SUPERCHARGING THE SAFETY SCIENCE OF ADVANCED BATTERIES

Compliance, research and risk management solutions across the global value chain

LEADING THE PACK

Universally recognized as the global leader in battery safety science, UL published its first standard for lithium batteries 30 years ago. Since then, batteries have expanded dramatically in size, chemistry, energy density and applications. UL is committed to advancing battery safety science in tandem with the fast pace of innovation: through targeted safety research, standards development activity and certification testing that deliver trust and acceptance to global markets.

RESEARCHING THE POTENTIAL

As a part of our public safety mission, UL conducts research into battery safety to provide better understanding of batteries, their safety profiles, material attributes and failure mechanisms. In addition to our self-funded ongoing research, our scientists also design and conduct investigations into specific customer questions. From microscopic material analyses to fire suppression simulations for large-scale storage, UL has the capabilities and expertise to accommodate most research needs.

DEVELOPING AND UPDATING STANDARDS

UL not only tests and certifies, we also contribute to the development and international harmonization of safety and performance standards relevant to the battery industry. UL standards cover most every type of battery product available, from cell to pack to energy storage system, and for chemistries from lithium ion to nickel cadmium.

Developed and maintained through a multi-stakeholder, consensus ANSI process, UL standards can deliver confidence to product developers and customers, as well as compliance to various codes, regulations and procurement policies. As technology advances, so do UL standards, enabling innovation to be met with acceptance and confidence.

SHARING THE SCIENCE

Knowledge is power. At UL, we also believe it's meant to be shared. That's why we use our research and experience to energize and grow the battery industry through education. By informing the industry about how new battery technologies are influencing risk profiles and safety considerations, everyone stays on top of the key issues.

ADVISING AGAINST SURPRISES

UL enhances understanding and reduces surprises through advisory services to manufacturers throughout the product lifecycle – from design advisory during R&D to hazard-based analysis during system integration. We also work with many non-manufacturers interested in better understanding and reducing the risks associated with advanced battery technologies, such as end users, insurers, and transportation organizations.

TRAINING SAFER WORKFORCES

To promote a safer working environment, UL offers self-paced training to factory, assembly, maintenance, transportation and shipment workers across the entire battery value chain. Engaging and effective, these online courses are available around the clock, either as off-the shelf or customized services for your organization, and cover everything from lithium-ion shipments to stress management.

All courses are developed by dedicated training experts in collaboration with our safety professionals and are continuously updated to address compliance requirements.

INFORMATIVE WEBINARS

We also hold regular webinars, which help manufacturers and other stakeholders navigate the increasingly complex regulatory environment. To join our mailing list for upcoming battery webinars, visit www.ul.com/batt

POWERING PROGRESS ACROSS THE BATTERY VALUE CHAIN

UL services cover the entire value chain of the energy storage industry. From suppliers, manufacturers and system integrators, to insurers, shippers, retailers and consumers, UL transforms decades of experience and expertise into tangible assistance. Here are some of the overarching services on which our customers depend.

SAFETY

Safety compliance testing, inspection and certification for accessing and achieving differentiation in global markets. UL has been a leader in safety testing and certification of battery technology for over 30 years.

PERFORMANCE

UL performance testing is available across the value chain, from competitive benchmarking for materials to charge/discharge and overcharge tests for cell and battery pack manufacturers as well as environmental & altitude simulation for system integrators. We also offer UL performance certification marks for battery products compliant to relevant IEC standards.

UN/DOT COMPLIANCE

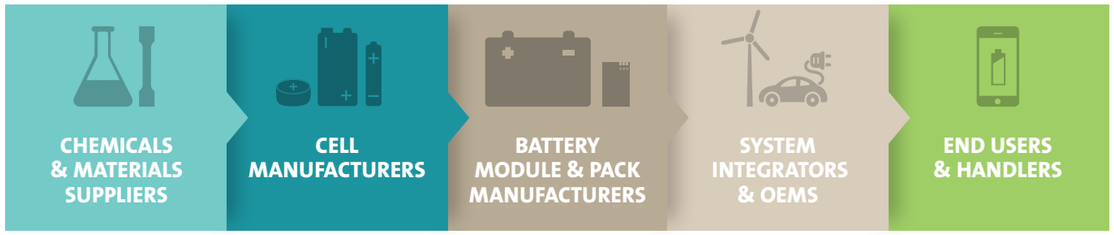
UN/DOT 38.3 is an international standard designed to ensure the safety of lithium batteries when transported. UL has multiple testing labs across the globe to demonstrate compliance with UN/DOT 38.3.

SUSTAINABILITY

UL Environmental Claims Validation provides manufacturers with credibility for their environmental sustainability claims, such as battery recycling programs. Validated products are featured on UL's publicly-available Sustainable Product Database.

TRANSPARENCY

Companies with effective responsible supply chain management systems gain competitive advantage for their brand. UL experts offer a range of services to help companies identify and track potential conflict minerals in their supply chain, supporting increased customer loyalty and corporate profitability.



CUSTOM RESEARCH

RISK MANAGEMENT

TRAINING AND WEBINARS

ENVIRONMENTAL CLAIMS VALIDATION

SAFETY COMPLIANCE TESTING, INSPECTION AND CERTIFICATION

PERFORMANCE TESTING AND CERTIFICATION

RESPONSIBLE SOURCING

UL'S PROSPECTOR MATERIALS DATABASE

DESIGN REVIEW AND ADVISORY

UN/DOT COMPLIANCE

SEPARATOR SAFETY

EMC COMPATIBILITY

FUNCTIONAL SAFETY

EV CONFORMITY

FIELD EVALUATION

FORENSIC ANALYSIS

CHEMICALS & MATERIALS SUPPLIERS

Our decades of experience have positioned us as the leader in chemicals and materials testing for a broad range of applications. Our technical experts assist customers in identifying and remediating potential product vulnerabilities throughout the entire production process.

RAW MATERIAL SELECTION WITH UL'S PROSPECTOR® DATABASE

UL's Prospector database is the premier database for battery manufacturers to quickly find the precise raw materials they need. Bringing together thousands of suppliers, UL's Prospector database offers a free online service to sort and search materials by properties, applications, safety data, performance characteristics and more. By combining unparalleled access to product technical data with state-of-the-art database interactivity, customers can easily find what they need, and even request samples with one click.

ULProspector.com

SAFETY TESTING AND CERTIFICATION

UL tests and certifies materials against an ever-expanding list of UL and other standards, including:

- UL 94
- UL 746 A, B and C
- CSA C22.2, NO. 0.17
- Subject 2591 Battery Separators
- ASTM D882 Standard Test Method for Tensile Properties of Thin Plastic Sheeting
- ASTM 3763 Standard Test Method for High Speed Puncture Properties of Plastics Using Load and Displacement Sensors

PERFORMANCE TESTING

UL has a very robust plastics and material science practice. We offer a variety of material-level testing for companies which are developing materials for lithium ion and other advanced battery technology. Our performance tests include:

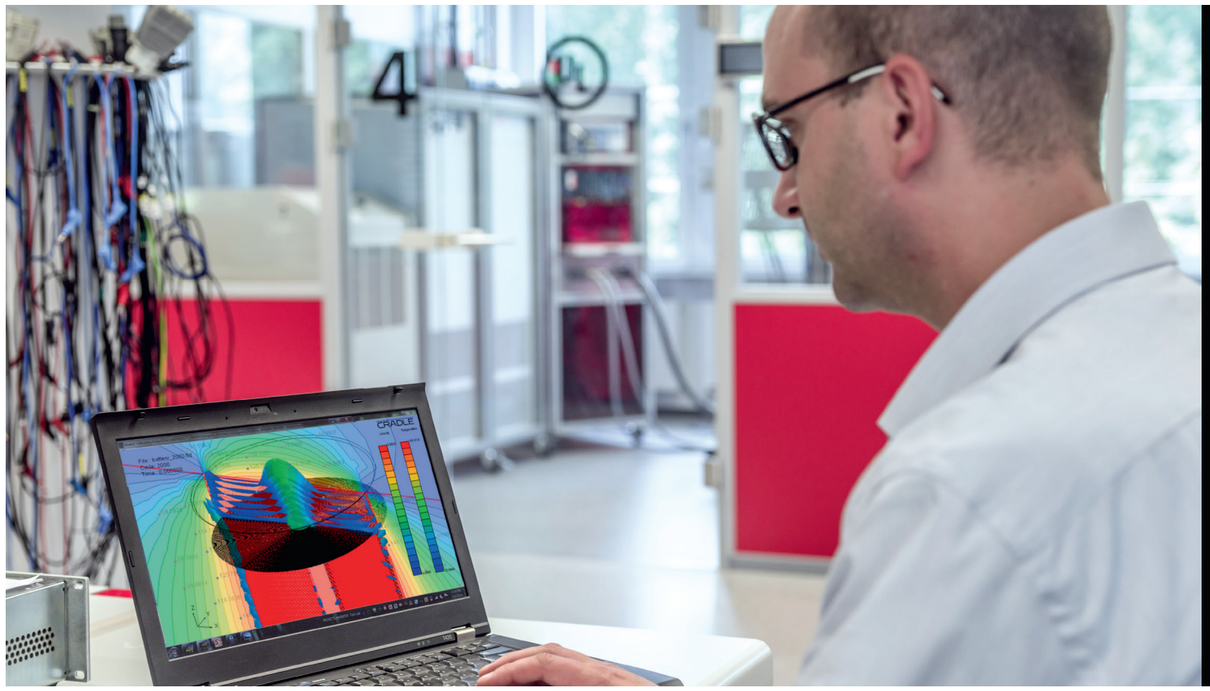
- Competitive materials benchmarking
- Materials attribute validation
- Analytical testing

CUSTOM RESEARCH

- Disassembly and failure inspection
- Material ID and properties analysis
- Morphology analysis
- Contamination characterization
- Battery effluence analysis
- Electrolyte elemental analysis
- Electrolyte viscosity-temperature dependence analysis
- Forensic analysis
- Materials aging and reliability study

OTHER UL SERVICES

- Supply chain leads and analytics
- VOC testing
- Restricted substances evaluation
- Raw materials traceability



CELL MANUFACTURERS

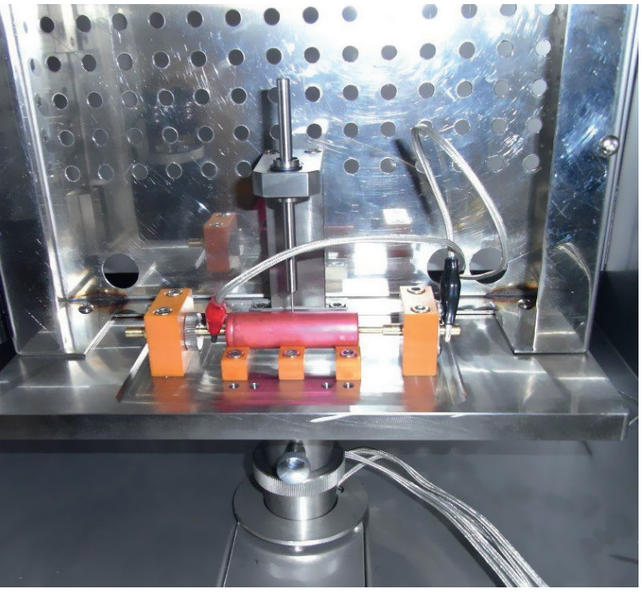
As portable electronic devices proliferate, the efficiency, reliability and safety of battery cells to power them becomes ever more critical. UL offers a targeted array of services designed to give manufacturers peace of mind and buyers and consumers increased confidence in their products.

BATTERY SEPARATOR SAFETY

UL provides many related services essential to the success of cell manufacturers. One example is our battery separator safety service. We test lithium-ion cell battery separators to UL 2591, to give battery separator manufacturers a competitive edge.

IN-HOUSE EMC COMPATIBILITY

UL also offers cell manufacturers an electromagnetic compatibility (EMC) service, providing a customized package to optimize their own testing capabilities. This enables manufacturers to identify and resolve EMC problems as early as possible.



SAFETY TESTING AND CERTIFICATION

UL has 3 accredited CTIA-Authorized Test Labs (CATLs) in China, Taiwan, and the USA. Our CTIA Battery Certification program offers manufacturers and suppliers a flexible and cost-effective way to gain industry recognition.

CTIA certification demonstrates that mobile battery products are in compliance with IEEE 1725 (rechargeable batteries for cellular telephones) or IEEE 1625 (rechargeable batteries for portable computing). CTIA certification is required by a number of telecom providers, and can be combined with other UL battery testing and certification service options to save time and money.

UL also tests and certifies battery cells to:

- UL 810A (electrochemical capacitors)
- UL 1642 (primary/rechargeable lithium cells)
- UL 1973 (large format cells for stationary applications)
- UL 2054 (primary/rechargeable non-lithium cells)
- UL 2580 (large format cells for EV applications)
- IATA / UN DOT / UN 38.3 T1-5, T6, T8 (or IEC 62281)
- IEC 60086-4 (non-rechargeable lithium cells)
- IEC 60086-5 (primary, aqueous electrolyte cells)
- IEC 62133 1st/2nd Edition (rechargeable nickel / lithium cells)
- IEEE 1625/1725 (CTIA)
- CNS 15364 (Secondary L-I – China / Taiwan)
- JIS C 8715-2 (Stationary – Japan)
- CQC Mark (China)
- CQC3306 (L-I portable equipment – China)
- GB/T18287 (L-I for mobile phone – China)
- CE Marking (Europe)
- D Mark (Denmark)
- DENAN Ordinance, Appendix 9 (Japan)
- GOST-R (Russia)
- KC Mark (Korea)
- MC (Malaysia)
- RPC Mark (Taiwan)

These tests can be combined into a turnkey conformity assessment based on individual customer needs, with UL handling the entire streamlined process and delivering the applicable certification marks/certificates upon successful completion.

PERFORMANCE TESTING AND CERTIFICATION

- Capacity Check
- Charge/Discharge Cycling
- Overcharge
- Environmental & Altitude Simulation

UL Performance Certification Mark offered:

- IEC 60086-1 & IEC 60086-2 (non-rechargeable performance)
- IEC 61960 (rechargeable lithium performance)
- IEC 61951-1 (rechargeable Ni-Cd performance)
- IEC 61951-2 (rechargeable Ni-MH performance)

CUSTOM RESEARCH

- Validation of charging/discharging protocol
- Pulse charging/discharging
- Aging Analysis
- L-I Cell Operation Window Assessment
- Construction Assessment
- Forensic Analysis/ failure investigation
- EIS Analysis
- CT Analysis
- ARC Analysis
- Internal Short Circuit Simulation and Failure Analysis
- Smoke Characterization
- Cell headspace gas analysis
- FTA of failure modes
- Cell characterizations

ADDITIONAL UL SERVICES

- UL Prospector **see p. 8**
- Design Review & Advisory **see p. 5**
- Workforce Safety Training **see p. 5**

BATTERY MODULE & PACK MANUFACTURERS

Reflecting a fast growing diversity of demands, cell chemistries are proliferating, cell energy density is increasing, and battery packs are growing in size and power. Battery pack manufacturers and users such as EV manufacturers and utilities need more support than ever to decrease the risk of and damage caused by short circuiting, overheating and thermal runaway.

EV CONFORMITY ASSESSMENT PROGRAM

Fire and electric shock hazard risks – while not prevalent with conventional vehicles – are comparatively high in electric vehicles (EV). To address the key industry challenges, UL offers two standards for large format batteries in EV:

- UL 2271 – Light Electric Vehicles (LEV)
- UL 2580 – Electric Vehicles (EV)

These standards have been designed jointly with the key stakeholders to help mitigate the potential risk of fire and electrical hazards and enhance the overall safety of batteries for electric vehicles. Through electrical, mechanical and environmental testing, they evaluate the ability of large batteries to safely withstand simulated abuse conditions based upon the manufacturer's specified charge and discharge parameters.

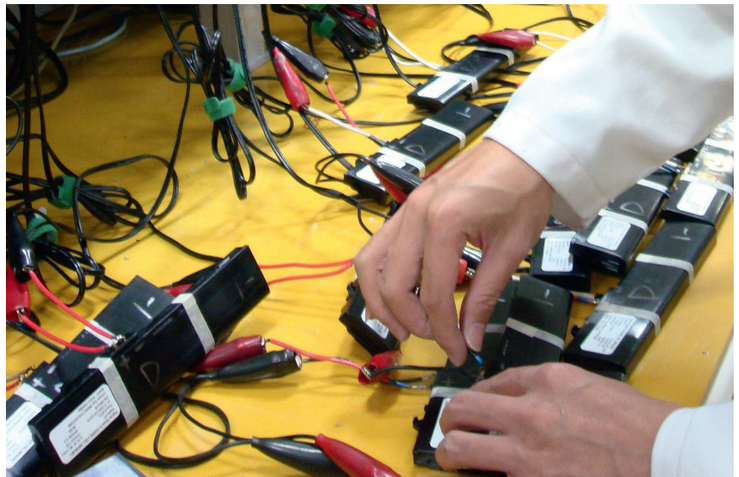
In addition to these safety requirements UL offers a broad range of component recognition, follow-up and performance verification services. Certifying products with UL extends compliance and provides unparalleled assurance, confidence and competitive differentiation in the marketplace.

FUNCTIONAL SAFETY FOR BATTERY MANAGEMENT SYSTEMS

UL Functional Safety for Battery Management Systems tests the safety of the sophisticated software crucial to the proper and safe functioning of the battery module or pack, as well as how the battery interacts with the system as a whole. UL functional safety certification provides everyone in the product value chain with peace of mind and prevents the costly consequences of malfunction.

LITHIUM-ION KNOWLEDGE

UL scientists are continually developing new methods to ensure the safe adoption of lithium-ion batteries. For instance, we developed a unique thermal model of the common 18650 lithium-ion battery cell that enhances our ability to mathematically simulate, explore and understand the causes and severity of internal short circuits. We also applied our materials science expertise to develop a testing approach that establishes a more robust evaluation of lithium-ion battery separators. In addition, we established a comprehensive thermal analysis capability that enables us to identify and measure exothermic and endothermic reactions within a lithium-ion battery cell.
UL science – at your disposal.



SAFETY TESTING AND CERTIFICATION

UL tests and certifies battery modules and packs to these important standards:

- UL 991 & UL 1998 for Battery Management Systems
- UL 1973 (stationary applications)
- UL 1989 (rechargeable stand-by batteries)
- UL 2054 (Primary and Secondary batteries; primary/rechargeable lithium or non-lithium packs)
- UL 2595 (Appliances)
- IATA / UN DOT / UN 38.3 T1-5, T7 (or IEC 62281)
- IEC 60086-4 (L-I) & 60086-5 (aqueous electrolyte) for Primary Safety
- IEC 62133 1st/2nd Edition (rechargeable nickel / lithium)
- IEEE 1625/1725 (CTIA)
- ISO FDIS 12405-3 Li-Ion EV Battery Safety
- SAE J2464 (RESS abuse manual)
- SAE J2929 (L-I r EV battery safety)
- CNS 14336-1 (L-I Power Bank – China / Taiwan)
- CNS 15364 (Secondary L-I – China / Taiwan)
- CNS 15387 (Secondary lithium-ion batteries for electric motorcycles – China / Taiwan)
- CNS 15424-1 and CNS 15424-2 (Electric motorcycles battery system – China / Taiwan)
- JIS C 8715-2 (Stationary – Japan)
- CQC Mark (China)
- QC/T743 (L-I EV – China)
- QC/T744 (Ni-MH EV – China)
- QC/T741 (Ultra-Caps for vehicle – China)
- GB/Z 18333.2 (Zinc-air EV – China)
- QB/T 2947.3 (L-I or Ni-MH e-Bike – China)
- CE Marking (Europe)
- D Mark (Denmark)
- DENAN Ordinance, Appendix 9 (Japan)
- GOST-R (Russia)
- KC Mark (Korea)
- MC (Malaysia)
- RPC Mark (Taiwan)
- PSE Mark (Japan)
- S Mark (Japan)
- SBA 1101 (Stationary – Japan)
- ANATEL Certification (Brazil)
- VPC Certification (Taiwan)
- GS Mark (Germany/EU)

PERFORMANCE TESTING AND CERTIFICATION

- Capacity Check
- Charge/Discharge
- Overcharge
- Environmental & Altitude Simulation

UL Performance Certification Mark offered:

- IEC 60086-1 & IEC 60086-2 (non-rechargeable performance)
- IEC 61960 (rechargeable lithium performance)
- IEC 61951-1 (rechargeable Ni-Cd performance)
- IEC 61951-2 (rechargeable Ni-MH performance)

CUSTOM RESEARCH

- Construction Assessment
- Forensic Analysis/ failure investigation
- FTA of failure modes
- Internal Short Circuit/Failure
- Smoke Characterization
- Failure Propagation

ADDITIONAL UL SERVICES

- Design Review & Advisory **see p. 5**
- Workforce Safety Training **see p. 5**

SYSTEM INTEGRATORS & OEMS

Large battery systems present unique safety considerations, as they contain high levels of energy and may utilize hazardous materials and moving parts. UL works hand-in-hand with system integrators and OEMs to better understand these considerations and address them.

SAFETY TESTING AND CERTIFICATION

UL 9540 is a new standard for safety of energy storage systems, which includes electrical, electro-chemical, mechanical and other types of energy storage technologies for systems intended to supply electrical energy. The standard covers a comprehensive review of energy storage systems, covering charging, discharging, protection, control, communication between devices, fluids movement and other aspects.

UL 9540 provides a basis for safety of energy storage systems that includes reference to critical technology safety standards and codes such as UL 1973, UL 1741, IEEE 1547 and 1547.1, CSA FC1, NFPA 70, NFPA 2, ASME B & PV Code, and ASME B31 piping codes, etc. It includes additional criteria to address materials, enclosures (including walk-in enclosures), controls, piping, utility grid interaction including special purpose interactive systems, hazardous moving parts, signage and instructions. Also included are tests for interactive systems, evaluation of electrical spacings and insulation, as well as moving parts that may not be covered in current technology standards to more fully address energy storage system safety.

The new standard fills a unique function, and is the result of a cooperation between UL and stakeholders in the industry, government, research institutes and the insurance sector. ESS certification can be achieved through a product testing engagement (typically for off-the-shelf ESS products) or through an on-site, non-destructive field evaluation for unique systems.

PERFORMANCE TESTING

- Environmental & Altitude Simulation

CUSTOM RESEARCH

- Simulation of Fire Suppression / Containment System
- Construction Assessment
- Forensic Analysis/ failure investigation
- Internal Short Circuit/Failure
- Smoke Characterization
- Battery aging study

ADDITIONAL UL SERVICES

- Design Review & Advisory **see p. 5**
- Field Evaluation **see p. 16**
- Workforce Safety Training **see p. 5**

END USERS & HANDLERS

Lithium-ion and other advanced batteries have quickly become a powerful and ubiquitous form of rechargeable energy storage around the world, extending from consumer electronics to large format applications such as transportation and utility-scale energy storage. As a user, handler, shipper or insurer of lithium-ion batteries, it's important to understand their inherent risks and hazard profiles for thermal runaway, combustion and toxic emissions. UL equips companies with tools to reduce these risks, helping to protect their people, organization and brand.

LITHIUM-ION HAZARD MANAGEMENT

A growing number of non-manufacturing stakeholders in the lithium-ion battery value chain turn to UL to better understand the risks of lithium-ion batteries to their businesses, customers and employees. UL now provides a comprehensive suite of research, analysis and advisory services designed to address the needs of these stakeholders. We can tailor a multidisciplinary program to suit specific customer needs, including field evaluations, hazard-based analysis and simulation, training and custom research. UL also supports organizations in addressing key hazards with preventative and/or corrective actions that will reduce or remove risk. This unique program delivers significant value to companies that insure, handle, ship or store lithium-ion batteries.

FORENSIC ANALYSIS

Building on extensive experience in system-level testing, UL's comprehensive suite of forensic analysis tools and techniques help to better identify and understand the root causes of lithium-ion battery failures, enabling manufacturers, integrators and end users to address the issues, improve battery safety and reduce the chance of future events.

FIELD EVALUATION

UL provides responsive, on-site field evaluation services to keep you on schedule. By assisting Authorities Having Jurisdiction (AHJ) in determining "acceptance" of a product leading to "approval" of an installation, your equipment can be energized without delays. Installing un-labeled equipment and getting an AHJ rejection (red tag) can cause you and your customer a variety of problems. UL's Field Evaluation Services are available worldwide to owners, manufacturers and contractors who care about their reputation and their bottom line.

CUSTOM RESEARCH

- Simulation of Fire Suppression / Containment System
- Construction Assessment
- Forensic Analysis/ failure investigation
- Internal Short Circuit/Failure
- Smoke Characterization

ADDITIONAL UL SERVICES

- Procurement Specification Support
- Workforce Safety Training **see p. 5**

DELIVERING GLOBAL ACCESS

FOR THE BATTERY INDUSTRY

UL helps simplify multiple market compliance by bundling product tests and certifications to meet all the requirements of national and regional market standards. Regardless of your location, UL can provide a single streamlined process that reduces administrative and project management costs, creating faster access to global markets. We call it Global Market Access.

TALK TO US RIGHT FROM THE START

Involving UL right from the product conceptualization stage helps your development team understand the intricacies of certification so you can avoid non-compliance early on and make the informed decisions that safeguard launch dates. Benefit from the added value of earlier market access and cost savings, as well as the confidence and comfort that come with a simplified process.

Explore the global marks/certifications that UL enables the global battery industry to achieve. Contact your local representative to start the certification process to target multiple markets.

For general information and illustration purposes only. The map and tables above represent some of the marks and certificates that UL may be able to assist you in obtaining. UL does not guarantee access to any market or that you will obtain any of the marks or certificates identified above. Mark and certificate requirements may vary from product to product.

MARK	NAME	MARKET ACCESS	MANDATORY/ VOLUNTARY
	IECEE CB Scheme	International	Voluntary
	UL Mark	US	Mandatory in specific applications
	Recognized Component Mark	US	Mandatory in specific applications
	US Cellular Carrier - Mobile Phones and Tablet Batteries & Systems	US	Mandatory
	Anatel Mark	Brazil	Mandatory
	CE Marking	Europe	Mandatory
	UL-EU Mark	Europe	Voluntary
	UL-GS Mark	Germany	Voluntary
	D Mark	Denmark	Voluntary
	Gost-R Mark	Russia	Mandatory
	CQC Mark	China	Voluntary
	KC Mark	Korea	Mandatory
	PSE Mark	Japan	Mandatory
	S Mark	Japan	Voluntary
	BSMI (RPC) Mark	Taiwan	Mandatory in specific applications
	TISI Mark	Thailand	Mandatory
	MC Mark	Malaysia	Mandatory
	C-Tick Mark	Australia	Mandatory
	ICAO mandated UN 38.3 Test Report	International	Mandatory
	IATA mandated UN 38.3 Test Report	International	Mandatory
	UN ECE developed Manual of Tests and Criteria – Section 38.3	International	Mandatory

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