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Recent safety trends and challenges facing the industry

Electric vehicles (EVs) have revolutionized the automotive industry, offering sustainable alternatives to traditional vehicles with an internal combustion engine. However, the rise in EV adoption has brought significant safety challenges, particularly concerning lithium-ion batteries. While essential for EV functionality, some consumers may have concerns about these batteries with overheating, fires, explosions, and other hazards. Considering both the EV battery's risks and rewards, recent safety trends and challenges facing the industry include:

- **The increase in EV-related incidents:** As more EVs hit the road, there has been an increase in reported incidents of battery malfunctions leading to fires. Manufacturing defects, damage during usage or improper handling of the batteries often cause these incidents.
- **Advancements in safety technology:** Manufacturers are developing advanced management systems and more stable electrode materials to combat these issues. Innovations such as solid-state batteries, which use solid electrolytes instead of liquid ones have been revealed to offer enhanced safety and stability
- **Regulatory actions:** Governments and agencies have updated lithium-ion battery production, transportation and disposal safety standards. These regulations aim to minimize risks and demonstrate that batteries meet stringent safety criteria before they reach the market. Notable standards include ISO 6469-1, SAE J2929, IEC 62660-3 and UL 2580 the Standard for Batteries for Use in Electric Vehicles.
- **Awareness and education:** An enhanced understanding of the risks has led to increased educational campaigns on proper battery use and disposal, with both consumers and industry professionals learning best practices for handling and maintaining lithium-ion batteries.

EV batteries: Where most failures and safety issues occur

Despite advancements, safety concerns persist due to the high energy density of lithium-ion batteries, which utilize reactive electrode materials and flammable electrolytes. A single manufacturing flaw can lead to catastrophic failures, emphasizing the need for continual improvement in safety standards. Categories that have experienced failures and safety issues include:

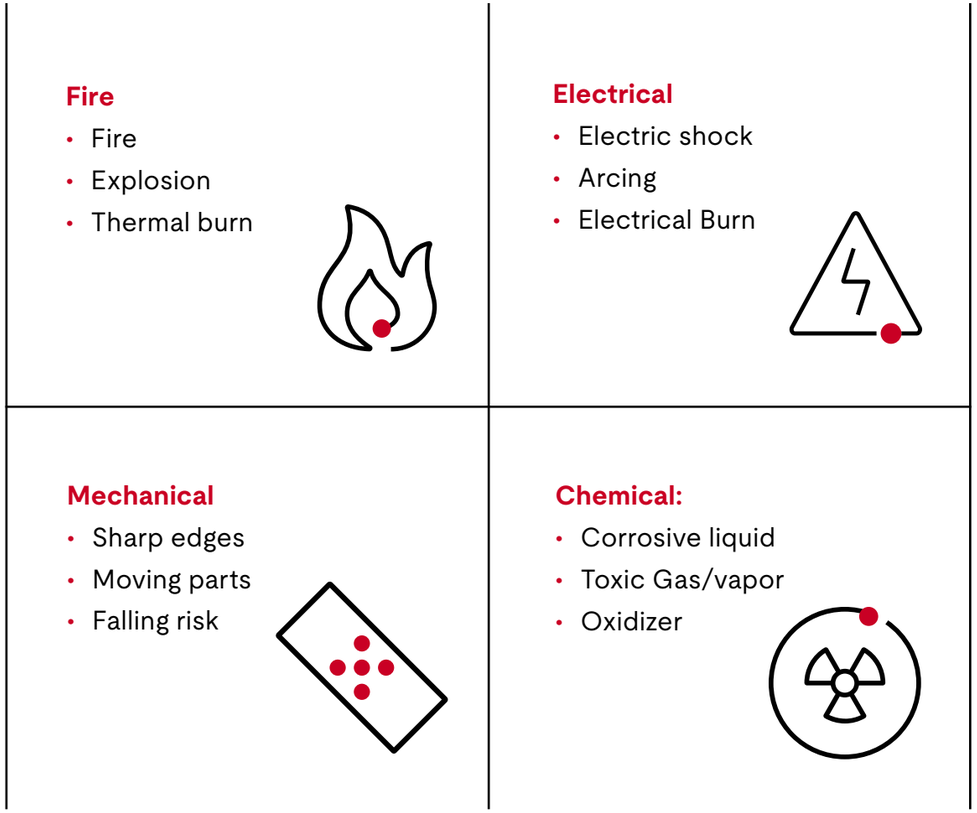
- **Energy:** Triggered by fire, explosion and thermal burn
- **Electrical:** Initiated by electric shock, arcing and electric burn
- **Chemical:** Affected by corrosion liquid, toxic gas/vapor and oxidizers
- **Mechanical:** Caused by sharp edges, moving parts and falling risk

Additionally, the physical handling of lithium-ion batteries can cause safety issues that include:

- Thermal runaway
- Off-gassing
- Stranded energy
- Electric shock
- Fire, explosion and chemical exposure

Combining the factors that increase these risks, like the use of uncertified batteries, modifications and mismatched parts, with the factors impacting their severity, such as underground garage events, blocked egress, adjacent exposures and re-ignition issues, creates a critical need for better safety solutions.

Today, battery manufacturers, OEMs and suppliers are overcoming these challenges by investing in innovative research and development to help them not just create safer battery designs but also improve safety-centered processes throughout the supply chain.



The role of safety standards

Safety and performance standards are crucial for the advancement and sustainability of electric vehicles and batteries. These industries' growth and success depend on consumers' and stakeholders' trust that these technologies perform without risk of harm. This is where standards come in, serving as a way to specify requirements in design and performance that are proven to drive safety.

Safety standards are created through a consensus process that integrates the input and agreement of relevant stakeholders and professionals. This collaborative approach helps to ensure that regulatory bodies deliver unbiased standards for use in relevant industries, balancing the needs and interests of various parties to garner broad support and implementation.

Industries seeking to operate in relevant markets turn to independent testing providers to perform testing to assess whether specified requirements are met. UL Standards & Engagement, the Society of Automotive Engineers (SAE), and the International Electrochemical Commission (IEC) have published standards for Electric Vehicles and EV batteries, providing the market with clear requirements for their products and components.

Applicable market	Standard no.	Standard name	Scope
North America	UL 2580	Standard for Batteries for Use in Electric Vehicles	Evaluate safety of cell, batteries to withstand simulated abuse conditions and prevents any hazards through testing and construction requirement.
North America	SAE J2929	Safety Standard for Electric and Hybrid Vehicle Propulsion Battery Systems Utilizing Lithium-based Rechargeable Cells	Evaluate safety of cell, batteries to withstand simulated abuse conditions and prevents any hazards through testing and construction requirement.
North America	SAE J1798	Performance Rating of Electric Vehicle Battery Modules	Provides for common test and verification methods to determine Electric Vehicle battery module performance
North America	SAE J2380	Vibration Testing of Electric Vehicle Batteries	Describes the vibration durability testing of a single battery (test unit) consisting of either an electric vehicle battery module or an electric vehicle battery pack.
North America	SAE J2464	Electric and Hybrid Electric Vehicle Rechargeable Energy Storage System (RESS) Safety and Abuse Testing	Describes a body of abuse tests for EV cells and batteries.
North America	FMVSS	Federal Motor Vehicle Safety Standards	U.S. federal vehicle regulations specifying design, construction, performance, and durability requirements for motor vehicles and regulated automobile safety-related components, systems, and design features.
North America	CMVSS	Canadian Motor Vehicle Safety Standards	Identify mandatory minimum safety performance requirements for new motor vehicles and vehicle equipment in Canada.
Europe	UN ECE R100	Uniform provisions concerning the approval of vehicles with regard to specific requirements for the electric power train	Safety requirements with respect to lithium System, of road vehicles of categories M and N.
Europe	UN ECE R136	Uniform provisions concerning the approval of vehicles of category L with regard to specific requirements for the electric power train	Describes the safety requirements with respect to the electric power train and REESS of vehicles of category L.

The role of safety standards

Applicable market	Standard no.	Standard name	Scope
China	GB 38031	Electric vehicle traction battery safety requirements	Safety requirements and testing methods for the traction cells, and battery systems for EV.
Korea	KMVSS	Korean motor vehicle safety standards	Covers various aspects related to vehicle design, construction, performance and safety features including test and verification methods to determine electric vehicle battery module performance.
Germany	LV 124	German automotive manufacturer testing standards	Quality and reliability test standard jointly established by German automotive manufacturers. The standard consists of Part I: electrical requirements and tests and Part II: environmental requirements and tests.
International	ISO 6469-1	Electrically Propelled Road Vehicles — Safety Specifications — Part 1: Rechargeable Energy Storage System (RESS)	Specifies safety requirements for rechargeable energy storage systems (RESS) of electrically propelled road vehicles for the protection of persons.
International	IEC 62660-3	Secondary Lithium-ion Cells for the Propulsion of Electric Road Vehicles — Part 3: Safety Requirements	Specifies test procedures and acceptance criteria for safety performance of secondary lithium-ion cells and cell blocks used for propulsion of electric vehicles (EV) including battery electric vehicles (BEV) and hybrid electric vehicles (HEV).
International	IEC 63057	Secondary Cells and Batteries Containing Alkaline or Other Non-acid Electrolytes — Safety Requirements for Secondary Lithium Batteries for Use in Road Vehicles Not for the Propulsion	Specifies safety tests and requirements for secondary lithium batteries permanently installed in road vehicles not for the propulsion.
International	ISO 6469-1	Electrically propelled road vehicles — Safety specifications — Part 1: Rechargeable energy storage system (RESS)	Specify safety requirements for lithium battery system of EV for the protection of persons.
International	ISO 26262	Road vehicle - Functional safety	Includes activities such as requirements analysis , safety analysis, quality management, design, implementation, integration, verification, validation, and configuration. This applies to road vehicles such as motorcycles, traditional oil-powered cars and trucks, hybrids, and autonomous vehicles.

Safe transport of lithium-ion batteries

Lithium-ion batteries are classified as dangerous goods under the “United Nations Recommendations on the Transport of Dangerous Goods Models Regulations,” transporting them involves unique risks. The UN 38.3 Transport Test helps ensure batteries withstand transport conditions through rigorous testing, including:

1. **Height Simulation:** Testing resilience at various altitudes.
2. **Thermal Test:** Assessing performance under extreme temperatures.
3. **Vibration:** Testing stability during transport vibrations.
4. **Shock:** Assessing the robustness of cells and batteries against cumulative shocks.
5. **External Short Circuit:** Testing safety under short circuit conditions.
6. **Impact/Crush:** Evaluating durability under crushing forces.
7. **Overcharge:** Evaluating the battery’s ability to withstand a overcharge condition.
8. **Forced Discharge:** Assessing behavior during forced discharge.

Interoperability, cybersecurity and functional safety in EV battery systems

Interoperability is vital for seamlessly integrating EV batteries across various models and manufacturers. Standardizing battery cells and systems facilitates easy swapping and replacement, enhancing the EV ecosystem's efficiency. These can include:

- Standardized batteries: By developing interchangeable batteries across different EV models, OEMS can simplify maintenance and repair and reduce costs and downtime for consumers and fleet operators.
- Battery management systems (BMS): These systems monitor and control battery charging and discharging to maintain safety and efficiency. A standardized BMS improves compatibility and performance across different vehicle and battery types.
- Communication protocols: Standardized communication protocols help to have interoperable communication between batteries, vehicles, charging stations and the systems used by charge point operators and utilities. These protocols enable seamless interaction between different components of the EV ecosystem, supporting functionalities such as smart/bidirectional charging and energy management.

Cybersecurity:
As EVs become more connected and integrated with smart grids, mitigating potential security incidents that could affect EV charging and battery communication management systems becomes increasingly important.

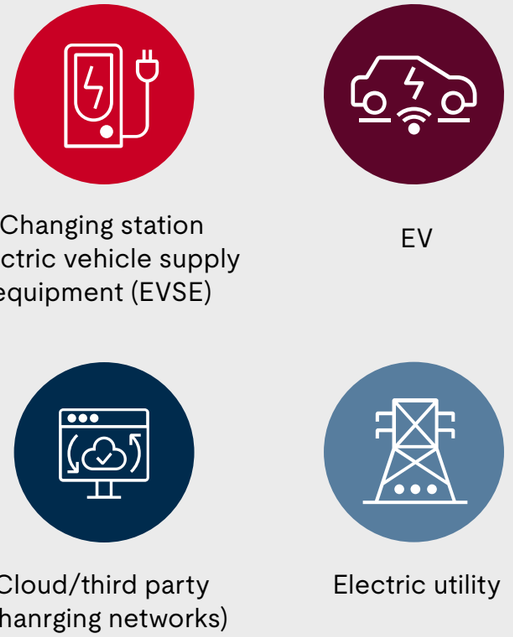
As a component of the EV, an EV battery is subject to the risk of a cyberattack targeting any node of the EV ecosystem, whether it is the charging station (EVSE), electric vehicle, cloud/third-party charging networks or the electric utility.

EV chargers process and communicate measurement data over open networks, which may be subject to cyberattacks.

Electrical grids used to power EV chargers and Charge Point Operations (CPOs) also face cyber threats. For example, the injection of false data from an EV charger into a vehicle can overcharge the battery, potentially damaging it and resulting in vehicle malfunction. Implementing robust cybersecurity measures is essential to safeguarding the integrity of EV batteries and charging infrastructure. Manufacturers can help to protect their systems against hacking, data breaches and other cyber threats by:

- Adhering to standards: Industry stakeholders are working towards creating universal standards for batteries, BMS and communication protocols. These standards will enable better interoperability and simplify the integration of new technologies.
- Applying advanced cybersecurity measures: Implementing advanced encryption and authentication protocols protects data and prevents unauthorized access. Regular security updates and audits help maintain the system's integrity.

Four components of the EV charging ecosystem



Role of functional safety in EV batteries

A Battery Management System (BMS) plays an important role in battery safety by performing various tasks to maintain a safe state during daily operation. The primary tasks of a BMS include protecting against overcharging and discharging, overvoltage and overtemperature of the battery.

The functional safety of an EV battery pack relies on the principles of conducting hazard analysis and risk assessment to identify the risk reduction measures required to maintain safety processes. Most functional safety-related standards require implementing a functional safety management (FSM) assessment of the BMS. This supports the product development realization where measures for addressing random hardware failures and systematic faults are required. These principles involve identifying the evaluation of the designed EV battery system risks, managing the development of the product safety lifecycle, verifying the implemented safety functions integrity levels (SILs) capability, including the action taken on fault detection, and the systematic assessment of the software safety lifecycle. In addition, the BMS periodically conducts diagnostics on the battery pack for health checks.

Various applicable EV battery pack standards, such as UL 2580 and UL 2271, The Standard for Batteries for Use In Light Electric Vehicle (LEV) Applications, directly refer to functional safety standards for validating the Battery Management Systems (BMS). For example, UL 2580 provides references to the following functional safety standards:

- UL 991, Tests for Safety-Related Controls Employing Solid-State Devices
- UL 1998, Software in Programmable Components
- ISO 13849, Safety-Related Parts of Control Systems (for machinery)
- UL 60730-1, (Annex H), Automatic Electrical Controls
- IEC 61508, Functional Safety of E/E/PE Systems
- ISO 26262, ISO 26262, Road Vehicles – Functional safety
- IEC 62061, Functional Safety of E/E/PE Systems (for machinery)

Note: Selecting one of the above-listed standards relies on risk evaluation and risk reduction factors. This may dictate using a particular safety-related standard, such as IEC 61508, where a safety integrity level (SIL) is required, or ISO 26262, where an automotive safety integrity level (ASIL) is required.

Safety
- Overcurrent charge
- Overcurrent discharge
- Over temperature
- Over voltage

Performance
- Current, voltage and temperature monitoring
- Cell balancing
- State of Charge
- Power limits

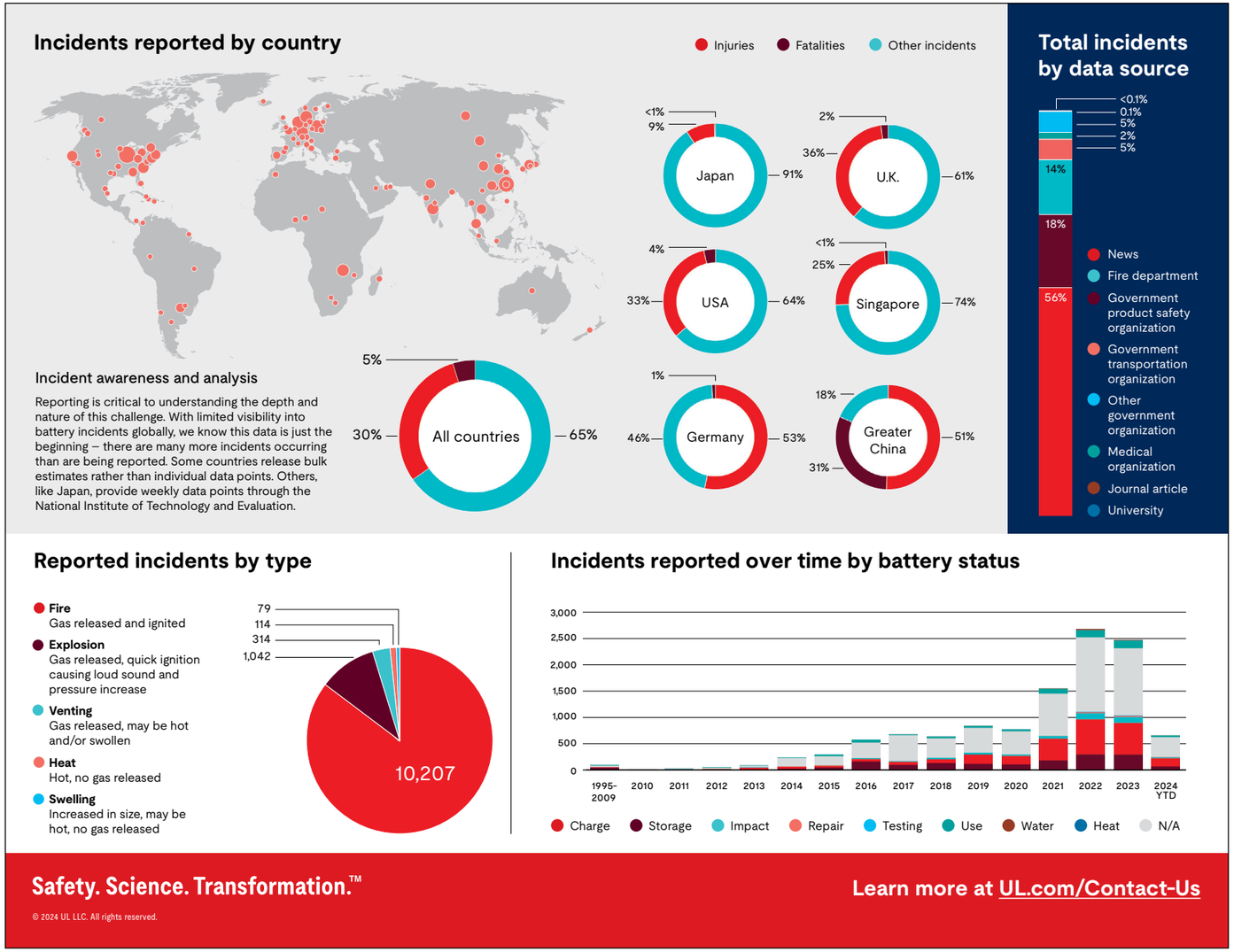
Diagnostics
- Battery State
- Health Check

The importance of lithium-ion battery incident reporting

OEMs

Tracking and transparent reporting of battery-related incidents — including product type, incident details and the impact — are critical to helping drive understanding of this technology and where the most significant risks exist.

The proliferation of lithium-ion batteries and the products that run on them has resulted in an exponential increase in incidents, including injuries and fatalities. Based on the belief that “knowledge is power,” UL Solutions offers an up-to-date incident reporting database where manufacturers, OEMs and customers alike can stay current with these industry risks. Discover the details here.



See full incident report here.

Safety First: The UL Solutions approach

At UL Solutions, we understand the critical importance of EV battery safety, reliability and performance to the future of the automotive industry. We stand committed to supporting EV battery OEMs, automotive manufacturers and materials suppliers, providing comprehensive, end-to-end testing services that help mitigate safety and compliance risks, improve dependability and drive confidence in the value of your products.

With more than one hundred years of experience in fire and electrical safety and over 30 years of experience in battery and energy storage system safety, we have a long-standing history of helping innovators demonstrate and convey the safety, quality and performance of their products.

Supporting you from our network of advanced battery testing laboratories across North America, Europe and Asia, our expert technicians employ the latest technologies and methods to test your battery products, components and materials. We offer testing at the battery cell, module, pack and system levels to validate performance, reliability, safety and other key characteristics that help differentiate your products.

Visit **UL.com/EVbattery** to connect with the experts and discover more about how to overcome today's EV battery safety challenges.

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