

CHAdeMO Quick Charger Connector with Excellent Operability

Atsushi YOSHIDA*, Hirofumi ZAITSU, Takatoshi KIKUTA, Shigehiro TSUDA, Hiroaki NII and Shikou KODAMA

Electric vehicles can be charged by either AC normal charge or DC quick charge. For the latter, a CHAdeMO DC quick charger was developed in Japan and has been widely used in Japan, Europe, and the US. We developed a DC charger connector that meets the CHAdeMO specifications, and have since supplied over 15,000 units of it and other connectors including those for vehicle to home applications. Our connectors have a good reputation for their operability and safety.

Keywords: electric vehicle (EV), direct current, CHAdeMO, quick charge, V2X

1. Introduction

Currently, two charging methods are available: normal charge method (alternating current: AC) for general applications, which takes around 8–11 hours to charge electric vehicles (EVs), and quick charge method (direct current: DC) for applications at public facilities and large commercial facilities, which takes 30 minutes for 80% charge. For the quick charge method, four types of protocols have been established based on the international standards. One of them is CHAdeMO*¹ that was developed in Japan. It has been employed worldwide, and has an established track record (Fig. 1).

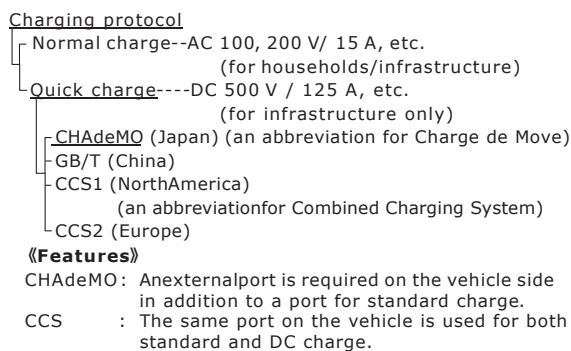


Fig. 1. Summary of charging protocols

The cable provided with a charging 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).

Since the release of the DC quick charger connector (SEVD-01) in 2011, we have developed various models of connectors for different applications (e.g., 20 kW-class, V2H) that deliver excellent operability and high reliability. A total of 15,000 connectors have been sold by the end of October 2016.

2. CHAdeMO DC Quick Charger Connector

While SEVD-01 featured an aluminum alloy case, SEVD-02 (released in 2014) features a resin case that helps in reducing the weight along with improving the operability. At present, SEVD-02 is the main product in our line-up (Table 1, Photo 1).

Table 1. Quick charger connector SEVD-02 model

Model	SEVD-02 Model	
Model number	SEVD-02	SEVD-02M
Capacity	50 kW	20 kW
Rating	DC 500 V / 125 A	DC 500 V / 60 A
Connector weight	0.8 kg	0.8 kg
Cable	Rubber cabtyre cable Power line: 38 mm ²	Rubber cabtyre cable Power line: 22 mm ²

Note: SEVD-02E / SEVD-02ME (50 kW/20 kW) for Europe, SEVD-02U / SEVD-02MU for North America

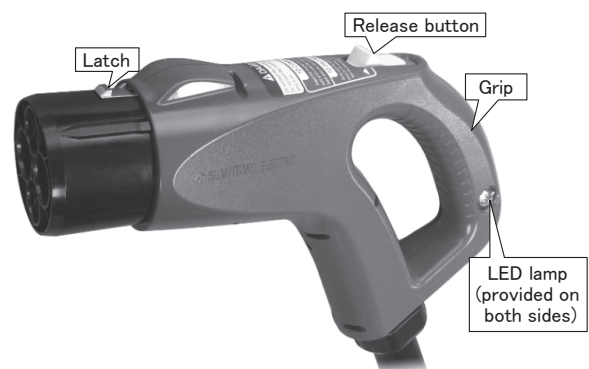


Photo 1. SEVD-02 quick charger connector

2-1 Design development concept

In developing a quick charger connector, the following design concept was formulated in addition to ensuring the CHAdeMO compatibility:

- (1) Excellent handling and operability.
Operable with one hand, easy-to-grip shape, easy-to-understand and intuitive operation
- (2) Simple structure
- (3) Extensive safety mechanism

2-2 Connector shape design

In order to ensure high operability, we employed a technique that reflected ergonomic findings for designing the shape. We fabricated a prototype of three models (Photo 2) selected from seven different design plans, and conducted a usability test on general users to check the mating operation (Fig. 2 [an excerpt of results]) to determine the basic shape.

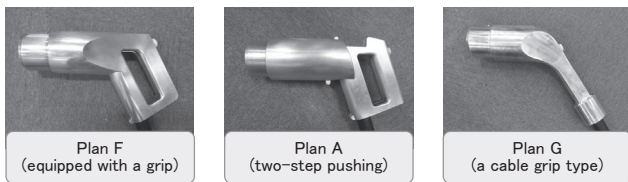


Photo 2. Three design plans for quick charger connector

Thanks to this design, our connector has been highly qualified in terms of operability (i.e., a shape that does not require gripping the cable, easy to balance, easy to operate even for users with weak strength).

2-3 Mating design to improve the operability

In terms of the operation to insert the connector plug for mating, the higher the insertion force (CHAdeMO

requirements specifications of 100 N or less), the poorer the operability. To minimize the insertion force, SEVD-02 is equipped with an alignment mechanism that enables independent movement of respective terminals. This mechanism has been achieved by improving the structure that secures the power line and the signal line terminals. Thus, the connector can be smoothly mated with the inlet, thereby achieving a sufficiently low insertion force (50–80 N). Even if there is a deviation in the inlet terminal position, mating can be ensured within the scope that it can be aligned on the connector side.

2-4 Safety design for charging

(1) Arrangement of a microswitch

When the connector of the charger and the port on a vehicle are matched completely, a microswitch (which is interlocked by the movement of the latch) is turned on to close the signal line circuit, thereby enabling charging. If the latch is not properly locked due to improper mating or other reasons, the microswitch is not turned on, and the signal circuit remains open, thereby disabling charging.

We developed the mechanism of incorporating a microswitch to interlock the circuit with a latch, and it now has become the CHAdeMO standard specification, significantly contributing to the increased safety of the CHAdeMO connector.

(2) Electrical lock mechanism using a solenoid

This mechanism allows a solenoid to function after the connector and the port are mated (CHAdeMO standard specification), and it directly restrains the latch operation.

When the solenoid is actuated, an LED is turned on. Thus, the users can know connector mating and the signal circuit condition at the same time with the release button operation.

The details are shown in Table 2 and Fig. 3.

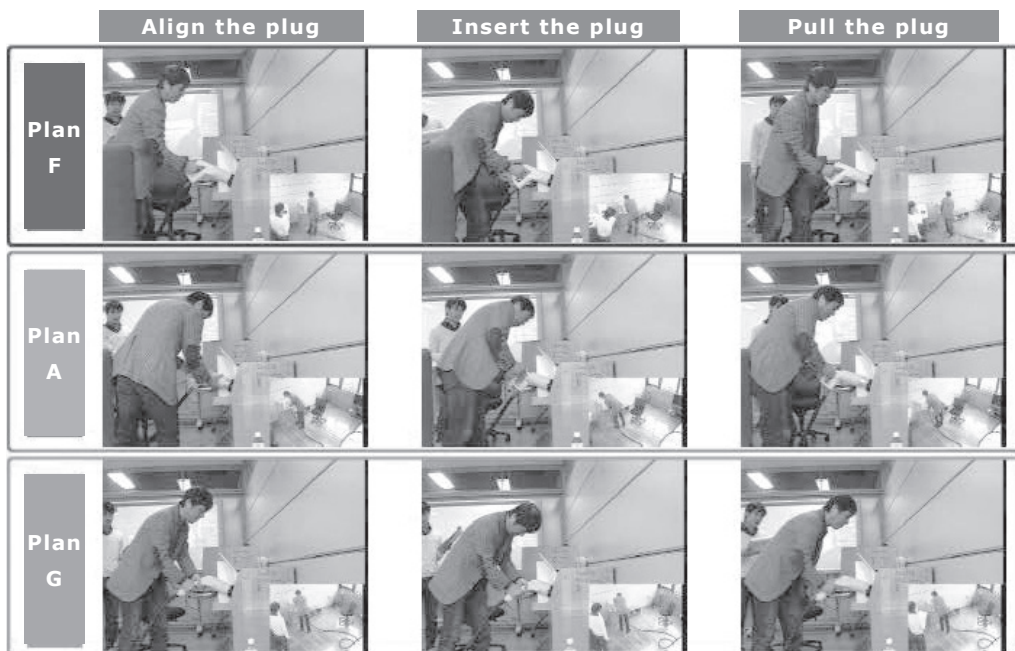


Fig. 2. Mating operation evaluation

Table 2. Lock conditions and their indications

Connector condition	Latch condition	Release button indication	Signal pin	Micro-switch	Signal circuit
Before mating	Horizontal	Red	Off not connected	On	Open
During insertion	Tilt downward	Red	Off not connected	Off	Open
Mated	Horizontal	Green OK mark	On connected	On	Close Circuit established

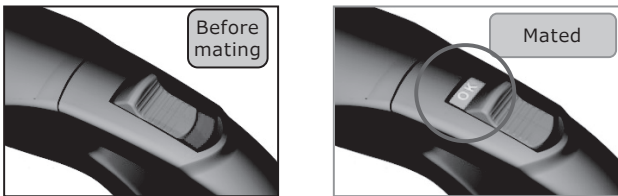


Fig. 3. Release button indication

2-5 Connector cable design

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, a high rubber cabtyre cable is employed because it is flexible at low temperatures (-30°C) (Table 3). This cable can be bent and twisted easily.

Table 3. Specifications of the rubber cabtyre cable for the quick charger connector

Type		SEVD-02 for 50 kW	SEVD-02M for 20 kW
Conductor size	Power line Signal line	$38\text{ mm}^2 \times 2$ $0.75\text{ mm}^2 \times 9$	$22\text{ mm}^2 \times 2$ $0.75\text{ mm}^2 \times 9$
Maximum overall diameter		$\phi 32\text{ mm}$	$\phi 28\text{ mm}$
Weight		1.46 kg/m	1.07 kg / m
Insulating material		EP rubber	
Sheath material		Chloroprene rubber	
Applicable standard		JIS C 3005, JCS 4522	

2-6 Evaluation test

We conducted a test to examine that the connector meets the CHAdeMO requirements. Satisfactory characteristics were confirmed in terms of strength, low-temperature resistance, and environmental resistance, which are the greatest concerns about a resin case (Photo 3).

An in-house evaluation was also made on non-CHAdeMO requirements (e.g., salt spray, severe cable bending, and thermal shock). We verified that the soundness of connector operation is maintained in expected environments and usage conditions (Photo 4).

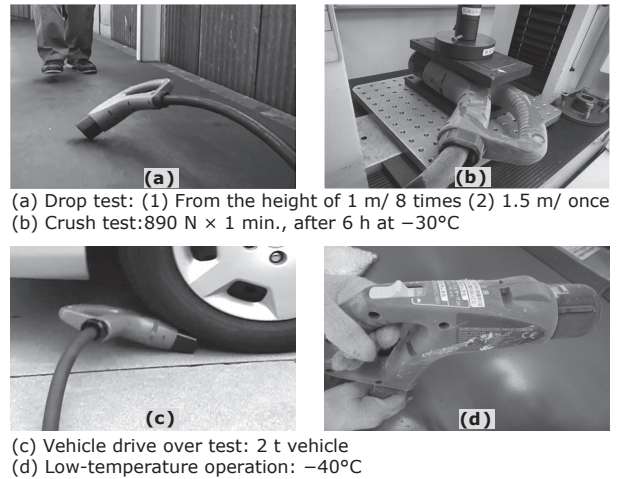


Photo 3. CHAdeMO required performance evaluation test (excerpt)

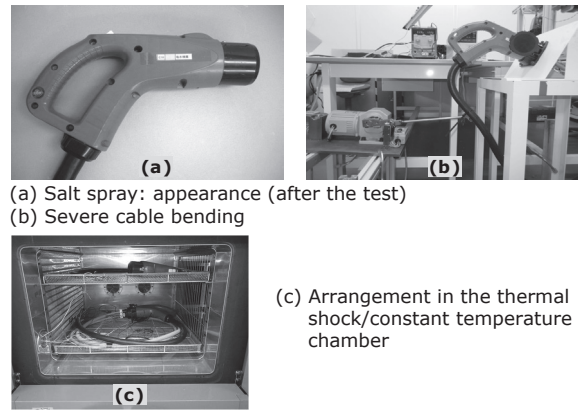


Photo 4. In-house evaluation test (excerpt)

2-7 Deployment outside Japan

(1) Conformity with the European market

For sales in the European market, the IEC 62196-1:2003 compliance certificate was obtained for the 01 model (SEVD-01E) in 2012 and for the 02 model (SEVD-02E, SEVD-02ME) (for 20 kW) in 2014. The CE marking*2 is indicated on the label.

These certified connectors are identical in design with the products sold in the Japanese market, except for the cable (in conformance with IEC 60502-1), and the basic characteristics are the same.

When the certification was obtained, we verified that the results were satisfactory for the following evaluation items (which are not required in the CHAdeMO specifications): (1) Resistance to heat, fire, and tracking (at a ball pressure test after exposure to 110°C , glow wire test at 850°C), and (2) ISO 4892-2 (at the UV evaluation for 500 h).

(2) Conformity with specifications in the European market (the latest standard)

In 2015, we became the first company in the world to obtain a certification for the 03 model (50 kW: SEVD-03E, 20 kW: SEVD-03ME), which is in compliance with the latest version [-3] of IEC 62196.

Notably, we verified that the connector is not subjected to destruction and that the function is retained in the Interlocks test (whose conditions are severest for this standard) (load: 750 N, direction: vertical/90°, retained for 1 min in three repeated cycles) (see Photo 5).

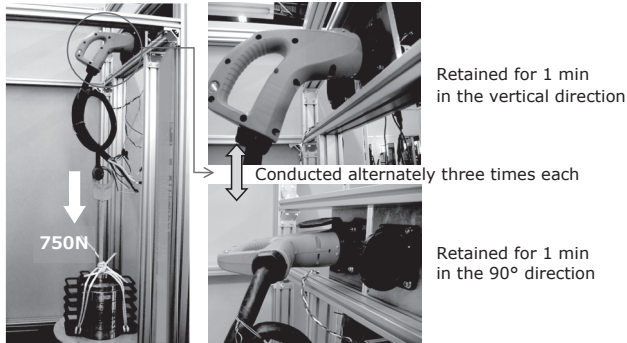


Photo 5. Interlocks test

This connector will be able to meet the requirements that are necessary to deliver products that conform to the latest version of IEC 62196 in the near future.

(3) Conformity with specifications in the North American market

For sales in the North American market, the UL 2251 compliance certificate was obtained for the 01 model (SEVD-01U) in 2012 and for the 02 model (SEVD-02U, SEVD-02MU) (for 20 kW) in 2015.

For the 02 model, since the beginning of the development, the materials that conform to UL 2251 (whose requirements are rigorous in terms of material characteristics) were used for all markets. Thus, these models are different from those sold in the Japanese market in the following two points: (1) Using a cable that conforms to UL 62, and (2) Enhanced waterproof measures inside the connector. However, the basic characteristics are the same.

The characteristics were evaluated based on UL 2251, UL 50E/8.3 Rain Test, UL 50E/8.5 External Icing Test, 746A, 746C, and UL 94, and it was verified that these characteristics are satisfactory.

As discussed above, certifications outside Japan indicate that the connectors can be used safely around the world.

3. V2X Connector

Recently, V2X^{*3} has drawn public attention as a solution to use electric power derived from the in-vehicle battery of electric vehicles for purposes other than driving. Demonstration tests have been conducted to use V2X as (1) an emergency power source in the event of disasters, (2) a power source for households, buildings, and communities, and (3) a solution for peak-load shifting and utilization of renewable energy. V2X has also been put to commercial use in some areas.

We developed SEVD-V1 (a V2X connector) in 2013 and became the first company to sell a product of this kind. In 2015, we were engaged in standardizing the CHAdeMO Certification Guidelines ver. 2.1. In 2016, we developed and began to sell SEVD-V2 in conformity with the guidelines as an improved model of SEVD-V1 that established a track record (Table 4, Photo 6).

Table 4. Overview of the V2X connector

Model	SEVD-V model	
	SEVD-V1	SEVD-V2
Model number	SEVD-V1	SEVD-V2
Capacity	6 kW	10 kW
Rating	DC 450 V / 15 A	DC 450 V / 25 A
Connector weight	0.6 kg	0.6 kg
Fuse	Rating 25 A	Rating 35.5 A
Solenoid	Push-pull type	Latching type
Cable specifications	Rubber cabtyre cable	Rubber cabtyre cable
· Power line :	2 mm ² × 2	3.5 mm ² × 2
· Signal line :	1.25 mm ² × 9	1.25 mm ² × 11
· Weight :	0.53 kg/m	0.53 kg/m
CHAdeMO certification	Guidelines ver. 1.0	Guidelines ver. 2.1



Photo 6. V2X connector: SEVD-V1, SEVD-V2

3-1 V2X connector design concept

In addition to conforming with the CHAdeMO specifications, SEVD-V2 is designed to ensure safety in handling and excellent operability even more than quick charger connectors on the assumption by taking into account the household usage.

3-2 Basic structure design

The basic design of the electrical and mechanical connection (mating) component was based on the design of the quick charger connectors that established a track record. To further improve the operability compared to the quick charger connectors, the weight has been reduced, and the size has also been reduced to almost equivalent to that of the standard charge connectors.

3-3 Safety design for charging and discharging

The safety design requires additional features to raise users' awareness in operating safely (Photo 7).

(1) Operation for mating: Mechanical lock

The latch can be mechanically locked by pushing the lock button after inserting the inlet. Inappropriate mating is

detected if the lock button cannot be pushed. The user can check the complete mating of the latch.

(2) Preparation for charging or discharging: Electrical lock

Pushing the lock button causes the interlocked micro-switch to turn on. This can be detected on the equipment side, enabling energization of the solenoid for charging or discharging. The release button for the latch is electrically locked in order to directly restrict the operation.

Until the lock button is pushed, the microswitch remains turned OFF. This is detected by the equipment, and the start of charging or discharging is disabled or immediately interrupted.

(3) Operation to release the lock after charging or discharging

When the solenoid is de-energized after charging or discharging is completed, the electrical lock is released. Thereafter, the release button must be pushed in two steps to remove the plug.

Step 1: The lock button returns to the original position, and the mechanical lock is released.

Step 2: The latch lowers to enable removal.

This mechanism requires two steps of operation until the plug is removed even if the user releases the lock while the solenoid is energized. Charging or discharging is terminated by the time the user completes these two steps of operation, thereby preventing removal while the solenoid is being energized.

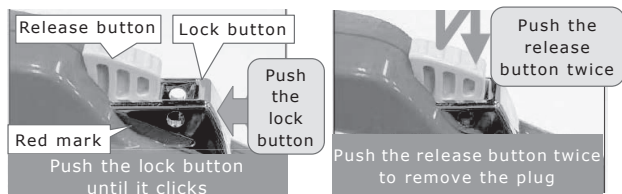


Photo 7. Mating and removal operation of a V2X connector

(4) Built-in fuse

A fuse is provided in the power line circuit to protect the cable against any overcurrents. If the fuse melts, the entire connector must be replaced due to the abnormality recorded. The design does not permit replacement of the fuse.

3-4 Evaluation test

An evaluation test has been conducted to examine that the V2X connector meets the CHAdeMO requirements as in the case of quick charger connectors. In-house evaluations based on the findings derived from quick charger connectors and environmental resistance evaluations reflecting customers' needs were also conducted. We verified that the characteristics are satisfactory (Photo 8).

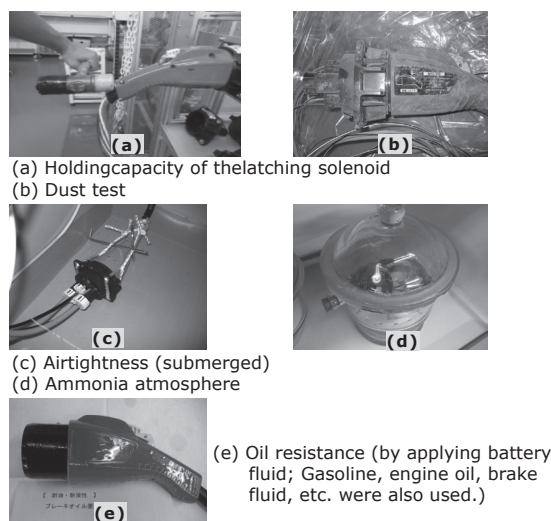


Photo 8. In-house evaluation test of the V2X connector (excerpt)

4. Future Activities

Development efforts have been made to increase the EV battery capacity and to increase mileage. Against this backdrop, there have been growing market needs for quick chargers to have further increased capacities.

According to the CHAdeMO roadmap, the EV charger capacity will increase to 350 kW (seven-fold of the current capacity) in 2020 or beyond. The charger connector cable is considered to be the key component to achieve this goal.

We will take steps to meet the market needs while placing the most importance on safety. As a leading company in the industry, we will continue our efforts for the design and commercialization of products that will meet the needs in line with the activities of the CHAdeMO Association.

5. Conclusion

Based on a specific policy (i.e., higher levels of safety and excellent operability), we have developed and released a CHAdeMO DC charger/discharger connector cables for EVs. These products have been well received by customers all over the world. We will continue to firmly adhere to the policy and manufacture ever better products.

• 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 CE marking: The CE marking shows that a product conforms to the EC directive and guarantees the free circulation of the product within the EU. Manufacturers are required to indicate the CE marking on their products. Manufacturers that obtain a certification to conform to the IEC standards can indicate the CE marking on their products.
- *3 V2X: V2X is a generic term for V2H (Vehicle to Home), V2L (Vehicle to Load), V2B (Vehicle to Building), V2G (Vehicle to Grid), etc. It shows the flow of electricity supply from EVs.

~~~~~  
**Contributors** The lead author is indicated by an asterisk (\*).

### A. YOSHIDA\*

• Assistant General Manager, New Energy Project Promotion Office



### H. ZAITSU

• Assistant General Manager, New Energy Project Promotion Office



### T. KIKUTA

• Senior Assistant General Manager, New Energy Project Promotion Office



### S. TSUDA

• Manager, Business Development Department, Sumiden Transmission and Distribution System Products, Ltd.



### H. NII

• Manager, Business Development Department, Sumiden Transmission and Distribution System Products, Ltd.



### S. KODAMA

• General Manager, Business Development Department, Sumiden Transmission and Distribution System Products, Ltd.

