Tracking battery safety right from the start

UL has been setting the standards on battery safety when batteries starting becoming more ubiquitous nearly 40 years ago. Laurie Florence, UL's Principal Engineer for Motive/Stationary Batteries, Energy Storage, Fuel Cells, and Capacitors reveals the history of battery standards developments.

As a premier standards development and safety certification organisation, UL has been involved in battery safety since the 1970's, starting with battery chargers (UL 1236) and in the 1980's publishing one of the first battery safety standards, UL 1642, for primary (non-rechargeable) lithium batteries followed by inclusion of requirements for secondary (rechargeable) lithium batteries (including lithium-ion). UL continues to be a leader in safety for the battery industry, which has come a long way. This includes utilisation of new battery technologies, many new battery applications, and facing new safety issues with the increased use of battery operated products.

The evolution of battery use through past decades has seen a change from the use of more traditional technologies such as lead-acid and Ni-Cd, to increasing use of lithium-ion. Use has also grown to include not only portable applications, but motive and stationary as well. In addition, battery standards have evolved from a more generic safety approach to the unique needs of specific applications. This issue was brought to light in the well-publicised notebook computer battery recalls of 2005 through 2006. The result of the findings from those large-scale recalls highlighted the reality that the high-tech industries' need for increased energy in an increasingly smaller footprint reduced the safety margins of the cells used in those products. As a result, a small contaminant in the cell introduced during production could result in the potential for catastrophic field failures. This realisation drove the industry and standards developers to drive battery standards forward, and come up with ways to better align the end product application and the battery used to power that application.

This experience also led UL to take a deeper look into the actual internal cell construction as part of the safety certification of the cell. UL helped industry improve requirements in UL 1642 (evolved to be only a portable lithium cell standard) and UL 2054 (portable lithium/nickel battery packs & nickel cells) including the certifications associated with those standards. UL then built off these concepts in other applications of batteries such as the portable tool industry.

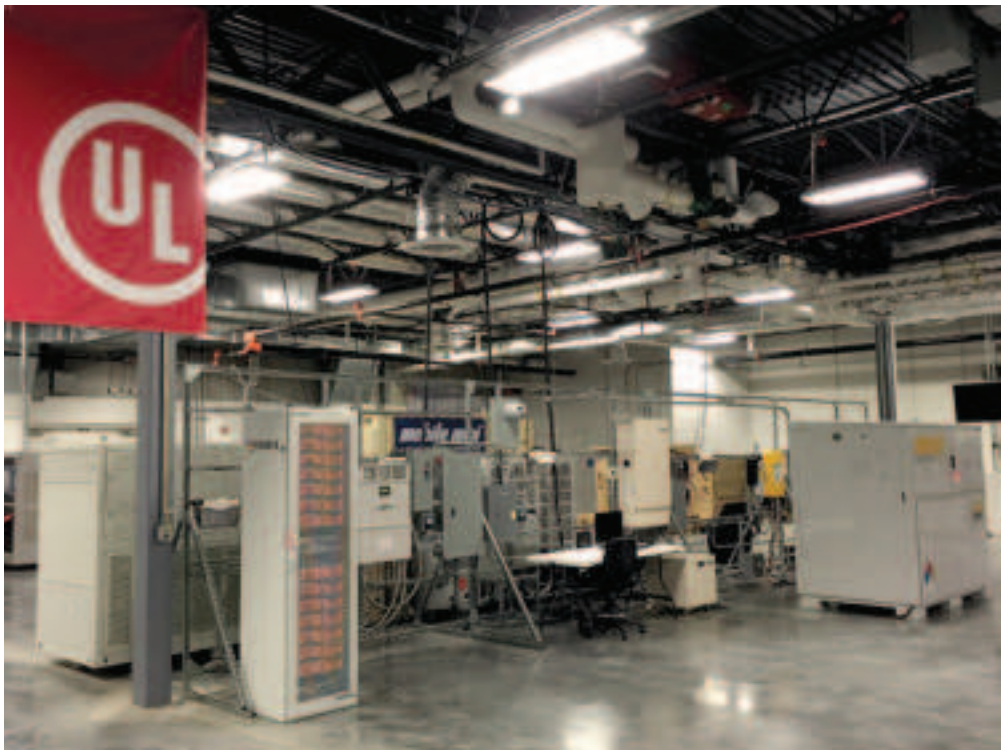
The portable-tool and appliance industries, which were becoming increasingly reliant on lithium-ion technology, approached the issue of battery safety for their industries by partnering with UL to develop UL 2575 in February 2011, later replaced by UL 2595 in May 2013. UL 2595, is a 'horizontal' standard that coordinates evaluation of the battery system of the particular tool or appliance. The critical development was to look at the combination of battery, charger and end-product using both UL 2595 requirements and the particular end-product standard requirements pertaining to the battery in order to determine that the system maintains the battery within its safety limits. This system approach to battery safety is necessary in order to help ensure that all parts of the electrical system effecting battery safety are evaluated together to validate the safety of the battery system.

As for the motive and stationary applications of batteries, it was around 2008 that the use of lithium-ion batteries in these applications,

such as electric vehicles, gained public notice. Up until this time, the batteries used in vehicles were primarily lead-acid for starting, lighting and ignition (SLI) and nickel metal hydride in hybrid electric vehicle (HEV) applications. The automotive industry began manufacturing vehicles more reliant on battery motive power such as plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs), as lithium-ion batteries provided sufficient energy density to be a practical solution for commercialisation. Although lithium-ion has the benefit of being one of the most energy-dense commercially available technologies, it also has a reputation for safety issues due to ongoing field incidents that continued to make headlines. Regulators and the general public need to have a level of confidence to accept these new technologies, which involve a very energy-dense battery in a large and complex system. There was also the issue of new players, outside of the traditional vehicle OEMs, developing electric vehicles that may have lacked the experience and resources to build a safe battery system. To address the concerns for safety, and because of UL's experience with evaluating lithium-ion batteries over the years, UL published UL Subject 2580 in November 2009 to address safety of batteries for EV applications. This later became the American National (ANSI) consensus Standard in October 2011 and a bi-national standard for the USA and Canada in December 2013. In December of 2013, UL also published the ANSI/ bi-national standard UL 2271 for the USA and Canada, which addresses light electric vehicle battery safety. This includes batteries for such diverse applications as motorcycles, wheelchairs or bicycles and other small motive applications. UL 2580 and UL 2271 are not technology specific, but they do include requirements for lithium-ion batteries and address concerns specific to the types of environments and abuses these motive applications may encounter.

Although UL 2580 and UL 2271 are specifically battery standards and do not include the charger requirements or other aspects of the vehicle electrical system, they address the safety of the battery management system (BMS) and require that the BMS along with any other protection controls in the battery system maintain the batteries in their specified operating region for voltage, temperature and current. This is critical for safety of all battery technologies but especially so for lithium-ion batteries that need to tightly control the voltage and temperature limits of the cells. These standards require a safety analysis of the battery system such as a failure modes and effects analysis (FMEA) and that electronics and software relied upon for safety are evaluated for functional safety. The FMEA needs to determine necessary performance level of the controls, which in turn impacts the scope of the functional safety investigation. The functional safety investigation of electronic controls consider single fault conditions and environmental stresses such as EMC, vibration, high temperature stress, temperature variation, etc. The software controls are evaluated for risks associated with both systematic faults due to software defects and random faults due to failures of microelectronics.

Just as lithium-ion batteries and other unique technologies are being



UL's Battery and Energy Storage Technology (BEST) test centre, located at the Battery Innovation Centre, is poised to advance the future of energy and the electrical grid.

utilised in new applications such as vehicle motive applications, stationary applications and energy storage applications there is less field experience and less information on the safety of these systems. Besides lithium-ion batteries, these stationary applications are less constrained by limitations for weight or even size in some cases and can consider more exotic technologies such as molten salt batteries and flow batteries. To address these various technologies and stationary battery safety, UL developed UL 1973 in July 2010 and later became an ANSI consensus standard in February 2013. UL 1973 continues to be in the forefront of safety for battery systems for these applications, and its inclusion of requirements for these various battery technologies was well in advance of other efforts to address stationary battery safety. Like the previous motive battery standards, UL 1973 requires a safety analysis such as an FMEA and includes requirements for functional safety if electronics and software are identified as critical to the battery system safety. Similar to UL 2580, UL 1973 also requires a propagation test for some technologies such as lithium-ion, where there is the potential for defects in production that could result in catastrophic failures not controllable by electronics in the field. The requirements evolved from UL's deep knowledge of battery safety, learnings from evaluation of unique stationary battery systems and input from the standards technical panel members, which includes a balanced mix of manufacturers, users of the technologies, government entities, authorities having jurisdiction, and other organisations. UL 1973 has gone through additional revisions since it was published in 2013 to address additional learnings that included major revisions published in June 2016 such as stationary lithium cell criteria. Since its publication, UL 1973 has been the go-to-standard for certification of these stationary systems and component packs and modules intended for stationary system installations. It has provided the industry, customers and regulators with a level of comfort that these stationary systems are safe for installation.

From UL 1973, it was a natural progression to development of UL Subject 9540 for energy storage systems in July 2015. This standard addresses the unique concerns of energy storage systems. This includes battery safety and grid/wiring system connectivity, as well as issues such as balance of plant components, HVAC and lighting systems and fire detection and suppression systems, and work space and life safety criteria applicable to walk-in systems. UL 9540 looks at the safety of these various critical components in a complete system, and like the other standards utilises safety analysis, component criteria and testing to evaluate for safety.

Razor's new, UL-certified, Hovertrax-Hologram

Again, UL was in the forefront of safety standards development and safety certification of these complete systems. UL 9540 stands out as a pioneering document to provide a framework for evaluating safety of energy storage systems and covers not only battery systems but mechanical, chemical and even thermal energy storage systems. UL 9540 is in the process of being finalised as an ANSI and bi-national standard for the USA and Canada.

Through these efforts, UL has offered the industry a means to validate the safety of their systems to promote acceptance. This continued with the effort to address hoverboard safety with the publication of UL 2272 in a matter of weeks. UL is now able to certify products to UL 2272, and some products that caused global concern are now certified by UL for safety, providing the public with ease of mind. UL 2272 is scheduled to be finalised as an American and Canadian National standard within a few months.

UL has taken the initiative to address the safety of batteries, and the industry, retailers and consumers alike have benefited from UL's efforts. Batteries are part of our world and they have been gaining traction as a way for providing reliable power, cutting the plug and reliance on fossil fuels. UL continues to be actively been involved in leading the efforts to address the safety of this evolving industry. From our battery research activities, to development of battery safety standards, to experience evaluating batteries for certification, to our outreach to retailers, regulators and consumers— UL has been a champion for battery safety for decades and we look forward to continuing to promote safe battery technologies.