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"A System-based View of the Standards and Certification Landscape for Electric Vehicles"

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Summary

This paper provides an overview of the Standards applicable to electric vehicles at the vehicle and system level, including the EVSE, plugs and connectors, and battery pack. Several relevant standard documents are listed, as well as areas of emerging technology for each system. The standards development process is discussed briefly to provide insight into where stakeholders can get involved in the process. General certification requirements for each system are reviewed.

Keywords: EV, standardization, RCS, EVSE, battery.

1. INTRODUCTION

As electric vehicles of all shapes and sizes gain popularity in the marketplace, it is imperative for all stakeholders of the industry to ensure that the safety of the public is paramount. In addition to the critical safety concerns, widespread adoption will also require ease of use for consumers. A robust and harmonized set of Regulations, Codes, and Standards ("RCS") can help to meet both of these objectives.

While individual Standards are typically geared towards the components of a system, it can be helpful to step back and view the entire system for an industry to provide an overview of the certification landscape for stakeholders. This paper is intended to provide a broad picture of the RCS requirements that impact the electric vehicle ("EV") as a system. Providing such a view for designers, manufacturers, and customers of EV's is intended to create a reference for beginning the process of compliance, understanding the magnitude of the global requirements, and helping to prepare for the certification process.

In addition, an overview of the standards development process is provided to help stakeholders to understand how they might get involved in the process.

2. SCOPE

The world of electric vehicles is rapidly growing, and EV's now touch nearly every aspect of transportation and industry. While automotive applications are often the first to come to mind, electric propulsion is being utilized in all manner of vehicles in industrial applications such as forklifts, light duty vehicles such as bicycles and scooters, aerospace applications such as unmanned aerial vehicles, or "drones", and the marine industry. This broad market cannot be covered in a single conference paper, so the scope must be narrowly defined.

Due to the complexity and broad appeal of the automotive market, this paper will focus on those standards and related documents that apply to this market. Documents will be included from major global Standard Development Organizations ("SDO's") such as the International Electrotechnical Commission ("IEC"), the International Organization for Standardization ("ISO"), the United Nations ("UN"), CSA Group ("CSA"), SAE International ("SAE"), UL LLC ("UL"), the Standardization Administration of the People's Republic of China ("SAC"), and finally the Automotive Industry Standards Committee ("AISC") for India. Many additional SDO's exist globally, but are outside the scope of the paper. In the interest of brevity, the IEC and North American documents take the bulk of the space allotted.

Just as the breadth of EV markets cannot be covered in a single paper, it is not the goal of this overview to provide a comprehensive list of every applicable document globally. This paper will list the most commonly used or referenced documents, those recently created, and those of broadest impact, in order to start the reader on the path to product knowledge and/or standards compliance. Technical experts from a Nationally Recognized Testing Laboratory ("NRTL") such as CSA Group should be consulted when determining detailed requirements of a component or system design, or when seeking widespread global certification.

To provide a topical viewpoint, standards specific to some of the emerging technologies related to the EV system will also be discussed. Emerging technologies typically develop in advance of the publication of a standard, so it is important to be involved in the Technical Committee process, in order to shape or be aware of the standards that might be applied to new technological advances.

3. THE STANDARD DEVELOPMENT PROCESS

Standards provide the foundation for commercialization and wide acceptance by ensuring conformity to minimum safety requirements. Without standards, products cannot be certified and accepted. Therefore, a thorough understanding of the standards landscape is required before undergoing testing and ultimately certification.

Prior to reviewing the standards and related documents in the field of EV's, we would like to explain some of the fundamentals of the standard development process, in order to help stakeholders understand how they can get involved in the process, or at least be aware of ongoing activities. This landscape is very complicated, so only a few basic issues and examples can be covered herein, but hopefully this will point the reader in the right direction to gain more information as needed.

Figure 1 shows a graphical representation of the Technical Committee structure for the USA and Canada, and how it interacts with the activities at the IEC/ISO level. Both Canada and the USA have established committees, called the Canadian Mirror Committee or the USA Technical Advisory Group ("TAG"), respectively. Members of these committees conduct standards development business for each country and then work through the SCC in Canada, or ANSI in the USA, to provide the country "vote" to the IEC process at the international level. Some of the important committees and sub-committees in the EV space are noted below:

- IEC/TC69, *Electric road vehicles and electric industrial trucks*
- IEC/TC23/SC23H, *Plugs, Socket-outlets and Couplers for industrial and similar applications, and for Electric Vehicles*
- IEC/TC21/SC21A, *Secondary cells and batteries containing alkaline or other non-acid electrolytes*

In order to have their opinions recognized in the industry, stakeholders are encouraged to participate in these committees through their national committees represented at IEC/ISO. When adopting IEC/ISO standards into North America the draft standards are made available to the general public through a public review process during which interested stakeholders can make their feedback known to the developing committee.

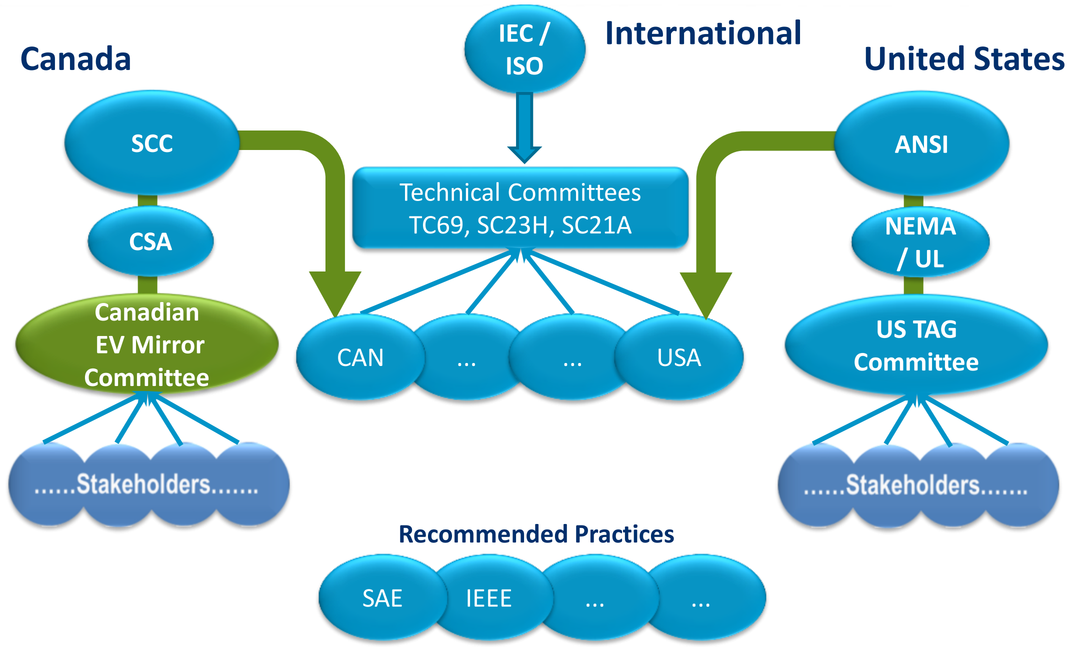

Figure 1: Graphical view of the Electric Vehicle Committee Structure

As shown in Figure 1, there are many additional agencies who are creating standards and recommended practices, with SAE being an important leader in the EV industry. SAE committees can be located on their website, and are another means for stakeholders to be active or aware of the emerging trends and standards in the industry.

4. OVERVIEW OF CERTIFICATION REQUIREMENTS

The ultimate goal of the component or vehicle manufacturer is to get a safe product to market and meet all their compliance requirements. The previous section outlined the standards landscape, so the next challenge is to understand how that translates into testing and certification – how does the manufacturer know what is "required" in order to be in compliance?

Unfortunately, there is rarely a simple answer to this question due to the complexity of EV systems and the varying regulations and practices across different countries, regions, and industries. It is always best to consult with an accredited certification body at the beginning of the design phase to understand the full range of potential requirements. To provide an overview for the EV system, first it is important to present the layers of requirements that must be considered, which are listed below.

- **Direct regulations** – these are mandated in the laws of the countries into which the product will be sold.
- **Indirect regulations** – in these cases, a component or system must meet a requirement by reference in a local or regional code. In Canada and the USA, codes and standards to support the integration of EV's are needed to achieve and secure clean energy and economic benefits. The Canadian Electrical Code is published by CSA Group and the National Electrical Code ("NEC" or "NFPA 70") is published by the

National Fire Protection Association ("NFPA") for addressing the installation and maintenance of electrical equipment in Canada and the USA. In their current editions, these codes recognize that other methods can be used to assure safe installations, but alternate methods must be acceptable to the authority enforcing the codes in a particular jurisdiction. Legislation generally adopts the codes by reference, usually with a schedule of changes that amends the code for local conditions. These amendments may be administrative in nature or may have technical content particular to the region. In practice, the Canadian Electric Code or NEC will require a component to be "listed" to an applicable standard. The Code will typically not provide a specific standard to use for this "listing" or certification, so it will be up to the interpretation of the local Authority Having Jurisdiction ("AHJ"). This is the most common area where an accredited certification body can help you to determine what is required, then provide testing and certification to obtain a recognized certification mark.

- **Customer requirements** – even if there are no direct or indirect codes or regulations that require your product to be certified, it is very common for your customer to require a certification. This is done for two primary reasons – to ensure a level of quality from the supplier, and to provide liability protection for the customer in the event of a failure in the purchased component or system.
- **Industry norms and historical guidelines** – in many industries, compliance to standards and recommended practices are followed by the members of the industry to promote the general safety position of the sector as a whole. By exhibiting a proactive approach to safety in the marketplace, companies can show that they are responsible corporate citizens, while improving their liability position and helping to avoid unnecessary regulation.
- **Individual Corporate Policies** – in many cases, companies will require their products to be certified, complete testing to standards and recommended practices, or pass internally created test protocols before going to production.

Within the context of the EV system, all of these different requirements play a role. At the risk of over-simplification, industry norms, historical guidelines, and individual corporate policies are the predominant source of requirements for the vehicle, while certification of the components is required from the EVSE to the plug.

Now that the standards development process and certification requirements have been outlined, further details for each part of the EV system will be provided in the subsequent sections.

5. VEHICLE STANDARDS

In reviewing the entire system involved with safely operating an EV, we start with the full vehicle and electric power train. We then call out three separate systems as shown in Figure 2 – the Electric Vehicle Supply Equipment ("EVSE"), commonly referred to as the charger; the plugs, receptacles, and connectors; and finally the battery pack.

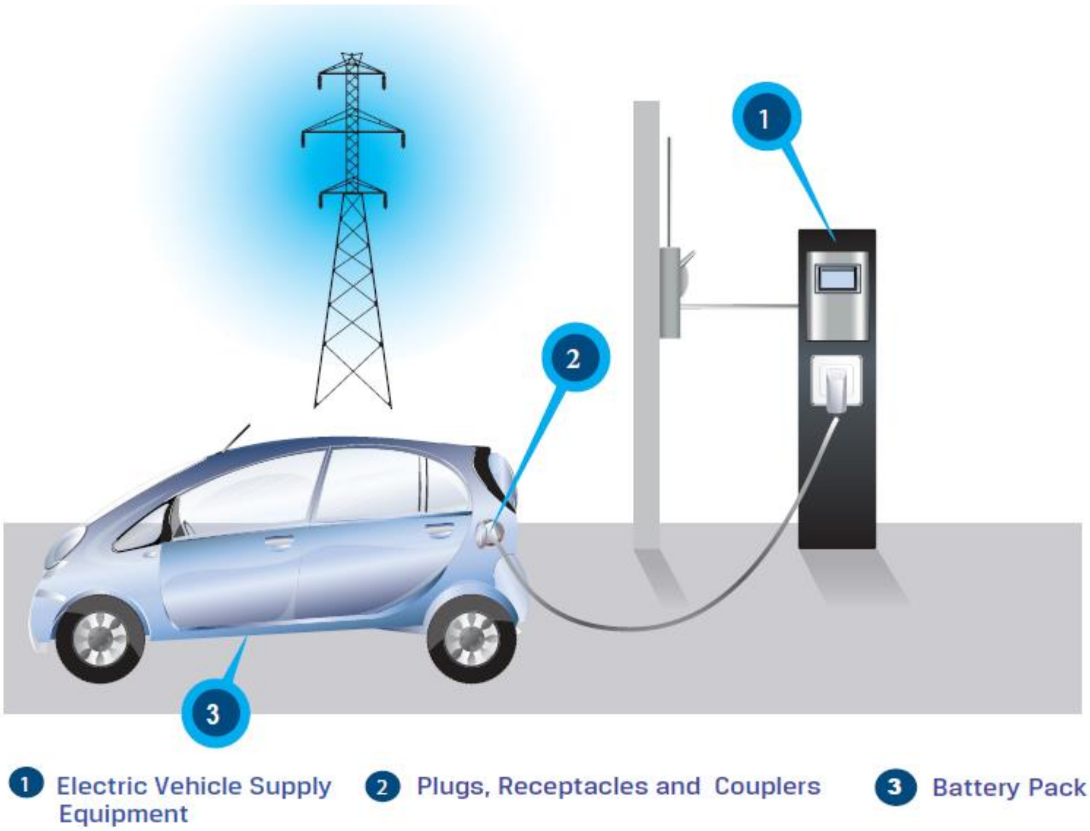

Figure 2: Graphical view of the Electric Vehicle System

Table 1 shows examples of several relevant documents related to the performance and safety of the vehicle itself. As mentioned in the introduction, this and similar tables list some of the most common documents globally and are not intended to be comprehensive lists, but provide a good start.

From a certification standpoint in North America for example, Federal regulations do exist for the full vehicle, but are very limited. The USA requires compliance to “49 CFR 571.305 - Standard No. 305; Electric-powered vehicles: electrolyte spillage and electrical shock protection”, and a similar regulation exists for Canada. For the most part, however, the industry relies on the recommended practices and standards of SAE, as well as industry protocols such as those defined in the USABC manuals.

While responsible manufacturers of vehicles have used these procedures to provide in most cases a fleet of safe vehicles for decades, the growth of EV’s in the marketplace has brought additional scrutiny to the issue of third party certification of the vehicle itself. Once the vehicle is plugged into the grid, many view it as a sophisticated electrical appliance, which in most cases would be subject to testing and certification. This argument gains strength when concepts such as vehicle to grid communication, use of the EV to provide backup power, and demand response management using EV batteries are discussed.

Another significant topic with respect to EV’s is compliance with electromagnetic compatibility (“EMC”) standards. With the widespread use of electronic controllers, sensors, and entertainment systems in modern vehicles, EMC regulations are important for traditional petroleum powered cars as well as EV’s. The EVSE adds another critical component that must meet applicable EMC standards, but due to the magnitude of this issue and the existing requirements for non-electric cars, this topic is outside the scope of the paper. Consult with a certification body such as CSA Group to understand the requirements for your product in the countries of interest.

Table 1: Example Standards and Documents for the Full Vehicle

SDO	DOCUMENT	REGION	TITLE
SAE	J2758	North America	Determination of the Maximum Available Power from a Rechargeable Energy Storage System on a Hybrid Electric Vehicle
SAE	J2344	North America	Guidelines for Electric Vehicle Safety
SAE	J1715	North America	Hybrid Electric Vehicle (HEV) & Electric Vehicle (EV) Terminology
UN	ECE 324 Regulation 100 Revision 2	International	Uniform provisions concerning the approval of vehicles with regard to specific requirements for the electric power train
SAC	GB/T 18384.2-2015	China	Electrically propelled road vehicles. Safety specifications. Part 2:Vehicle operational safety means and protection against failures
SAC	GB/T 18384.3-2015	China	Hybrid electric vehicles safety specification
SAC	GB/T 19751-2005	China	Safety requirements on hybrid EV, working voltage up to 600V AC or 1000V DC
SAC	GB/T 4094.2-2005	China	Electric vehicles. Symbols for controls, indicators and tell-tales
SAC	GB/T 19596-2004	China	Terminology of electric vehicles
SAC	GB/T 18385-2005	China	Electric vehicles. Power performance. Test method
SAC	GB/T 18386-2005	China	Electric vehicles. Energy consumption and range. Test procedures
SAC	GB/T 18388-2005	China	Electric vehicles. Engineering approval evaluation program
SAC	GB/T 19750-2005	China	Hybrid electric vehicles. Engineering approval evaluation program
AISC	AIS 049	India	Type Approval of Electric Vehicles – Brake performance, grade ability, pass-by noise level, EMI, wiper, lighting system, safety belt, steering column, dashboard etc.
AISC	AIS 102 (Part 1)	India	Type Approval of Hybrid Electric Vehicles – Category L, M, N (GVW < 3500 kg)
Emerging Technologies (documents may be under development)			
SAE	J3016	North America	Levels of Driving Automation
SAE	J2990	North America	Hybrid and EV First and Second Responder Recommended Practice
SAE	J2931/1	North America	Digital Communications for Plug-in Electric Vehicles
SAE	J2931/7	North America	Security for Plug-in Electric Vehicle Communications
SAE	J3061	North America	Best practices for Cybersecurity
ISO	15118 Series	International	Road vehicles -- Vehicle to grid communication interface, including Parts 1, 2, and 3

Emerging Technologies

For the general vehicle section, emerging technologies include topics such as "vehicle to vehicle" and "vehicle to grid" communications, cyber security, interoperability, and first responder safety. Another major emerging technology is the development of autonomous vehicles. SAE has published a guidance document on the terminology to use for consistency in the research community, and autonomous vehicles will undoubtedly be a major area of concern for standards developers in the future.

5.1 Electric Vehicle Supply Equipment

The initial success of the hybrid EV has provided the foundation for the EV market and paved the way for the game-changing plug-in hybrid EV ("PHEV") and battery EV ("BEV") models that are now changing the industry. After customers ask the inevitable question about how much range they can achieve with their potential BEV purchase, many must follow that up with "How and where can I charge it?"

Currently, three types of EVSE are prominent in the North American market. These devices are typically referred to as "chargers", but the industry uses the term EVSE largely due to the fact that the bulk of the charging circuitry is on board the vehicle, which allows the EVSE to provide a standard power specification. Level 1 chargers run off typical household power of 120VAC and 20A, and charge the vehicle in around 8 to 12 hours. Level 2 chargers require a dedicated 40A, 240VAC circuit, and charge the vehicle in approximately 4 to 6 hours. DC Fast Chargers exist in different formats and may be brand specific. They charge the vehicle in approximately 30 minutes to an hour, and require a 480VAC circuit. Charging time of course varies depending on the state of charge of the battery, the outside temperature, and many other factors.

Since charging in the home is the most popular location, it is important for products to carry appropriate safety certification marks. Standards such as those listed in Table 2 are used for these products, and many have been harmonized across North America. Charging stations in industrial or public locations will also be subject to certification requirements by local codes as adopted from the Canadian Electric Code or NEC in North America.

Emerging Technologies

In the first section on the full vehicle, communication between the vehicle and the grid was introduced as an important emerging technology, and the EVSE plays an important role in that communication. In addition, documents are being developed by SAE to guide the development of communication requirements between the EVSE and the home area network ("HAN") or smart meter.

One of the most widely studied emerging technologies for EVSE are wireless chargers, which are discussed in several documents shown in Table 2 by organizations including IEC, SAE, and UL. These types of chargers create a range of both opportunities and challenges. For example, the ability to charge buses at each stop or provide ease of use for home or business based charging is very appealing, but is balanced by additional concerns for electromagnetic interference and possibly human factors issues due to the large amounts of power being transferred.

Table 2: Example Standards and Documents for EVSE

SDO	DOCUMENT	REGION	TITLE
CSA Group, UL, ANCE	NMX-J-677-ANCE-2013/C22.2 No. 280–13/UL 2594	Canada, USA, Mexico	Electric vehicle supply equipment
CSA Group, UL, ANCE	NMX-J-668/1-ANCE/C22.2 No. 281.1–12/UL 2231-1	Canada, USA, Mexico	Standard for safety for personnel protection
CSA Group, UL, ANCE	NMX-J-668/2-ANCE/C22.2 No. 281.2-12/UL 2231-2	Canada, USA, Mexico	Standard for safety for personnel protection systems for electric vehicle (EV) supply circuits: Particular requirements for protection devices for use in charging systems
CSA Group	C22.2 No. 107.1	Canada	General Power Use (Currently under revision to increase rated voltage to 1500V)
UL	2202	USA	Standard for Electric Vehicle (EV) Charging System Equipment
IEC	61851 Series	International	Electric vehicle conductive charging system, including Parts 1, 21, 22, 23, and 24
SAC	GB/T 18487 Series, 2015	China	EV Conductive Charging system, including Parts 1, 2, and 3
Emerging Technologies (documents may be under development)			
SAE	J2954	North America	Wireless Charging of Electric and Plug-in Hybrid Vehicles
CSA Group	CAN/CSA-E61980-1	Canada	Electric Vehicle Wireless Power Transfer (WPT) Systems – Part 1: General Requirements
CSA Group	C22.2 No. 317	Canada	Wireless Power Transfer (WPT) for EV’s
UL	2750	USA	Wireless Charging of Electric and Plug-in Hybrid Vehicles
IEC	61980 Series	International	Electric Vehicle Wireless Power Transfer (WPT) Systems, including Parts 1, 2, and 3
SAC	GB/T 27930-2015	China	Communication protocols between off-board conductive charger and battery management system for electric vehicle

5.2 Plugs, Receptacles, and Connectors

One of the most visible and important aspects of the electric vehicle system from a customer’s point of view is the plug. Currently, the industry worldwide has created several different geometries for plugs, and this could present a significant challenge to worldwide adoption, or at the very least additional cost to the infrastructure. For example, if a family wished to purchase two different models, or replace a previous unit with a new one, imagine their dissatisfaction to realize that the plug on their existing charger did not work for the new model. If a business wishing to serve the cross-country EV driver was considering an investment in a charger, which should they choose, or how much extra will it cost to provide all the different plug options? Will safety issues be introduced when people try to convert one model to a different plug? These type of questions are crying out for standardization, and although they might not be safety issues for the most part, it is important for the industry as a whole to standardize.

From a safety standpoint, the list of standards for this part of the system is not as extensive, and is listed in Table 3. These devices will generally require a certification mark, similar to the EVSE described above.

Table 3: Example Standards and Documents for Plugs, Receptacles, and Couplers

SDO	DOCUMENT	REGION	TITLE
CSA Group, UL, ANCE	NMX-J-678-ANCE/C22.2 No. 282– 13/UL 2251	Canada, USA, Mexico	Plugs, receptacles, and couplers for electric vehicles (currently under revision)
SAE	J1772	North America	SAE Electric Vehicle and Plug in Hybrid Electric Vehicle Conductive Charge Coupler
IEC	62196-3	International	Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 3: Dimensional compatibility and interchangeability requirements for d.c. and a.c./d.c. pin and contact-tube vehicle couplers
UL	2251	USA	Standard for Plugs, Receptacles, and Couplers for Electric Vehicles
SAC	GB/T 20234 Series - 2015	China	Connection set for conductive charging of electric vehicles, including Parts 1, 2, and 3

5.3 Batteries

The battery pack is both an enabling technology and the primary source of hazards associated with the growth of the EV market. The pressures on manufacturers to increase vehicle range, reduce battery weight and cost, reduce charging time, and provide innovative new styling constantly drives the battery pack design to the limit of its performance envelope. While these pressures to increase performance are very real, the industry as a whole is deeply committed to producing safe products, and the wide array of standards and reference documents for the battery pack are evidence of this effort.

Table 4 indicates some of the predominant documents related to the EV battery performance and safety. One of the most important series of standards currently under development by IEC TC21 is the 62660 series for lithium-ion battery use in EV’s. The first two parts of this Standard, performance and reliability/abuse testing, have been adopted by CSA Group as National Standards of Canada. The third part, on the safety requirements of cells and modules, is expected to be published in the fourth quarter of 2016, after which it will also be adopted as a Canadian Standard.

Other major SDO’s have created battery related standards for EV’s, as shown in Table 4. In addition to these SDO’s, several key members of the US auto industry have led the development of the United States Council For Automotive Research LLC (“USCAR”), along with the United States Advanced Battery Consortium (“USABC”), which produced and maintains the USABC Manuals. These documents provide guidance on topics such as life verification, system configuration, hazard analysis, and test procedures. The weight of these documents is further evidenced by the fact that they are used as a basis for standards documents in India for AIS048, as shown in Table 4.

Table 4: Example Standards and Documents for the Battery Pack

SDO	DOCUMENT	REGION	TITLE
CSA Group	CAN/CSA-E62660 Series	Canada	Secondary lithium-ion cells for the propulsion of electric road vehicles - Part 1: Performance testing; Part 2: Reliability and abuse testing
SAE	J1798	North America	Recommended Practice for Performance Rating of EV Battery Modules
SAE	J2936	North America	Vehicle Battery Labeling Guidelines
SAE	J2929	North America	Electric and Hybrid Vehicle Propulsion Battery System Safety Standard
SAE	J2380	North America	Vibration Testing of Electric Vehicle Batteries
SAE	J2464	North America	Electric Vehicle Battery Abuse Testing
SAE	J2288	North America	Life Cycle Testing of EV Battery Modules
SAE	J2289	North America	Electric-Drive Battery Pack System: Functional Guidelines
USABC	USABC Manuals	North America	Several relevant manuals, such as “USABC Battery Test Manual For Electric Vehicles”
IEC	62660 Series	International	Secondary lithium-ion cells for the propulsion of electric road vehicles - Part 1: Performance testing; Part 2 – Reliability and Abuse Testing; (Part 3 under development)
IEC	61982	International	Secondary batteries (except lithium) for the propulsion of electric road vehicles - Performance & endurance tests
ISO	12405 Series	International	Electrically propelled road vehicles -- Test specification for lithium-ion traction battery packs and systems; Parts 1, 2, and 3
UL	2580	USA	Batteries for Use In Electric Vehicles
SAC	GB/T 18384.1-2015	China	Electrically propelled road vehicles. Safety specifications. Part 1:0n-board rechargeable energy storage system (REESS)
SAC	GB/T 18332.1-2009	China	Lead-acid batteries used for electric road vehicles
SAC	GB/T 18332.2-2001	China	Nickel-metal hydride batteries for electric road vehicles
SAC	GB/Z 18333.1-2001	China	Lithium-ion batteries for electric road vehicles
SAC	GB/T 18333.2-2015	China	Zinc-air batteries for electric road vehicle
AISC	AIS 048	India	Safety Requirements for Traction Batteries – Electrical & Mechanical Abuse Tests
Emerging Technologies (documents may be under development)			
SAE	J2997	North America	Standards for Battery secondary use
SAE	J2974	North America	Technical Information Report on Automotive Battery Recycling
IEC	62576	International	Electric double-layer capacitors for use in hybrid electric vehicles - Test methods for electrical characteristics
UL	810A	USA	Standard for Electrochemical Capacitors

Emerging Technologies

Promising new research in battery chemistries, manufacturing processes, and related technologies are announced on an almost daily basis, and the standards documents need to keep pace with these advancements. Several emerging areas of interest are being researched, including:

- Secondary use of EV batteries in applications such as stationary storage
- Stranded energy and how to deal with it after a crash or fire
- Recycling of EV batteries
- Start/stop “micro-hybrid” architecture

One major technology that must be covered is the use of electric double-layer capacitors (“EDLC”), commonly referred to as super capacitors or ultracapacitors. While these devices are actually a fairly mature technology and are currently in mass production, they are continuing to develop in both design and application. Batteries and EDLC’s are being merged together, either internally in a device or externally in a system, to create energy storage products that provide the benefits of both technologies. Advancements in EDLC’s in general, and in these hybrid battery/ EDLC systems, is increasing their potential for use in EV’s. Organizations such as the IEC and UL have published or are developing standards for this technology as shown in Table 4.

Finally, while this paper focuses on the light duty automotive market, it is important to mention one timely and important development. Electric buses used for public transit are an excellent means to advance the technology of EV’s and provide broad benefit to the public, but due to the large batteries they employ and the large number of people on board, a major failure could have catastrophic repercussions. In addition, these buses are not only manufactured as new vehicles, but they also may be refurbished petroleum powered buses (typically diesel) that are retrofitted with batteries. Many in the industry feel that the lack of testing and certification for the batteries employed in these vehicles and their rapid international growth presents a hazard, and in addition to potential harm to the public, a major failure could erase substantial progress in the industry towards electrification. For these reasons, the topic is actively being pursued by both SAE and NAATBatt International, with the support of both CSA Group and UL, to develop awareness documents, recommended practices, and ultimately standards for certification.

6. CONCLUSION

The objective of this paper has been to expose the reader to the broad array of RCS documents that affect stakeholders of the EV industry on a daily basis, with the goal of ensuring the public safety. While many Technical Committees and SDO’s strive for global harmonization when possible, the vast differences in governments, infrastructure, and regulatory processes around the world create a difficult maze of standards which must be navigated to ensure compliance.

This paper can provide a starting point to conduct the research needed to help individuals determine their compliance requirements, and it is strongly suggested that designers consult with an accredited SDO or NRTL, such as CSA Group, to fully understand all the certification requirements of a particular design early in the process. It is suggested with equal emphasis that companies send technical experts to participate actively on Technical Committees to shape the global safety needs of the industry.

AUTHORS

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About CSA Group

CSA Group is an independent, not-for-profit member-based association dedicated to advancing safety, sustainability and social good. We are an internationally-accredited standards development and testing & certification organization. We also provide consumer product evaluation and education & training services. Our broad range of knowledge and expertise includes: transportation, energy storage, industrial equipment, plumbing & construction, electro-medical & healthcare, appliances & gas, alternative energy, lighting, and sustainability. The CSA mark appears on billions of products around the world.