CHAdeMO-Conformity High-Power Charger Connector Assembly for Over 100 kW-Class EV Charge

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There are two categories for electric vehicles charging systems. One is normal charging (AC) and the other is quick charging (DC). In recent years, the application of the latter has been expanding due to an increase in the capacity of in-vehicle batteries. In 2011, we began supplying the SEVD series as a CHAdeMO-conformity 50 kW-class quick charger cable assembly and have since delivered 27,000 units mainly in Europe, U.S.A. and Japan. Our connectors have a high reputation for superior safety and operability. We responded quickly to the CHAdeMO specification ver. 1.2, which described high output, and began shipping SEVD-11 for over 100 kW-class high power charger connectors in the beginning of 2018.

Keywords: electric vehicle (EV), direct current, CHAdeMO, quick charge, high power

1. Introduction

Currently, many voices have called for an end to emissions of environmental contaminants and for the building of a carbon-free society. Electric vehicles (EVs) are coming into wide use on a global scale and auto manufacturers have shifted towards EVs. Along with these trends, quick charge method (direct current: DC) has been introduced for applications at public facilities and large commercial facilities. For the quick charge method, four types of protocols have been established based on the international standards. One of them is CHAdeMO,*[1] which was developed in Japan. It has been employed worldwide, and has an established track record (Fig. 1).

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Charging protocol
 ┌Normal charge--AC 100, 200 V / 15 A, etc.
 │                       (for households/infrastructure)
 └Quick charge----DC 500 V / 125 A, etc.
                         (for infrastructure only)
    ┌CHAdeMO (Japan)
    ├GB/T (China)
    ├CCS1 (North America)
    │      (an abbreviation for Combined Charging System)
    └CCS2 (Europe)
《Features》
 CHAdeMO:  An external port is required on the vehicle side in
           addition to a port for AC charging.
 CCS    :  The same port on the vehicle is used for both ACand
           DC charging.
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Fig. 1. Summary of charging protocols

The cable provided with a charger connector (hereafter, "the connector") for a CHAdeMO DC quick charger is a critical component that serves as the interface between the charging equipment and an EV (i.e., to charge an EV and exchange information with an EV).

As shown in Table 1, since the release of the 50-kW DC quick charger connector in 2011, we commercialized the SEVD - 02 model, which made the aluminum alloy case into a resin case for weight saving, and it is the main product of the lineup now. A total of 27,000 units of all models have been sold by the end of October 2018.

This paper describes our efforts directed towards the development of an over 100 kW-class high power connector (rated at 200 A current) complied with CHAdeMo certification described high output, which was launched on the market in January 2018 (Table 1 and Photo 1).

Table 1. Approaches to development and commercialization of SEVD series

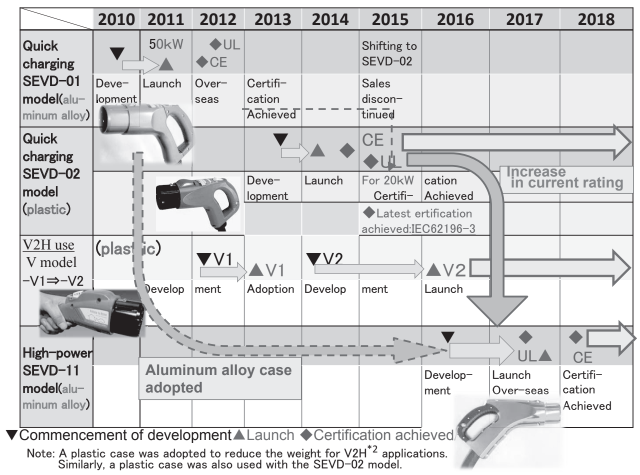


Photo 1. SEVD-11 high-power charger connectors and SEVD-02 quick charger connectors

2. Development of High-Power Charger Connector

We commercialized a high-power charge (HPC) connector rated at 200 A and compliant with CHAdeMO specification 1.2 ahead of competitors in the world, as shown in Table 2. This connector comes with the world's highest charging capacity, operating under non-cooled conditions.

Table 2. Characteristics of the charger connector SEVD-11 model (HPC)

Model	SEVD-11	Current SEVD-02
Capacity	Over 100 kW class	50 kW class
Rating	500 V/200 A	500 V/125 A
Connector weight	1.4 kg	0.8 kg
Cable	Rubber cabtyre cable Power-line: 70 mm^2	Rubber cabtyre cable Power line: 38 mm^2

Note: Our product lineup includes the SEVD-11E destined for Europe and the SEVD-11U for North America, which are HPC versions and have achieved the CE marking and UL certification, respectively.

Table 1 shows our approaches to commercialization and the development history of high-power charger connectors. The newly developed connector involved an increase in the current rating, as shown in Table 2. To address the issue of dropping and shocks arising from the resultant increases in the weight of the cable and the connector, the aluminum alloy case used for the SEVD-01 model was adopted to enhance the strength of the newly developed connector.

2-1 Designing electrical characteristics

(1) Optimizing charging cable size

Table 3 lists the characteristic requirements of the CHAdeMO specification for temperature rises occurring under current-carrying conditions.

Table 3. Characteristics requirements of CHAdeMO specification for temperature rise

Part	Item		Requirement	Remarks
Connector and cable	Portion held by person		60°C	As per the requirements for over-temperature protection at an ambient temperature of 40°C
	Portion accessible to person		85°C	
Inside connector	Power terminal	Max. temp. rise	ΔT ≤ 50 K	
		Allowable temp.	80°C (*1) (90°C (*2))	

*1 Japan domestic standard, *2 IEC standard

To raise the current rating, the suitable charging cable size was determined to be 70 mm^2 for the following reasons.

- The charging cable size must be commensurate with the current rating.
- The charging cable size is required to comply with the dimensional requirements of the CHAdeMO specification for the vehicle inlet socket.
- Both cable conductor temperature and sheath surface temperature fail to meet the requirements under the conditions of an ambient temperature of 40°C and a current of 250 A.

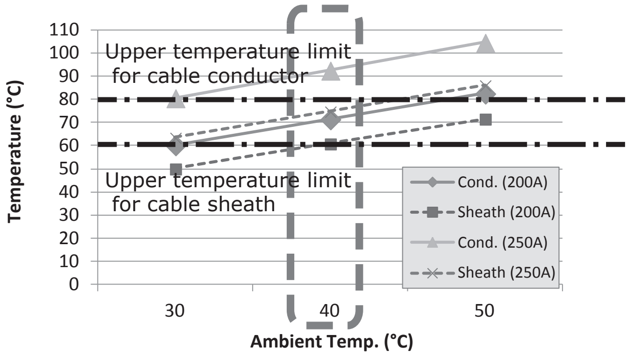


Fig. 2. Calculation results for temperature rise characteristics of 70 mm^2 charging cable

- The standards are met under the conditions of an ambient temperature of 40°C and a current of 200 A.

Meanwhile, the charger connector cable, which is subject to a high energizing current, is thick and heavy for general users. For easy handling of the connector, rubber cabtyre cable is employed because it is flexible at low temperatures (–30°C). This cable can be bent and twisted easily. The newly developed high-power connector is similar in this regard (Table 4 and Photo 5).

Table 4. Characteristcs of the rubber cabtyre cable for connector

Connector		Over 100 kW SEVD-11	50 kW SEVD-02
Cable Specification	Power Signal	70 mm^2 × 2 0.75 mm^2 × 13(*)	38 mm^2 × 2 0.75 mm^2 × 9
Max. overall diameter		φ40 mm	φ31 mm
Weight		2.7 kg/m	1.6 kg/m
Insulating material		EP rubber	
Sheath material		Chloroprene rubber	
Applicable standard		JIS C 3005, JCS 4522	

* Including four temperature sensor signal wires

(2) Temperature rise due to increased current rating

Figure 3 shows temperature rise test results for the newly developed SEVD-11 model, obtained when carrying

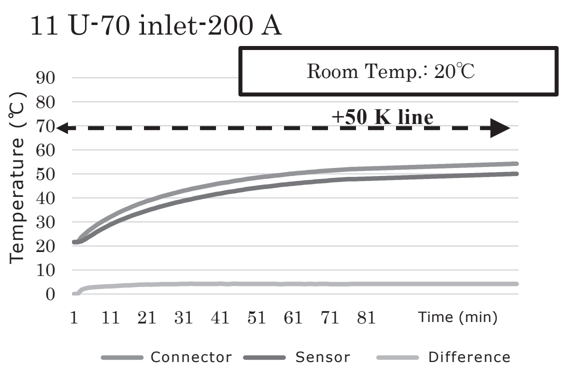


Fig. 3. Temperature rise test results for connector, obtained using 70 mm^2 cable on inlet side

the rated current. A similar 70 mm^2 cable was used on the side of the vehicle inlet connected to the connector. The results show that the connector met a temperature rise requirement for power terminals of $\Delta T = 33$ K in a saturated condition after carrying the rated current for 2 h and the standards presented in Table 3.

Additionally, Fig. 4 presents the results of connecting the connector to a current standard vehicle inlet (38 mm^2 cable). The temperature rise (ΔT) of the power terminals reached approximately 57 K. The reason is that the size of the inlet cable is small in proportion to the flowing current.

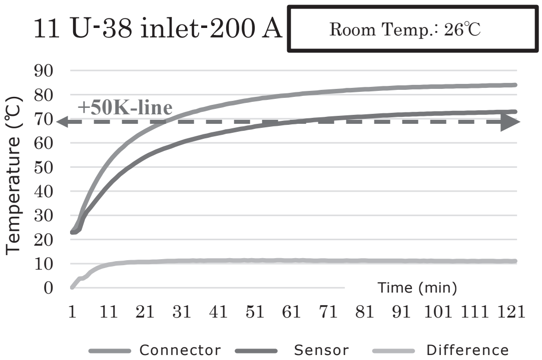


Fig. 4. Temperature rise test results for connector, obtained using 38 mm^2 cable on inlet side

2-2 Mechanical strength design

(1) Adhering to the operability and safety concepts of the previous specification

Photo 2 shows the SEVD-11 model during use for charging. This model adheres to the operability concept of the SEVD-02 model in that it can be operated with one hand, is easy-to-understand, is shaped to be comfortable to hold, is designed for intuitive and natural operation, and has a simple structure. The SEVD-11 model also offers the following extensive safety mechanism of the previous model for parts commonality.

1) Transmission of information on the charge preparation status, such as detecting incomplete fitting of the micro-switch, and on the charging ready state after full fitting of the micro-switch (A structure developed by Sumitomo Electric Industries, Ltd. is incorporated in the CHAdeMO specification version 1.0 and later.)
2) Electrical lock for removal prevention during charging
3) Deployment of the SEVD-02 design for lighting up LEDs and letting the user know the fitting condition by color indication when operating the release button (see Fig. 6)

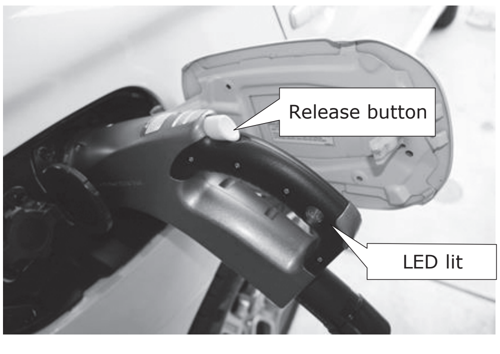


Photo 2. High-power charger connector SEVD-11 connected to vehicle inlet

Our Connectors are highly regarded by users because the handle is shaped to eliminate the need to hold the cable, by offering a good balance, and is easy to operate. These features were incorporated when commercializing high-power connectors.

(2) Connector geometry design

The increased cable size and the use of a metal case resulted in a heavier connector weight. Accordingly, the connector was expected to be subject to increasing shocks due to drops. The connector geometry was designed with the following in mind to be robust.

1) Development of an ideal case geometry and determination of the overall length to accommodate the increased minimum bending radius resulting from the enlarged outside diameter of the cable (see Fig. 5)
2) Exposure of the metal part at the edges in the lower part of the handle without the use of a plastic cover (see Photo 3)
3) No plastic part protruding upwards from the connector by repositioning the release button to reduce the magnitude of shocks to the edges of the connector (see Fig. 6)

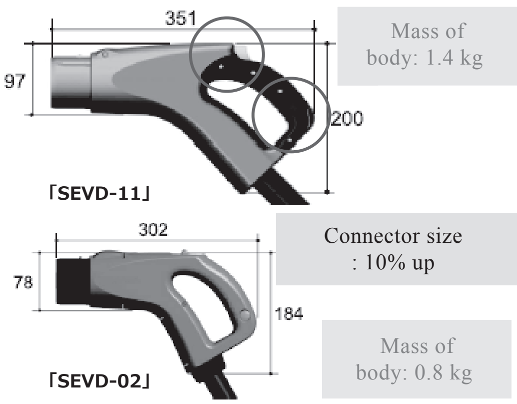


Fig. 5. Comparison of structures between high-power and quick charging models

photo 3. Exposed metal parts at edges
(enlarged view of the circled part ○ shown in Fig. 5)

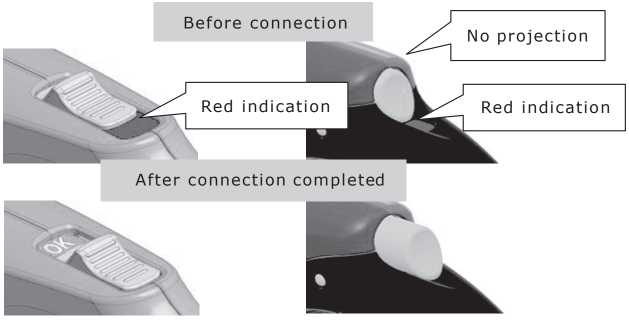
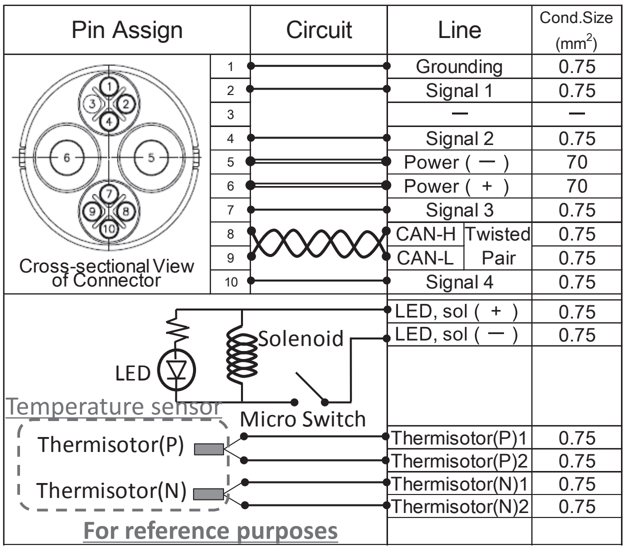


Fig. 6. Change in shape of release button (elimination of projection)

2-3 Use of temperature sensor to detect anomalies

A temperature sensor was incorporated when developing the high-power connector to respond to market demand. Figure 7 illustrates the pin assignment of the connector. Four signal wires were added to the cable. The sensor was placed on the cable insulation near the power terminals in the connector.

This section examines the results of the above-described temperature rise tests.



Pin Assign	Circuit	Line		Cond.Size (mm^2)
1		Grounding		0.75
2		Signal 1		0.75
3		─		─
4		Signal 2		0.75
5		Power (─)		70
6		Power (＋)		70
7		Signal 3		0.75
8		CAN-H	Twisted	0.75
9		CAN-L	Pair	0.75
10		Signal 4		0.75
		LED, sol (＋)		0.75
		LED, sol (─)		0.75
		Thermisotor(P)1		0.75
		Thermisotor(P)2		0.75
		Thermisotor(N)1		0.75
		Thermisotor(N)2		0.75

Note: According to the classification indicated by the requirement matrix for over-temperature protection (0–400 A) output specified in the CHAdeMO specification, our product falls under the category of non-cooled 200 A cable assembly. Consequently, our product does not require a temperature sensor. However, the temperature sensor was attached for reference purposes.

Fig. 7. Pin assignment of high-power connector

The temperature sensor is effective for detecting the operating state under regular charging conditions, allowing the user to detect the temperature of the power terminals at a measurement deviation of approximately 5 K, as illustrated in Fig. 8. In sum, temperature estimates can be obtained as follows: Power terminals temperature = Sensor measurement + 6 K.

Meanwhile, in the event of an anomaly such as overheated power terminals, a noticeable measurement deviation (5 K–12 K) occurs along with a difference in time response (proportional slope of graph), as shown in Fig. 9. In this condition, unlike under regular conditions, it is difficult to monitor the terminal temperature.

Viewing the purpose of installing a temperature sensor for detecting anomalous heat, we have not considered the use of a temperature sensor for monitoring or controlling purposes, as categorized in the CHAdeMO specification that specifies the high-power requirements described in Section 4-3. However, the results of the above-described attempt verified that a newly installed temperature sensor can be used to determine anomalies. This outcome has been presented to charger manufacturers as an attachment to our connector specification to recommend them to use sensor measurements to monitor charging anomalies.

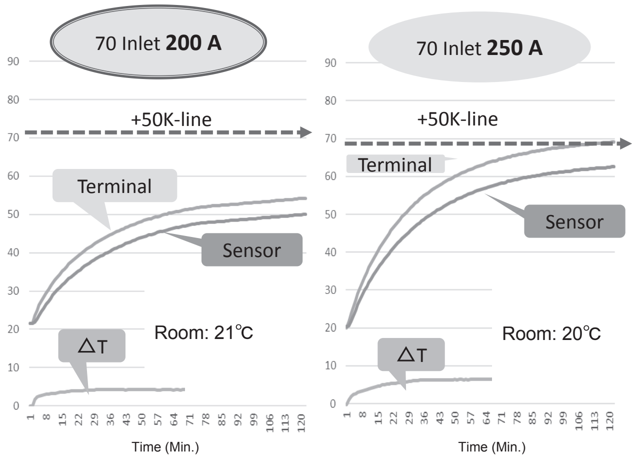


Fig. 8. Measurement by temperature sensor under regular charging conditions

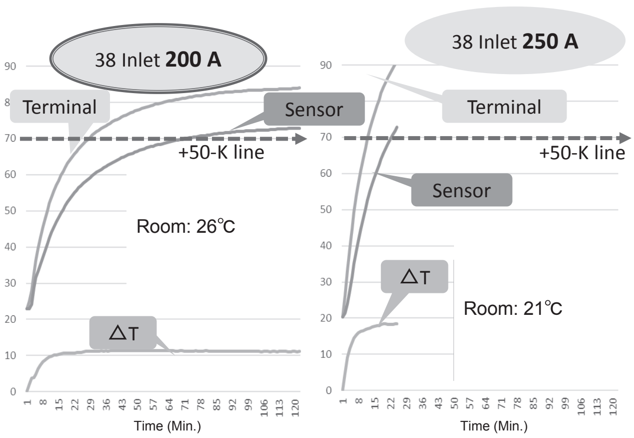


Fig. 9. Measurement with temperature sensor under overheat conditions at power terminals

3. Test Results and Achieving Certification

3-1 Test results

Table 5 and Photo 4 show the mechanical strength results as part of the results of testing conducted according to the standard characteristic requirements of the CHAdeMO specification.

Additionally, to evaluate the connector in terms of requirements other than those of the CHAdeMO specification, environmental resistance, salt spray, rigorous cable bending, heat shock, and other tests were conducted. The connector has been verified to operate normally under the environmental and operating conditions assumed for these tests. Moreover, the cable, if wound, can be picked up without any practical hindrance, as shown in Photo 5. There is no concern that operation is hindered due to the flexibility of the cable when fitting the connector to an inlet.

Table 5. Results of part of mechanical strength tests conforming to CHAdeMO specification

Test item	requirement	Appea-rance	Operation check	Insulation resistance	Withstand voltage
Drop impact	Drops from a height of 1 m to a concrete floor (8 directions)	Good	Good	Good	Good
Crush	890 N load for 1 min	Good	Good	Good	Good
Drive over	2 t vehicle driving over the connector	Good	Good	Good	Good

Photo 4. Evaluation as to performance requirements of CHAdeMO (excerpts)

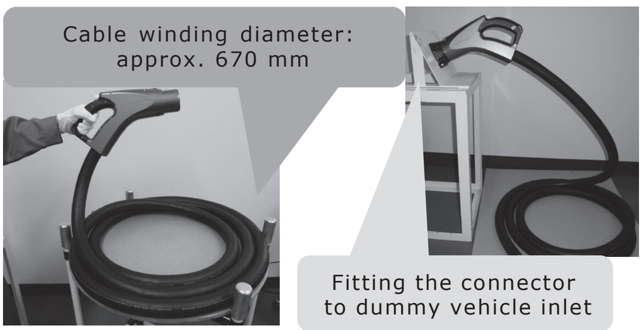


Photo 5. In-house test (excerpts)

3-2 Achieving overseas certification for HPC

To sell the connector in overseas markets, product certification is required to be achieved. For that purpose, it is necessary to develop a cable that is compliant with the specifications used in specific markets. We use varying product specifications, as listed in Table 6 to comply with standards used in the individual markets below.

- North America (including regions where the UL Standards are in use): UL 2251
  UL 2251 requires a thick cable sheath. Accordingly, finished cables have a larger outside diameter and a larger mass.
- Europe (including regions where the IEC Standards are in use): IEC 62196-1

We have achieved certification meeting these standards since the early days of the development of the SEVD models. Similarly, HPC was UL-certified in December 2017, commencing sales of UL-compliant products earlier than others. As a track record, about 450 units have been sold as of the end of October 2018. In July 2018, we also achieved CE certification complying with the IEC Standards. Sales of CE-certified models commenced in September 2018.

Table 6. Design specifications for HPC connector, by market

Model		**SEVD-11**		
Rating		DC 500 V / **200 A**		
Dimensions (mm)		351 × 200 × 83		
Weight of connector		1.4 kg (excluding cable)		
Overseas certification		(Japan)	CE	UL (600 V)
Power	Size	70 mm^2	70 mm^2	2/0 AWG 67.4 mm^2
	Number of Line	2		
Signal	Size	0. 75 mm^2	0. 75 mm^2	18 AWG 0.82 mm^2
	Number of Line	13 7 for signals, 2 for solenoid, and 4* for temperature sensor * Incorporated for reference purposes only		
Cable	diameter (mm)	40	36	43
	Weight (kg/m)	2.73	2.48	2.8

We have expanded sales of HPC by gaining overseas certification, ensuring safe use of HPC throughout the world. For the Japanese market, we commenced mass production and shipping in November 2018.

4. Future Development: Further Efforts for Even Higher-Power Charging

4-1 Use of boost mode (quick and high current)

Efforts have been directed towards improving EV battery capacity to extend the range of EVs. Against this backdrop, there is a growing market demand for a more powerful quick charger. As over 50 kW·h-class batteries have been commercialized, efforts are under way for the development of a boost mode (quick and high current) for high-power charging within a limited period of charging time. We have conducted a temperature rise test passing a high current of 300 A. The test results showed that it is possible to charge in boost mode at over 100 kW-class power if within a short period of time (Fig. 10).

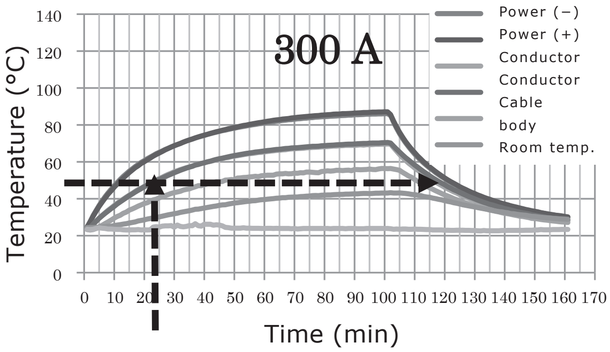


Fig. 10. High-current test results (70 mm^2 inlet conductors)

4-2 Use at high voltages (compliance with CHAdeMO 2.0)

In the design stage during the development of the high-power connector, we made it possible to use the connector at a nominal voltage of 1,000 V. Currently, the IEC Standards for high-power applications of the connector are under development. Therefore, we are planning to achieve certification keeping in step with the revision to the standards.

4-3 Use of even higher-power charging

Along with the growing demand for EVs, even higher power is demanded. The current CHAdeMO specification sets forth the need to provide temperature monitoring, cooling, and temperature regulation functions if the output current (current rating) exceeds 200 A. Based on the findings about temperature sensors described in this paper, we intend to support the shift to even higher power. We also intend to make the cable assembly suitable for use at higher power to comply with overseas specifications for quick charging methods.

To realize this, the charger connector assembly is regarded as a key component. We are committed to meeting market needs to the greatest extent possible, while placing importance on fully ensuring safety. We are working on the development of relevant products and considering commercialization as a leading company in the industry, in close liaison with the CHAdeMO Association and in line with revisions to overseas standards.

5. Conclusion

Sumitomo Electric has globally sold a diverse range of CHAdeMO specification-compliant charger connector assembly products for EV chargers, placing priority on safety and superb operability. We will remain committed to developing and providing ever better products, positively responding to customer needs to meet robust demand for EVs.

• CHAdeMO is a trademark or registered trademark for a DC quick charging method for EVs.
• SEVD is a trademark or registered trademark of Sumitomo Electric Industries, Ltd.

Technical Terms

∗1 CHAdeMO: CHAdeMO is a DC quick-charging protocol for EVs. The CHAdeMO Association was organized in 2010. Its members include automakers, electric power companies, charger manufacturers, local governments, charging service providers, relevant non-profit organizations, and certification organizations. The association has been promoting activities to develop technologies and spread the use of the protocol.

∗2 Vehicle-to-home (V2H): V2H denotes the flow of power supplied from EVs. Other similar terms include vehicle-to-grid (V2G), vehicle-to-load (V2L), and vehicle-to-building (V2B), which are collectively termed vehicle-to-everything (V2X).

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