have been the primary technologies used in stationary standby applications for many years and have had a good track record when it comes to safety. Some of the infrequent field Incidents involving these technologies have been the result of abuse to the batteries through improper charging, sloppy installation that may result in shorting or damage to the batteries and poor maintenance of the batteries. These issues can be addressed through using the appropriate chargers, and following the manufacturer's guidance for proper installation and maintenance of the batteries. The main hazard that may be associated with these battery technologies is the hydrogen off gassing that may occur during the use of the battery. This issue has been addressed through code criteria that requires ventilation to maintain a maximum of 25% LFL be provided in the installation. The IEEE 1635 / ASHRAE 21 *Guide for the Ventilation and Thermal Management of Batteries for Stationary Applications* provides a comprehensive way to determine the potential hydrogen off gassing based upon the battery technology and rating, which can be used to determine suitable ventilation of the installation area.

Codes such as NFPA 70, *National Electrical Code* (NEC) Article 480, and ICC *International Fire Code* IFC Chapter 608 addressed these batteries through limitations based upon quantity of electrolyte contained, and installation safety through requirements for electrical disconnects, wiring, flame arrestors, and spill control, as well as the ventilation criteria in the area of installation. Lead-acid batteries were specifically exempted from the need to be listed in the NEC, and there were no other criteria for listing (i.e., third party certification) of battery systems in other applicable model Codes, although the electrical equipment that the batteries may be connected to such as UPS systems were required to be listed. There were commonly certifications of valve regulated lead acid batteries to the standard UL 1989, *Standby Batteries*, but vented types, although not excluded from the scope of UL 1989, were not typically certified. For the most part, if following the installation criteria and battery manufacturers specifications, this approach worked.

With the increasing use of renewable energy and the need for battery support for these systems, the use of energy storage systems (ESS) for renewable energy support and other applications has been steadily increasing over the years as well. With the use of ESS for renewable energy support, there has also been an increase in the use of new battery technologies. Energy storage systems are subjected to significantly more cycling than a standby application and these newer technologies not previously used for stationary applications are now being used for this energy storage. Technologies such as lithium-ion batteries are being used due to their performance capability, energy density and low level of maintenance. In addition, the cost of lithium-ion batteries has been decreasing. Some of the acceptance with using lithium-ion batteries for energy storage applications has come from the experience and knowledge gained in the electrical vehicle world using these technologies. In addition to lithium-ion batteries, some more exotic technologies such as flowing electrolyte batteries and high temperature sodium batteries are also being utilized for energy storage systems. With these new technologies and applications come hazards that may not be applicable to the traditional lead acid and nickel cadmium batteries used in standby applications.

As a result of these changes in the stationary battery industry, there has been a lot of standards and code work conducted to address the hazards associated with these new chemistries and applications. A new article 706 in NFPA 70 for energy storage, a new section 1207 in Chapter 12 in the ICC IFC and a new installation standard, NFPA 855, *Standard for the Installation of Stationary Energy Storage Systems* have been developed to address the safety of installations for energy storage. A new product safety standard, UL 9540, Energy Storage Systems and Equipment was published and is currently in its 2nd edition. In addition, battery systems used in UL 9540 equipment are required to comply with UL 1973, *Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications*. A large-scale fire test method, UL 9540A, Test *Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems* was published as a 4th edition consensus standard to address exceptions allowed in the various codes.

With these various code and standard developments were stricter criteria for all technologies including those used in standby applications. Limits were applied to lead acid and nickel cadmium stationary battery standby systems that were not in place previously. One of the first documents where these limits were included was NFPA 855. Some examples of the limits placed on lead acid and nickel cadmium with regard to size and separations distances, etc. are outlined in Figure 1. There were some limited exceptions for these technologies such as those used in voltage limited applications in telecom facilities or those that are installed at utility substations in accordance with the IEEE C2 *National Electrical Safety Code* and small UPS applications. Finally, with very few exceptions, energy storage systems, as loosely defined in NFPA 855, required that these systems be listed to UL 9540.

Figure 1 - Limits applied to lead acid and nickel cadmium in NFPA 855

Parameter	Limit Value	Exceptions
Threshold quantities (aggregate) non-residential	70 kWh	-
Threshold quantities (aggregate) residential	1 kWh	-
Individual BESS capacity (non-residential)	50 kWh	Telecom (50 Vac/60 Vdc), Utility for dc for control of substations per IEEE C2, used with Listed UL 1778 UPS, Large Scale Fire Test (UL 9540A)
Individual BESS Capacity for residential	20 kWh	If larger, will be required to meet other limits for non-residential applications
Maximum allowable quantities (MAQ) for non-residential	N/A	Not applicable to lead acid or nickel cadmium
Maximum aggregate quantities for residential for garages and outdoors	80 kWh	If larger, will be required to meet other limits for non-residential applications
Maximum aggregate quantities for residential indoor utility spaces	40 kWh	If larger, will be required to meet other limits for non-residential applications
Separation between individual BESS	3 ft	Telecom (50 Vac/60 Vdc), Utility for dc for control of substations per IEEE C2, Large Scale Fire Test (UL 9540A)
Separation between BESS and walls (indoor installations)	3 ft	Telecom (50 Vac/60 Vdc), Utility for dc for control of substations per IEEE C2, Large Scale Fire Test (UL 9540A)
Separation between BESS and exposures (outdoor installations)	10 ft	Reduced to 3 ft based upon Large Scale Fire Test (UL 9540A)
Separation between BESS and egress path	10 ft	Reduced to 3 ft based upon Large Scale Fire Test (UL 9540A)
Separation between BESS and windows, doors and other openings (outdoor wall mount)	5 ft	Large Scale Fire Test (UL 9540A)
Fire Suppression (sprinklers requirements)	0.3 gpm/ft^2	Can be reduced or a different type of suppression system per Large Scale Fire Test (UL 9540A)
BESS – Battery energy storage system. In NFPA 855, energy storage systems are defined in a manner that includes standby power system as well as grid connected systems.		

The NFPA 855 2020 edition limits on lead acid and nickel cadmium batteries were included in 2021 edition of NFPA 1 Fire code, since NFPA 855 is a reference for energy storage systems in the latest edition of that fire code. In addition, the 2018 and 2021 editions of the ICC International Fire Code (IFC) Section 1207, are closely harmonized with the criteria in NFPA 855. The limits placed on various ESS battery technologies were also applied to lead acid and nickel cadmium batteries with the reasoning that they can have safety issues associated with them as well as the other technologies. The NFPA committee responsible for developing NFPA 855 requested that actual data would have to be provided by the industry to support easing of the restrictions.

One of the problems facing the industry with the approach outlined in the codes is that lead acid or nickel cadmium batteries are typically sold as individual cells or batteries for installation in the field rather than being assembled as battery systems for certification to UL 1973, which is typical for lithium-ion battery systems and other technologies. In addition, the standby systems using these batteries were not listed to UL 9540. Lead acid and nickel cadmium batteries do not have battery management systems, but instead rely upon a suitable charging system such as a UL 1778, *Uninterruptible Power Supplies* UPS or UL 1012, *Power Units Other Than Class 2,* charger to control charging with some short circuit protection in accordance with the codes. There are no complex controls required for these batteries to operate safely in the field. Another issue is that the old UL 1989 certification program was not considered sufficient, because it relied upon testing in the end use application to evaluate the suitability of the lead acid or nickel cadmium battery compatibility with the product. The typical testing to UL 1989 consists of evaluation of the pressure relief mechanism or the flame arrestor assemblies along with flame rating criteria for the case. End product standards that used these, such as UL 1778, had their own testing and criteria to evaluate the safety of the batteries in the end use application. There were no series of tests conducted on individual cells and batteries to ensure a level of safety similar to what was in UL 1973.

As a result of the discussions during the development of the 2020 edition of NFPA 855, there has been an effort to provide support for easing some of the restrictions on lead acid and nickel cadmium stationary standby system applications for the next edition. There has also been some effort to separate Article 480 of NFPA 70 (NEC) from Article 706 to address only stationary standby systems while further limiting the scope of Article 480 to lead acid and nickel cadmium technologies. All other technologies whether used for stationary standby systems or energy storage systems will be under the scope of Article 706. Also, any lead acid or nickel cadmium system used for energy storage will fall under the scope of Article 706. Information has also been provided to the NFPA 855 committee on a history of field incidents involving lead acid and nickel cadmium battery systems for standby applications to show the safety of these technologies for standby applications. One source of this information has been research conducted by the NFPA Research Foundation outlined in a report entitled "*Fire Hazard Assessment of Lead Acid Batteries*".

There has also been some effort into developing criteria within UL 1973 to evaluate lead acid and nickel cadmium batteries that makes sense for the technologies and how they are used in the field. The criteria, which is included in a new proposed Appendix H in the standard, provides a set of construction, markings and instruction criteria as well as tests that effectively address the safety of both valve regulated and vented lead acid and nickel cadmium batteries. The criteria addresses the flammability of the battery casings as an example, and includes a thermal runaway overcharge test that has also been proposed as a test method for UL 9540A for lead acid and nickel cadmium batteries that the UL 9540/UL9540A Standards Technical Panel (STP) will review and ballot. The UL 1973 Appendix H test program is as noted in Figure 2. The tests were developed from a modified approach of the current UL 1989 protection device tests and construction criteria and UL 1973 general test program along with methods for testing based upon other standards addressing lead acid and nickel cadmium batteries including IEC standards with input from various industry stakeholders including manufacturers and users of the technologies. Installation instruction criteria include items currently provided in lead acid and nickel cadmium battery specifications such as spacings during installation, charging criteria, environmental limitations, appropriate wiring and overcurrent protection, etc. Additional proposals to revise UL 9540 Appendix D for lead acid and nickel cadmium batteries to align with the UL 1973 Appendix H criteria have also been submitted for the UL 9540/UL 9540A STP to consider. As a result, individual cells and batteries that have been evaluated to the criteria in UL 1973 should be able to be installed in a UL 9540 energy storage application with minimal additional testing at the system level.

This criteria can be applied for certification of the individual cells or monobloc batteries or a battery system composed of multiple batteries with an enclosure. For example, a lead acid cell or monobloc battery that has gone through this evaluation program can be safely installed in the field within a stationary battery storage application by following the manufacturer's installation instructions. A single lead acid or nickel cadmium cell or battery subjected to this program can now be certified under a new certification program at UL called "Vented and Valve Regulated Batteries for Use in Stationary Applications" under the category code YEXB. This designates that the individual cell or battery has met a level of safety and have been provided with the necessary instructions and markings to install them in the field without the need for further testing of those batteries for most applications. This approach takes into consideration the reality of how these batteries have been installed for many years in stationary applications in the field including battery rooms containing racks of these cells and batteries. It also ensures an increased level of safety oversight compared to the previous approach, where the batteries were either certified with a limited UL 1989 test program or not certified at all. Besides the additional testing and other criteria that these batteries will need to meet, certification ensures that there will be ongoing production inspections of the batteries taking place.

Listing to UL 1973 has been proposed as a choice for lead acid and nickel cadmium batteries for the next edition of NFPA 855 for stationary standby applications rather than listing to UL 9540. As noted, this makes more sense for these batteries that are typically installed in the field as individual cells or batteries for a stationary standby battery application, which has been the approach for these technologies and these applications over many years. As noted previously, if the lead acid and nickel cadmium batteries are intended to be used in an energy storage application, the system will still be required to be listed to UL 9540. However, even in this case, the new approach outlined in Appendix H of UL 1973 for cells and batteries will make this an easier path to achieving UL 9540 on the system.

This new approach to evaluating lead acid and nickel cadmium batteries, including the proposed criteria for UL 9540A, is additionally intended to provide a way for lead acid and nickel cadmium batteries to meet the exceptions in NFPA 855 that are allowed through the use of large-scale fire testing. The Overcharge Thermal runaway test is a 168-hour overcharge test, where temperatures are measured on the test batteries and target batteries installed next to the test battery in accordance with the manufacturer's instructions. Temperatures are measured on the test battery and target batteries as well as the black painted alcove they are installed in during the test. Also, during the test, the battery under overcharge is draped in a layer of cheesecloth indicator. In addition to its proposal in UL 1973 Appendix H, this same test is being proposed for inclusion in UL 9540A as a method to attempt to drive these types of cells and batteries into thermal runaway. UL 9540A also includes the gas collection and identification currently in the standard for these cells and batteries or allows the use of the methodology in IEEE 1635/ASHRAE Guide 21 to calculate the hydrogen produced during this testing with some additional guidance for the calculations. Lead acid or nickel cadmium cells and batteries that comply with the performance criteria at the cell or battery level can be considered to meet the UL 9540A criteria with appropriate ventilation per the codes.

Figure 2 - UL 1973 Appendix H Test Program for Lead Acid and Nickel Cadmium Batteries		
Test	**Test item Samples**	
	Cell and Battery	**Battery System**
Pressure Release (UL 1989 test for valve regulated cells and batteries)	1	-
Flame Arrester Vent Cap test (UL 1989 tests for vented cells and batteries): • Back pressure • Test for sustained burning • Test for flame propagation	6 (vent assemblies with flame arrestors)	-
Overcharge	3	-
Short circuit	3	-
Over-discharge Protection	3	-
Temperature and Operating Limits Check	1	-
Dielectric Voltage Withstand	1	1
Continuity	-	1
Static Force Test	-	1
Impact Test	-	1
Drop Impact	3	-
Mold Stress	-	1
Wall Mount Fixture/Support Structure/Handle	-	1
Salt Fog	1	-
Overcharge Thermal Runaway[a]	3	-
[a] This test in combination with off gas evaluation is proposed for inclusion in UL 9540A. NOTE: Battery system consists of a multi-cell or battery system that may be enclosed and provided with its own rack/support mechanisms, etc.		

Summary

The development of the UL 1973 Appendix H criteria for lead acid and nickel cadmium cells and batteries represents what can be accomplished when industry and standards development organizations such as UL work together to provide suitable safety criteria for evaluation of these batteries. This work continues with the effort to get acceptance of this approach into the various codes impacting lead acid and nickel cadmium batteries. This should also benefit the industry as it ensures that cells and batteries evaluated to these enhanced safety criteria will be installed into ongoing stationary applications. This is a positive development for all stakeholders utilizing these batteries for stationary applications.