

North American Charging Standard
TS-0023666



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1. Scope

The scope of this document covers implementation of the North American Charging Standard (NACS), including Electric Vehicle (EV) and Electric Vehicle Supply Equipment (EVSE) systems for both AC and DC charging systems.

All requirements are normative unless otherwise indicated. Informative references indicated as such.

Explanatory notes are denoted in small subtext.

2. References

Unless otherwise explicitly stated, implementation & validation of the North American Charging Standard is compatible with IEC 61851-1, IEC 61851-23, IEC 62196-1, IEC 62196-2, IEC 62196-3, and IEC 62196-23. Exceptions to the standards are noted below.

3. Definitions

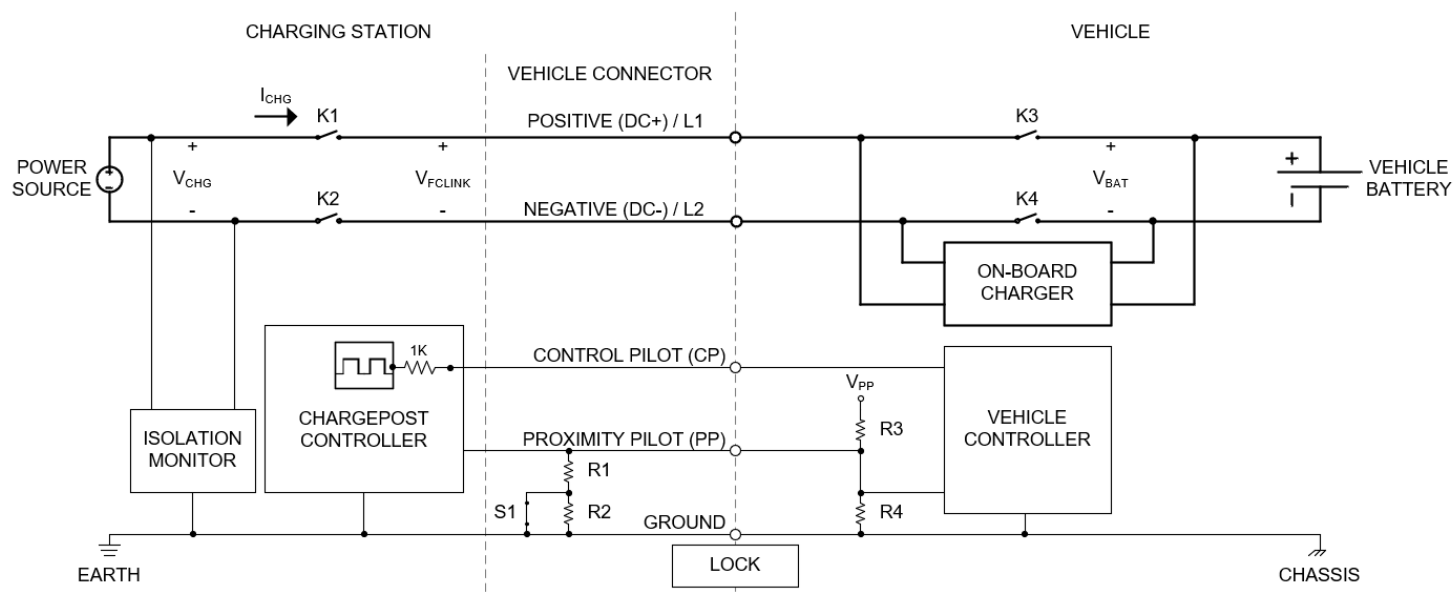
EVSE	Electric Vehicle Supply Equipment. Also called chargepost or charging station.
EV	Electric vehicle
Connector	Apparatus attached to EVSE cable, which connects to EV to charge it. Sometimes called handle.
Inlet	Area on EV where connector is plugged in, to charge it. Also called Chargeport or Charge Port.
Socket	A receptacle style electrical contact. Mates to a pin.
Pin	A plug style electrical contact. Mates to a socket.
Interface Contact	The electrical contact at the pin/socket interface.
Cable	A flexible conductor used to transmit current from a source to a load.

3. Definitions,
cont.

Busbar	A rigid conductor used to transmit current from a source to a load.
EVSE End	The end of the connector assembly which connects to the EVSE.
Door	The vehicle closure or customer facing A-class that hides the inlet when not in use.
BIW	Body-in-White, the sheet metal portion of the vehicle body that the inlet interfaces with.
B+/B-	The DC pins on the charging interface.

4.Functional Specifications

The following is a simplified schematic block diagram of the system while charging. Component and reference descriptions are given in Section 4.1.



4.1 Component and Reference Descriptions

- 4.1.1 Charging Station**
The charging station is an assembly of components required for charging of a vehicle battery.
- 4.1.2 Power Source**
The power source provides regulated power to charge the vehicle battery. For DC charging, the DC power source shall be isolated from the grid from which it derives power.
- 4.1.3 V_{CHG}**
 V_{CHG} is the power source output bus or voltage.
- 4.1.4 I_{CHG}**
 I_{CHG} is the power source output current. The maximum output current shall be limited by the power source capabilities and thermal limits of the system.
- 4.1.5 K1 and K2**
K1 and K2 are contactors or relays used to control the connection of the power source to the vehicle through the vehicle connector.
K1 and K2 are not mandatory and may be excluded in certain systems.
- 4.1.6 V_{FCLINK}**
 V_{FCLINK} is the voltage bus that links the charging station to the vehicle through the vehicle connector.

4.1 Component and Reference Descriptions, cont.

4.1.7 Isolation Monitor

The isolation monitor measures the isolation to earth and vehicle chassis of V_{CHG} , V_{FCLINK} , and V_{BAT} depending on the state of K1, K2, K3 and K4. The isolation monitor may be placed on the vehicle side of the charging station contactors K1 and K2. Isolation monitoring is only relevant for DC charging.

4.1.8 Charging Station Controller

The charging station controller monitors and controls critical safety systems and interactions with the vehicle controller to control the charging process.

4.1.9 Earth

The earth connection is used as a reference by the isolation monitor to measure isolation to earth of V_{CHG} , V_{FCLINK} , and V_{BAT} .

4.1.10 Vehicle Connector

The vehicle connector is an operator moveable part of the charging system which provides conductive connection to the vehicle.

4.1.11 Positive (DC+) / L1

DC+ / L1 is the positive side of V_{FCLINK} . DC+ / L1 is used for power transfer and may be implemented as a single or dual connection point. DC+ refers to the voltage while DC charging, while L1 refers to the voltage while AC charging.

4.1.12 Negative (DC-) / L2

DC- / L2 is the negative side of V_{FCLINK} . DC- / L2 is used for power transfer and may be implemented as a single or dual connection point. DC- refers to the voltage while DC charging, while L2 refers to the voltage while AC charging.

4.1.13 Control Pilot (CP)

CP is used as a digital communication path between the charging system and vehicle. The control pilot uses pulse width modulation to communicate charging state and current in accordance with Annex A of IEC 61851-1. Power Line Communication is superimposed onto the control pilot line while DC charging.

4.1.14 Proximity Pilot (PP)

PP is a low voltage signal generated by V_{PP} , R1, R2, R3, R4, and S1 (pilot proximity circuit) and is used to determine the status of the vehicle connector. The pilot proximity circuit and vehicle connector status relationship are described in section 4.1.28.

4.1.15 Ground

The ground conductor provides a connection between earth and vehicle chassis.

The connection provides a common reference point for the isolation monitor to measure isolation of V_{CHG} , V_{FCLINK} , and V_{BAT} to earth and vehicle chassis.

The connection also provides a common reference point for the charging station and vehicle digital communication and low voltage signals.

4.1 Component and Reference Descriptions, cont.

4.1.16 Lock

The lock is used to prevent insertion or removal of the vehicle connector from the vehicle as required.

4.1.17 S1

Normally closed switch used in conjunction with V_{pp} , R1, R2, R3, and R4 as part of the proximity pilot circuit to determine the connection status of the vehicle connector. S1 is located in the vehicle connector and is operator accessible. S1 is opened to indicate desire to stop the charge session and disconnect the vehicle connector. Implementation of S1 is optional.

4.1.18 R1 and R2

Resistors used in conjunction with V_{pp} , R3, R4, and S1 as part of the proximity pilot circuit to determine the connection status of the vehicle connector. R1 and R2 are located in the vehicle connector.

4.1.19 Vehicle

The vehicle is an assembly of components containing a vehicle battery which may be charged using the charging station.

4.1.20 K3 and K4

K3 and K4 are contactors used to control the connection of the vehicle battery to the charging station. K3 and K4 are closed during DC charging and open during AC charging.

4.1.21 V_{BAT}

V_{BAT} is the vehicle battery output bus or voltage.

4.1.22 Vehicle Battery

The vehicle battery is a rechargeable energy storage device use to provide power to an electric vehicle drive train.

4.1.23 On-Board Charger

The on-board charger is used to convert AC to DC power to charge the vehicle battery with AC charge systems. The on-board charger is bypassed when DC charging.

4.1.24 Vehicle Controller

The vehicle controller monitors and controls critical safety systems and interactions with the charging station controller to control the charging process.

4.1.25 V_{pp}

Voltage source used in conjunction with R1, R2, R3, R4 and S1 as part of the proximity pilot circuit to determine the connection status of vehicle connector.

4.1.26 R3 and R4

Resistors used in conjunction with V_{pp} , R1, R2, and S1 as part of the proximity pilot circuit to determine the connection status of vehicle connector.

4.1.27 Chassis

The chassis connection is used as a reference by the isolation monitor to measure isolation to vehicle chassis of V_{CHG} , V_{FCLINK} , and V_{BAT} .

4.1 Component and Reference Descriptions, cont.

4.1.28 Proximity Pilot Circuit

The pilot proximity circuit equivalent parameters are given in Table 1. The associated vehicle connector status is given in Table 2.

Proximity Pilot Circuit Component	Equivalent Value
V_{PP}	$5V \pm 10\%$
R1	$150\Omega \pm 10\%$
R2	$330\Omega \pm 10\%$
R3	$330\Omega \pm 10\%$
R4	$2.7K\Omega \pm 10\%$

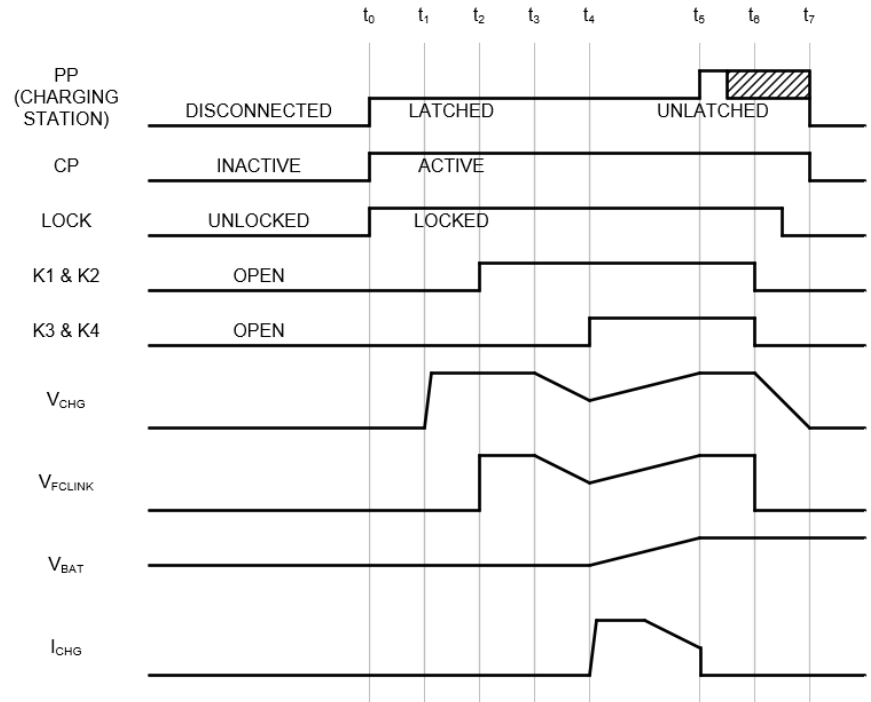
Table 1: Pilot Proximity Circuit Equivalent Parameters

Vehicle Coupler Status	PP Charging Station Voltage (Nominal)	PP Vehicle Voltage (Nominal)
Disconnected	0V	4.5V
Latched (S1 Closed)	1.5V	1.5V
Unlatched (S1 Open)	2.8V	2.8V

Table 2: PP and Vehicle Connector Status

4.2 Charging Process: DC Charging

The sequence diagram and description of normal charging process for DC charging are shown in the figure below and described in section 4.2.1.

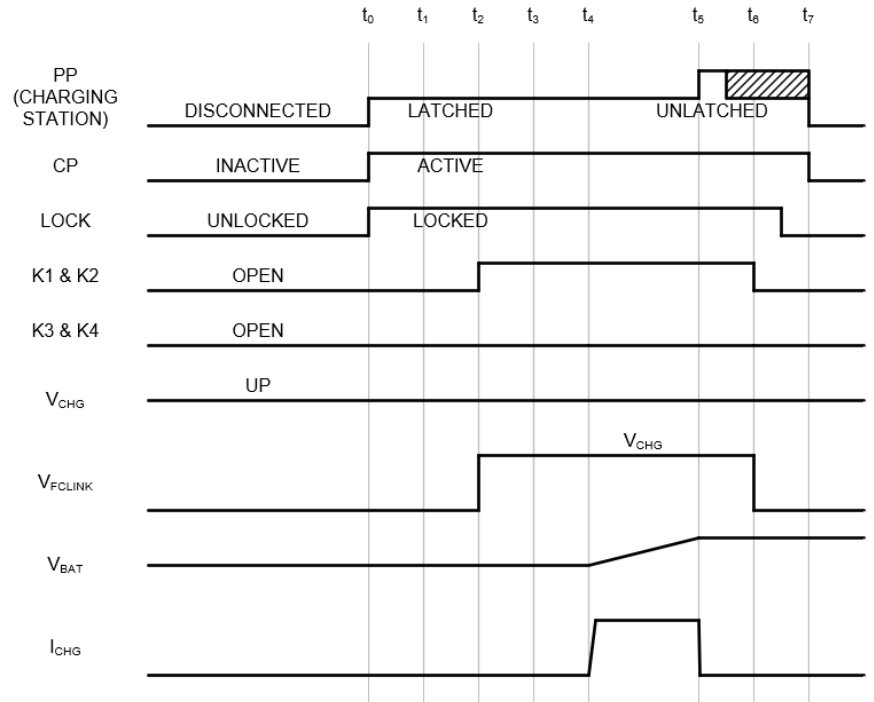


4.2.1 Sequence Description

- $t < t_0$: The operator uses any provided method to indicate the desire to begin a charge session. If the vehicle is prepared to begin a charge session, vehicle connector insertion is allowed.
- $t_0 - t_1$: The vehicle connector is inserted into the vehicle. The lock is engaged to prevent vehicle connector removal and control pilot communication is used for initial parameter exchange and compatibility check. The lock remains engaged and digital communication remains active throughout the charge session.
- $t_1 - t_2$: An optional internal isolation test is performed on V_{CHG} .
- $t_2 - t_3$: K1 and K2 close and an isolation test is performed on V_{CHG} and V_{FCLINK} .
- $t_3 - t_4$: V_{CHG} and V_{FCLINK} are adjusted to match V_{BAT} .
- $t_4 - t_5$: K3 and K4 close and energy transfer from the DC power source to the vehicle battery takes place.
- $t_5 - t_6$: S1 is opened momentarily or for a sustained period, or another provided method is used to indicate the charge session should be stopped and I_{CHG} is turned off.
- $t_6 - t_7$: K1, K2, K3 and K4 open and V_{FCLINK} is removed.
- $t > t_7$: The lock is disengaged to allow vehicle connector removal, ending the charge session.

4.3 Charging Process: AC Charging

The sequence diagram and description of normal charging process for AC charging are shown in the figure below and described in section 4.3.1.



4.3.1 Sequence Description

- $t < t_0$: The operator uses any provided method to indicate the desire to begin a charge session. If the vehicle is prepared to begin a charge session, vehicle connector insertion is allowed.
- $t_0 - t_1$: The vehicle connector is inserted into the vehicle. The lock is engaged to prevent vehicle connector removal and control pilot communication is used for initial parameter exchange and compatibility check. The lock remains engaged throughout the charge session.
- $t_1 - t_2$: Optional internal readiness testing is performed on the EVSE.
- $t_2 - t_3$: K1 and K2 close and the onboard charger senses and matches the voltage of V_{FCLINK} .
- $t_3 - t_4$: The output voltage of the onboard charger matches the voltage of V_{BAT} .
- $t_4 - t_5$: The onboard charger begins switching and energy transfer to the battery begins.
- $t_5 - t_6$: S1 is opened momentarily or for a sustained period, or another provided method is used to indicate the charge session should be stopped and I_{CHG} is turned off.
- $t_6 - t_7$: K1 and K2 open and V_{FCLINK} is removed.
- $t > t_7$: The lock is disengaged to allow vehicle connector removal, ending the charge session.

4.4 Safety Systems

The following safety systems protect operators from hazards.

4.4.1 PP Monitor

Upon detection of any PP state other than latched or unlatched the power source shall be disabled and K1, K2, K3 and K4 shall be opened to remove V_{FCLINK} voltage. V_{FCLINK} shall be < 60V within 1s of detection.

4.4.2 CP Monitor

Upon detection of loss of digital communication the power source shall be disabled and K1, K2, K3 and K4 shall be opened to remove V_{FCLINK} voltage. V_{FCLINK} shall be < 60V within 1s of detection.

4.4.3 Isolation Monitor

While DC charging, upon detection of V_{CHG} , V_{FCLINK} , or V_{BAT} isolation to earth or vehicle chassis < 100Ω/V the DC power source shall be disabled and K1, K2, K3 and K4 shall be opened to remove V_{FCLINK} voltage. V_{FCLINK} shall be < 60V within 1s of detection.

4.4.4 Voltage and Current Monitor

Upon detection of V_{CHG} , V_{FCLINK} , or V_{BAT} over-voltage or I_{CHG} over-current the power source shall be disabled and K1, K2, K3 and K4 shall be opened to remove V_{FCLINK} voltage. V_{FCLINK} shall be < 60V within 1s of detection.

4.4.5 V_{FCLINK} Monitor

Upon detection of $V_{FCLINK} > 60V$ the inlet lock shall remain engaged to prevent removal of the vehicle connector.

These safety systems are not comprehensive, nor do they fully guarantee safety. Additional safety systems (e.g. temperature monitoring) may be required for safe operation.

4.5 Communication between the EV and EVSE

- 4.5.1 For DC charging, communication between the EV and EVSE shall be power line communication over the control pilot line as depicted in DIN 70121.
- 4.5.2 The North American Charging Standard is compatible with “plug and charge” as defined in ISO-15118.

4.6 Vehicle to X (V2X)

- 4.6.1 The North American Charging Standard is compatible with Vehicle to X (i.e. Vehicle to load, Vehicle to home, vehicle to grid) power transfer. Future versions of this technical specification will specify the functional requirements and specifications required to achieve vehicle to X power transfer.

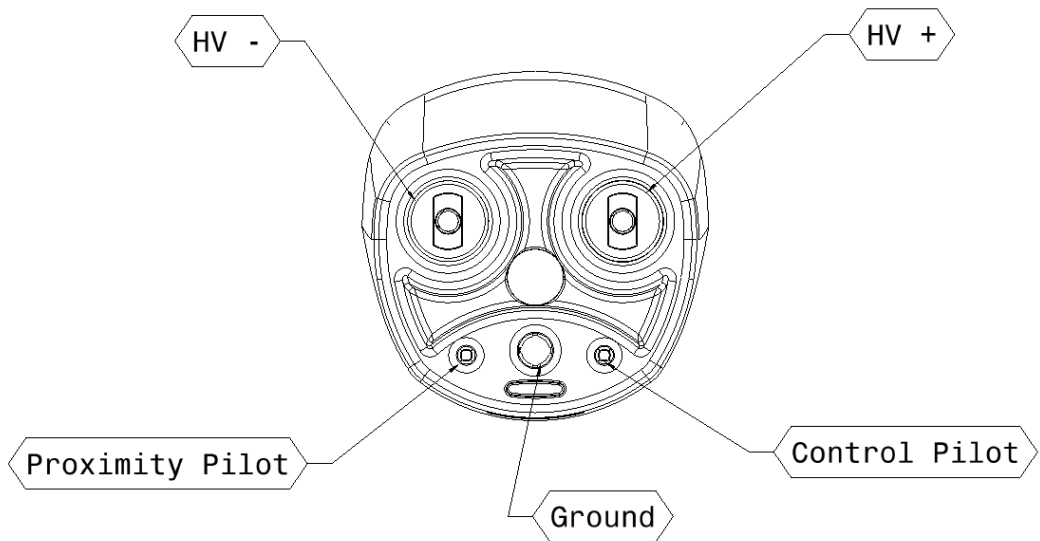
5. General Construction

Mechanical details of the North American Charging Standard are detailed below. For all dimensions not explicitly specified, refer to 3D model.

Two interfaces are shown below, a 500V configuration and 1,000V configuration. The two interfaces are mechanically interoperable (i.e. the 1,000V inlet can mechanically receive the 500V connector and the 500V inlet can receive the 1,000V connector).

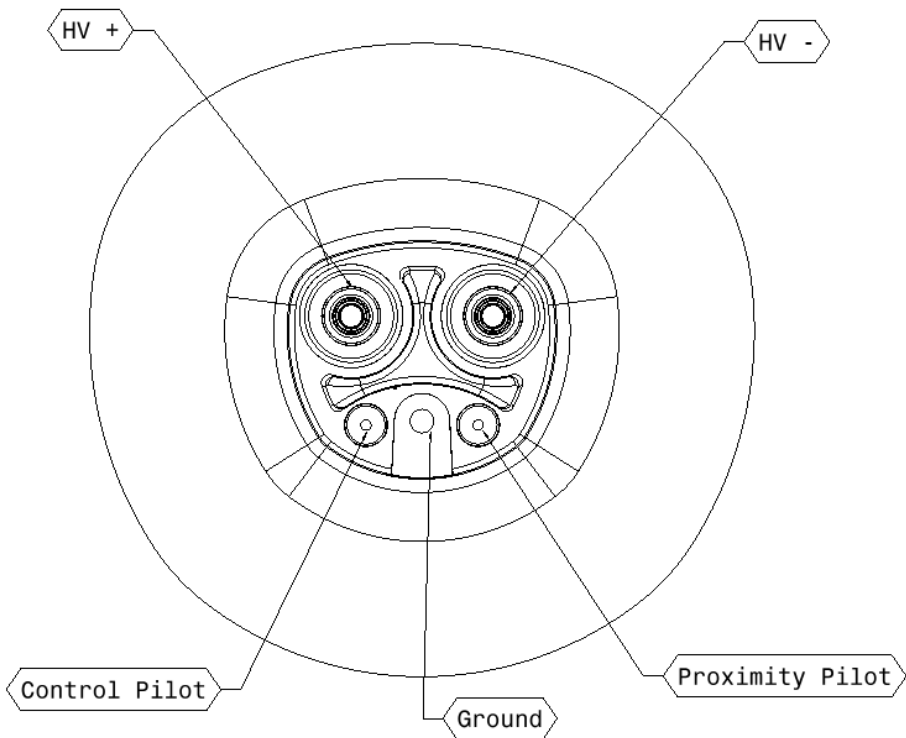
5.1.1 Interface

5.1.1.1 Connector



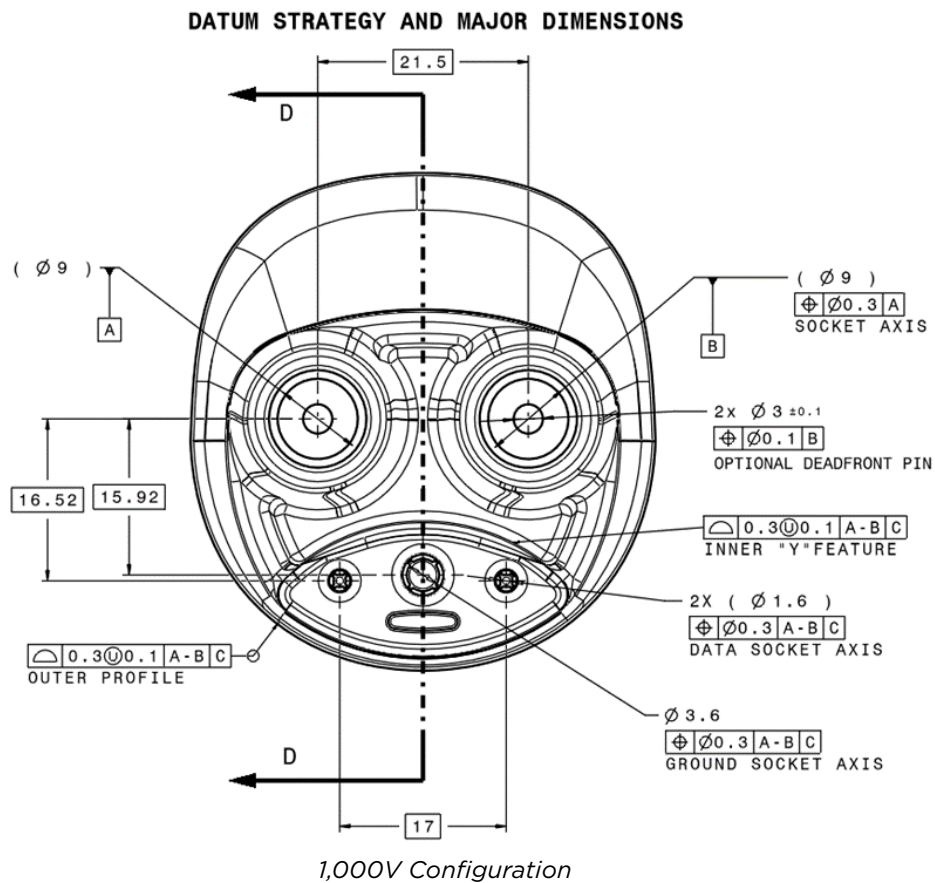
Connector - 1,000V and 500V Configuration

5.1.1.2 Inlet

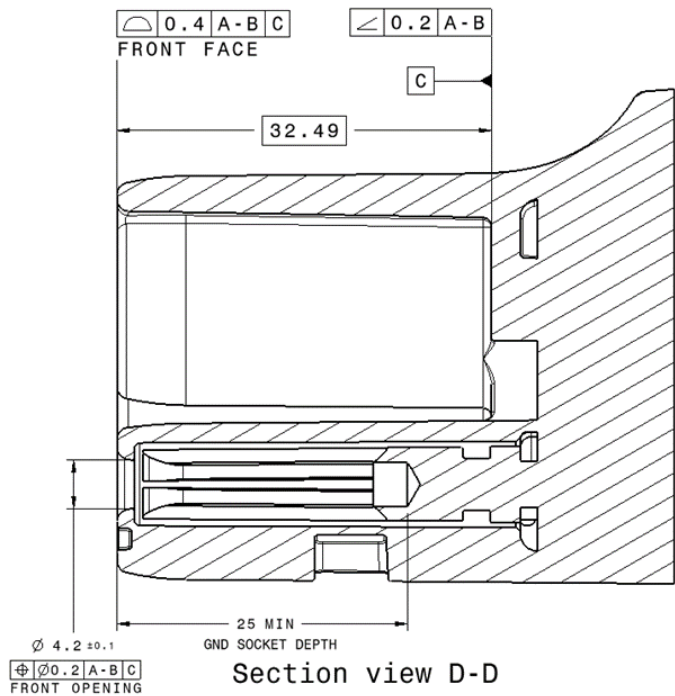


Inlet - 1,000V and 500V Configuration

DATUM STRATEGY AND MAJOR DIMENSIONS

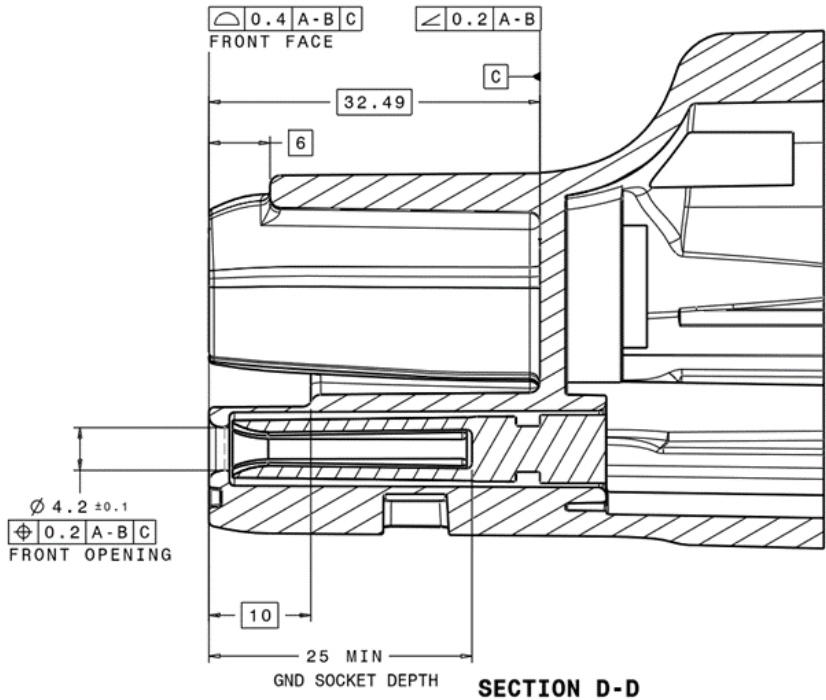


DATUM STRATEGY AND MAJOR DIMENSIONS



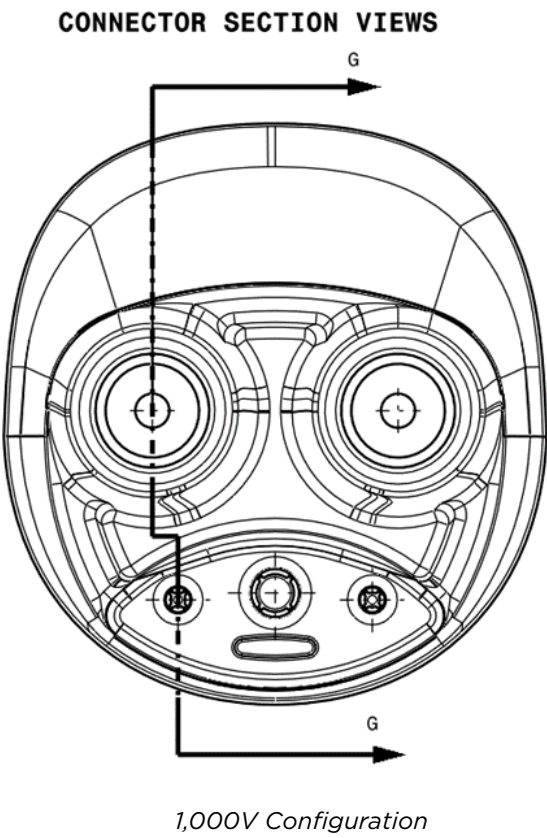
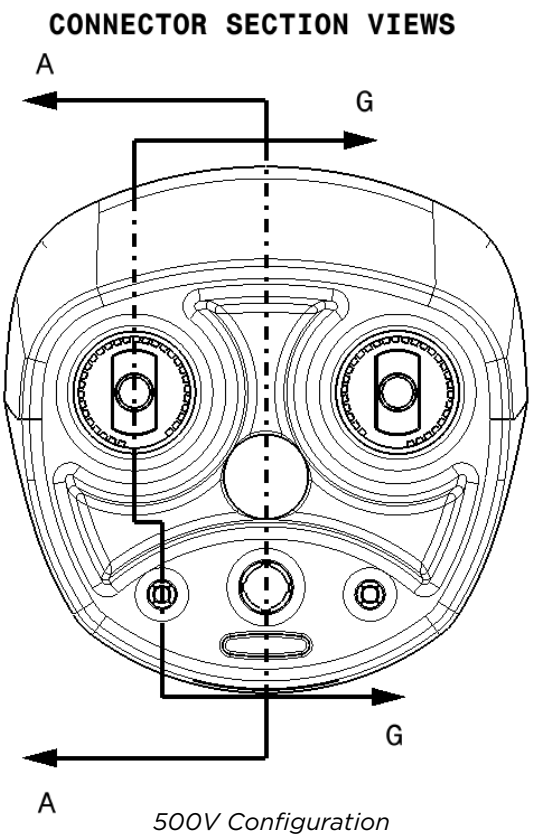
500V Configuration

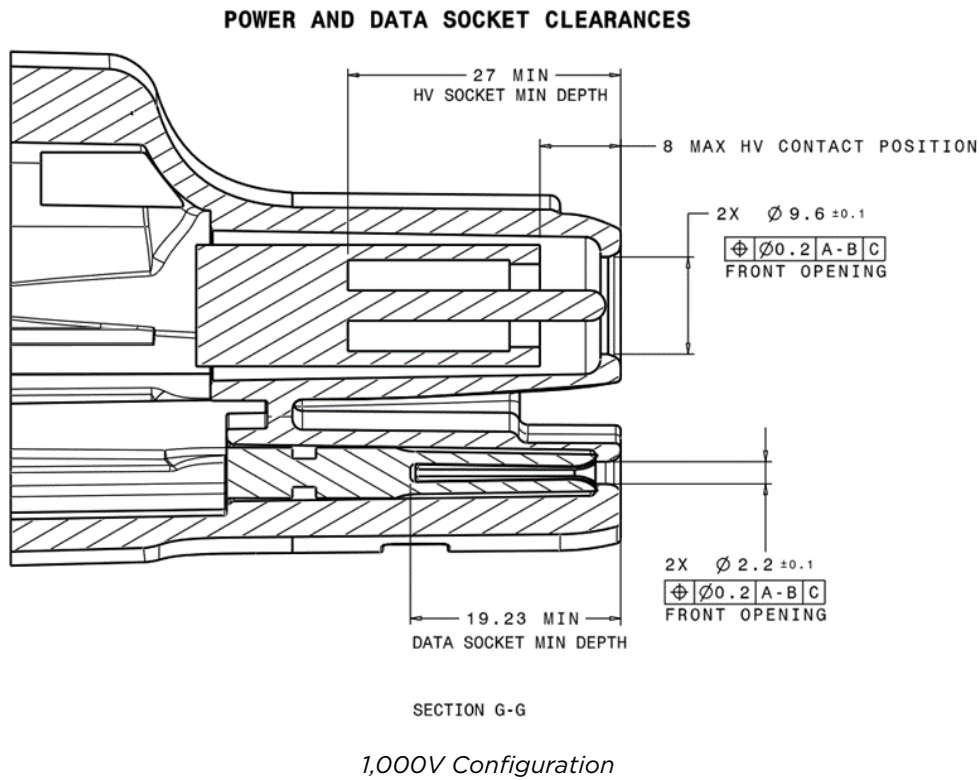
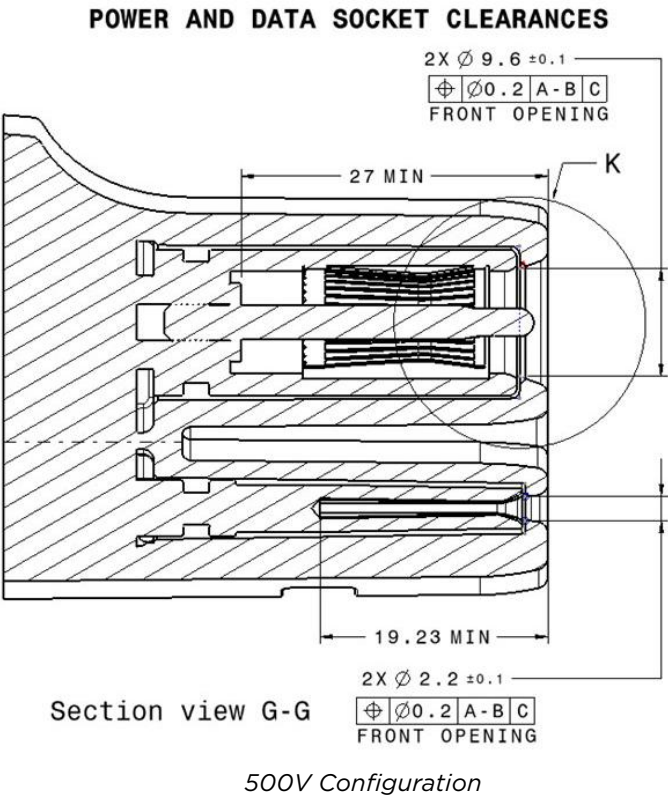
DATUM STRATEGY AND MAJOR DIMENSIONS



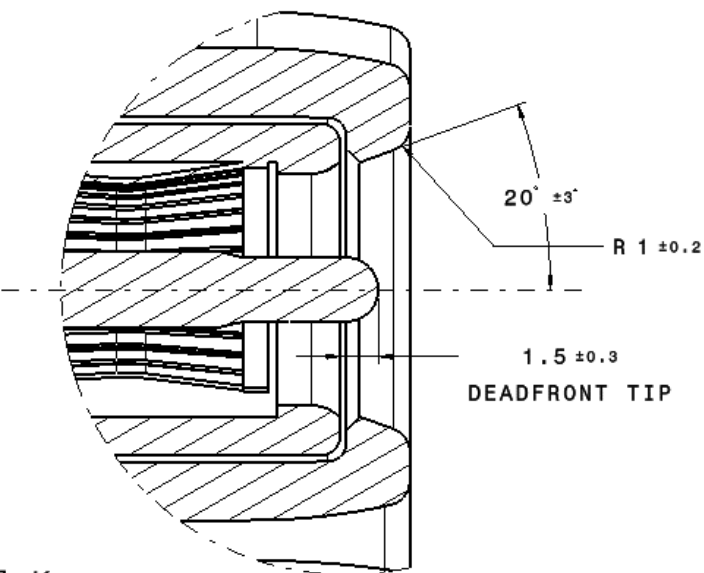
1,000V Configuration

5.1.2 Connector Dimensions, cont.





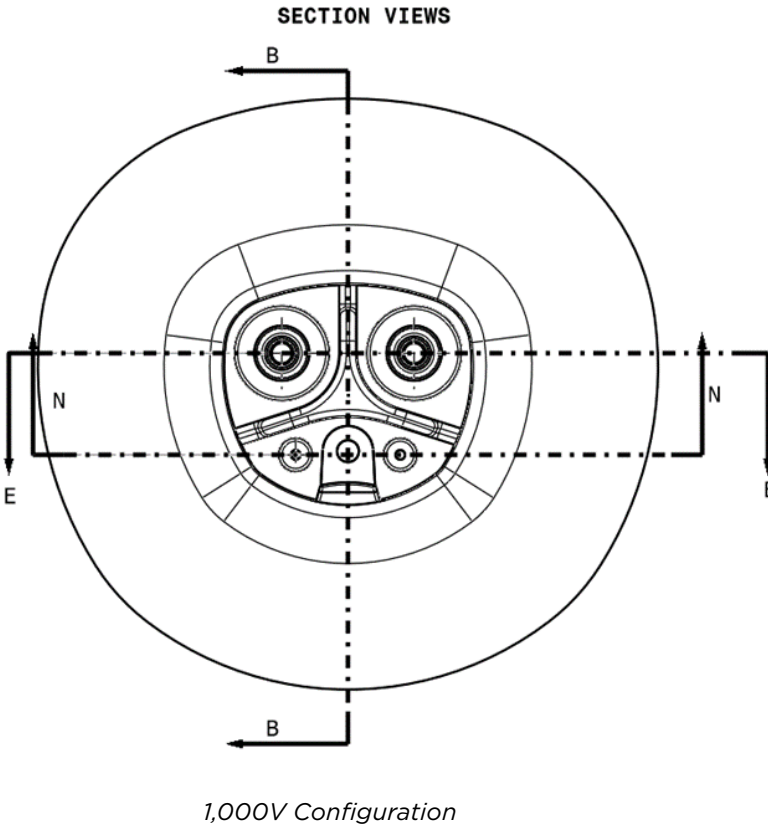
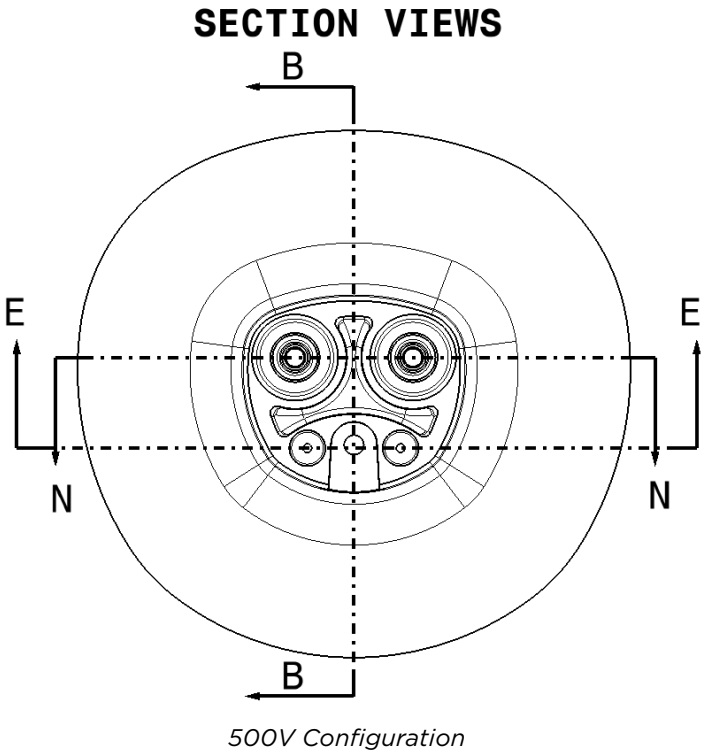
5.1.2 Connector Dimensions, cont.



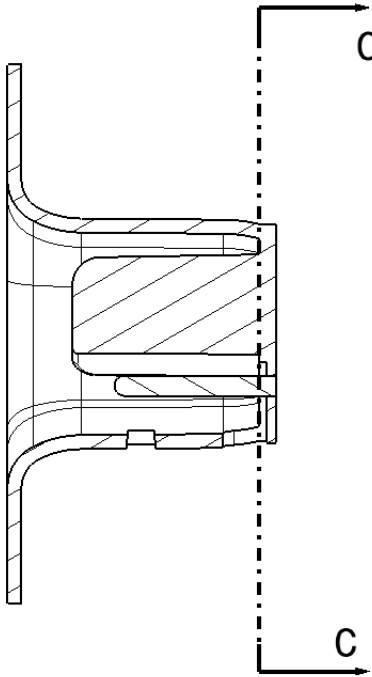
Detail K
LEAD-IN, 2 PLACES

500V and 1,000V Configuration

5.1.3 Inlet

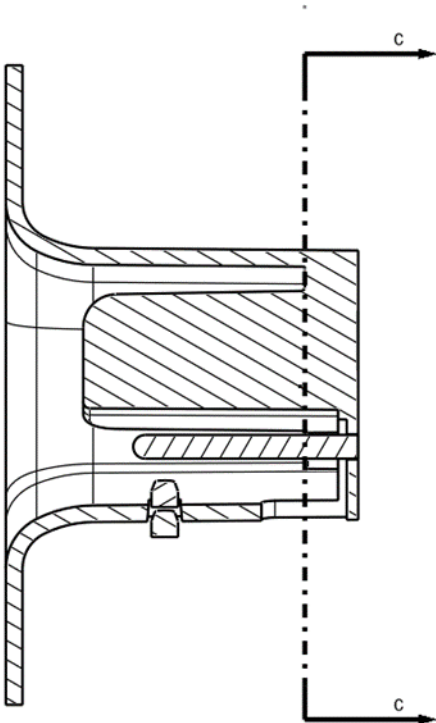


5.1.3 Inlet, cont.



Section view B-B

500V Configuration



1,000V Configuration

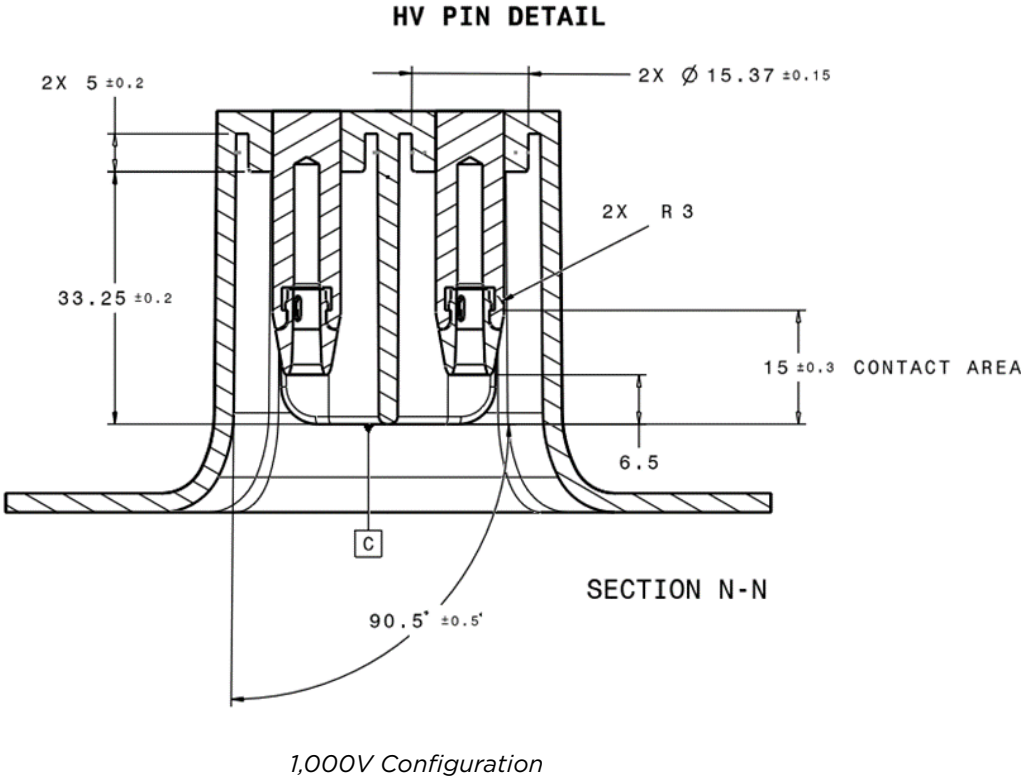
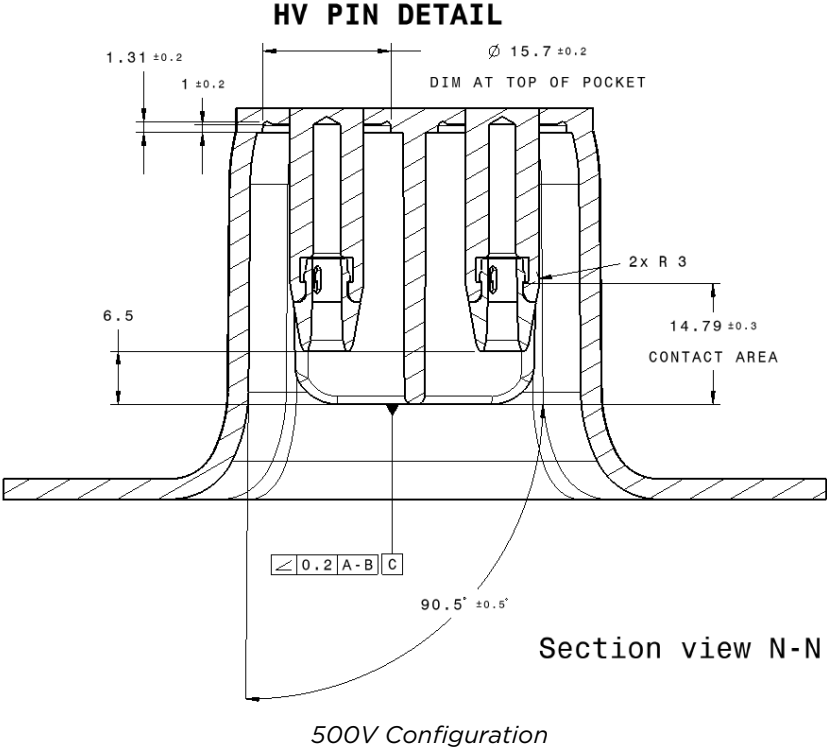
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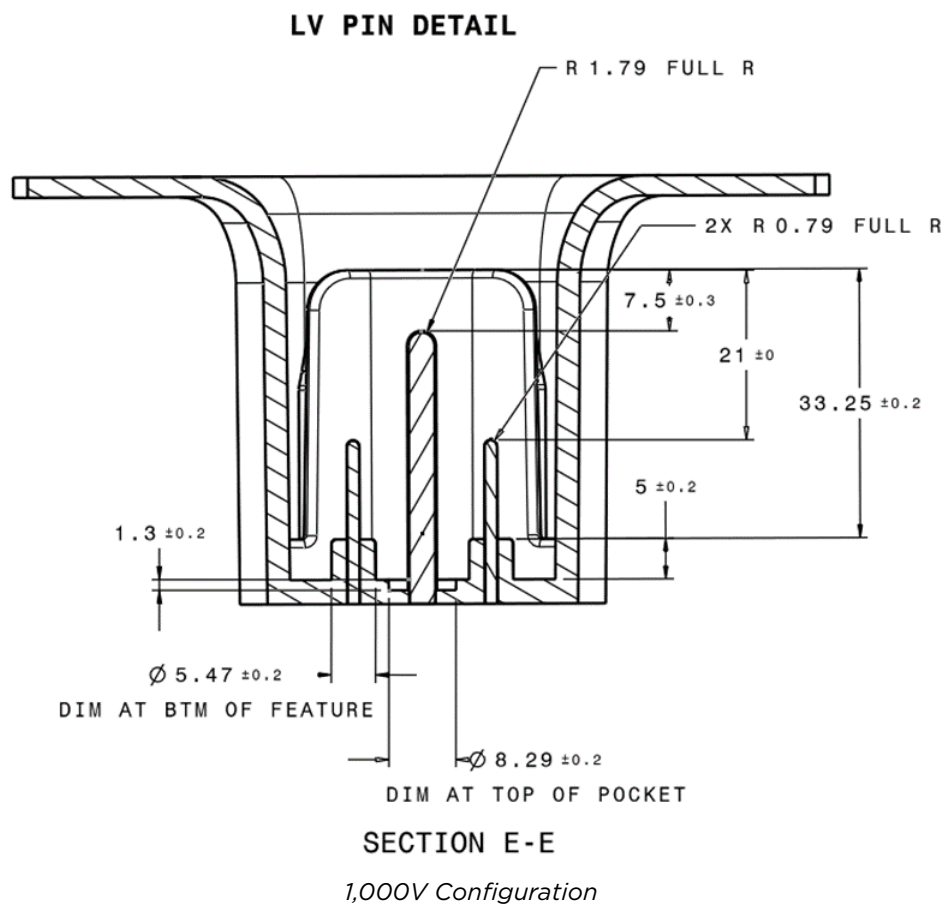
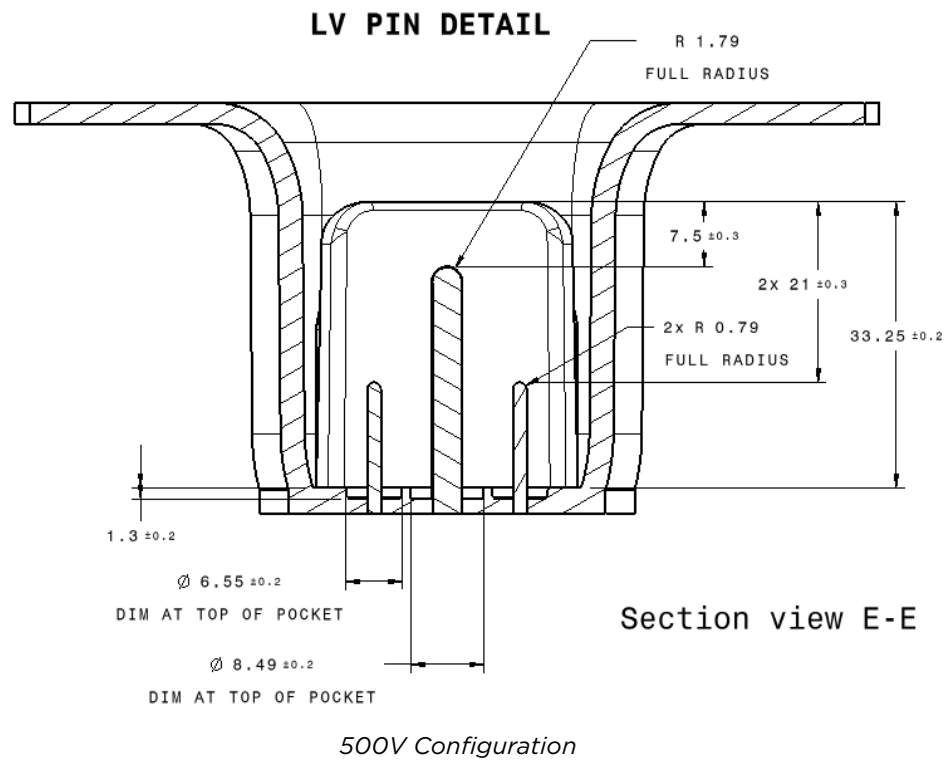
DATUM STRATEGY AND MAJOR DIMENSIONS



5.1.3 Inlet, cont.

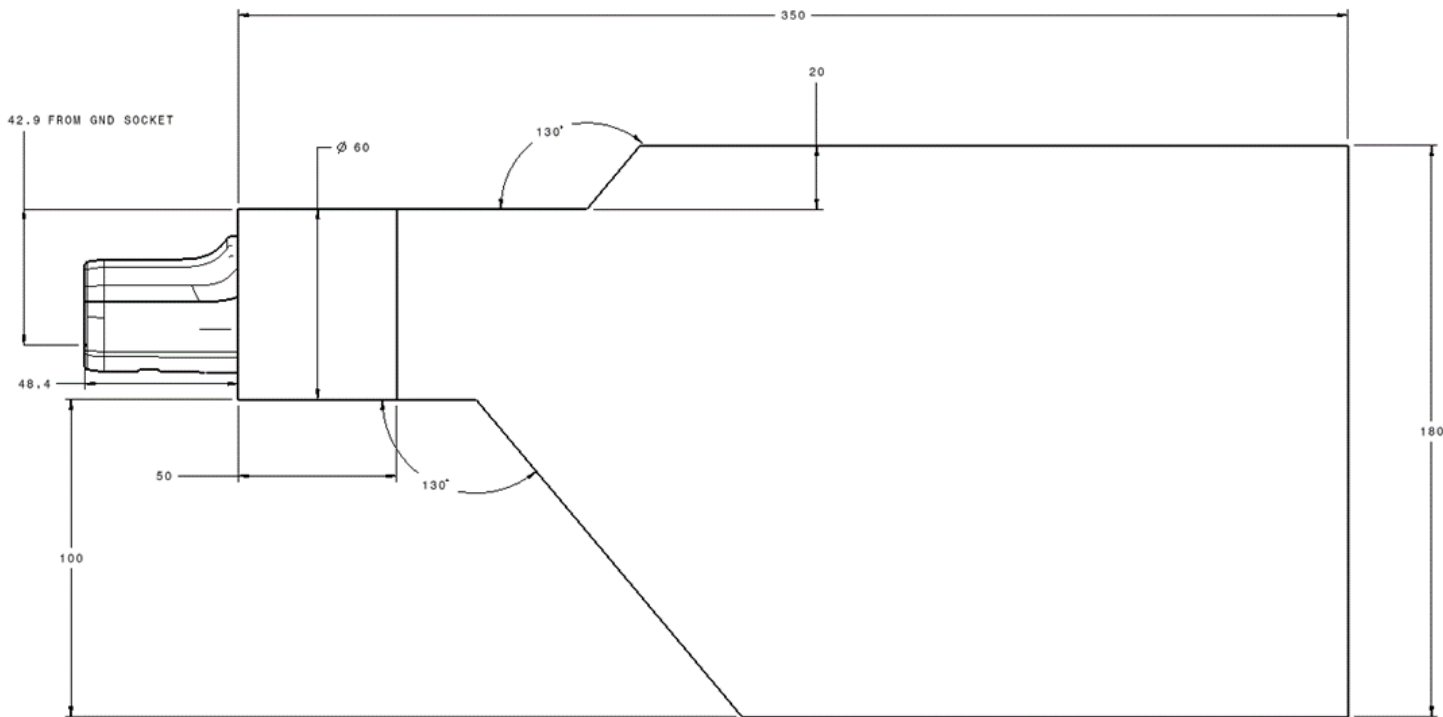
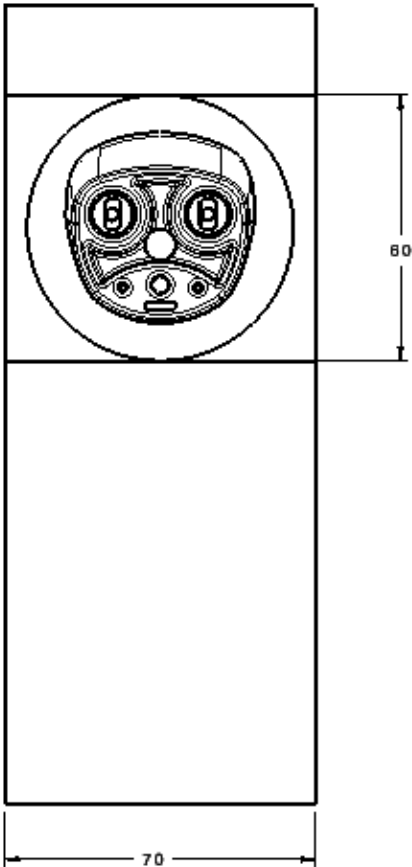


5.1.3 Inlet, cont.



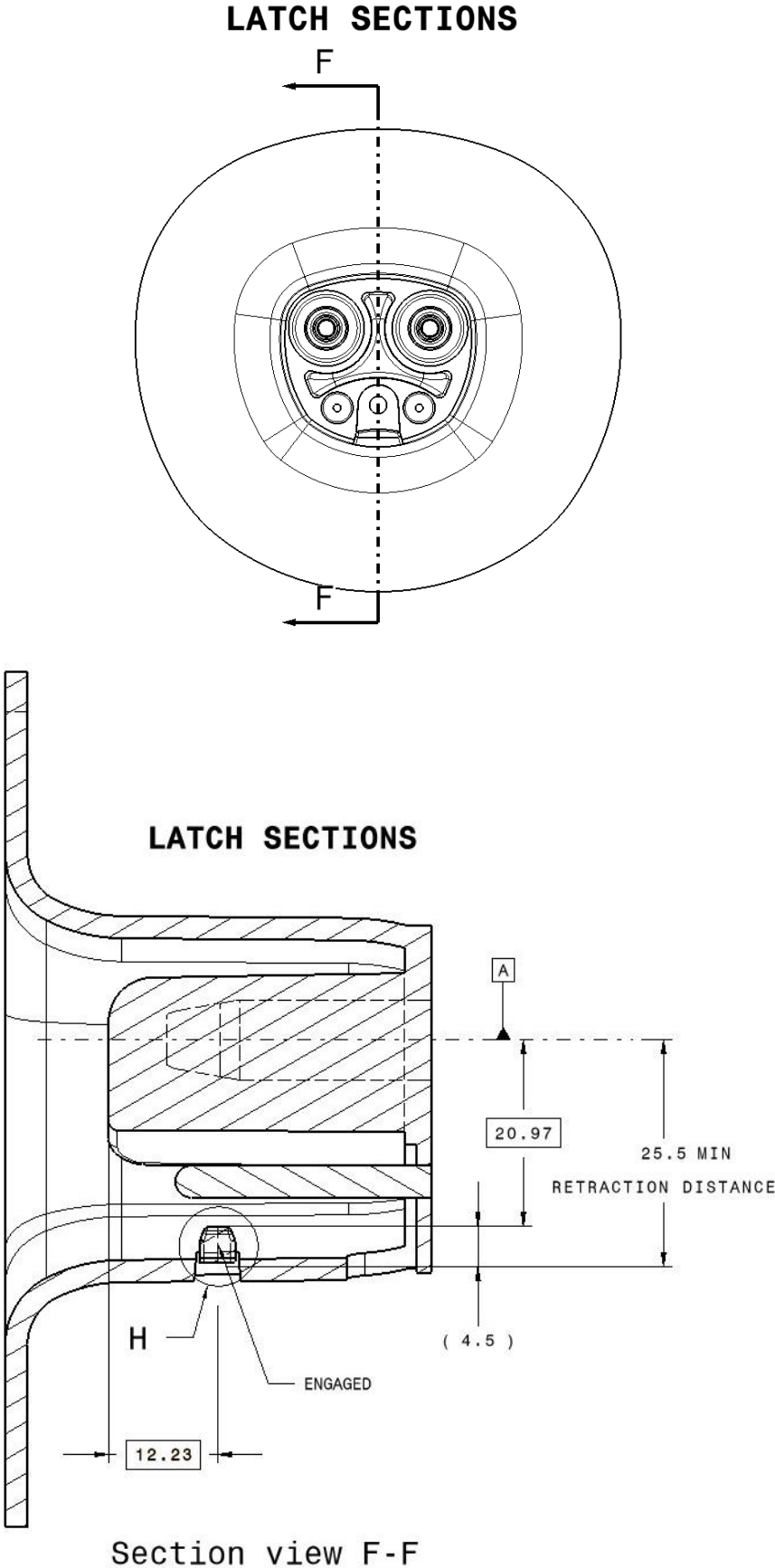
5.1.4 Keep Out Zone

The design of the connector must remain within the keep out zone dimensioned below in order to prevent clashes or contact with the vehicle body. Keep Out Zone geometry is identical between the 500V and 1,000V configurations.

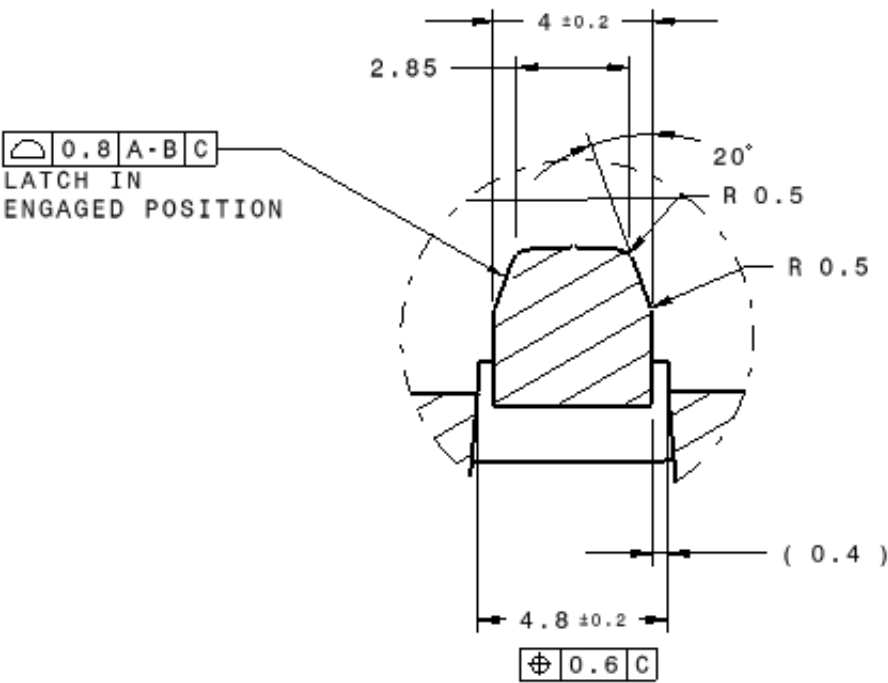


5.1.5 Latching

Latching geometry is identical between the 500V and 1,000V configurations.

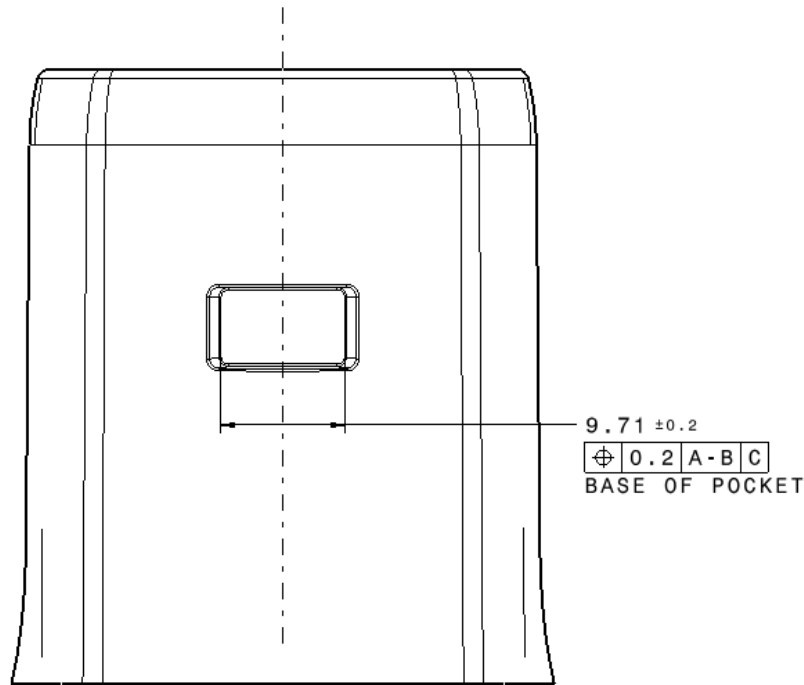


5.1.5 Latching, cont.

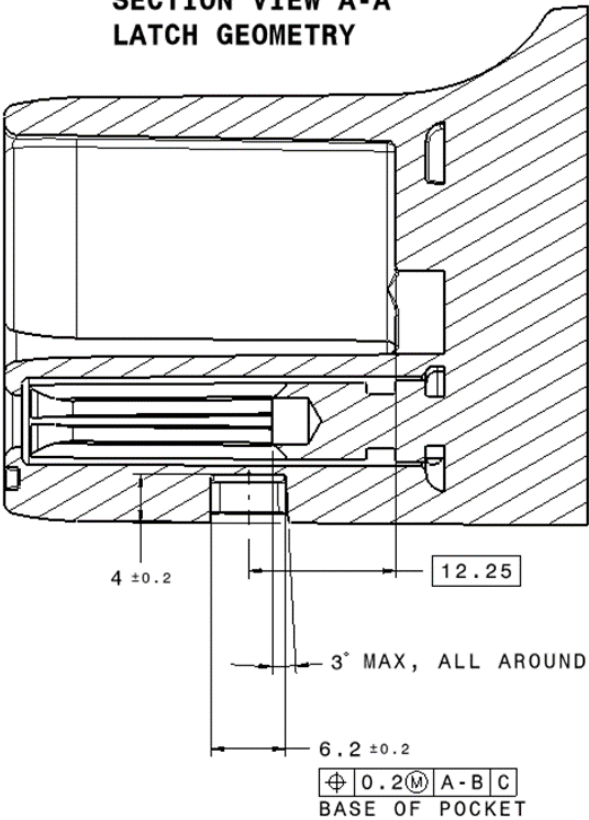


Detail H

LATCH POCKET POSITION



SECTION VIEW A-A
LATCH GEOMETRY



6. Ratings

6.1 Voltage Rating

The North American Charging Standard exists in both a 500V rated configuration and a 1,000V rated configuration. The 1,000V version is mechanically backwards compatible (i.e. 500V inlets can mate with 1,000V connectors and 500V connectors can mate with 1,000V inlets).

6.2 Current Rating

The North American Charging Standard shall specify no maximum current rating. The maximum current rating of the inlet or connector shall be determined by the manufacturer, provided that the temperature limits defined in section 8 are maintained.

Tesla has successfully operated the North American Charging Standard above 900A continuously with a non-liquid cooled vehicle inlet.

7. Degrees of Protection (Informative)

In addition to the connector and inlet ingress protection requirements outlined IEC 61851-1, the following additional validation is recommended to maximize product reliability.

7.1 Connector

- 7.1.1 When unmated to the inlet, the connector shall withstand an IP67 water and dust test as described in IEC 60529.
- 7.1.2 Upon completion of the test, no water or debris shall be present on live parts inside the connector enclosure. Compliance is checked via a high potential test between HV+ and HV-, and HV and ground/low voltage at the rated test voltage.

7.2 Inlet

- 7.2.1 When mounted to a representative vehicle body panel and unmated to the connector, the inlet shall withstand an IP67 water and dust test as described in IEC 60529.
- 7.2.2 Upon completion of the test, no water or debris shall be present on hazardous live parts of the inlet, excluding the exterior facing pins. Compliance is checked via a high potential test between HV+ and HV-, and HV and ground/low voltage at the rated test voltage.
- 7.2.3 When mounted to a representative vehicle body panel and unmated to the connector, the inlet shall withstand an IP6K9K water test as described in IEC 60529.
- 7.2.4 Upon completion of the test, no water or debris shall be present on hazardous live parts of the inlet, excluding the exterior facing pins. Compliance is checked via a high potential test between HV+ and HV-, and HV and ground/low voltage at the rated test voltage.

7.3 Connector and Inlet System

- 7.3.1 With the inlet mounted to a representative body panel and the connector mated to the inlet, the system shall withstand an IP44 test as described in IEC 60529.
- 7.3.2 Upon completion of the test, the system isolation shall be maintained. Compliance is checked via a high potential test between HV+ and HV-, and HV and ground/low voltage at the rated test voltage.

Informative Requirement strongly recommended based on field experience.

8. Temperature Rise

- 8.1.1 When subject to the temperature rise test of IEC 62196-1 section 24, the maximum interface contact temperature shall be 105°C.

Modern thermoplastics are commonly rated to 120°C and higher. The IEC 62196 limit of 90°C artificially limits performance capabilities of EVs and EVSEs.

- 8.1.2 The maximum temperature rise of the interface contacts shall be calculated by the maximum ambient temperature rating of the product and the maximum upper contact temperature of 105°C. E.g. if the product is rated to a 50°C ambient, the maximum allowable temperature rise shall be 55°C.
- 8.1.3 The maximum surface temperatures shall be in accordance with IEC 62196-1 section 16.5.

9. Mechanical Requirements

9.1 Insulated End Caps (informative)

- 9.1.1
- In lieu of the insulated end cap test from IEC 62196-1 26.7-26.9, the following additional validation is recommended for end caps on the vehicle inlet:

 - The insulated end caps shall be aged at 85°C / 85% relative humidity for 500 hours
 - After aging, a force of 450N shall be applied axially to the end caps for 1 minute

The test passes if the end cap remains in place with no cracking or visible damage observed.

9.2 Impact Test (informative)

- 9.2.1
- The connector shall be dropped from 1m height in accordance with IEC 62196-1 figure 13.
- 9.2.2
- The number of drops shall be 100.
- 9.2.3
- Upon completion of the impact test (100 drops), the connector shall show no obvious damage, withstand the water ingress test to which it is rated, and maintain the creepage and clearance distances to which it was designed.

EVSE cables tend to fall on one side more frequently than the other. Rather than rotating the connector every 45 degrees as suggested in section IEC 62196-1 26.3, it is recommended to conduct the test in a field representative way. It is also recommended to conduct the test on a variety of surfaces (e.g. concrete, asphalt).

10. Revision History

Revision	Date	Description
1.0	2022-08-10	Initial publication
1.1	2022-11-03	<ul style="list-style-type: none">Updated 5. General Construction to include mechanical details for both 500V and 1,000V configurationsUpdated 6.1 Voltage Rating to include voltage rating for both 500V and 1,000V configurations