ALTERNATIVE FUELS

PAVING THE ROAD TO THE WIDESPREAD USE OF ELECTRIC VEHICLES

THE SUPPORTING ROLE OF TESTING, CERTIFICATION, AND STANDARDS

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The world of electric vehicles (EVs) is rapidly expanding, touching nearly every aspect of the transportation industry and beyond. While automotive applications are often the first to come to mind, electric propulsion is being utilized in a variety of settings – from industrial vehicles such as forklifts, to light duty vehicles such as bicycles and scooters, to aerospace applications such as unmanned aerial vehicles or "drones", to the marine industry. As the popularity of EVs surges in the marketplace, industry stakeholders are challenged with ensuring that public safety remains paramount. In addition, widespread adoption of EVs largely depends on ease of use for consumers. A robust and harmonized set of regulations, codes, and standards (RCS) can help industry meet both of these objectives.

Standards and related documents play an important role in this broad and complex market, and major global standard development organizations (SDOs) reference EV components and systems in their documents. Individual standards are typically geared towards the components of a system, however with emerging technologies such as EVs, in order to get a comprehensive overview of the certification landscape it is beneficial to step back and view the entire system from an industry-level perspective. Providing a broad picture of RCS requirements creates a reference for all stakeholders – including designers, manufacturers, and EV customers – to help foster an understanding of compliance issues, the magnitude of global requirements, and the necessary preparation for the certification process. Further, when stakeholders have an understanding of the standards development process, they get a better idea as to how they can get involved.

In an effort to paint a comprehensive picture of product knowledge and/or standards compliance, it is necessary to take an in-depth look at the most commonly used or referenced documents, those recently created, and those with the broadest impact. 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. As emerging technologies typically evolve before standards are published, it is critical that product designers offer their input early in the process through national technical committees (TCs) so they can help shape – and be aware of – the standards that might be applied to technological advances.

The Standards Development Process

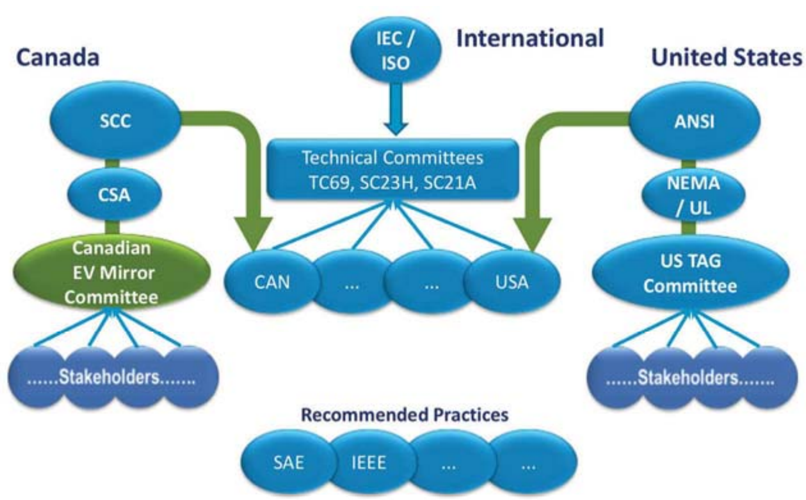
Standards provide the foundation for commercialization and wide acceptance by helping to ensure conformity to minimum safety or performance requirements. Without standards, products cannot be certified and accepted, resulting in major losses and missed opportunities. Therefore, a thorough understanding of the standards landscape is extremely beneficial before undergoing testing – and ultimately certification. Prior to reviewing the standards and related documents in the EV field, a review of the fundamentals of the standard development process can help stakeholders understand how they can get involved in the process, along with providing awareness of ongoing activities.

Figure 1 shows a graphical representation of the TC structure for the U.S. and Canada, and how it interacts with the activities at the IEC/ISO level. Both Canada and the U.S. have established committees, called the Canadian Mirror Committee or the U.S. 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 U.S., 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 through their national committees represented at IEC/ISO. When adopting IEC/ISO standards in North America, the draft standards are made available to the general public through a public review process during which interested stakeholders can provide their feedback to the standards development 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, among others, are another means for stakeholders to be active or aware of the emerging trends and standards in the industry.

Overview of Certification Requirements

The ultimate goal of the component or vehicle manufacturer is to get a product to market that meets safety and performance requirements. Manufacturers must understand how the standards landscape translates into testing and certification in order to ensure compliance.

The complexity of EV systems and the varying regulations and practices across different countries, regions, and industries make it essential to consult with an accredited certification body at the beginning of the design phase. To understand the full range of potential requirements, obtaining an overview for the EV system and the "layers" of requirements that must be considered is key. These include:

Direct Regulations – These are mandated in the laws of the countries into which the product will be sold.

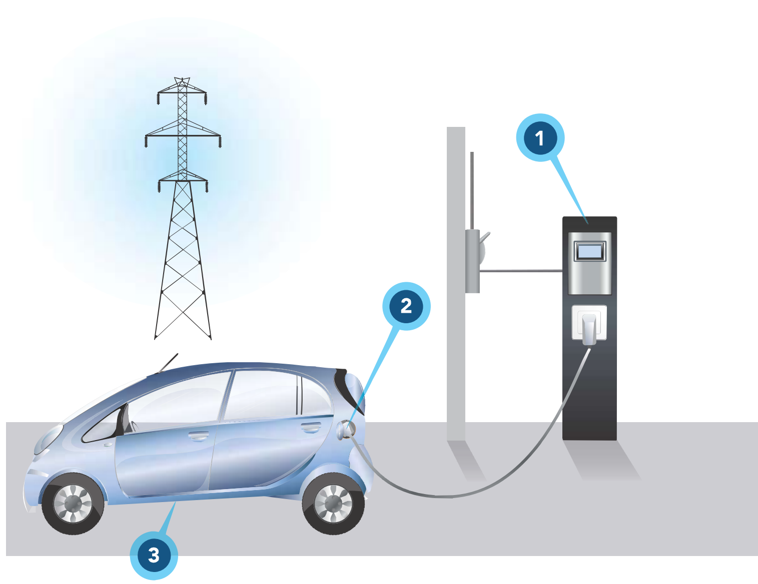
Indirect Regulations – In these cases, a component or system must meet a requirement referenced in a local or regional code. In Canada and the U.S., codes and standards supporting the integration of EVs are needed to secure clean energy and achieve economic benefits. The *Canadian Electrical Code*, published by CSA Group, and the *National Electrical Code* ("NEC" or "NFPA 70"), published by the National Fire Protection Association ("NFPA"), address the installation and maintenance of electrical equipment. Current editions of these codes recognize that other methods can be used to assure safe installations, but those 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 amend 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 Electrical 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 customers to demand certification. They do this to ensure they are receiving a quality product from the supplier and for liability protection in the event of a failure in the purchased component or system.

Industry Norms and Historical Guidelines – Members of many industries comply with standards and follow recommended practices to promote the general safety position of the sector as a whole. By taking a proactive approach to safety in the marketplace, companies can show that they are responsible corporate citizens, while minimizing the need for further 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.

Figure 2: Graphical View of the Electric Vehicle System



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 itself, while certification is required for the various components required to operate an EV, such as plugs, power supply equipment, and receptacles. With a general understanding of the standards development process and certification requirements, stakeholders can explore further details for each part of the EV system.

Standards, Scrutiny, and Emerging Technology in World of 'Vehicles'

The entire system involved with safely operating an EV can be categorized into 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.

Table 1 shows examples of several relevant documents related to the performance and safety of the vehicle itself. While not intended to be a comprehensive list, it does provide some of the most common global documents.

From a certification standpoint in North America for example, federal regulations exist for the full vehicle, but they are very limited. The U.S. 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 United States Advanced Battery Consortium (USABC) manuals.

While responsible vehicle manufacturers have used these procedures to help provide a fleet of safe vehicles for decades, the growth of EVs 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 EVs 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 EVs. Consulting with a certification body such as CSA Group can help the manufacturer gain a better understanding of the requirements for their product in the countries of interest.

Emerging technologies for general vehicles include topics such as "vehicle to vehicle" and "vehicle to grid" communications, cybersecurity, interoperability, and first responder safety. Another major emerging technology is the development of autonomous vehicles, which will undoubtedly pose significant safety concerns for those involved in creating standards in the future.

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

Electric Vehicle Supply Equipment (EVSE) – The initial success of the hybrid EV built the foundation for the EV market, paving the way for the game-changing plug-in hybrid EV (PHEV) and battery EV (BEV) models. The rapidly evolving industry is also causing a shift in the types of questions that customers are asking. Whereas customers previously asked "What range can I expect from my BEV purchase?" they are now asking, "How and where can I charge my vehicle?"

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 because 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 eight to 12 hours. Level 2 chargers require a dedicated 40A, 240VAC circuit, and charge the vehicle in approximately four to six 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 the home is the most common location to charge a vehicle, 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 Electrical Code* or NEC in North America.

An important emerging technology associated with the full vehicle is the communication between the vehicle and the grid. The EVSE plays a critical 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 present 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 that is balanced by additional concerns for electromagnetic interference and human factors may be a possible issue 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, U.S., Mexico	Electric vehicle supply equipment
CSA Group, UL, ANCE	NMX-J-668/1-ANCE/C22.2 No. 281.1–12/UL 2231-1	Canada, U.S., 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, U.S., 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. 107.1-16	Canada	Power Conversion Equipment (Currently under revision to increase rated voltage to 1500V)
UL	2202	U.S.	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	U.S.	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

Plugs, Receptacles, and Connectors – From a customer's perspective, one of the most visible and important aspects of the electric vehicle system is the plug. Currently, the global industry has created several different geometries for plugs, which can present a significant challenge to worldwide adoption, or at the very least result in additional infrastructure costs. For example, if a family wishes to purchase two different models of a vehicle, or replace a previous model with a new one, imagine their dissatisfaction when realizing that the plug on their existing charger does not work for the new model. If a business wishing to serve a 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 types of questions can be addressed through standardization, and they highlight the importance standardization plays in the industry – for safety issues and beyond.

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.

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 documents at the forefront of EV battery performance and safety. One of the most important series of standards currently under development by IEC TC21 is the IEC 62660 series for lithium-ion battery use in EVs. 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, published in 2016.

Other major SDOs have created battery related standards for EVs, as shown in Table 4. In addition to these SDOs, several key members of the U.S. auto industry have led the development of the United States Council for Automotive Research LLC (USCAR), along with the 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.

Promising new research in battery chemistries, manufacturing processes, and related technologies are announced on an almost daily basis. This rate of emerging technology means that standards documents need to be updated to keep pace with change. 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

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, U.S., 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	U.S.	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

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	U.S.	Batteries for Use In Electric Vehicles
SAC	GB/T 18384.1-2015	China	Electrically propelled road vehicles. Safety specifications. Part 1: On-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	U.S.	Standard for Electrochemical Capacitors

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 evolve in both design and application. Batteries and EDLCs 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 EDLCs in general, and in these hybrid battery/ EDLC systems, are increasing their potential for use in EVs. Organizations such as the IEC and UL have published or are developing standards for this technology as shown in Table 4.

When thinking about the EV industry, the focus tends to be on the light duty automotive market, but it is important to remember the timely developments in the commercial market – as well as their constraints. Electric buses used for public transit are an excellent means to advance the technology of EVs and provide broad benefits to the public. However, with public safety always paramount, it is important to consider the potential catastrophic repercussions, particularly those related to potential failures of the large batteries that these commercial vehicles require. 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 present significant risks to public safety. A major failure could also 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 CSA Group and UL, to develop awareness documents, recommended practices, and ultimately standards for certification.

The Path Forward

A broad array of RCS documents exist that clearly affect stakeholders of the EV industry on a daily basis, all with the common goal of helping promote public safety. While many TCs and SDOs strive for global harmonization where possible, the vast differences in governments, infrastructure, and regulatory processes around the world create an intricate maze of standards which must be navigated to help ensure compliance. A general overview and understanding of the standards and certification landscape is a great starting point on the path to understanding compliance requirements, but it is strongly recommended that designers consult with an accredited SDO or NRTL, such as CSA Group, early in the design process. And finally, it is suggested with equal emphasis that companies send technical experts to participate actively on TCs to help shape the global safety needs of the industry.

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