NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Aviation Engineering Division
Washington, DC 20594

March 4, 2019

BATTERY AND VEHICLE DOCUMENTATION FACTUAL REPORT OF INVESTIGATION

A. **ACCIDENT:** HWY18FH013

LOCATION: Fort Lauderdale, Florida

DATE AND TIME: May 8, 2018, 6:46 p.m. local time

VEHICLE: 2014 Tesla Model S, P85D, Florida License

B. BATTERY AND VEHICLE INSPECTION GROUP:

Chairman: Robert L. Swaim
NTSB
Washington, DC

Member: Thomas Barth, PhD
NTSB
Denver, Colorado

Member: Timothy Cunningham
NTSB (Intern)
Denver, Colorado

C. SUMMARY:

For a summary of the accident events, refer to the *Factual Report of the Investigation* in the docket for this investigation.

On June 7, 2018, representatives of the NTSB, Fort Lauderdale Police, and Florida Highway Patrol met to examine and document the vehicle at Westway Towing at 3681 W. Oakland Park Blvd, Lauderdale Lakes, FL 33325. The City of Fort Lauderdale provided support with a fire truck and crew.

The NTSB participants also examined for any fragments remaining at the scene of the accident in the 1300 block of Seabreeze Boulevard in Fort Lauderdale, Broward County, Florida. At this location, Seabreeze Boulevard is also State Route A1A.

D. DETAILS OF THE INVESTIGATION:

BACKGROUND:

The NTSB group convened at the tow yard and first reviewed safety procedures which would be followed. The NTSB investigators had previous experience with damaged Tesla batteries, training, and the procedures included the use of high voltage tools, personal protection equipment, and high voltage protocols. The City of Fort Lauderdale provided a fire truck and fire fighters in case the 400 VDC battery began to smoke or burn again. A thermal imaging camera was used to occasionally monitor the battery during the day.

A press photo showed the vehicle in flames, apparent damage to the front right door and flames emanating from the front fender area where impact and burn damage were subsequently found to the primary 400 VDC high voltage (HV) traction battery.[1] An additional photo showed the vehicle interior in flames and the right front passenger door displaced. (See Figures 1 and 2)

Figure 1. Still image from Florida Sun Sentinel website showing flames at front of vehicle.[2]

[1] As described later in this report, the car was equipped with a 12 volt direct current (VDC) battery which powers the on-board systems and a 400 VDC traction battery which powered the front and rear drive motors. Further details about the 400 VDC battery design and construction are contained in documentation for the NTSB investigation into a Tesla Model X accident at Forest Lake, California, NTSB Case HWY17FH013.

[2] Sun Sentinel is a newspaper in the Fort Lauderdale region. http://www.sun-sentinel.com Channel 7 is WSVN, a Fox-affiliated television station broadcasting to the greater area of Miami and Fort Lauderdale. https://wsvn.com/news

Figure 2. CBS News website photo showing vehicle interior engulfed in flames.

The firefighters related that the fire was extinguished on scene and allowed to cool. The forward portion of the vehicle had extensively fragmented and the 400 volt traction battery was found separated from the bottom of the vehicle. The firefighters further reported that the wreckage re-ignited during loading onto a flat bed tow truck, was extinguished, and transported to the tow yard.

GENERAL ASPECTS OF THE ACCIDENT VEHICLE:

The accident vehicle was a 2014 Tesla Model S with the model code P85D.[3] The P85D related to the following unique characteristics of this Model S:

> The P denoted the word Performance. A Tesla description states "*Model S Performance comes standard with All-Wheel Drive Dual Motor, pairing the high performance rear motor with a high efficiency front motor to achieve supercar acceleration, from zero to 60 miles per hour in 3.1 seconds.*"
>
> The 85 denoted the kilowatt hour (kWh) capacity of the traction battery.
>
> The D denoted that this vehicle had dual drive motors.

[3] The Tesla descriptions of the automobile are quoted from Appendix A.

The differences between this and other versions of the Model S are summarized in a Tesla graphic. (See Figure 3)

70D	85	85D	P85D
All-Wheel Drive	Rear Wheel Drive	All-Wheel Drive	All-Wheel Drive
70 kWh battery with all-wheel drive	85 kWh battery with rear wheel drive	85 kWh bbattery with all-wheel drive	85 kWh battery with high performance all-wheel drive
240 miles range (EPA)	**265** miles range (EPA)	**270** miles range (EPA)	**253** miles range (EPA)
5.2 seconds 0-60 mph	**5.4** seconds 0-60 mph	**4.4** seconds 0-60 mph	**3.1** seconds 0-60 mph
329 hp	**362** hp	**422** hp	**691** hp motor power **221** hp front, **470** hp rear
140 mph top speed	**140** mph top speed	**155** mph top speed	**155** mph top speed

Figure 3. Model code designations for 2014 Tesla Model S automobiles.

The accident damaged the vehicle to the extent that much of the car ahead of the passenger compartment was in small fragments and/or extensively burned. The front right of the vehicle and battery had been crushed on a diagonal and the front of the bottom right passenger doorframe was bent upward. Fragments of the 12 VDC battery, front drive motor, hood, fenders, front suspension, and supporting structure were accounted for. (See Figures 4 through 10)

Figure 4. The overall view of right front corner.

Figure 5. The right side of the vehicle. The added arrow to the left points to a sticker showing a circular saw, described later. The added arrow at the right shows the bend in the passenger door frame.

Figure 6. The overall view of the right rear. The P85D model code is below the right tail light. The license number has been obscured.

Figure 7. The left rear of the vehicle.

Figure 8. The mid left of the vehicle.

Figure 9. The forward left of the vehicle.

Figure 10. The overall view of the front left corner.

The front drive motor and outer panel of the left front door were laying loosely on the traction battery with other loose debris. The right rear wheel/tire assembly was found on the 400 VDC traction battery, and the left wheel and tire assemblies remained attached to the vehicle. Fragments of the front right tire, loose battery cells, and small loose debris were found on a blue tarp to the left of the vehicle. (See Figures 11, 12, and 13)

Figure 11. Right side of the 400V traction battery with debris on top. The unburned red item is the 12V systems battery.

Figure 12. Debris stacked on the 400V traction battery. To the left is the front left door, the traction motor is in the yellow rectangle, and the red ovals surround most of modules 15 and 16. The material under the lower right module was the front trunk liner.[4]

Figure 13. The torn front right tire, small debris, and loose battery cells were found on a blue tarp.

The Tesla website contains Emergency Response Guides (ERG) for each model and Quick Response Sheets (QRS) for all of the models which the company makes.[5] Firefighters need onsite internet connection and to select the correct model (See Figure 5) for download. Differences exist between the single and dual motor Model S vehicles and with different

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[4] As shown in Figure 30, the modules are numbered from back to front, with metal partitions between modules. Module 16 is mounted in the leading edge of the battery over module 15.

[5] Each QRS summarizes portions of the more complete ERG contents. See Appendices B through E for each cited in this report.

production years. The ERG and ERS documents have illustrations which differ between models for the locations of high voltage components. (See Figures 14-16)

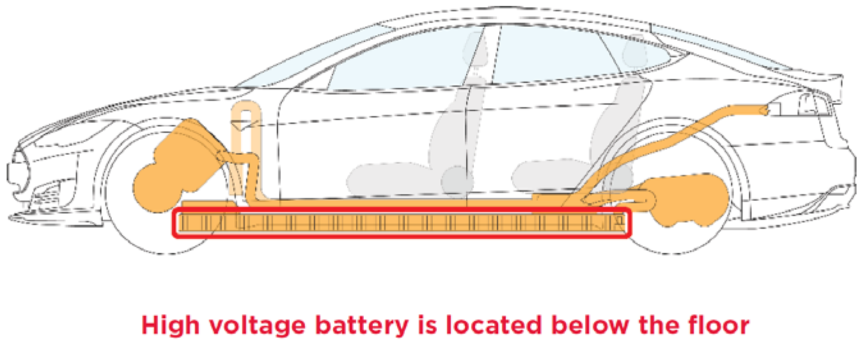


Figure 14. Tesla dual motor ERG illustration depicting side view of the 400 VDC traction battery location and high voltage components which are shown in orange.

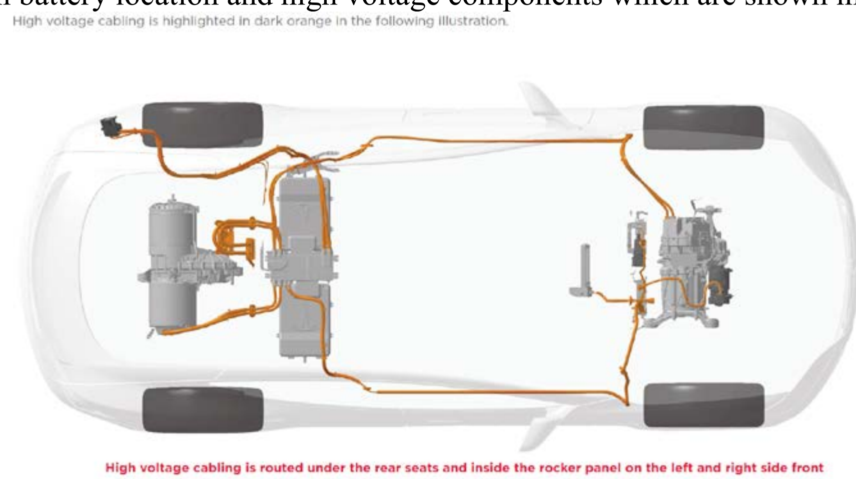


Figure 15. Tesla dual motor ERG illustration depicting top view of the 400 VDC traction battery location and high voltage components which are shown in orange.

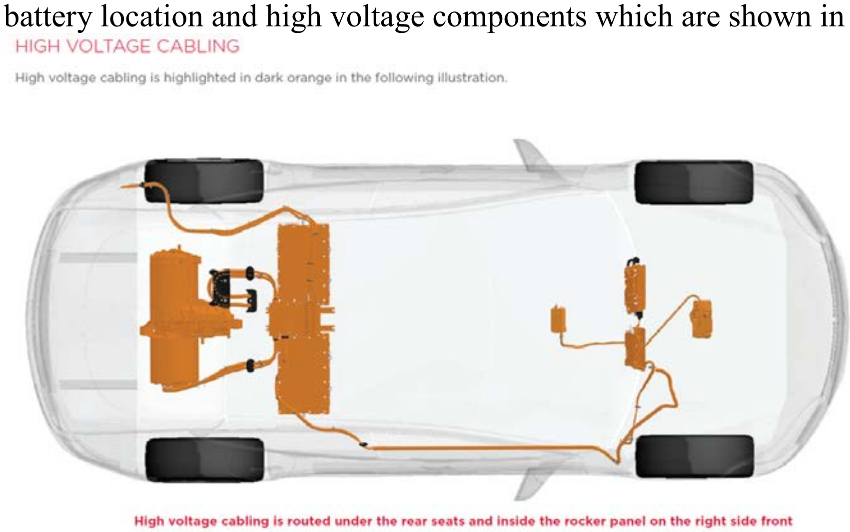


Figure 16. Single motor ERG for the same page has differences in which components are depicted in orange, denoting high voltage.

In the event of emergencies, Tesla provides an electrical "cut loop" to ensure that the 400 VDC battery circuit is disabled. The voltage in the cut loop wires is 12 VDC and not high voltage. Cutting the circuit opens an electric path to remove control power for the high voltage contactors within the battery management system. Removal of control power normally isolates the high voltage components within the case of the 400 VDC traction battery case. If the vehicle senses a collision, the restraint control module (RCM) fires a pyrotechnic fuse in the traction battery, also isolating high voltage energy to within the battery case. The cut-loop should be redundant and unpowered if the vehicle senses a collision. Deployed airbags are an indication that the RCM fired.

The ERG and QRS instruct firefighters to find and sever the wire cut loop next to the 12V battery, in the front trunk (also known as the front hood and the "frunk"), forward of the windshield. Tesla personnel at a previous accident examination noted that firefighters are trained to cut the battery cables of internal combustion engine (ICE) vehicles, so the cut loop and the 12 VDC battery were placed where firefighters were already trained to look.[6]

The ERG also shows that an additional cut-loop is contained within the frame of a rear door. The 2014 dual motor ERG illustration shows the cut loop in a location on the opposite side of where the sticker was found attached to the accident vehicle. (See Figure 17)

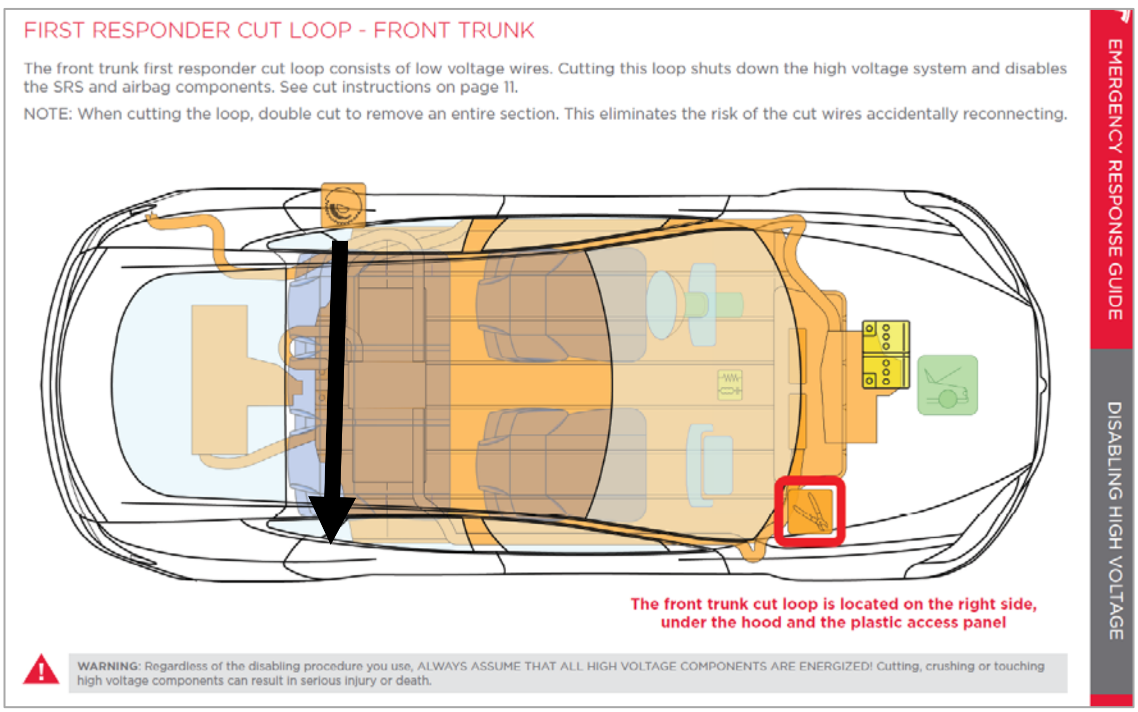


Figure 17. Illustration copied from the 2014 dual motor ERG shows the high voltage components in orange, with the 12 VDC battery shown in yellow. At the back of the left rear door pillar is an illustration of a circular saw, showing first responders an alternate location to cut in order to disable the high voltage circuit. A black arrow has been added to show where the denoted circular saw sticker was

[6] The previous examination followed an accident and fire in Lake Forest, California, NTSB Case HWY17FH013.

found on the accident vehicle. (See Figure 23) The red text is part of the original illustration.

Orange is associated with high voltage. National Highway Traffic Safety Administration (NHTSA) Federal Motor Vehicle Safety Standard (FMVSS) 305 states "S5.4.1.2 High voltage cables. Cables for high voltage sources which are not located within electrical protection barriers shall be identified by having an outer covering with the color orange."[7] The NHTSA January 2012 document DOT HS 811 574 Interim Guidance for Electric and Hybrid Electric Vehicles Equipped With High Voltage Batteries states "Avoid contact with orange high voltage cabling and areas identified as high voltage risk by warning labels." The ERG and QRS were found to be inconsistent in denoting what were high voltage components and use of the color orange. (Compare Figures 17-23 as copied from Appendices B through E)

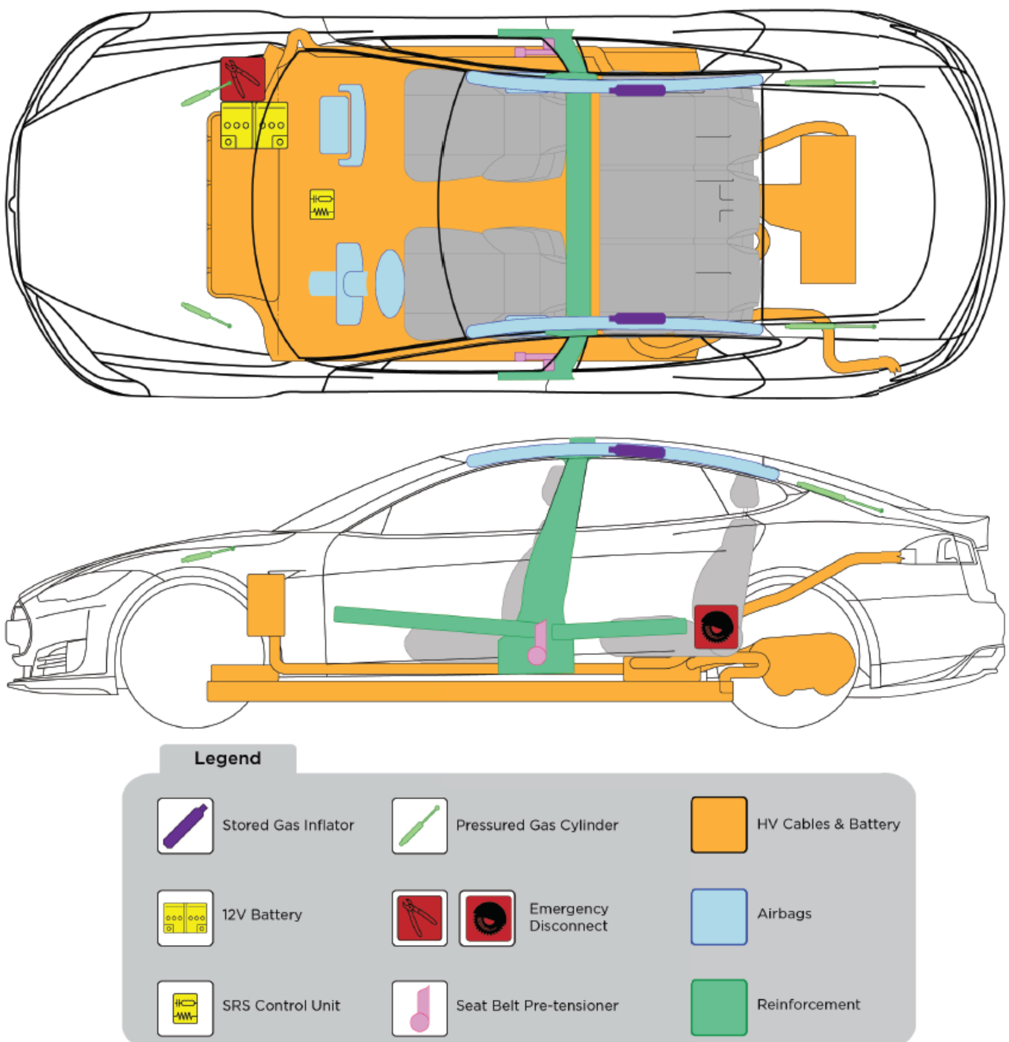


Figure 18. Quick Response Sheet. The Tesla website shows this to be the selection for years 2012-2015, although the QRS itself is marked "Model S 2012-

[7] See Appendix F for 49 CFR 571.305, titled "Electric-powered vehicles: Electrolyte spillage and electrical shock protection" is also known as Standard 305.

2013." The cut loop and circular saw are shown in red, which differs from other illustrations and the car shown in Figures 22 and 23.

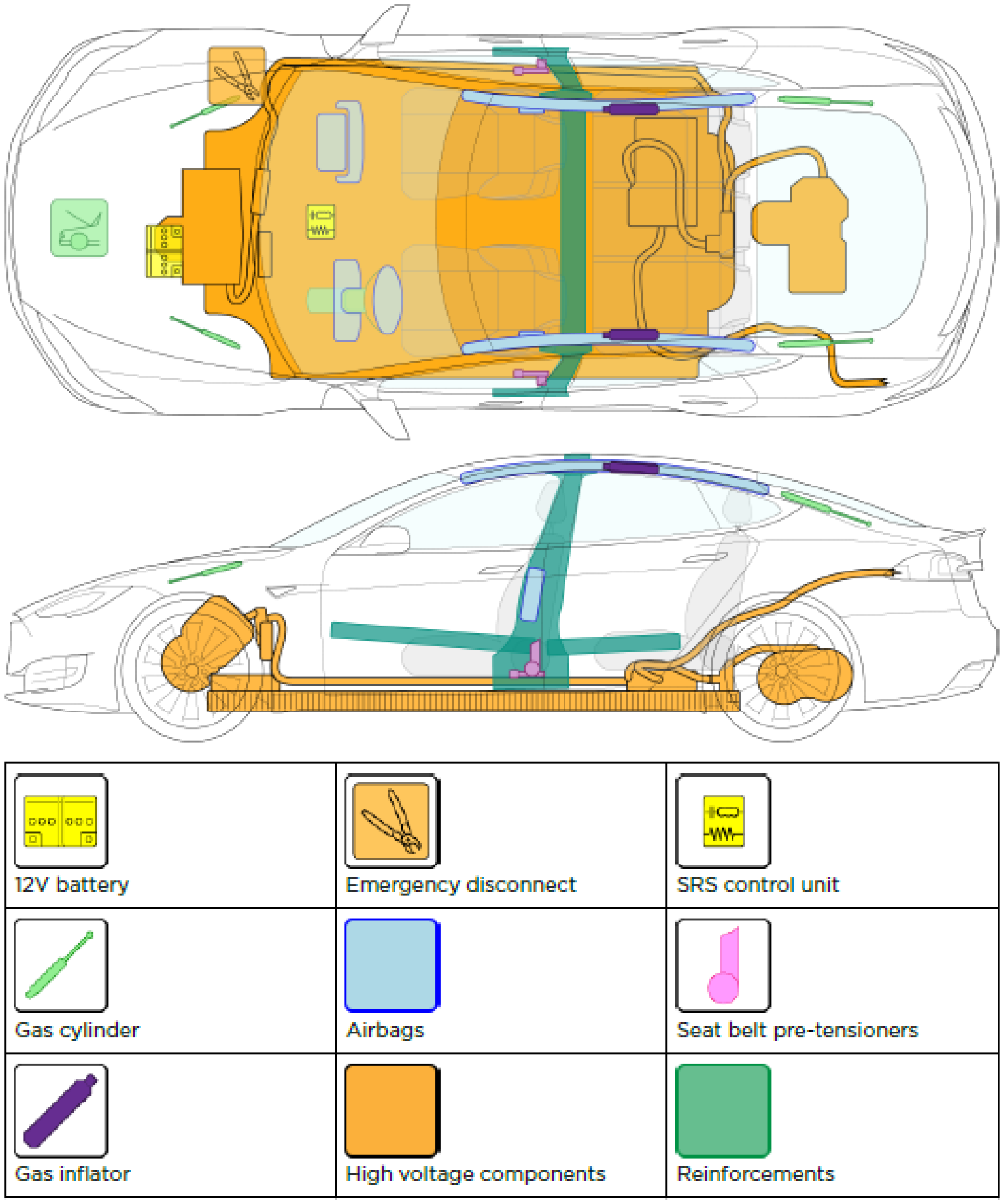


Figure 19. Quick Response Sheet. The Tesla website shows this to be the selection for years 2016+. The cut loop colored red in the previous Figure is shown here in orange.

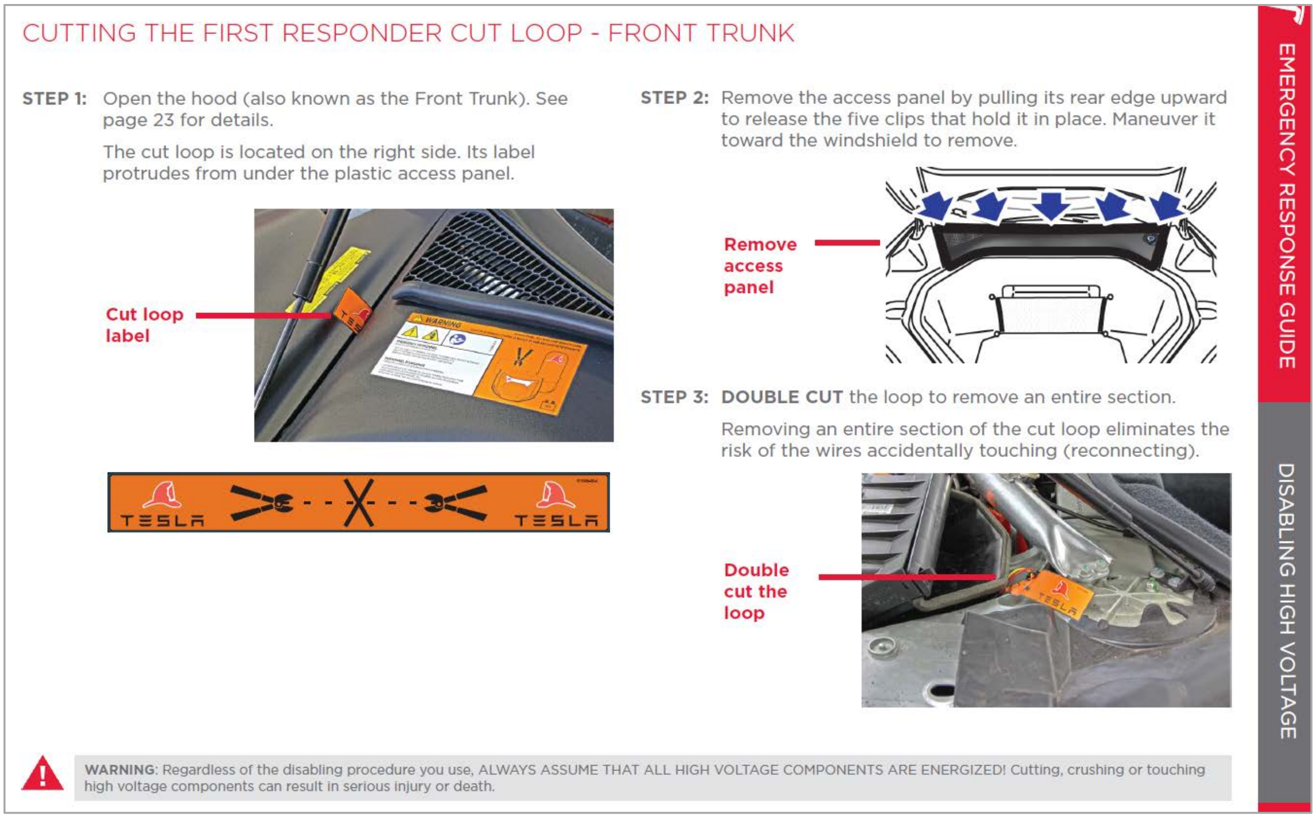


Figure 20. This ERG page shows the cut loop provided to disable the high voltage system. The actual cut loop markings are shown in the lower left. Inspection of other vehicles found that the cut-loop could be mis-placed beneath the panel. The photo in the upper left shows a large sticker with additional information which is on a removable access panel covering the cut loop.

While the sticker on the removable access removable panel notes that the cut loop is 12 VDC, the cut-loop and instructions differ in what they tell firefighters to do. The sticker on the cut-loop shows a single X in what appears to be the location to cut and includes a cutting tool which is oriented toward the X. In contrast, the Emergency Response Guide cited below and the access panel (Figure 20) state that the loop should be cut twice, including the reason for the second cut.

> When cutting the first responder loop, double cut the loop to remove an entire section. This eliminates the risk of the cut wires accidentally reconnecting.

The cut loop from the accident vehicle was found intact and attached to the traction motor, which had separated from the vehicle. Firefighters at the tow yard stated that the front of the vehicle had been the location of the fire and even if they had known to look for the cut loop in accordance with the ERG at the time of the first response, the fire made the area inaccessible. (See Figures 1, 2, 21)

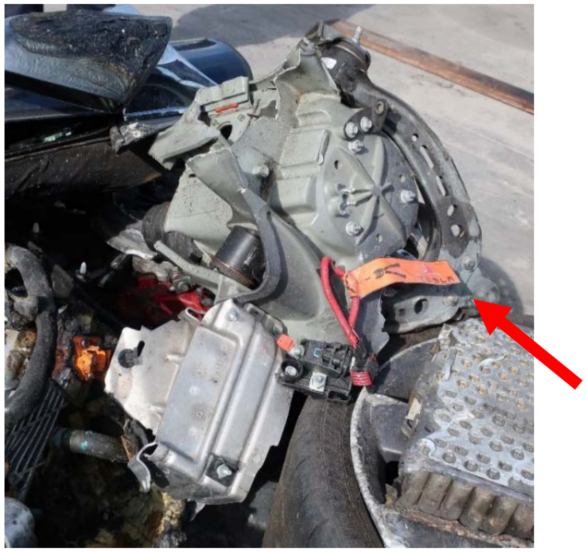


Figure 21. The arrow points to the intact cut loop found attached to front motor.

For vehicles built after June 2013, an additional disconnect point was provided in the left rear door frame in case the cut loop at the front of the vehicle could not be accessed. Disconnection at this location requires both use of a circular saw and the ability to judge the depth of cut. (See Figures 17, 18, 22, 23) This provision is not shown in the ERS for 2016+ Model S vehicles. (See Figure 19)

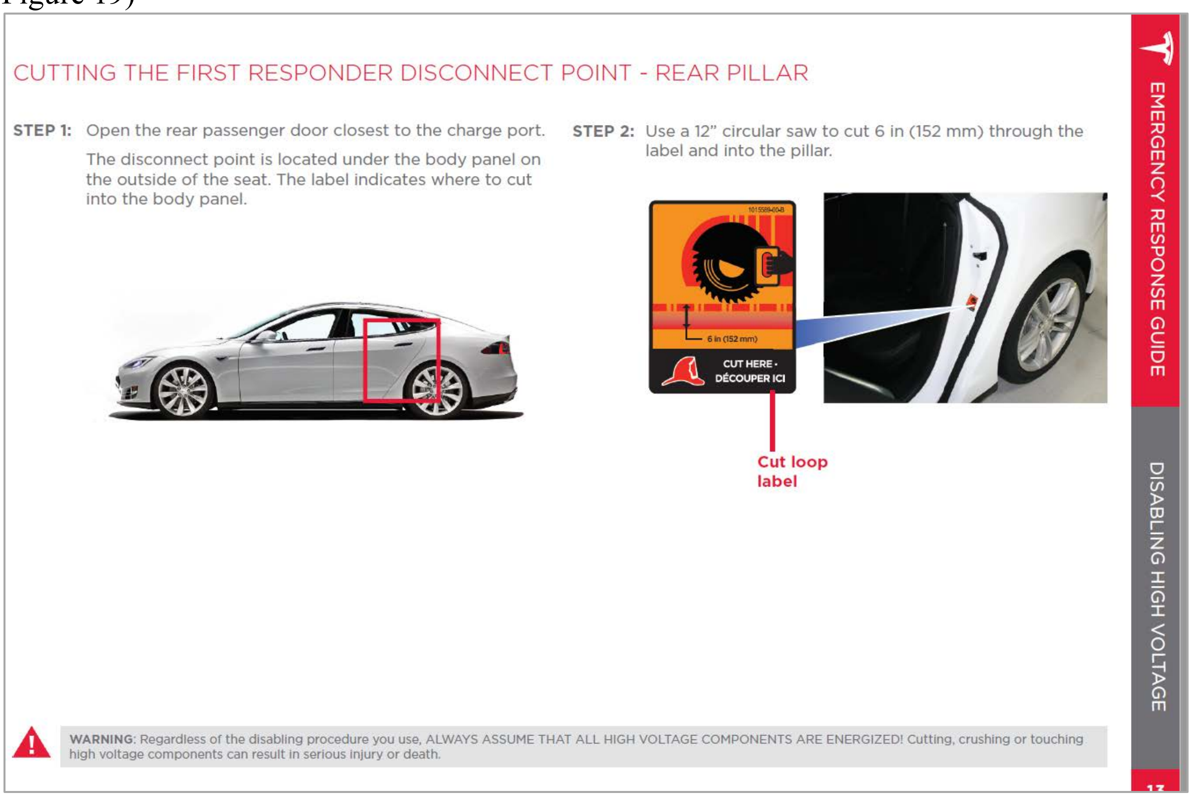


Figure 22. Disconnect cut point provided to disable the high voltage system. Illustration copied from 2014 Tesla Model S Emergency Response Guide.

The sticker denoting the cut point was found in the right rear door pillar, not the left as shown in the ERG and QRS. The sticker calls for cutting to a specific depth to sever the circuit. Cutting the as-found location for the sticker would have left the power circuit intact in the left rear door frame. (See Figures 5, 17, and 23)

Figure 23. Circular saw sticker in right rear door frame of accident vehicle, as seen in Figure 5.

At the front of the vehicle, the sticker with the voltage of the cut loop was on the access panel to be removed, but the voltage was not marked on the orange cut loop. The sticker in the rear door frame was a mixture of black, red, and orange, without showing the voltage inside.

Fire damage had consumed much of the passenger compartment, with the most damage and extensive melting of the structural aluminum in the right forward portion above the major opening in the battery. The front right corner of the passenger cabin was open with melted edges. (See Figures 3 and 4) Loose battery cells were found inside the cabin on and near the top of other burned debris. (See Figure 24) Witnesses to this accident and one in San Mateo, California, (See Footnote 6) had described popping after the accident and seeing small parts fly.

Figure 24. Loose battery cells found under the left front corner of the passenger seat. For orientation, the front of the vehicle is to the right.

Lifting the vehicle revealed a hole melted in the bottom of the passenger footwell. (See Figures 25-26)

Figure 25. Bottom of passenger cabin, showing hole melted in floor of passenger footwell. For orientation, the bottom of the photo is toward the rear of the vehicle.

Figure 26. Closer view with scale shows the hole was about three inches in longest dimension.

Examination of the 400 VDC traction battery revealed what appeared to be an elongated single hole in the steel top of the battery case, near a major bend in the battery was found to be a set of holes. The figure 8 shape of the hole in the bottom of the passenger floorboard matched the holes in the top of the battery case.[8] (See Figures 27-29) The top steel cover of the aluminum battery case was removed later in the day and a high voltage connection beneath the holes was found to have been consumed. (The examination of the 400 VDC battery interior is documented later in this report.)

[8] While technically two holes, the feature was usually referred to as a single hole. The terminology may reflect both in this report.

Figure 27. Top of 400 VDC traction battery with arrow to show location of what appeared to be a five inch oblongated hole melted through steel top of the case.

Figure 28. Closer examination found a set of oblongated holes (similar to the figure "8") melted through the steel cover over module 11. The plastic water barrier and sheet of insulation have been removed.

Figure 29. Close view of holes with a scale marked in inches.

LACK OF STANDARDIZED MEANS TO DISABLE HIGH VOLTAGE:

The holes and cut-loop markings were discussed with the firefighters at the tow yard activities, which led to discussion about a lack of standardized means for them to disable high voltage circuits. They were aware that the traction battery contained high voltage and had potentially harmful levels of energy but did not know how many volts or the level of power and damage that a short circuit could release until the hole in the steel cover was seen.

They said that they felt that the removable panel in the front trunk seemed to have been marked for them to locate the cut-loop. Once the access panel was away from focusing on the cut-loop the additional instructions on the panel might not be noticed.

One firefighter said that while they were trained to cut 12V battery cables in two locations and even if the single versus dual locations to cut did not create confusion, they were also aware that orange was the color used to denote high voltage. He said that he was concerned with the thought of cutting into a source of high energy which could injure himself and the people around him; to which the others agreed. He pointed out that the orange color of the cut loop contradicted with what they had been taught was safe to cut with hand tools.

The firefighters said that every hybrid and electric vehicle seemed to have a unique way of disabling the high voltage and that the mechanisms might be in the front, the trunk, or in the interior. There is no requirement to mark the outside of a vehicle with the location or means to disable the high voltage that the vehicle may contain.

They discussed ways in which some vehicles have pull-plugs to sever a high voltage circuit without tools and cited more than one model from a number of auto makers. They questioned why the design of this car had cut loops which required them to get and use tools. This method of protection against high voltage required the time involved to get a saw, cut the door frame, to a specific depth, into an unmarked amount of power. Some of the firefighters questioned whether cutting at both the front trunk and rear door pillar was required. (While this was an open discussion without a copy of the Tesla ERG, the ERG clearly shows the two provisions to be redundant.)

400 VDC 100 kWh PRIMARY BATTERY, AS-FOUND:

The traction battery located beneath the floor of the car body is divided into 16 modules, plus a compartment for the battery management system (BMS). Each module contains numerous cells stacked vertically. The modules are numbered from the aft right toward the front. (See Figures 30-31)

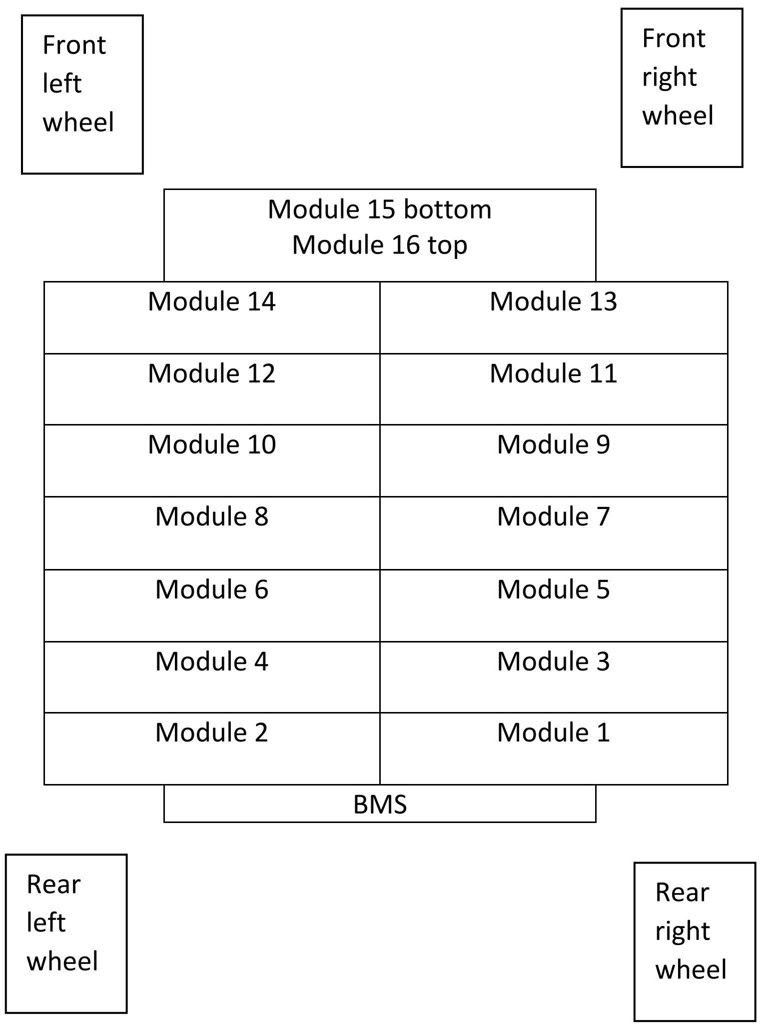


Figure 30. Module numbering in the Tesla High Voltage Numbering Scheme. This view looks down on an assembled battery, with the front at the top of the illustration.

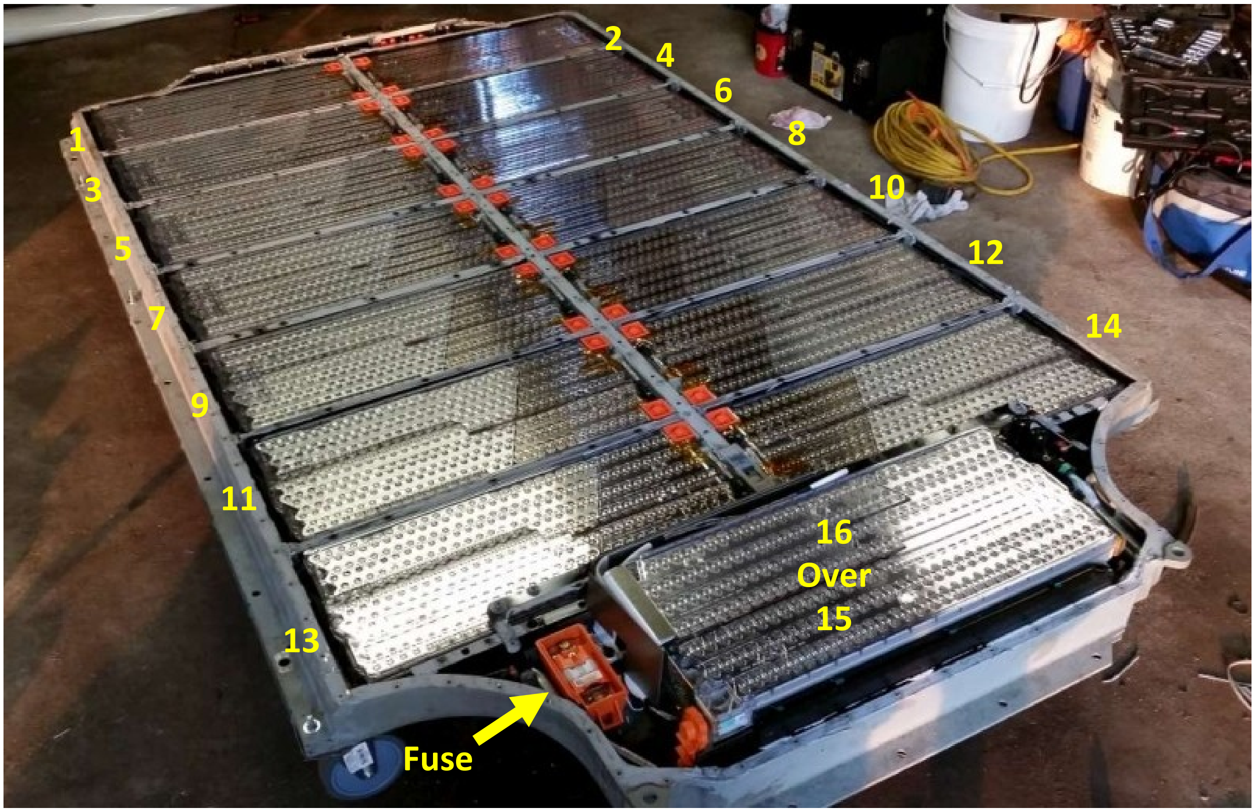


Figure 31. This undamaged exemplar battery with the top of the case removed shows the organization of vertically stacked cells into 16 modules. Between the visible cells and steel top of the case are the clear plastic frames and sheets of mica insulating material (removed here). (See Figure 66) Text depicting the module numbers and pyrotechnic fuse location have been added to this photo. The orange caps along the centerline are silicone-like rubber insulators which cover each of the module connection terminals.

The 400 VDC 85 kWh battery had been slightly twisted with the right front corner raised. The right front corner crushed on about a 45 degree diagonal and raised further from the rest of the battery. The steel top surface was pushed back and exhibited corrosion typical of severe heat exposure. The contents of modules 15 and 16 had been found separate (See Figure 12) and the rusted module 15/16 portion of the battery case was empty. (See Figures 32-34)

Figure 32. Twist in battery with forward right higher than the aft left.

Figure 33. Looking down on the leading edge of the 400 VDC traction battery with forward at the bottom of the photo. Yellow dashed crush line added to photo.

Figure 34. Looking up at the bottom of the 400 VDC traction battery with forward at the top of the photo. Yellow dashed crush line added to photo.

Most of the battery to body mounting bolts had broken and ripped mounting material from the battery. (See Figures 35-36)

Figure 35. Two mounting bolts along the rear edge of the traction battery are shown at the arrows. (Next Figure shows closer detail of one.) The ovals show the normal battery electrical connections above the battery management system module.

Figure 36. Fracture of a mounting bolt for the 400 VDC traction battery in gloved fingers.

A plastic water liner and a layer of insulation covering the battery were found intact over more than half of the battery assembly. In addition to the holes burned through the layers, the set were found heat damaged on a diagonal which passed over Module 11, and were missing in the burned area over Modules 13 and 14. (See Figures 37-38)

Figure 37. Insulation and plastic water liner covering forward portion of 400 VDC traction battery. The arrow points to the holes in Figures 28 and 29.

Figure 38. Intact insulation and plastic water liner layers covering rear portion of 400 VDC traction battery.

When the layers of insulation and water protection material were lifted from the rear portion, ripples or buckles were found to extend across the steel top of the battery case. These were oriented aft right / forward left at greater than 0.1” in depth for each module. (See Figures 28 and 39)

Figure 39. Rippled top steel surface of the 400 VDC traction battery after lifting insulation and water proofing layers.

The rusted steel cover for module 16 had folded back over the leading edges of modules 13 and 14. (See Figure 40)

Figure 40. View from front into exposed and empty modules 15 and 16.

The front of the rusted cover was lifted by hand to expose the interior forward features of the battery. Two exposed bus bars extended from module 14 across the leading edge of module 13. Voltage measurements which were taken for residual energy and continuity found 0 VDC and no resistance between each bus bar to the aluminum traction battery case.[9] Despite finding no electrical resistance between each and the case, measuring between the two exposed bus bars found 2.7V. Only small fragments of the pyrotechnic fuse which had been contained in this portion of the battery were found. (See Figures 41-42)

Figure 41. The photo shows the interiors of modules 13-16 after lifting the rusted battery case cover was lifted. The flat metal beneath the hand is a bus bar.

[9] Measurements were made with a Fluke 73 Series II Multimeter. A fresh battery was installed at the beginning of the day and the indication of zero ohms resistance was verified with a cleaned piece of copper.

Figure 42. Remnants of the pyrotechnic fuse.

The under-side of battery was generally flat and without local deformations, other than at least three major gouges oriented from front to rear. The right rocker cover was missing beneath module 9 and forward. (See Figure 43) The paint was browned under Module 13. There was soot present under Modules 9 and 11 (where the end of the rocker exposed the modules). The bottom of the overall battery had a slight gradual twist with the front right higher than the rear of battery. The module 15/16 orange vent grille was found intact. A burned demarcation existed between Modules 9/10 to 11/12.

Figure 43. Bottom of the traction battery, as viewed from the left after removal of the rocker covers and vent valves.

The rocker covers were removed to expose the silicone module vents, also known as tulip or umbrella valves due to their shape. The complete left rocker was intact and once removed, the interior surface was found completely washed in appearance and indeterminate for fire residue.

Despite photos (Figures 1 and 2) showing flames along the right rocker cover, the general appearance of each was washed and indeterminate in appearance for fire, other than as noted below where remnants of residues existed.

LEFT SIDE UMBRELLA/TULIP VENT VALVES: (even numbers from aft to front):

The module 2 valves were not visibly thermally damaged. Wet tan sand-like material was found inside of each and each had a washed appearance. The color was later found to be that of the mica insulation material used in the battery assembly. (See Figure 66) Blackness existed on the outer edges (rocker cover face rather than the module face) and not on the internal features. (See Figures 44-46)

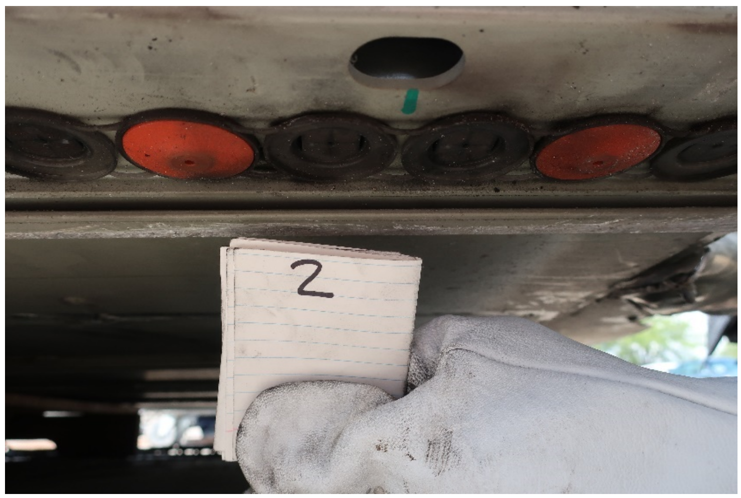


Figure 44. Module 2 umbrella/tulip valves before removal.

Figure 45. Module 2 valves after removal, showing module faces. Note that the valves are wet and contain tan sandy material which resembled the mica sheets covering each module, beneath the steel top of the battery case.

Figure 46. Rocker cover interior surface from beneath module 2.

The module 4 valves were not visibly thermally damaged. Wet tan sand-like material was found inside of each and each had a washed appearance. Blackness existed on the outer edges (rocker cover face rather than the module face) and very slight amounts existed on the internal features.

The valves for modules 6, 8, and 10 were removed and water flowed from the openings. Black residue appeared to be more embedded in plastic than in modules 2 and 4. Otherwise, the module 2 valve descriptions applied.

The module 12 valves were removed and no water flowed from the openings. The valves did not appear thermally damaged when removed and each had a washed appearance. What appeared to be off-white dried aqueous fire fighting foam (AFFF[10]) was found inside the valves. Blackness existed on the outer edges (rocker cover face rather than the module face) and not on the internal features. The tan sandy material was found in larger grains. (See Figure 47)


Figure 47. Module 12 valves showing larger grains of tan material and a flake of the mica-like insulation material used above and below each

[10] The firefighters provided an example of the AFFF used. The label stated: FireAde 2000, AFFF LIQUID FOAM CONCENTRATE, 3%, WETTING AGENT, UL Classified at 0.25% for Class A Fires and 0.50% for Class B Non-Water Miscible Fires. Fire Service Plus, Inc, 190 Etowah Trace, Fayetteville, Georgia 30214, Phone 770-460-7793

module internal to the battery case. (See Figure 66) The insulation easily crumbled.

Module 14 was the front-most module on the left side of the vehicle and the front of the module had been open.[11] The valves were removed and no water flowed from the openings. The valves were not visibly thermally damaged had a washed appearance. Blackness existed on the outer edges (rocker cover face rather than the module face) and not on the internal features. The tan sandy mica-like material was found in larger grains. (See Figures 48-50, 66)

Figure 48. Module 14 valves prior to removal.

Figure 49. Module 14 valves after removal.

Figure 50. Module 14 rocker cover interior surface.

[11] Along the centerline of the vehicle, modules 15 and 16 were located further forward.

RIGHT SIDE UMBRELLA/TULIP VENT VALVES: (odd numbers from aft to front):

The module 1 valves were removed and water flowed from the openings, accompanied by a rotting smell. The valves did not appear to be thermally damaged. Little of the tan sand-like material was found inside and each valve had a washed appearance. Blackness existed on the outer edges (rocker cover face rather than the module face) and not on the internal features. (See Figure 51)

Figure 51. Module 1 valves after removal. Note extensive water on ground which was released during removal.

The module 3 valves were removed, water flowed from the openings, and the description was similar to the module 1 description. (See Figure 52)

Figure 52. Interior faces of module 3 valves.

The module 5 valves were removed and water flowed from the openings. The remnants of internal labels were found partially blocking the openings when the water stopped flowing. Tan paste was found in two of the vents. (See Figures 53-54)

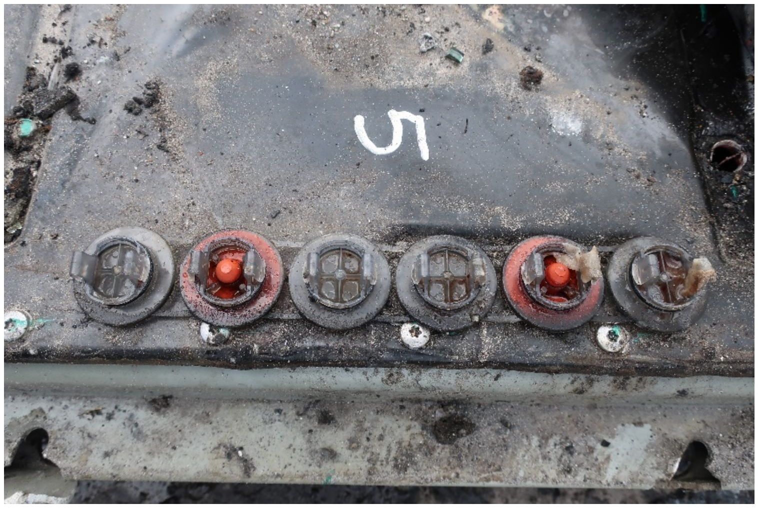


Figure 53. Tan paste visible in two of the module 5 vents after removal.

Figure 54. The remnants of internal labels partially block module 5 vent openings.

The module 7 valves were removed and water flowed from the openings. A nearly white material similar to dried AFFF was found in the valves. (See Figures 55-56)

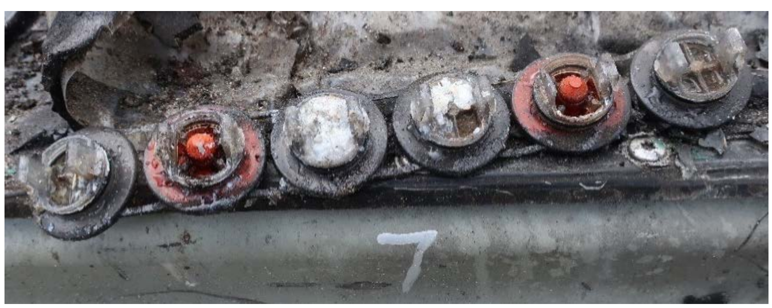


Figure 55. Module 7 valves contain material resembling nearly dried AFFF residue.

Figure 56. Dried material is visible in the open module 7 valve openings.

The module 9 valves were removed and no water was released. The module was missing two valves and had three with extensive fire damage. (See Figures 57-59)

Figure 57. Module 9 valve damage prior to removal.

Figure 58. The four remaining module 9 valves were extensively damaged.

Figure 59. Module 9 vent openings.

Module 11 contained no water when the valves were removed. The valves did not have the extent of thermal damage found to the valves from module 9. Each was found filled with fire residue and what appeared to be dried AFFF. (See Figures 60-62)

Figure 60. Module 11 valve damage prior to removal.

Figure 61. Module 11 valve fire residue contents.

Figure 62. Module 11 vent openings. The outer edge of the buckle in the battery is along the partition between modules 11 and 13, denoted by the bolt (lower arrow) which fastens the partition internally, and spacing between the vents (upper arrow).

The twisted module 13 vents contained no valves, extreme fire and mechanical damage, and fire residue. The front of the forward most opening had been destroyed and second opening was torn. (See Figure 63)

Figure 63. Module 13 vent openings.

A work safety plan for removal of the steel battery cover was developed. The plan included high voltage procedures, safety equipment such as special high voltage tools and flame resistant clothing, firefighters standing by after a safety meeting on procedures and potential actions to take. The NTSB personnel had training with high voltage and high energy systems and experience, plus had worked previously with damaged Tesla automobile batteries. The plan had review and approval from NTSB headquarters prior to proceeding on site. Only two NTSB people were allowed to be near the battery during removal of the cover. Both had been to the Tesla factory and knew the internal configuration of the battery including locations of high voltage connections, worked directly with Tesla engineers on prior investigations, and had other qualifications.

> NOTE: Beyond what is stated below, the disassembly plan is not provided because working with damaged batteries involves severe risk for personal injury or death.

The external plastic water barrier and insulation were first removed. (See Figure 64)

Figure 64. Forward portion of traction battery after removal of the water barrier and insulation blanket. Numbers have been added to denote modules. Note the holes at the inboard forward corner of module 11.

The steel cover of the traction battery was then carefully removed to examine the interior features and for "trapped energy."[12] The cover was found to be attached by a series of screws and adhesive. As the adhesive was broken, the cover was slowly lifted and a large sheet of rubber continually advanced between the cover and interior components, as close as possible to the tools being used.

The hole inside the steel top of the battery case aligned with the missing material around where the forward terminal had been on module 11. (See Figure 65)

[12] "Trapped energy" is an industry term to denote electrical power within a battery which may not be detected by external means.

Figure 65. The inside surface of the top steel battery cover has a set of holes over where the forward terminal had been for module 11. Numbers have been added to denote modules.

Following removal of the cover, sheets of a mica material were found covering each module. See Figures 66-67)

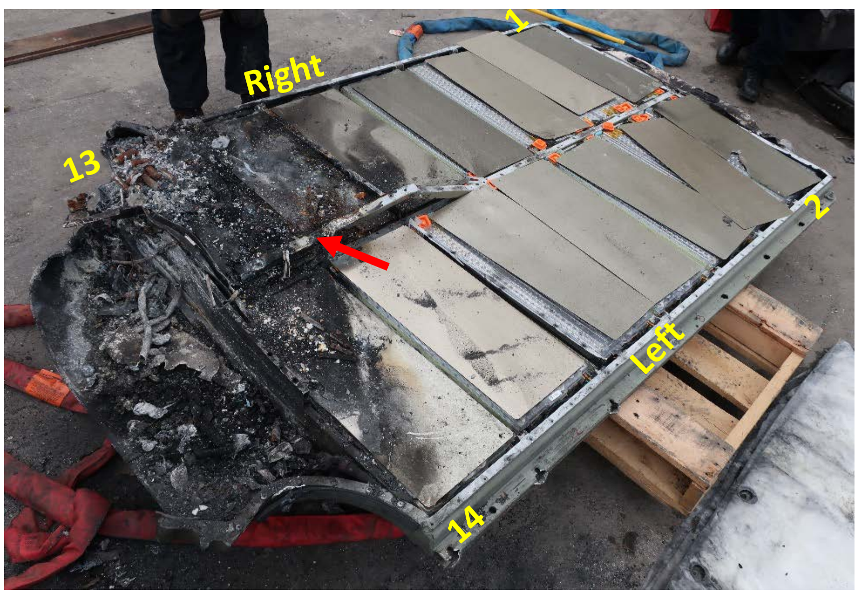


Figure 66. Mica-like sheets cover the individual modules.[13] Numbers have been added to denote modules. The red arrow points to the area of the missing module 11 terminal which was beneath the set of holes.

[13] Mica is the name for a group of minerals which can be manufactured into insulating sheets and other shapes.

Figure 67. Close view of a hole in the mica covering module 11, the missing terminal, and surrounding damage. Numbers have been added to denote modules. The red arrow is in the same orientation as in the previous photo.

A burn line existed diagonally from the outboard rear of module 11 to the outboard front of module 14 and all material ahead of this line had extreme fire damage. The contents of modules 15 and 16 were essentially missing and the remaining portions were examined separately. (See Figure 68)

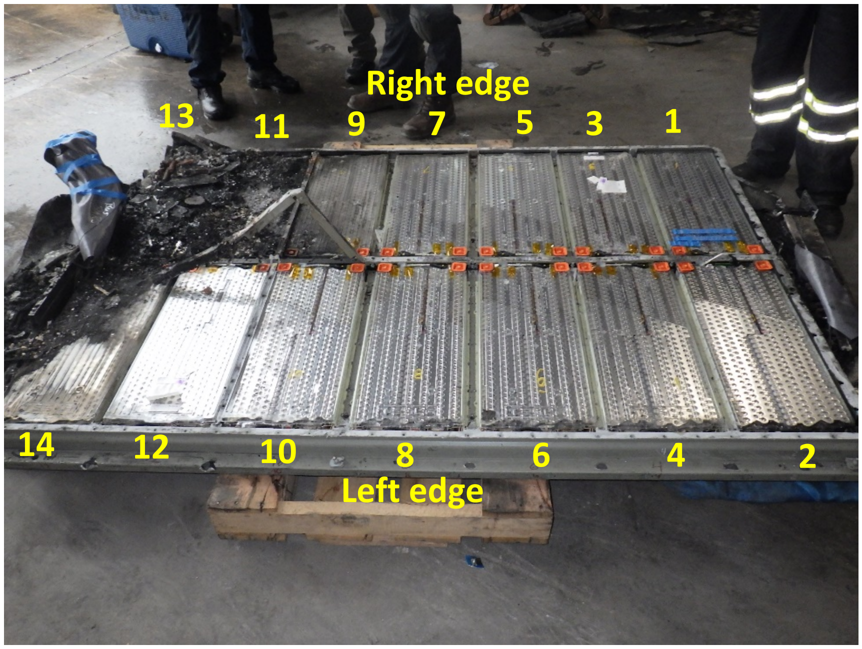


Figure 68. The traction battery after removal of the mica insulation. The front end of the traction battery is to the left. Numbers have been added to denote modules.

Beneath the mica sheets, clear plastic liners covered each of the modules and orange rubber inserts covered each of the bolt heads at the high voltage connections for the positive and negative terminals at each of the modules. (See Figure 69)

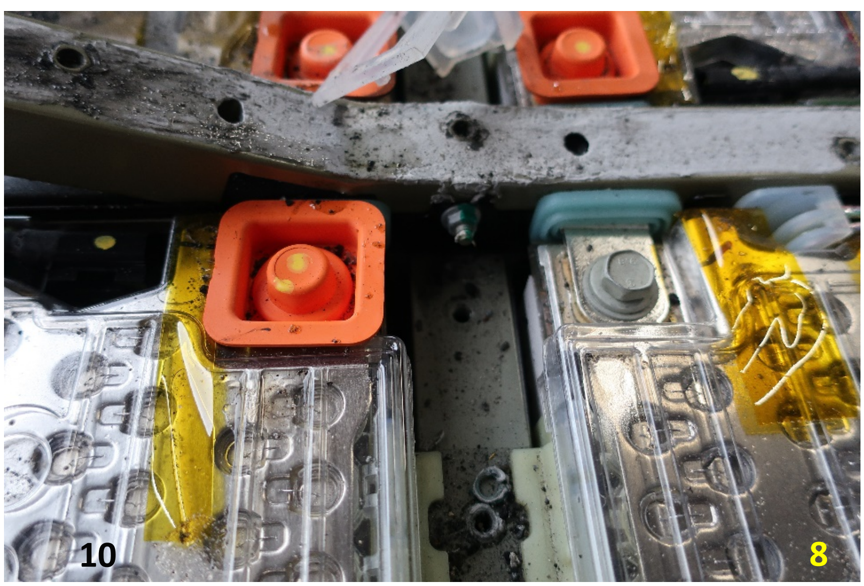


Figure 69. Clear plastic covers on each module and orange silicone-like rubber insulators were found on the terminals for each of the modules. One orange cover has been removed to show the high voltage terminal

bolt. Note the visible water droplets trapped under the clear plastic in the areas of the added “8” and “10” numbers.

The module 11 forward orange silicone-like rubber material was missing and cleaning the area revealed a void which had been filled with fire residue. For module 13, a displaced fragment of the aft terminal cover still existed. (See Figure 70)

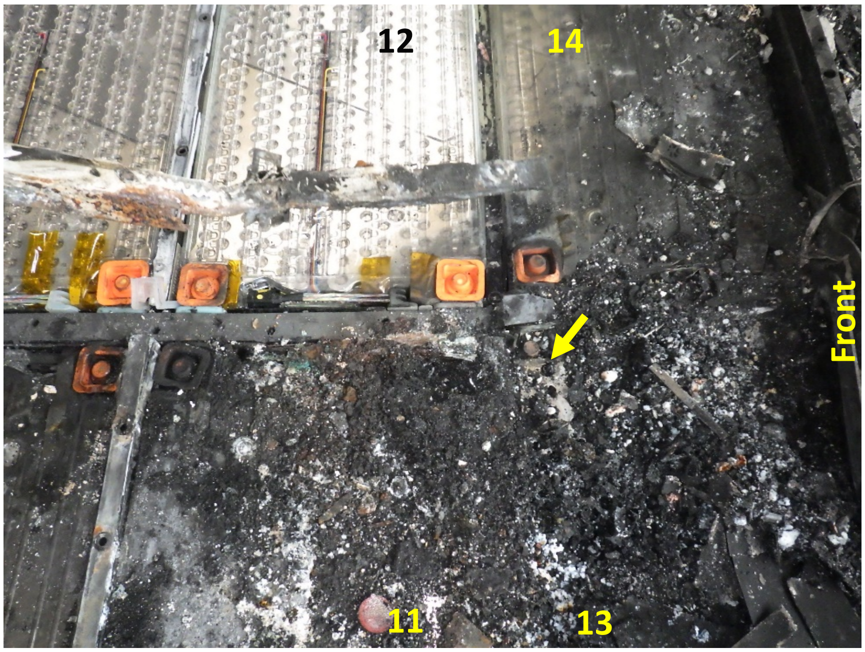


Figure 70. The internal damage to the right front area of the traction battery. Numbers have been added to denote modules. The forward terminal area of module 11 is a hole filled with fire debris. The arrow points to the remaining fragment of the module 13 orange cover.

Water was found throughout the traction battery. In addition to finding water through-out the bottom of the traction battery, water was found beneath the top clear plastic in the modules noted. (See Figure 71)

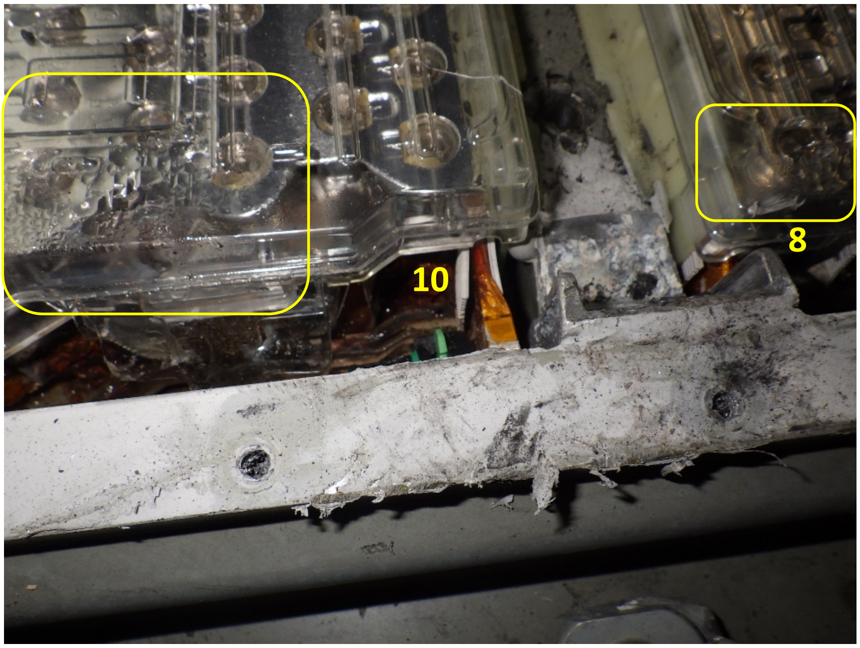


Figure 71. Water visible beneath the top clear plastic of modules 8 (small rectangle) and 10 (large rectangle). Water is visible at the base of module 10.

Examination of the partitions between the modules for how water traveled through the battery found that minor passages did exist. For example, the lower half of the barriers were solid and the upper half were constructed of square tubing with gaps of up to 0.12 inches existing at the outboard ends of the tubes. Plastic clips at the inboard ends appeared to restrict inter-module communication but did not appear to be water-tight. Silicone-like material was also found between the upper and lower portions of the module dividers. (See Figure 72)

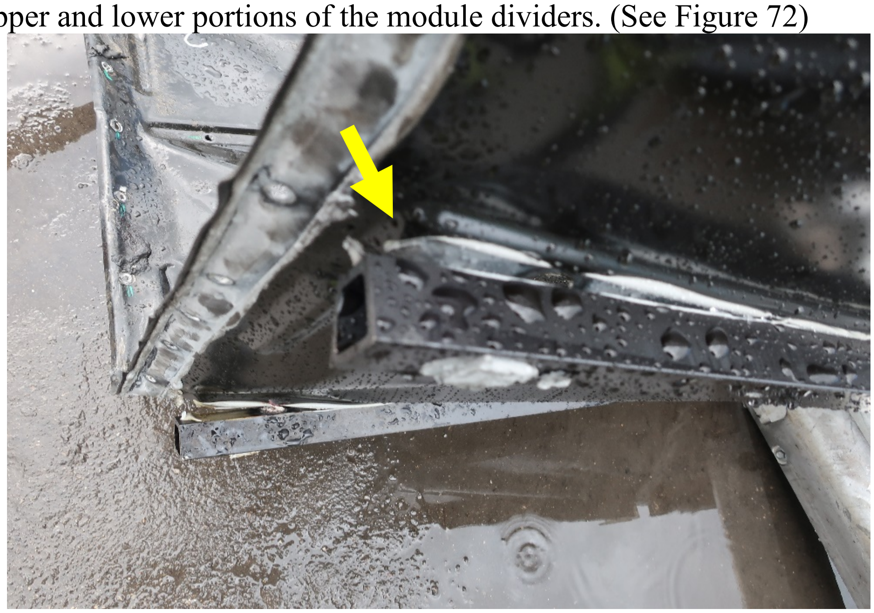


Figure 72. Outboard end of a square tube which was the upper half of a partition between modules. The arrow points to an open gap between modules. (The water visible is from a passing rain shower.)

Each of the modules were then examined visually. The modules were not removed from the case. Modules 1, 2, 4, 6, 8 had no visible thermal or mechanical damage and water was under the clear plastic covers.

Module 3 had some light colored discoloration at the outboard edge and water was under the clear plastic cover. The light discoloration resembled dried AFFF. The mounting tray was found cracked at the locator pins. A sticker on the module stated:

T15F0090051R1
March 5, 2018
SOC 40%
Corrosion on BNB

Modules 5 and 7 had some light colored discoloration at the outboard edge and water was under the clear plastic cover inboard edges. White/gray discoloration of metal plates existed on aft outboard edges. See Figure 73)

Figure 73. Outer edge of module 7, showing water droplets and light discoloration which resembled the color of dried AFFF.

Module 9 had thermal damage on forward inboard cover extending about 4” outboard and 6” aft; gray/black discoloration extending across entire forward edge and aft across the whole inboard edge and approximately 8” on the outboard edge. There was no visible water under plastic cover. The plastic cover had melted on the inboard front corner and outboard front corner.

Module 10 had water under the plastic cover on the inboard and outboard edge. Grayish/white discoloration of the metal plate existed on the forward outboard corner. The plastic cover retention tab was raised at the forward outboard edge.

Module 11 had the entire plastic cover covered with soot and debris and the outboard edge had melted to about 1.5 inches inward. The melted inboard edge extended outward 11 inches at the front, and about 8 inches further aft. Round red rubber caps of about one inch diameter were found on top of the module. No visible water was present on the module.

Module 12 had evidence of water under the plastic cover on the inboard and outboard edge extending across the entire front. The plastic cover had whitish/gray discoloration across the front edge, concentrated at the inboard and outboard corners. A sticker on the module stated:

T15F0090051R1
March 5, 2018
SOC 40%
Group 3VSH

Module 13 had extensive thermal and mechanical damage, increasing toward the destroyed forward outboard corner. The battery case surrounding the module disruption extended 12 inches inboard and 13 inches aft to the partition with module 11; Displaced cells were found randomly across the top of the module from the front to the back of the module on the outboard edge, for about 6 inches at mid-module, and for about 2 inches at the inboard edge of the module.

Module 14 had no visible water under plastic cover. The outboard edge of the plastic cover had melted. The front inboard corner was covered with ash and debris and the plastic cover exhibited thermal damage which extended across the entire forward edge, extending 3 inches aft at the outboard edge, and about 8 inches aft at the middle of the module, and across entire module at the inboard edge. Battery cells had fire damage along the inboard edge of the module which extended about 18 inches along the forward edge.

The case for modules 15 and 16 was nearly empty and the majority of two modules were found apart from the traction battery case. The two were simply referred to as the larger and smaller fragments. Both had evidence of physical damage, missing plastic covers, and missing cells. Numerous loose individual cells were found in the pile of loose debris.

The Battery Management System (BMS) compartment walls had been grossly deformed, separating the walls from the top cover. The walls of the case were brittle and fractured when force was applied during removal of the BMS cover. The interior of the module was found to have more thermal and fire damage than the outside, which retained most of the original color. The burned interior of the compartment contrasted with the intact appearances of modules 1 and 2. Water was found in the BMS compartment. The BMS was not disassembled for detailed examination of the contactors or for other more detailed purposes. (See Figures 74-76)

Figure 74. The BMS compartment was found with dislocated and open ends as shown. The exterior paint was had soot on the surface but was not burned.

Figure 75. The end of the aluminum BMS compartment wall separated when force was used to open the top cover. This view shows the burned interior around the large contactors.

Figure 76. The burned interior of the BMS contrasted with the intact nature of modules 1 and 2.

The BMS large contactors had orange rubber covers. All covers had been thermally damaged and perforated to the aluminum BMS cover. Measuring for voltage from each of the contactors to any pole or the battery case to any pole or ground found, the multimeter displayed continuously changing small values which never exceeded 1 VDC. The resistance across left contactor was measured as 6.9 M Ohms. The resistance across the right contactor was measured as 1.4 M Ohms. All four posts measured from 1.4 M ohms to 6.9 M ohms.

Electrical measurements were made to check for energy trapped within the traction battery. National Highway Traffic Safety Administration Regulation 49 CFR Part 571.305, also known as Standard 305 and titled *Electric-powered vehicles: electrolyte spillage and electrical shock protection*, defines high voltage as that exceeding 30 volts alternating current or 60 VDC. Five of the 16 modules exceeded 60 VDC, with the highest voltage of 167.3 volts found between the module 1 forward terminal post to ground.

The three measurements taken were for voltage between the positive and negative terminals (labeled as Module Voltage), between the aft terminal post to the battery case (Aft to Ground), and between the forward terminal post to the battery case (Forward to Ground) The results of the electrical measurements are shown in Table 1.

Table 1. Voltage measurements in traction battery. Measurements exceeding the NHTSA definition of minimum for high voltage at 60V are highlighted in yellow.

Module	Module Voltage (V)	Aft to Ground (V)	Forward to Ground (V)
1	23.02	138.7	167.3
2	23.77	139.6	115.9
3	23.37	92.4	115.9
4	22.66	92.5	69.5
5	22.61	46.8	69.9
6	23.31	46.9	23.88
7	21.34	2.7	24
8	22.07	2.76	19.29
9	0.026	18.8	18.7
10	18.56	19.1	37.7
11	N/A	21.5	N/A
12	21.69	21.6	0.03
13	19.41	2.64	16.96
14	0	0	0.02
15	Two large fragments of modules were found separate from the battery case. The larger more in-tact fragment had 12.06 V corner to corner, and the greatest voltage between any two cells was 23.78 VDC.		
16	For the smaller fragment, the highest voltage between any two cells was 3.27 VDC. Probing between most cells (2/3 of surface) found no voltage.		

Robert L. Swaim
Aircraft Systems Engineer
National Resource Specialist

APPENDIX A

Tesla Model S Description

Model S

Premium Electric Sedan

TESLA

An evolution in automobile engineering

Tesla's advanced electric powertrain delivers exhilarating performance. Unlike a gasoline internal combustion engine with hundreds of moving parts, Tesla electric motors have only one moving piece: the rotor. As a result, Model S acceleration is instantaneous, silent and smooth. Step on the accelerator and in as little as 3.1 seconds Model S is travelling 60 miles per hour, without hesitation, and without a drop of gasoline. Model S is an evolution in automobile engineering.

TESLA

Rear Wheel Drive

All-Wheel Drive Dual Motor

Performance All-Wheel Drive

All-Wheel Drive Dual Motor

Dual Motor Model S is a categorical improvement on conventional all-wheel drive systems. With two motors, one in the front and one in the rear, Model S digitally and independently controls torque to the front and rear wheels. The result is unparalleled traction control in all conditions.

Conventional all-wheel drive cars employ complex mechanical linkages to distribute power from a single engine to all four wheels. This sacrifices efficiency in favor of all weather traction. In contrast, each Model S motor is lighter, smaller and more efficient than its rear wheel drive counterpart, providing both improved range and faster acceleration.

All-wheel drive is standard on Model S 70D and available as an option on Model S 85. Model S Performance comes standard with All-Wheel Drive Dual Motor, pairing the high performance rear motor with a high efficiency front motor to achieve supercar acceleration, from zero to 60 miles per hour in 3.1 seconds.

Highest Safety Rating in America

THE NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

Model S is designed from the ground up to be the safest car on the road, as proven by a 5-star rating in all categories of the National Highway Traffic Safety Administration (NHTSA) crash test. Much of its safety is owed to the unique electric drivetrain that sits beneath the car's aluminum occupant cell in its own subframe. This unique positioning lowers the car's center of gravity, which improves handling and minimizes rollover risk, and replaces the heavy engine block with impact absorbing boron steel rails.

Side impacts are met by aluminum pillars reinforced with steel rails to reduce intrusion, protecting occupants and the battery pack while improving roof stiffness. In the event of an accident, eight airbags protect front and rear occupants, and the battery system automatically disconnects the main power source. Should the worst happen, there is no safer car to be in than Model S.

Autopilot

Autopilot combines a forward looking camera, radar, and 360 degree sonar sensors with real time traffic updates to automatically drive Model S on the open road and in dense stop and go traffic. Changing lanes becomes as simple as a tap of the turn signal. When you arrive at your destination, Model S will both detect a parking spot and automatically park itself. Standard equipment safety features are constantly monitoring stop signs, traffic signals and pedestrians, as well as for unintentional lane changes.

TESLA

Inspired by an endurance athlete

Tesla's design and engineering teams have gone to extraordinary lengths to ensure that air flows smoothly above, around and below Model S to reduce drag, which in turn maximizes battery range. The smart air suspension lowers the car's height at highway speeds to reduce its frontal area. Electronically controlled vents stay closed until sensors detect that cooling is necessary. The front bumper routes air uninterrupted beneath the battery's flat skidplate and past the rear diffuser. The result is a seven seat sedan with the stance of a coupe and supercar aerodynamics.

Zero profile door handles

Model S door handles are a work of art. When a key is in close proximity, they automatically extend. When no longer in use, they retract into the body of the car, creating a seamless surface for air to pass over.

Hidden in plain sight

Scan the streamlined body panels and you'll discover that Model S lacks a fuel door. Approach the driver's side taillight with a charging connector and the hidden charge port automatically opens. The charging connector cannot be removed until Model S is unlocked.

Built around the driver

Model S is a driver's car. The cabin combines meticulous noise engineering with Tesla's uniquely quiet powertrain to obtain the sound dynamics of a recording studio. The gem of the interior is the 17 inch touchscreen, which is angled toward the driver and includes both day and night modes for better visibility without distraction. It puts rich content at your fingertips and provides mobile connectivity so you can easily find your destination, favorite song or a new restaurant.

TESLA


SATELLITE
TRAFFIC

The touchscreen

The Model S 17 inch touchscreen controls most of the car's functions. Opening the all glass panoramic roof, customizing the automatic climate control, and changing the radio station all happen with a swipe or a touch. The touchscreen, digital instrument cluster, and steering wheel controls seamlessly integrate media, navigation, communications, cabin controls and vehicle data.

MEDIA
AM/FM/HD radio, online radio, on-demand Internet radio, Bluetooth®, and USB audio devices

CAMERA
High definition backup camera, optimized for visibility and safety

MAP
Simple, intuitive Google Maps™ with real time traffic information

PHONE
Bluetooth-enabled, voice controlled handsfree phone system

CONTROLS
Driving personalization, climate controls, and cabin controls

CALENDAR
Calendar synchronization for daily schedule and tap to navigate

ENERGY
Real time energy consumption and range estimation

Battery, Performance, and Drive Options

Every Model S includes free long distance travel using Tesla's Supercharger network
and an eight year, infinite mile battery and drive warranty.

70D	85	85D	P85D
All-Wheel Drive	**Rear Wheel Drive**	**All-Wheel Drive**	**All-Wheel Drive**
70 kWh battery with all-wheel drive	85 kWh battery with rear wheel drive	85 kWh bbattery with all-wheel drive	85 kWh battery with high performance all-wheel drive
240 miles range (EPA)	**265** miles range (EPA)	**270** miles range (EPA)	**253** miles range (EPA)
5.2 seconds 0-60 mph	**5.4** seconds 0-60 mph	**4.4** seconds 0-60 mph	**3.1** seconds 0-60 mph
329 hp	**362** hp	**422** hp	**691** hp motor power **221** hp front, **470** hp rear
140 mph top speed	**140** mph top speed	**155** mph top speed	**155** mph top speed

Design your Model S

BATTERY & DRIVE
- 70 kWh All-Wheel Drive
- 85 kWh Rear Wheel Drive
- 85 kWh All-Wheel Drive
- 85 kWh Performance All-Wheel Drive

PERFORMANCE
- Carbon Fiber Spoiler
- Tesla Red Brake Calipers

OPTIONS
- Autopilot Convenience Features
- Premium Interior and Lighting
- Smart Air Suspension
- Ultra High Fidelity Sound
- Executive Rear Seats
- Subzero Weather Package
- Rear Facing Seats

ROOF
- Solid Body Color Roof
- All Glass Panoramic Roof

PAINT
- Solid Black
- Solid White
- Titanium Metallic
- Midnight Silver Metallic
- Obsidian Black Metallic
- Deep Blue Metallic
- Pearl White Multi-Coat
- Red Multi-Coat

WHEELS
- 19" Wheels
- 19" Silver Cyclone Wheels
- 21" Silver Turbine Wheels
- 21" Grey Turbine Wheels

SEATING
- Black Multi-Pattern
- Leather Seats in Black
- Leather Seats in Tan
- Leather Seats in Grey
- Next Generation Seats in Black
- Next Generation Seats in Tan
- Next Generation Seats in Grey

DÉCOR
- Piano Black
- Matte Obeche Wood
- Glossy Obeche Wood
- Carbon Fiber

HEADLINER
- Textile
- White Alcantara
- Black Alcantara

STANDARD EQUIPMENT
- Maps and navigation
- Mobile connectivity
- Automatic keyless entry
- Power-folding and heated mirrors
- LED daytime running lights
- Parking sensors
- Lane departure warning
- Automatic emergency braking
- Supercharging enabed
- GPS enabled Homelink
- 8 year, infinite mile battery and drive unit warranty

For pricing and ordering

- Visit a Tesla Store or Gallery
- Online at teslamotors.com
- By phone: (888) 518-3752

TESLA

APPENDIX B

Pages from
2014 Tesla Model S, Single Motor
Emergency Response Guide

TESLA

2014

MODEL S

EMERGENCY RESPONSE GUIDE

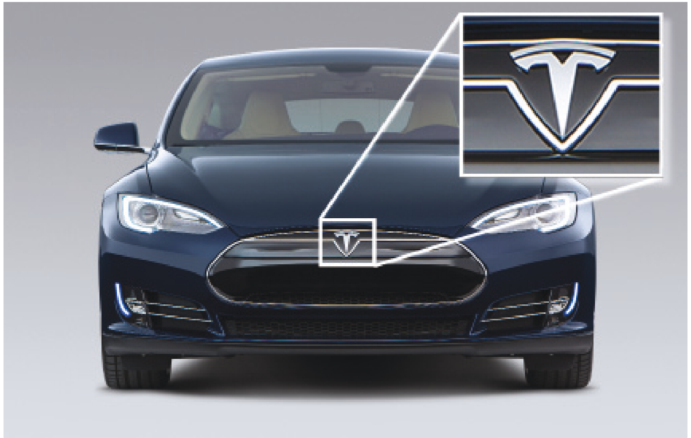
This guide is intended only for use by trained and certified rescuers and first responders. It assumes that readers have a comprehensive understanding of how safety systems work and have completed the appropriate training and certification required to safely handle rescue situations. Therefore, this guide provides only the specific information required to understand and safely handle the fully electric Model S in an emergency situation. It describes how to identify Model S, and provides the locations and descriptions of its high voltage components, airbags, inflation cylinders, seat belt pre-tensioners, and high strength materials used in its body structure. This guide includes the high voltage disabling procedure and any safety considerations specific to Model S. Failure to follow recommended practices or procedures can result in serious injury or death.

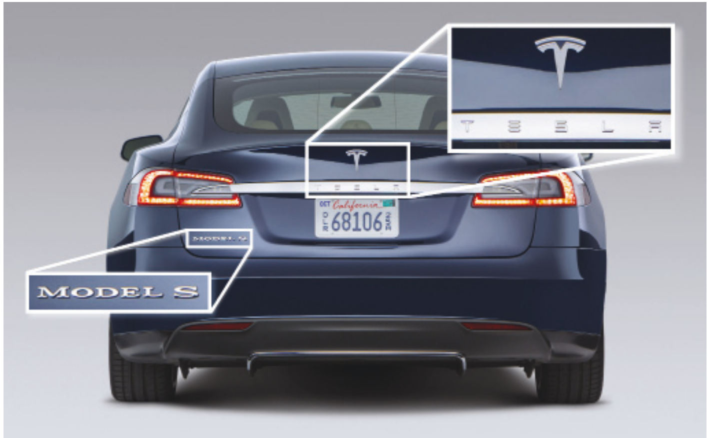
The high voltage battery is the main energy source. Model S does not have a traditional gasoline or diesel engine and therefore does not have a fuel tank.

P/N: SC-14-94-001.1

BADGING

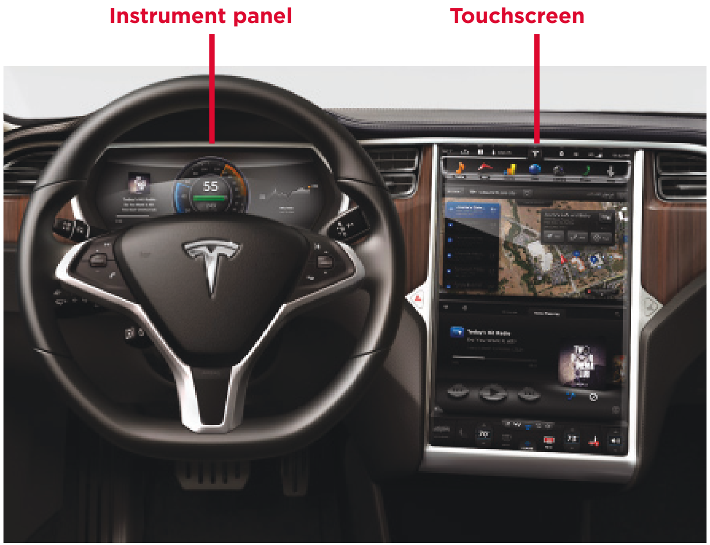
Model S has three main badges to distinguish it.





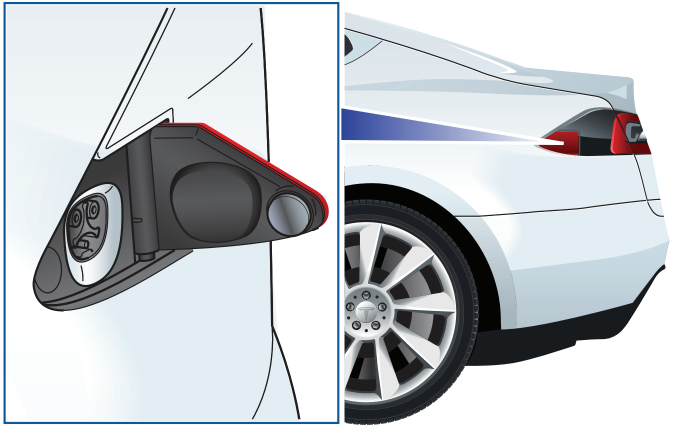
LARGE SCREEN

Model S has a large 17” touchscreen.



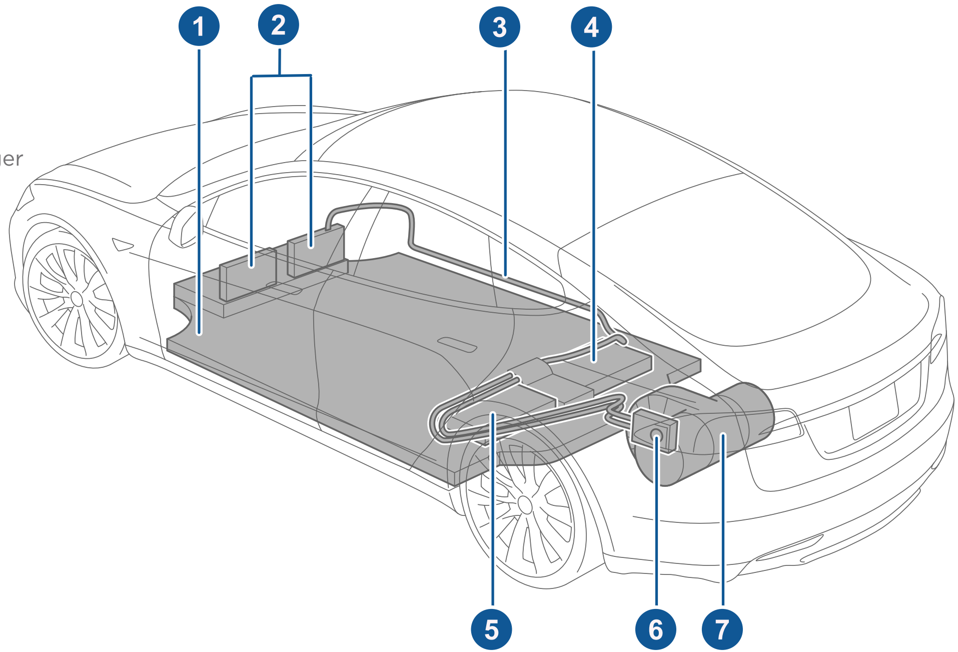
CHARGE PORT

Model S has a charge port that is integrated into the taillight on the rear left side fender.



OVERVIEW OF HIGH VOLTAGE COMPONENTS

1. High Voltage Battery
2. DC-DC converter and front junction box
3. High voltage cabling (colored orange)
4. 10 kW on-board master charger
5. OPTIONAL: 10 kW on-board slave charger
6. Charge port
7. Drive unit



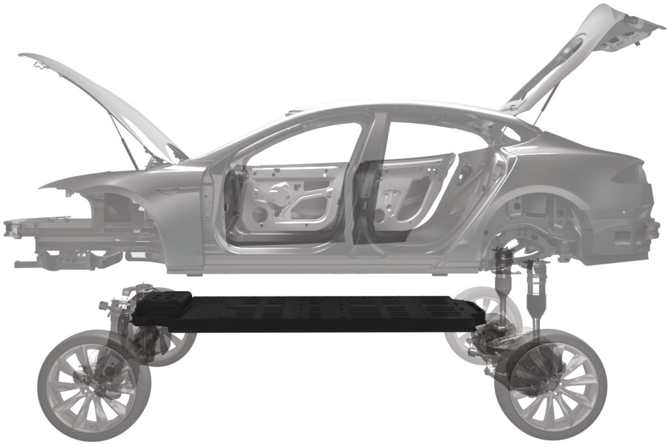
WARNING: After deactivation, the high voltage circuit requires two minutes to deplete.

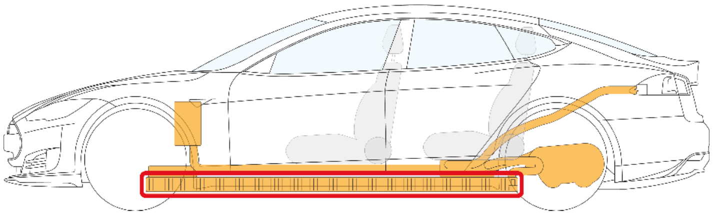
WARNING: The SRS control unit has a backup power supply with a discharge time of approximately ten seconds.

WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

HIGH VOLTAGE BATTERY

Model S is equipped with a floor-mounted 400 volt lithium-ion high voltage battery. Never breach the high voltage battery when lifting from under the vehicle. When using rescue tools, pay special attention to ensure that you do not breach the floor pan.



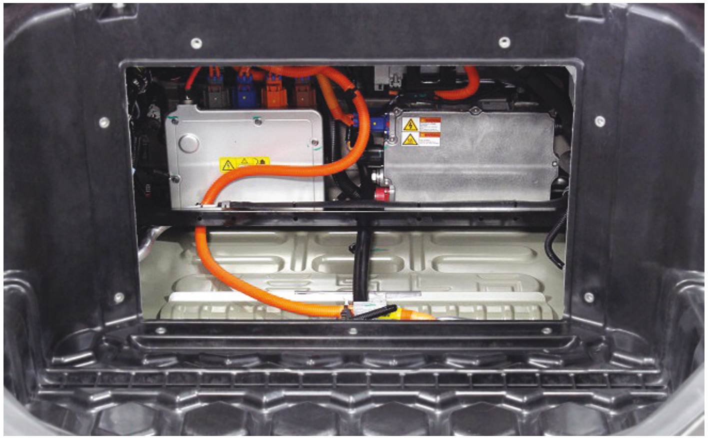


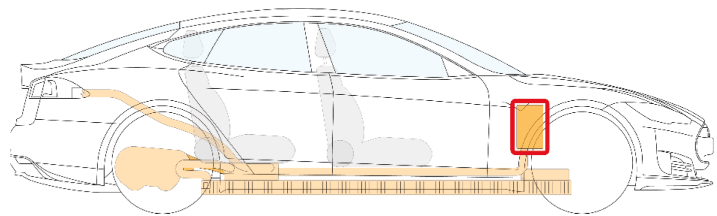
High voltage battery is located below the floor

WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

DC-DC CONVERTER AND FRONT JUNCTION BOX

High voltage is present at the DC-DC converter and front junction box, located behind the front trunk. The DC-DC converter transforms the high voltage current from the 400 volt battery to low voltage to charge the Model S 12 volt battery. The front junction box provides power to various components, such as the Battery heater, the air conditioning compressor and the cabin heater. Use caution when cutting in this area during a dash lift (dash roll) procedure—use work-around techniques, if necessary.



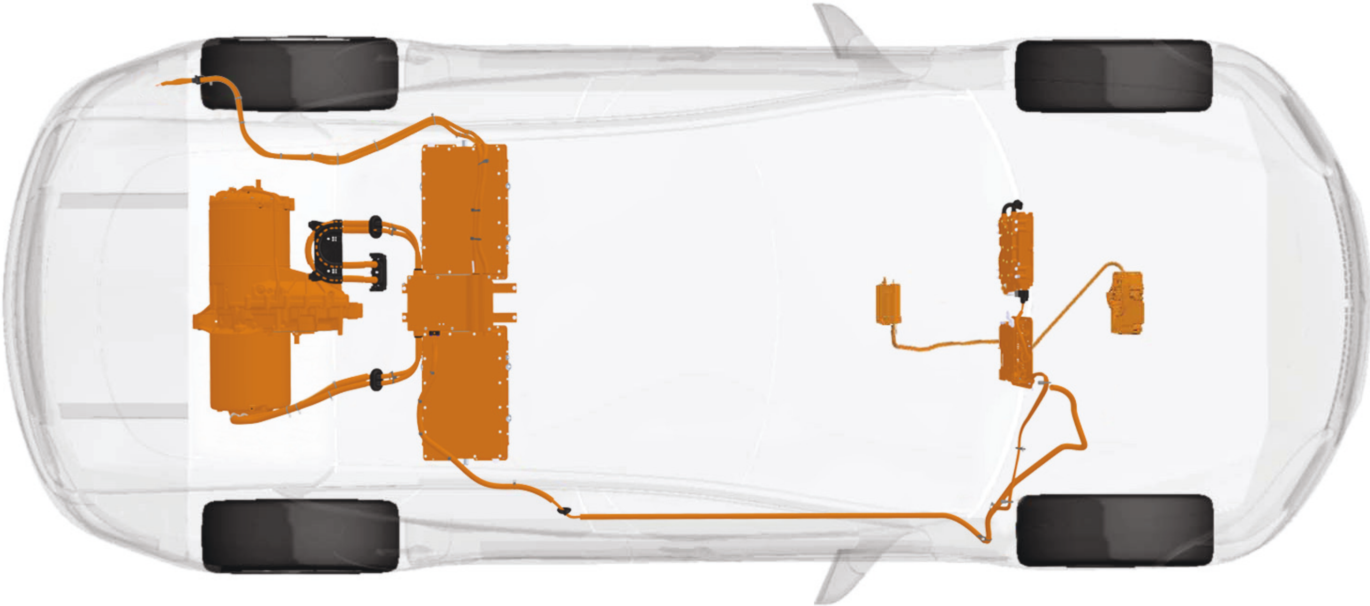


DC-DC converter and front junction box are located behind the front trunk, near the center of the vehicle

WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

HIGH VOLTAGE CABLING

High voltage cabling is highlighted in dark orange in the following illustration.

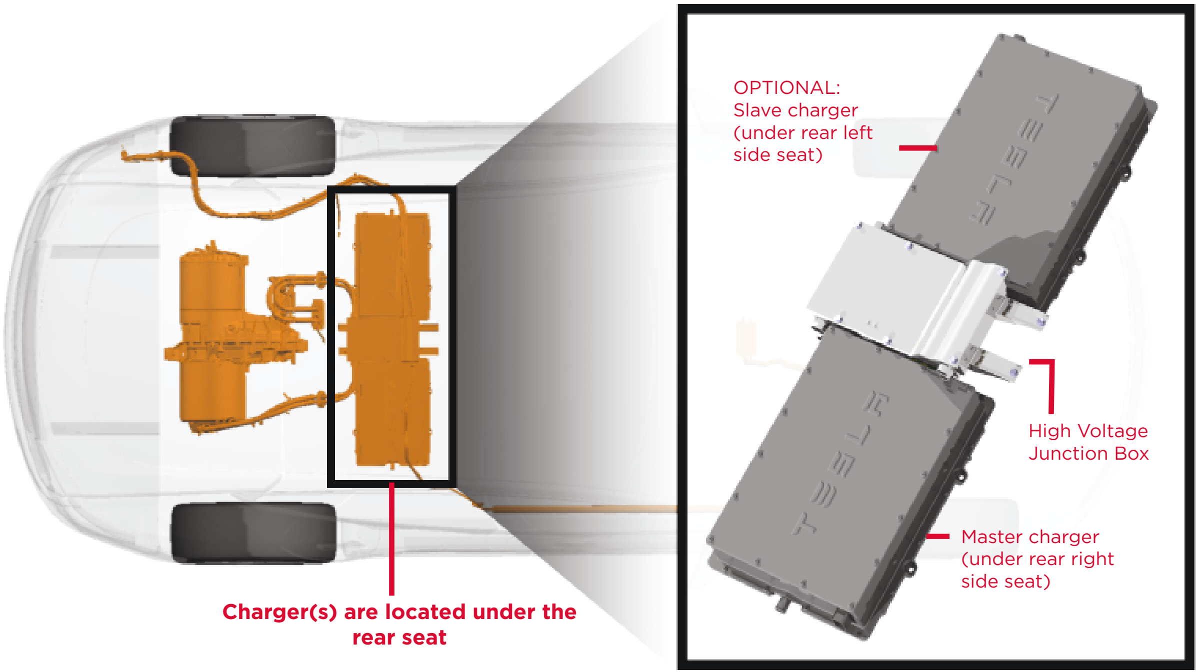


High voltage cabling is routed under the rear seats and inside the rocker panel on the right side front

WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

CHARGERS

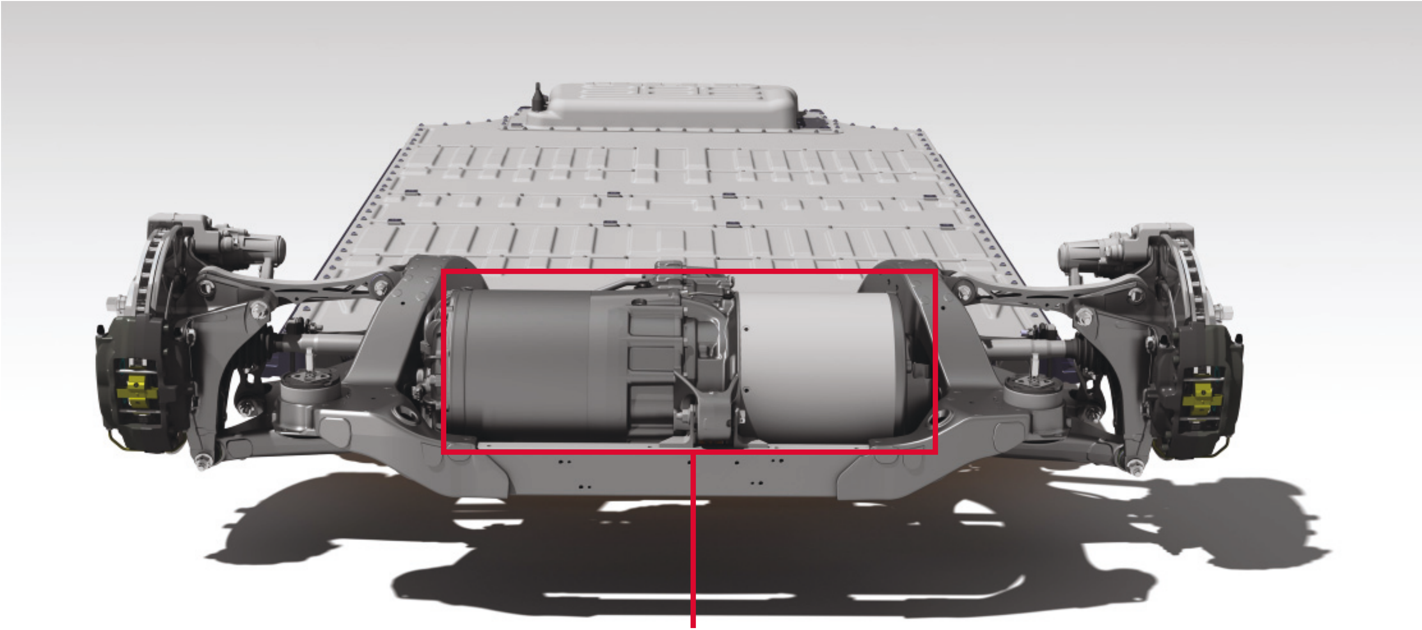
Model S has one (standard) or two (optional) chargers under the rear seat. These chargers convert the AC current from a charging station to DC for charging the high voltage battery. The high voltage junction box, located between the chargers, routes any surplus energy from regenerative braking back to the battery.



WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

DRIVE UNIT

The drive unit is located between the rear wheels under the floor pan of the Model S. It converts the DC current from the high voltage battery into the 3-phase AC current that the electric motor uses to power the wheels.



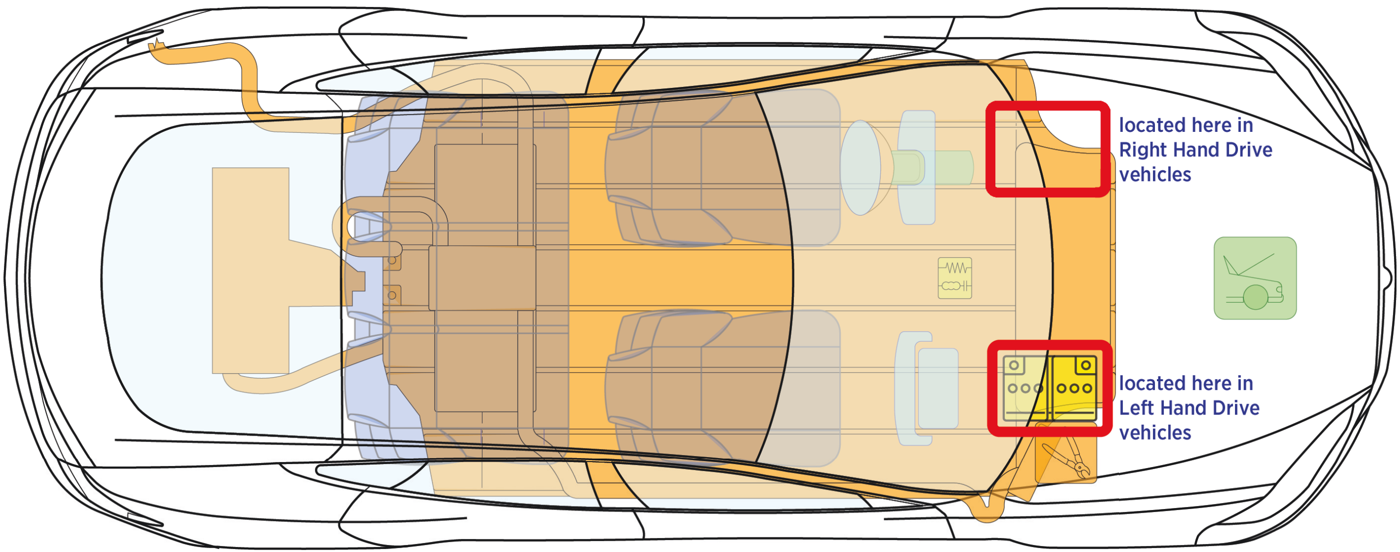
Drive unit is located between the rear wheels

WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

12V BATTERY

In addition to the high voltage system, Model S has a low voltage system, powered by a traditional 12 volt battery. The low voltage system operates the same electrical components found in conventional vehicles, including the supplementary restraint system (SRS), airbags, ignition, touchscreen, and interior and exterior lights.

The low voltage system interacts with the high voltage system. The DC-DC converter supplies the 12V battery with power to support low voltage functions, and the 12V battery supplies power to the high voltage contacts to allow power to flow out of the high voltage battery.



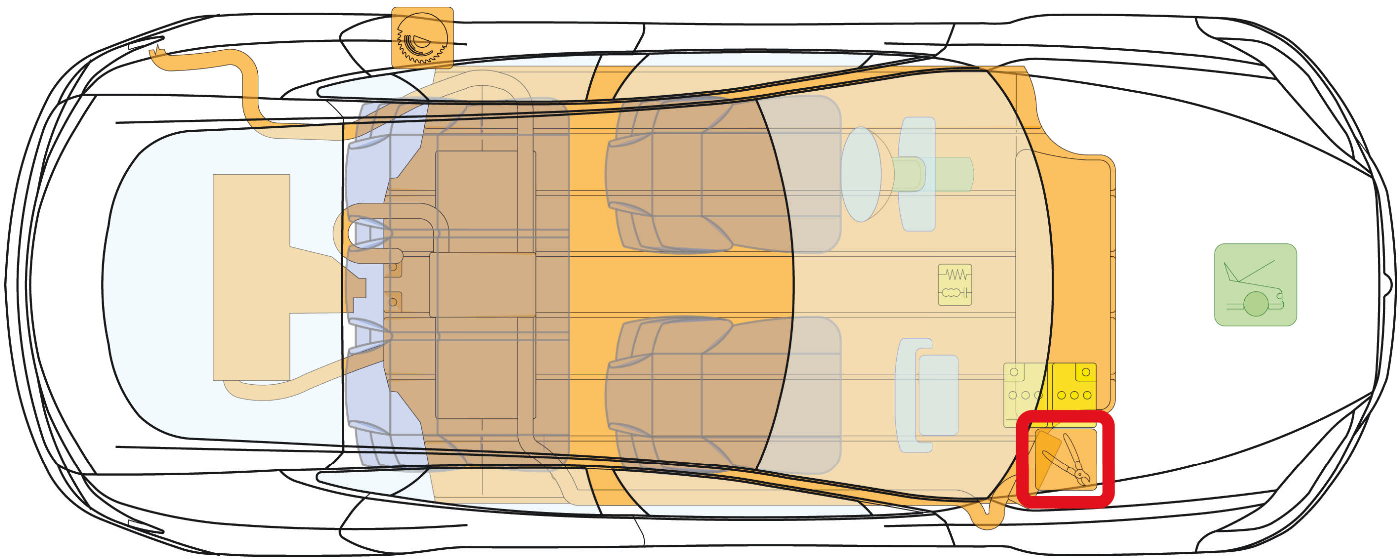
12V battery is located under the hood and the plastic access panel

WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

FIRST RESPONDER CUT LOOP - FRONT TRUNK

The front trunk first responder cut loop consists of low voltage wires. Cutting this loop shuts down the high voltage system and disables the SRS and airbag components. See cut instructions on page 11.

NOTE: When cutting the loop, double cut to remove an entire section. This eliminates the risk of the cut wires accidentally reconnecting.



The front trunk cut loop is located on the right side, under the hood and the plastic access panel

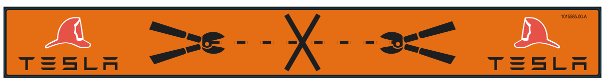
WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

CUTTING THE FIRST RESPONDER CUT LOOP - FRONT TRUNK

STEP 1: Open the hood (also known as the Front Trunk). See page 23 for details.

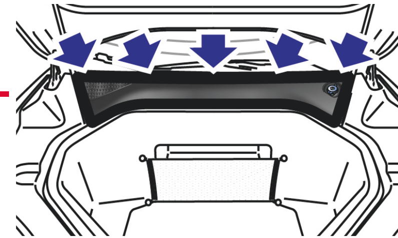
The cut loop is located on the right side. Its label protrudes from under the plastic access panel.

Cut loop label



STEP 2: Remove the access panel by pulling its rear edge upward to release the five clips that hold it in place. Maneuver it toward the windshield to remove.

Remove access panel



STEP 3: **DOUBLE CUT** the loop to remove an entire section.

Removing an entire section of the cut loop eliminates the risk of the wires accidentally touching (reconnecting).

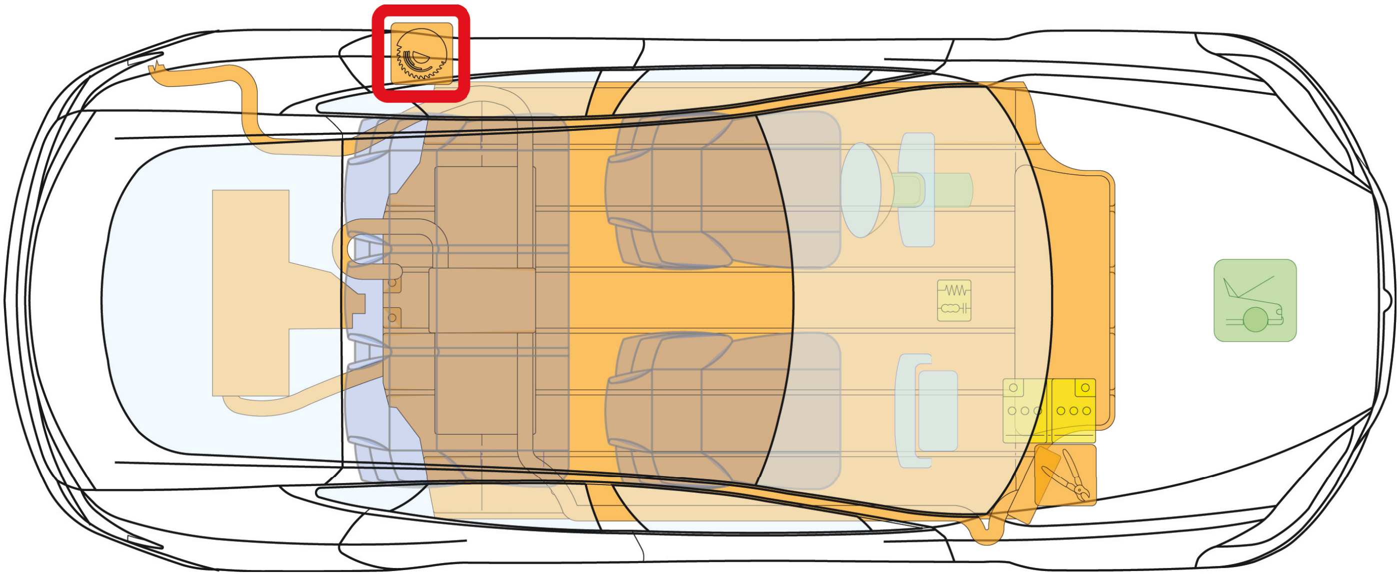
Double cut the loop

WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

FIRST RESPONDER DISCONNECT POINT - REAR PILLAR

If the front trunk cut loop is inaccessible, the rear pillar disconnect point can shut down the high voltage system and disable the SRS and airbag components in the same manner as the front trunk cut loop. See cut instructions on page 13.

NOTE: Only one point needs to be disconnected, not both.



WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

CUTTING THE FIRST RESPONDER DISCONNECT POINT - REAR PILLAR

STEP 1: Open the rear passenger door closest to the charge port.

The disconnect point is located under the body panel on the outside of the seat. The label indicates where to cut into the body panel.

STEP 2: Use a 12” circular saw to cut 6 in (152 mm) through the label and into the pillar.

WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

STABILIZING MODEL S

CHOCK ALL FOUR WHEELS

Drivers can choose a setting that determines whether or not Model S will “creep” when a driving gear is selected. If this setting is off, Model S does not move unless the accelerator is pressed, even if shifted into Drive or Reverse. However, never assume that Model S will not move. Always chock the wheels.

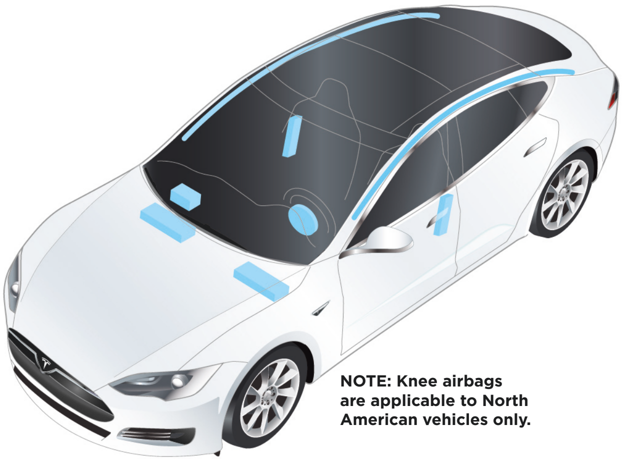
SHIFT INTO PARK

Model S is silent so never assume it is powered off. Pressing the accelerator pedal even slightly can cause Model S to move quickly if the currently active gear is Drive or Reverse. To ensure that the parking brake is engaged, press the button on the end of the gear selector to shift into Park. Whenever Model S is in Park, the parking brake is automatically engaged so that the vehicle will not move if the accelerator pedal is pressed.

WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

AIRBAGS

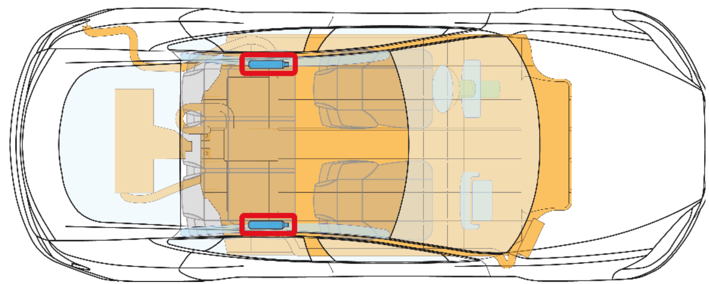
Model S is equipped with six airbags (eight in North America). Responders should de-energize the airbags by cutting the First Responder Cut Loop (see page 11) or Disconnect Point (see page 13). Airbags are shown below in blue.



NOTE: Knee airbags are applicable to North American vehicles only.

AIRBAG INFLATION CYLINDERS

Airbag (stored gas) inflation cylinders are located toward the rear of the vehicle, as shown below in red.

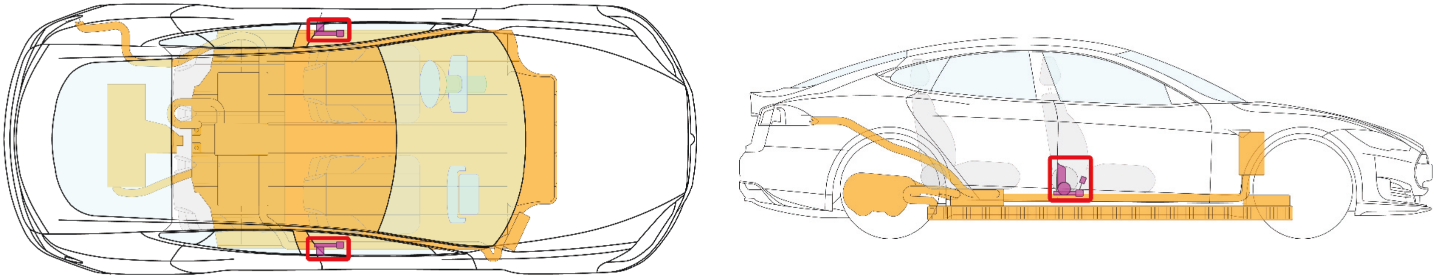


Airbag inflation cylinders are located toward the rear

WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

SEAT BELT PRE-TENSIONERS

Seat belt pre-tensioners are located by the B-pillars, as shown below in red.



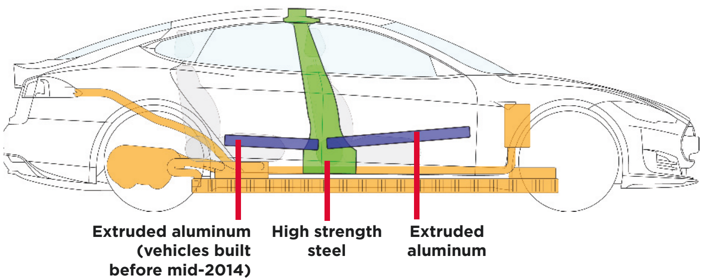
Seat belt pre-tensioners are located by the B-pillars

WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

LOCATION OF REINFORCEMENTS AND HIGH STRENGTH STEEL

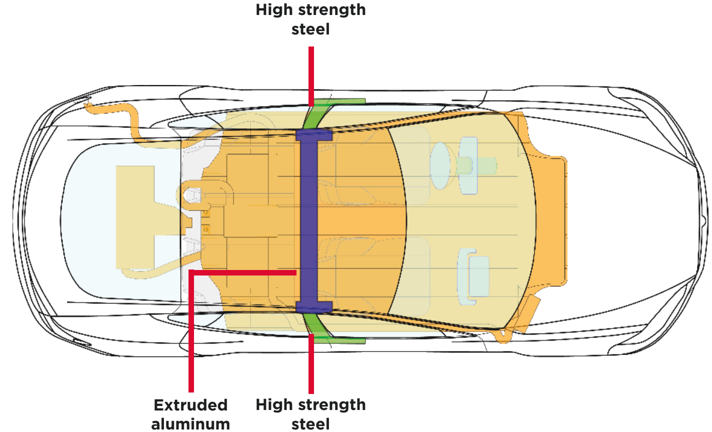
Model S is reinforced to protect occupants in a collision. Reinforcements are shown below in green (high strength steel) and blue (extruded aluminum).

Depending on the tools used, high strength steel can be challenging or impossible to cut. If necessary, use workaround techniques.



Only the side B-pillars are reinforced with high strength steel

The side doors and roof support are reinforced with extruded aluminum

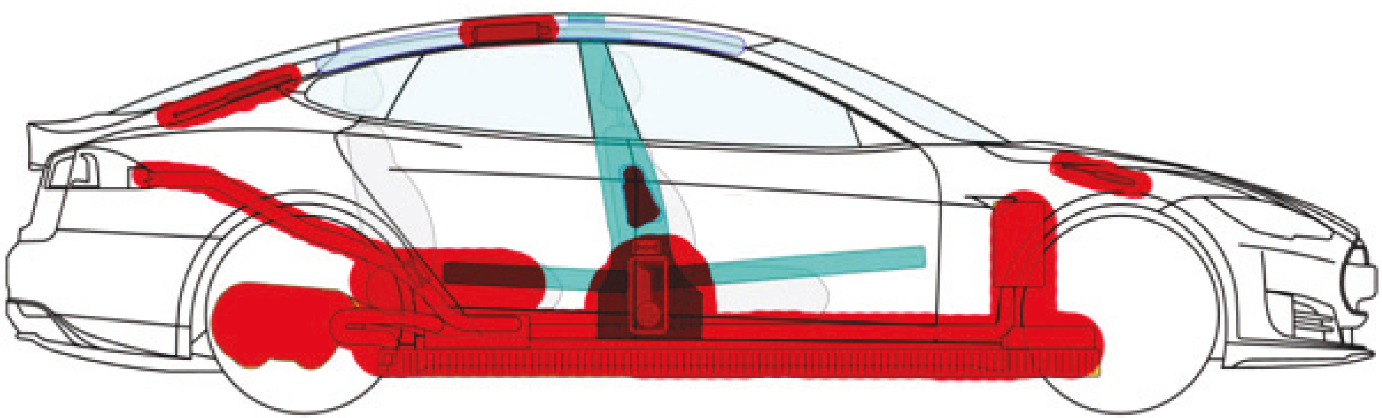


WARNING: Always use appropriate tools (such as a hydraulic cutter), and always wear appropriate personal protective equipment (PPE) when cutting Model S. Failure to follow these instructions can result in serious injury or death.

WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

NO-CUT ZONES

Model S has areas that are defined as "no-cut zones" due to high voltage, gas struts, and SRS or airbag hazards. Never cut or crush these areas—doing so can result in serious injury or death.



Do not cut through areas shown in red

WARNING: Always use appropriate tools (such as a hydraulic cutter), and always wear appropriate personal protective equipment (PPE) when cutting Model S. Failure to follow these instructions can result in serious injury or death.

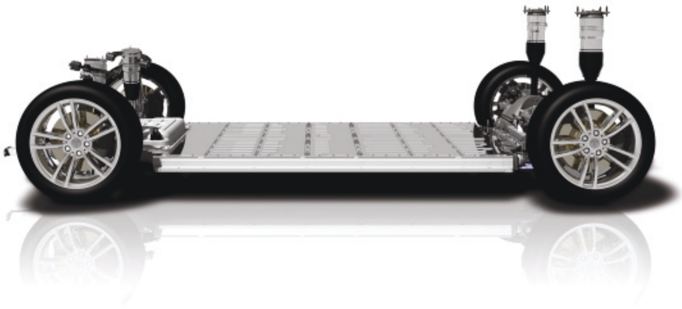
WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

FULLY OR PARTIALLY SUBMERGED VEHICLES

Treat a submerged Model S like any other vehicle. The body of the vehicle does not present a risk of shock in water. However, as a precautionary measure, handle any submerged vehicle while wearing the appropriate personal protective equipment (PPE). Remove the vehicle from the water and continue with normal high voltage disabling.

PUSHING ON THE FLOOR PAN

The high voltage battery is located below the floor pan. Never push down on the floor pan from inside Model S. Doing so can breach the high voltage battery, which can cause serious injury or death.



WARNING: Failure to handle a submerged vehicle without appropriate personal protective equipment (PPE) can result in serious injury or death.

WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

FIREFIGHTING

Extinguish small fires, that do not involve the high voltage battery, using a CO_2 or ABC extinguisher.

During overhaul, do not make contact with any high voltage component. Always use insulated tools for overhaul.

Stored gas inflation cylinders, gas struts, and other components can result in a boiling liquid expanding vapor explosion (BLEVE) in extreme temperatures. Perform an adequate “knock down” on the fire before entering the incident’s “hot zone.”

If the high voltage battery becomes involved in fire or is bent, twisted, damaged, or breached in any way, or if you suspect that the battery is heating, use large amounts of water to cool the battery. DO NOT extinguish fire with a small amount of water. Always establish or request an additional water supply.

Battery fires can take up to 24 hours to fully extinguish. Consider allowing the vehicle to burn while protecting exposures.

Use a thermal imaging camera to ensure the high voltage battery is completely cooled before leaving the incident. If a thermal imaging camera is not available, you must monitor the battery for re-ignition. Smoke indicates that the battery is still heating. Do not release the vehicle to second responders until there has been no sign of smoke from the battery for at least one hour.

Always advise second responders (law enforcement, tow personnel) that there is a risk of the battery re-igniting. After a Model S has been involved in a submersion, fire, or a collision that has compromised the high voltage battery, always store it in an open area with no exposures within 50 feet.

HIGH VOLTAGE BATTERY - FIRE DAMAGE

A burning or heating battery releases toxic vapors. These vapors include sulfuric acid, oxides of carbon, nickel, aluminum, lithium, copper, and cobalt. Responders should wear full personal protective equipment (PPE), including self-contained breathing apparatus (SCBA), and take appropriate measures to protect civilians downwind from the incident. Use fog streams or positive pressure ventilation (PPV) fans to direct vapors.

The high voltage battery consists of lithium-ion cells. These are considered dry cell batteries. If damaged, only a small amount of battery fluid can leak. Lithium-ion battery fluid is clear in color.

The high voltage battery, the drive unit, the charge controllers, and the DC-DC converter are liquid cooled with typical glycol-based coolant. If damaged, blue fluid can leak out of the battery.

A damaged high voltage battery can cause rapid heating of the battery cells. If you notice smoke coming from the battery area, assume the battery is heating and take appropriate action as described under the heading “FIREFIGHTING” on this page.

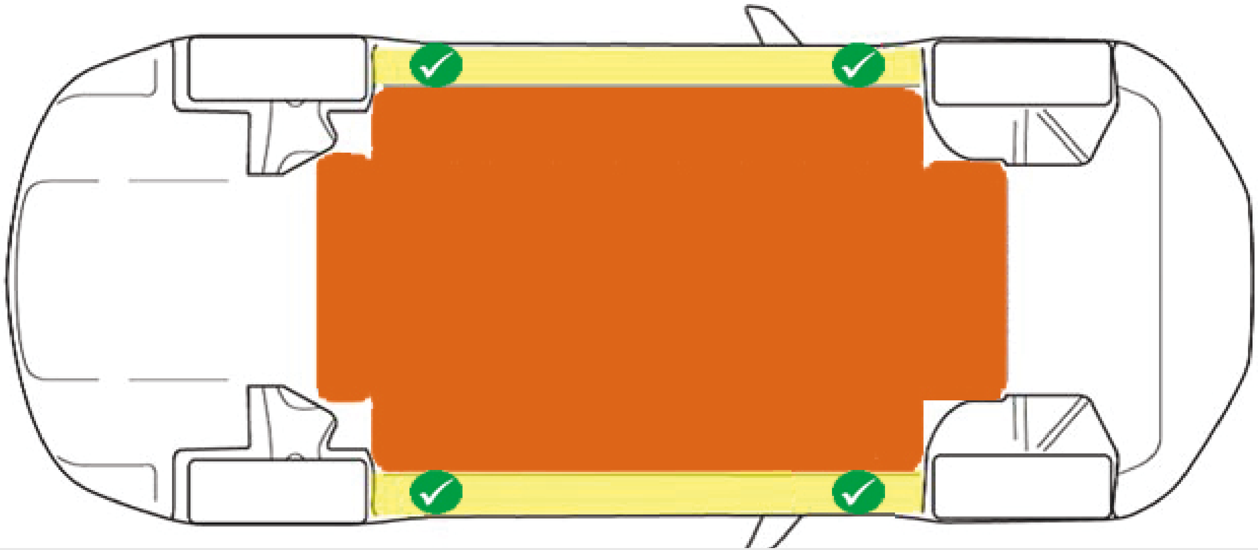
WARNING: When fire is involved, consider the entire vehicle energized and DO NOT TOUCH any part of the vehicle. Always wear full PPE, including SCBA.

WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

LIFT AREAS

The high voltage battery is located below the floor, under a floor pan. A large section of the undercarriage houses this battery. When lifting Model S, do not push on the high voltage battery. When lifting or jacking, use only the designated lifting areas.

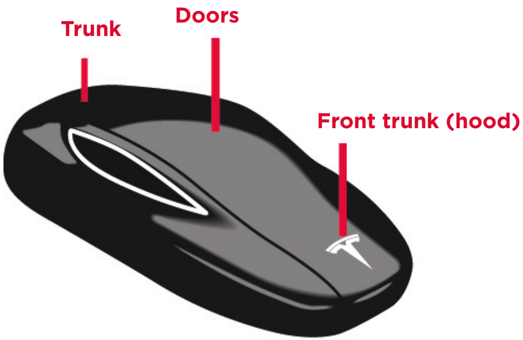
✓	Appropriate lifting locations
Yellow	Safe stabilization points for a side-resting Model S
Orange	High voltage battery. **DO NOT USE THIS AREA TO LIFT OR STABILIZE MODEL S!**



WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

USING THE KEY

Use the key's buttons as shown below.



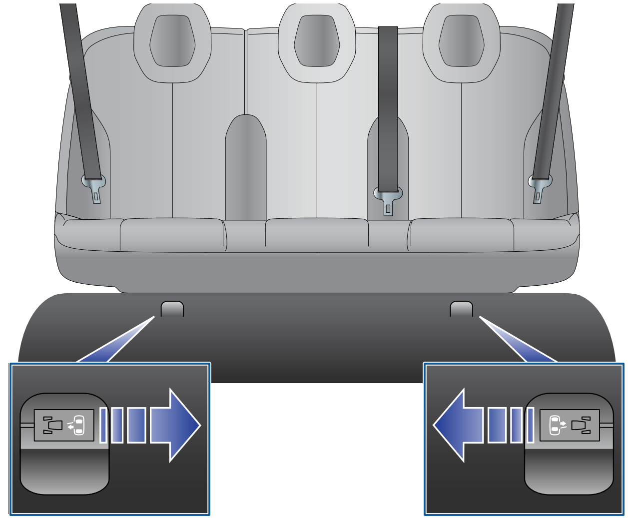
OPENING DOORS

Model S has unique door handles. Under normal conditions, when you press a handle, it extends* to allow you to open the door.

If door handles do not function, open the door manually by reaching inside the window and using the interior handle.

OPENING REAR DOORS WITH NO POWER

Open rear doors from inside by folding back the edge of the carpet below the rear seats to access the mechanical release cable. Pull the mechanical release cable toward the center.

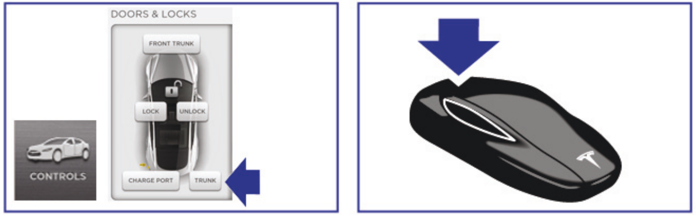


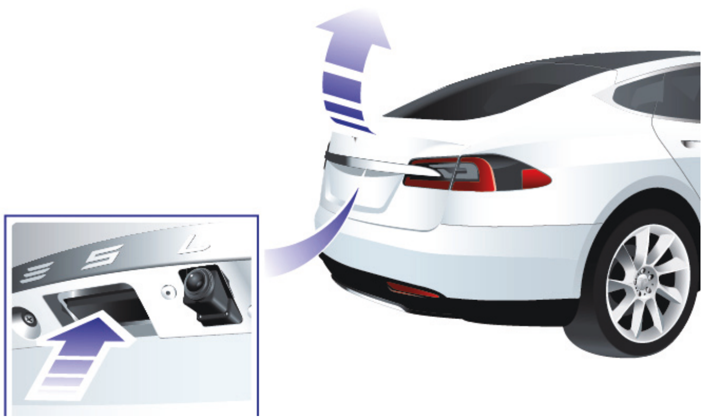
*NOTE: When an airbag inflates, Model S unlocks all doors, unlocks the trunk, and extends all door handles.

OPENING THE TRUNK

Use one of the following methods:

- Press the switch located under the handle.
- Touch Trunk on the touchscreen CONTROLS window.
- Double-click the trunk button on the key.



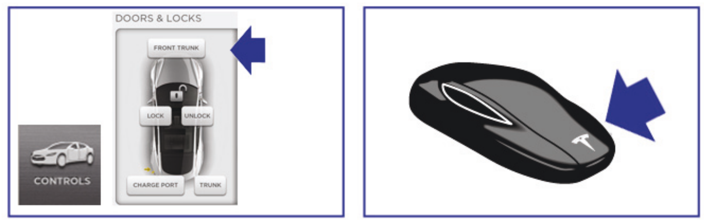


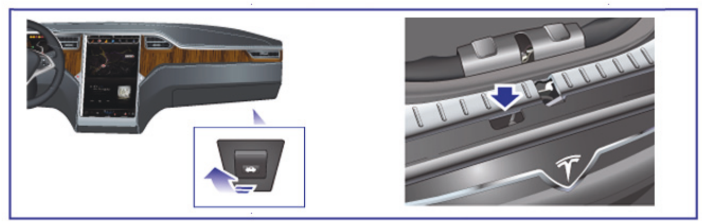
OPENING THE HOOD (FRONT TRUNK)

Model S does not have a traditional engine. Therefore, the area that would normally house the engine is used as additional storage space. Tesla calls this area the “Front Trunk” or “Frunk”.

To open, use one of the following methods:

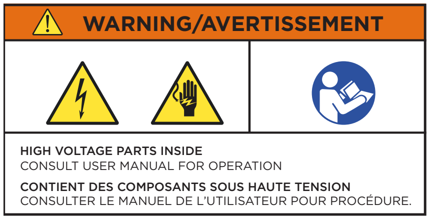
- Touch Front Trunk on the touchscreen.
- Double-click the Front Trunk (hood) button on the key.
- Pull the release handle located under the glove box, then push down on the secondary catch lever. To release the pressure against the secondary catch, you may need to push the hood down slightly.

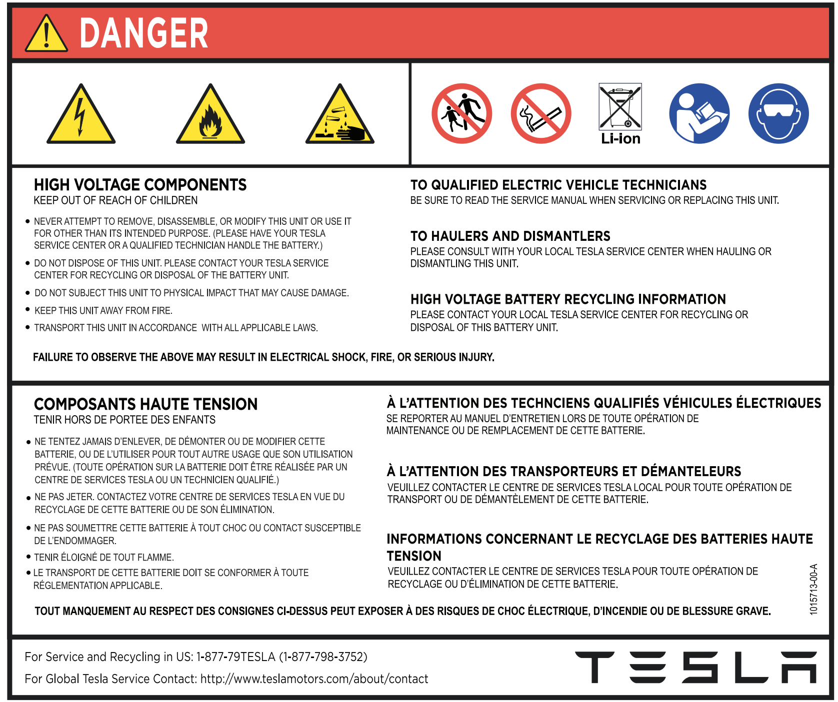




HIGH VOLTAGE LABELS

Vehicle labels associated with high voltage components are shown below. These are examples only. Depending on the region, these labels may be translated into other languages.





WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

TESLA

3500 Deer Creek Road
Palo Alto, CA 94304

APPENDIX C

Pages from
2014-2015 Tesla Model S, Dual Motor
Emergency Response Guide

2014-2015 ALL-WHEEL DRIVE DUAL MOTOR

MODEL S

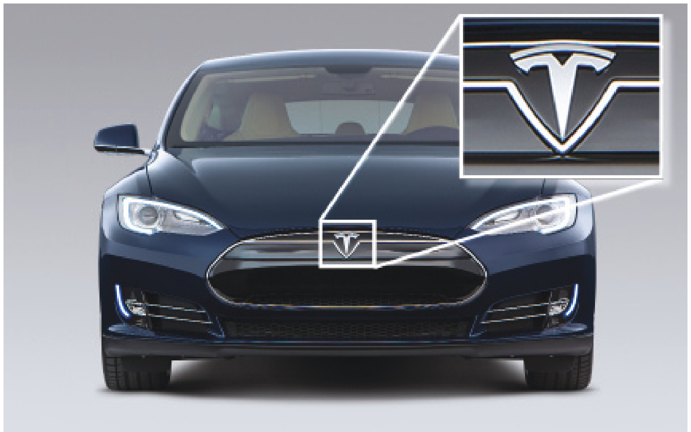
EMERGENCY RESPONSE GUIDE

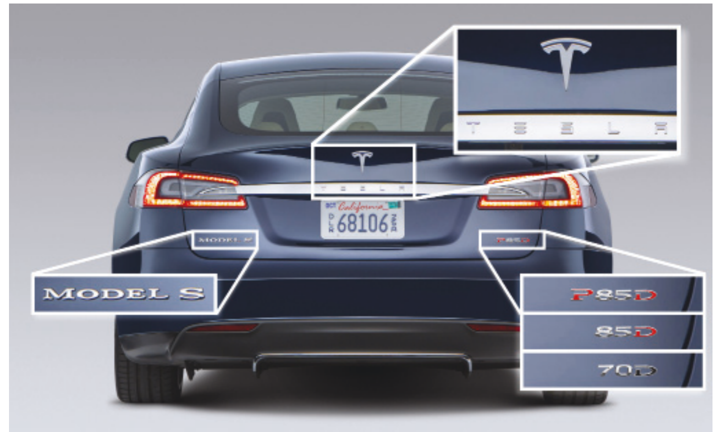
This guide is intended only for use by trained and certified rescuers and first responders. It assumes that readers have a comprehensive understanding of how safety systems work and have completed the appropriate training and certification required to safely handle rescue situations. Therefore, this guide provides only the specific information required to understand and safely handle the fully electric Model S in an emergency situation. It describes how to identify Model S, and provides the locations and descriptions of its high voltage components, airbags, inflation cylinders, seat belt pre-tensioners, and high strength materials used in its body structure. This guide includes the high voltage disabling procedure and any safety considerations specific to Model S. Failure to follow recommended practices or procedures can result in serious injury or death.

The high voltage battery is the main energy source. Model S does not have a traditional gasoline or diesel engine and therefore does not have a fuel tank. The rear motor in dual motor Model S comes in two types: regular and high performance. The images in this guide might not match the vehicle you are working on.

BADGING

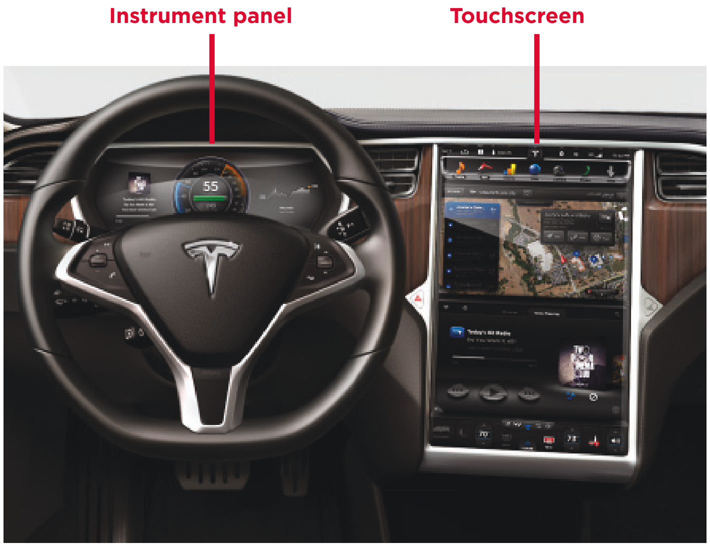
Dual motor Model S has four main badges to distinguish it.





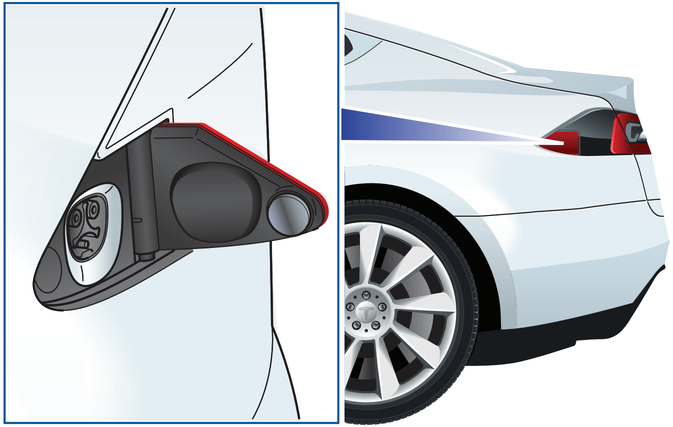
LARGE SCREEN

Model S has a large 17" touchscreen.



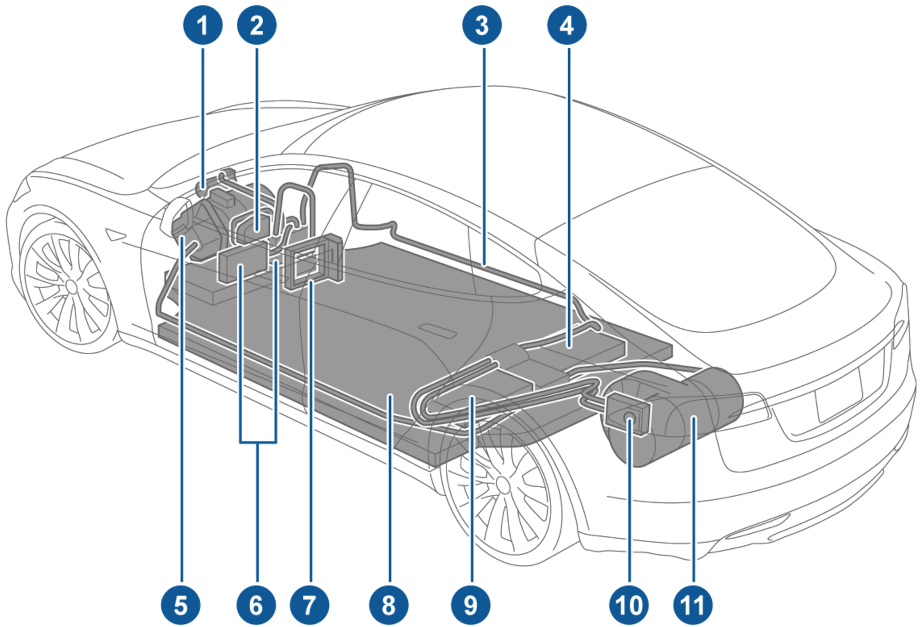
CHARGE PORT

Model S has a charge port that is integrated into the taillight on the rear left side fender.



OVERVIEW OF HIGH VOLTAGE COMPONENTS

1. A/C compressor
2. Battery coolant heater
3. High voltage cabling (colored orange)
4. 10 kW on-board master charger
5. Front motor
6. DC-DC converter and front junction box
7. Cabin heater
8. High Voltage Battery
9. OPTIONAL: 10 kW on-board slave charger
10. Charge port
11. Rear motor/rear high performace motor



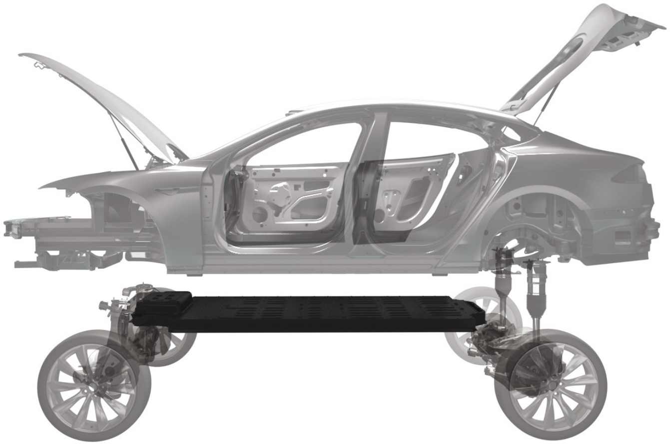
WARNING: After deactivation, the high voltage circuit requires two minutes to deplete.

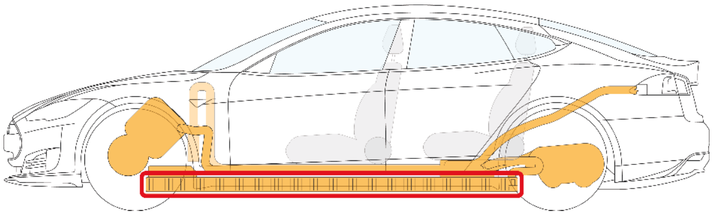
WARNING: The SRS control unit has a backup power supply with a discharge time of approximately ten seconds.

WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

HIGH VOLTAGE BATTERY

Model S is equipped with a floor-mounted 400 volt lithium-ion high voltage battery. Never breach the high voltage battery when lifting from under the vehicle. When using rescue tools, pay special attention to ensure that you do not breach the floor pan.



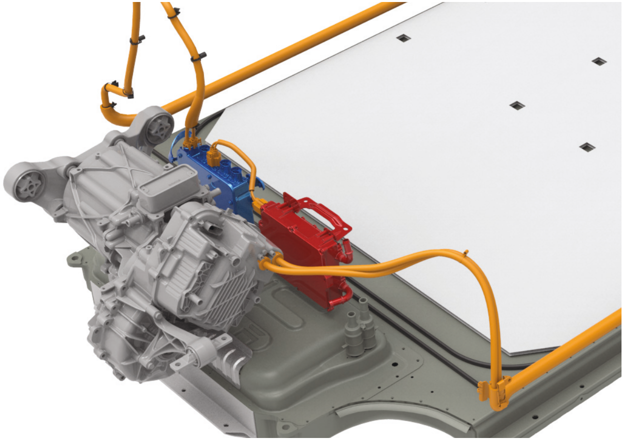


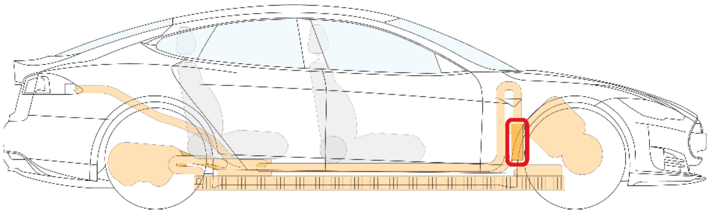
High voltage battery is located below the floor

WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

DC-DC CONVERTER AND FRONT JUNCTION BOX

High voltage is present at the DC-DC converter and front junction box, located behind the front motor. The DC-DC converter transforms the high voltage current from the 400 volt battery to low voltage to charge the Model S 12 volt battery. The front junction box provides power to various components, such as the Battery heater, the air conditioning compressor and the cabin heater. Use caution when cutting in this area during a dash lift (dash roll) procedure—use work-around techniques, if necessary.



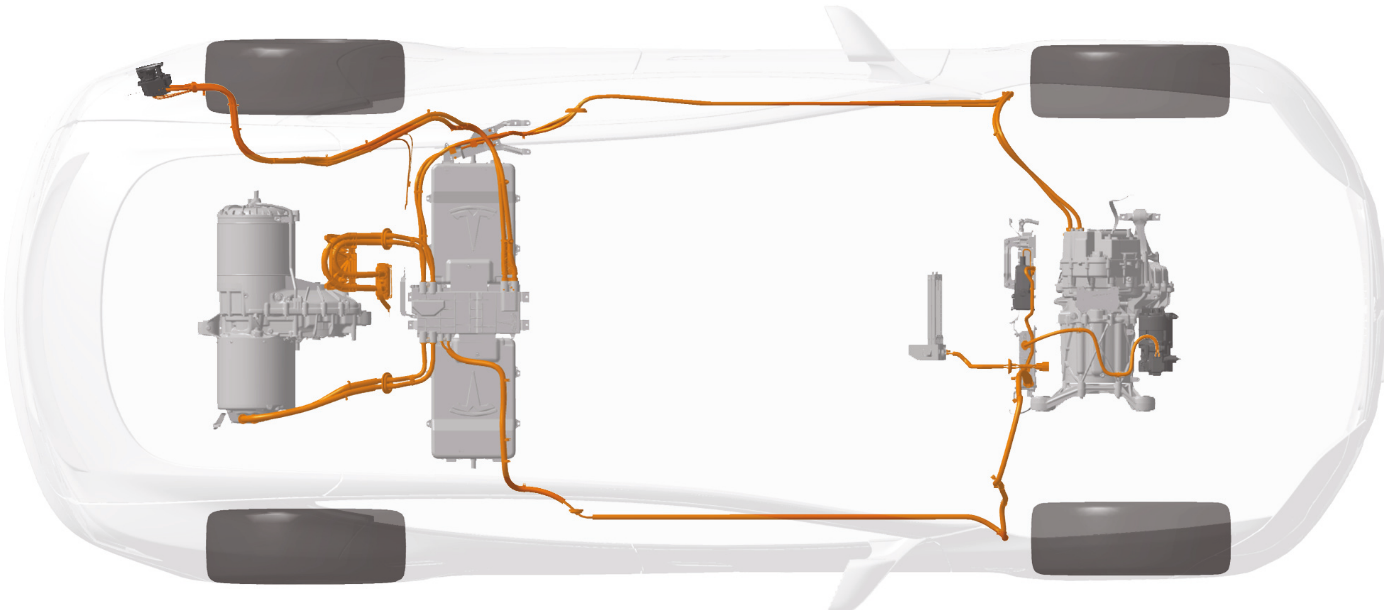


DC-DC converter and front junction box are located behind the front trunk, near the center of the vehicle

WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

HIGH VOLTAGE CABLING

High voltage cabling is highlighted in dark orange in the following illustration.

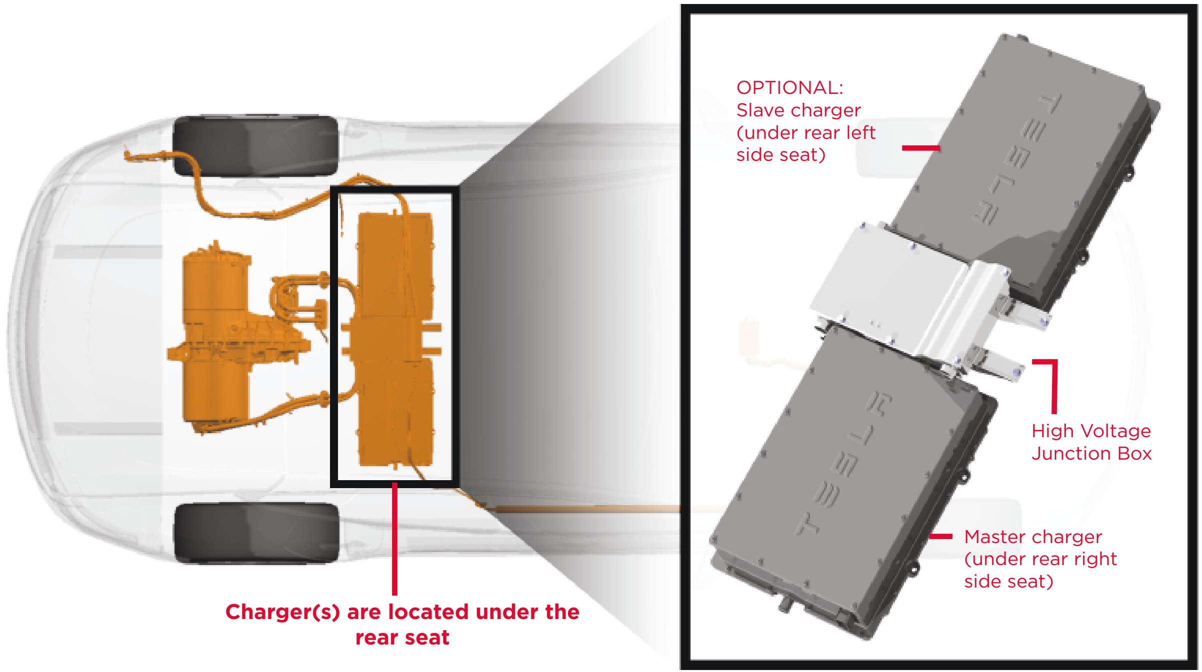


High voltage cabling is routed under the rear seats and inside the rocker panel on the left and right side front

WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

CHARGERS

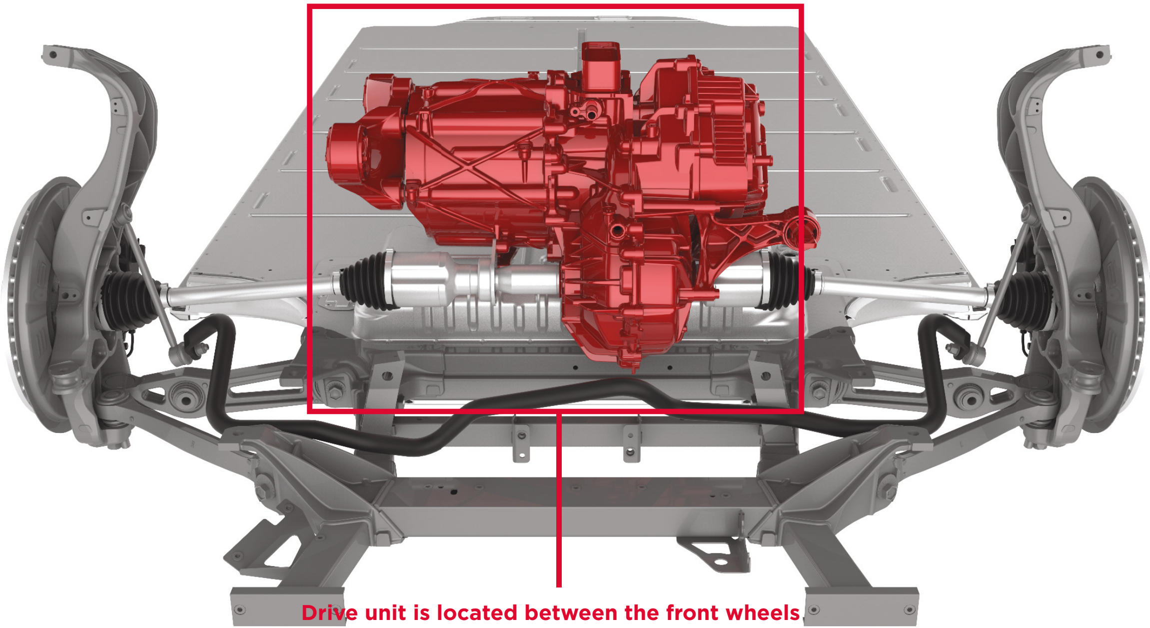
Model S has one (standard) or two (optional) chargers under the rear seat. These chargers convert the AC current from a charging station to DC for charging the high voltage battery. The high voltage junction box, located between the chargers, routes any surplus energy from regenerative braking back to the battery.



WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

FRONT DRIVE UNIT

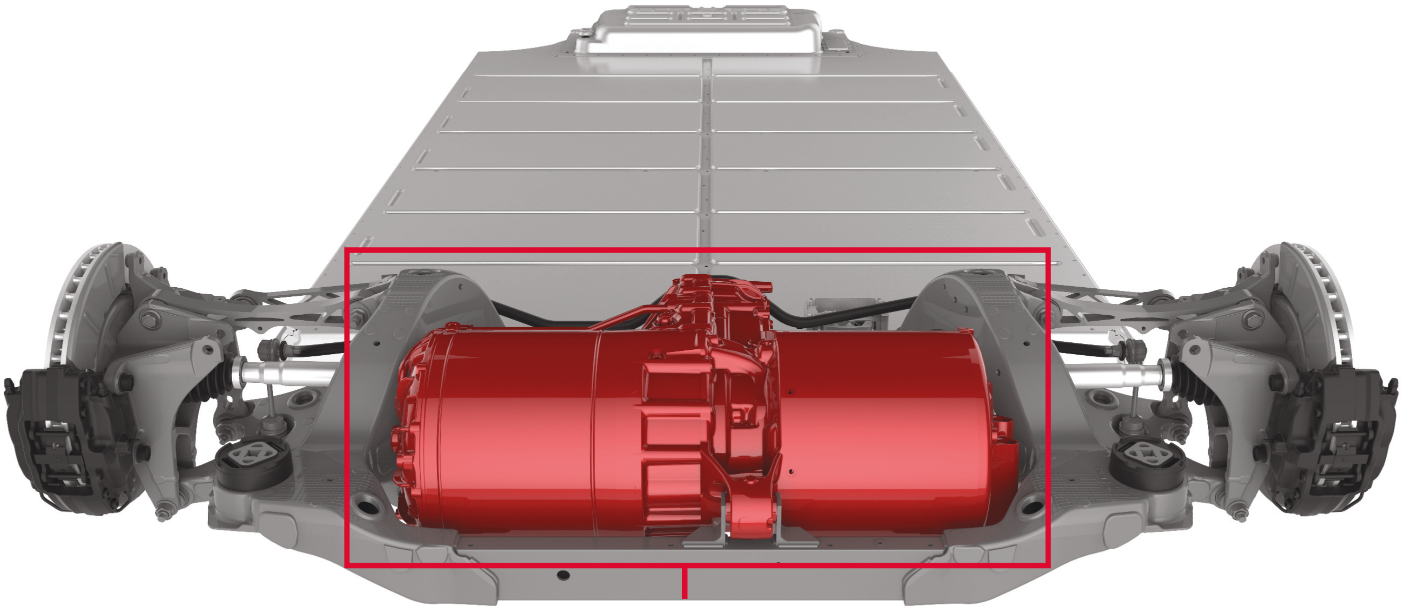
The front drive unit is located between the front wheels in front of the dash panel of the Model S. It converts the DC current from the high voltage battery into the 3-phase AC current that the electric motor uses to power the front wheels.



WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

REAR DRIVE UNIT

The rear drive unit is located between the rear wheels under the floor pan of the Model S (high performance drive unit shown below). It converts the DC current from the high voltage battery into the 3-phase AC current that the electric motor uses to power the rear wheels.



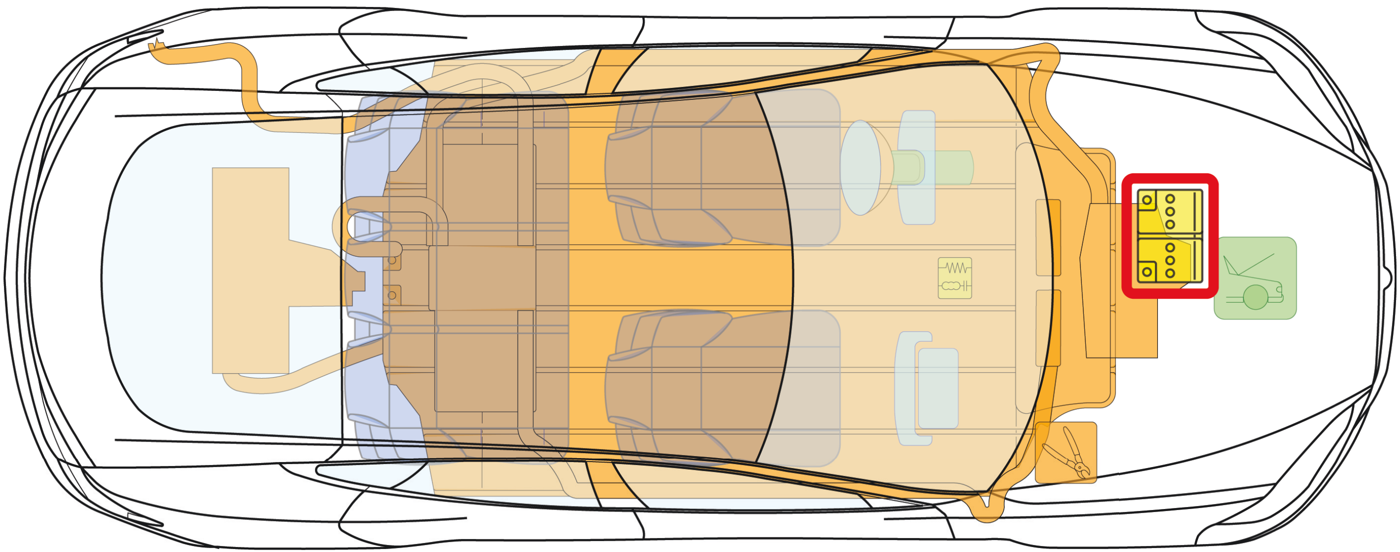
Drive unit is located between the rear wheels

WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

12V BATTERY

In addition to the high voltage system, Model S has a low voltage system, powered by a traditional 12 volt battery. The low voltage system operates the same electrical components found in conventional vehicles, including the supplementary restraint system (SRS), airbags, ignition, touchscreen, and interior and exterior lights.

The low voltage system interacts with the high voltage system. The DC-DC converter supplies the 12V battery with power to support low voltage functions, and the 12V battery supplies power to the high voltage contacts to allow power to flow out of the high voltage battery.



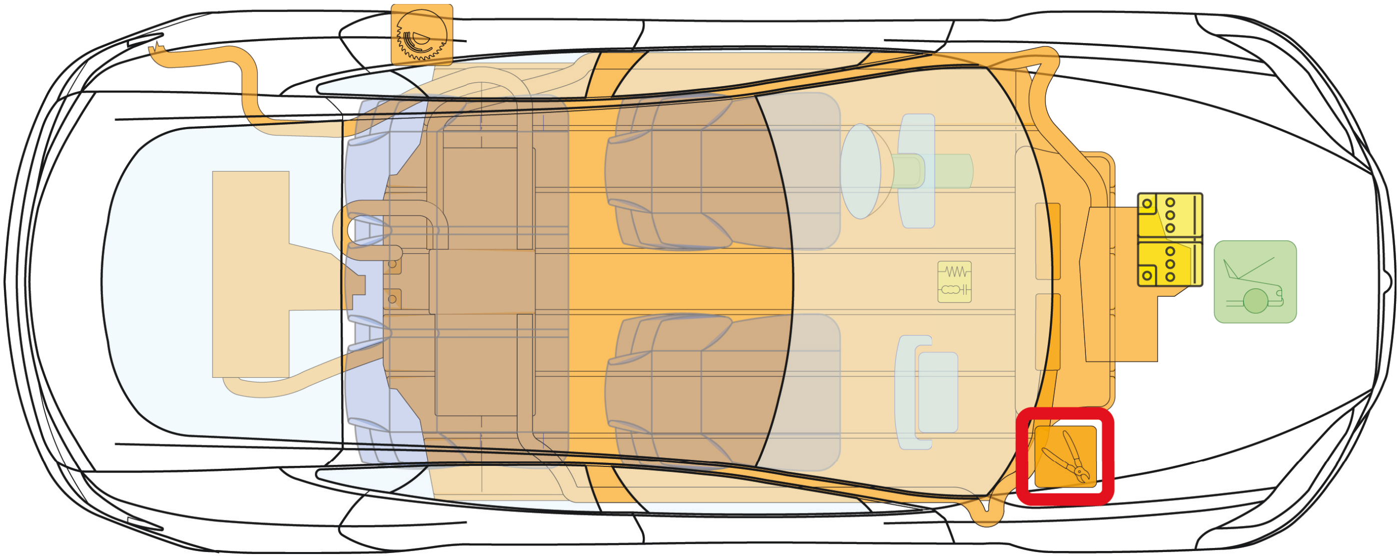
12V battery is located under the hood and the plastic access panel

WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

FIRST RESPONDER CUT LOOP - FRONT TRUNK

The front trunk first responder cut loop consists of low voltage wires. Cutting this loop shuts down the high voltage system and disables the SRS and airbag components. See cut instructions on page 11.

NOTE: When cutting the loop, double cut to remove an entire section. This eliminates the risk of the cut wires accidentally reconnecting.



The front trunk cut loop is located on the right side, under the hood and the plastic access panel

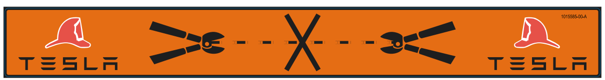
WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

CUTTING THE FIRST RESPONDER CUT LOOP - FRONT TRUNK

STEP 1: Open the hood (also known as the Front Trunk). See page 23 for details.

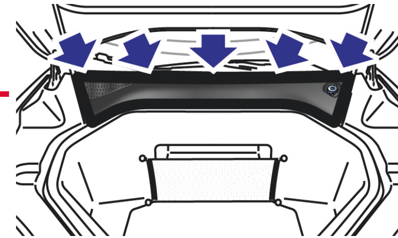
The cut loop is located on the right side. Its label protrudes from under the plastic access panel.

Cut loop label



STEP 2: Remove the access panel by pulling its rear edge upward to release the five clips that hold it in place. Maneuver it toward the windshield to remove.

Remove access panel



STEP 3: **DOUBLE CUT** the loop to remove an entire section.

Removing an entire section of the cut loop eliminates the risk of the wires accidentally touching (reconnecting).

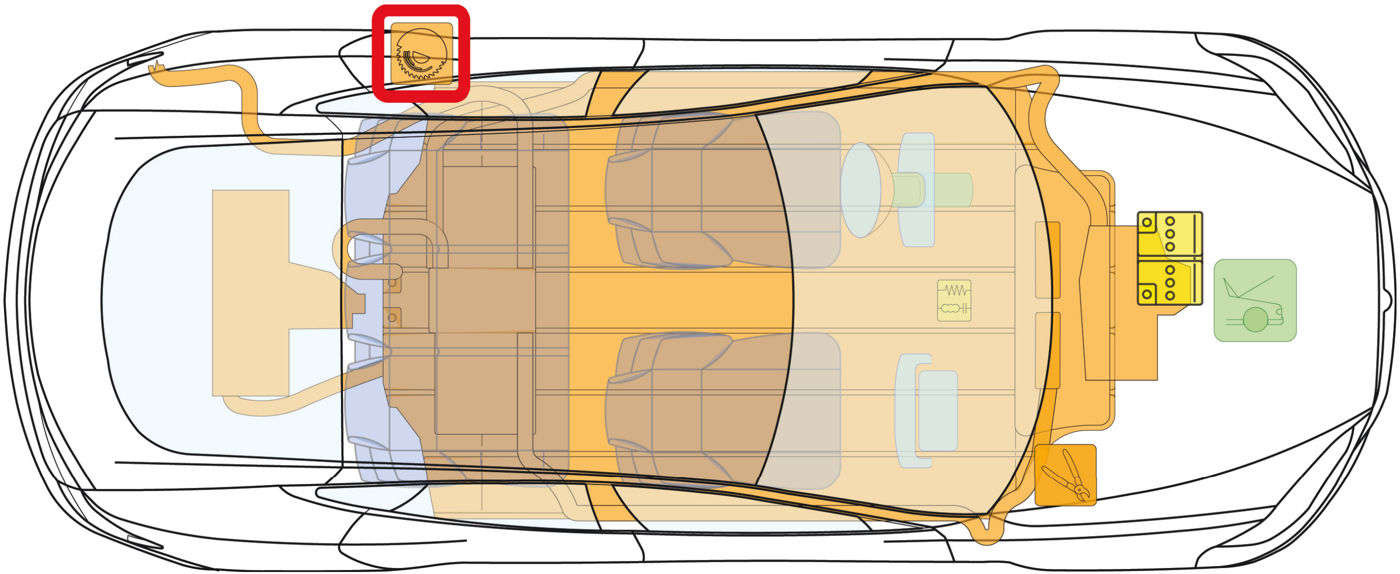
Double cut the loop

WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

FIRST RESPONDER DISCONNECT POINT - REAR PILLAR

If the front trunk cut loop is inaccessible, the rear pillar disconnect point can shut down the high voltage system and disable the SRS and airbag components in the same manner as the front trunk cut loop. See cut instructions on page 14.

NOTE: Only one point needs to be disconnected, not both.



WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

CUTTING THE FIRST RESPONDER DISCONNECT POINT - REAR PILLAR

STEP 1: Open the rear passenger door closest to the charge port.

The disconnect point is located under the body panel on the outside of the seat. The label indicates where to cut into the body panel.

STEP 2: Use a 12” circular saw to cut 6 in (152 mm) through the label and into the pillar.

Cut loop label

WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

STABILIZING MODEL S

CHOCK ALL FOUR WHEELS

Drivers can choose a setting that determines whether or not Model S will “creep” when a driving gear is selected. If this setting is off, Model S does not move unless the accelerator is pressed, even if shifted into Drive or Reverse. However, never assume that Model S will not move. Always chock the wheels.

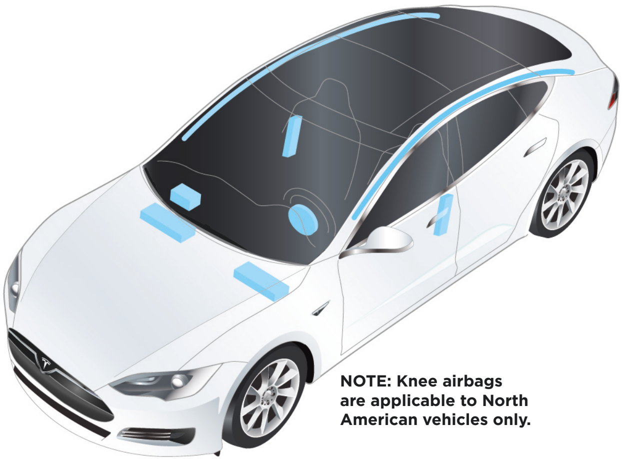
SHIFT INTO PARK

Model S is silent so never assume it is powered off. Pressing the accelerator pedal even slightly can cause Model S to move quickly if the currently active gear is Drive or Reverse. To ensure that the parking brake is engaged, press the button on the end of the gear selector to shift into Park. Whenever Model S is in Park, the parking brake is automatically engaged so that the vehicle will not move if the accelerator pedal is pressed.

WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

AIRBAGS

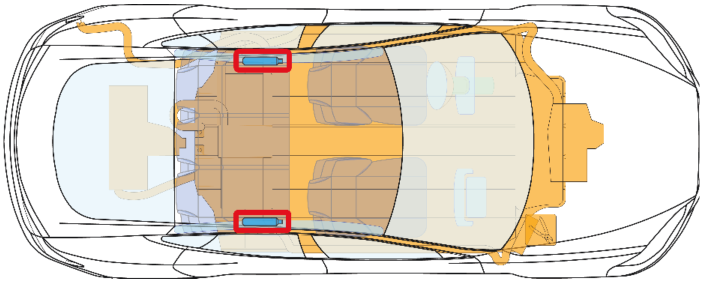
Model S is equipped with six airbags (eight in North America). Responders should de-energize the airbags by cutting the First Responder Cut Loop (see page 11) or Disconnect Point (see page 13). Airbags are shown below in blue.



NOTE: Knee airbags are applicable to North American vehicles only.

AIRBAG INFLATION CYLINDERS

Airbag (stored gas) inflation cylinders are located toward the rear of the vehicle, as shown below in red.

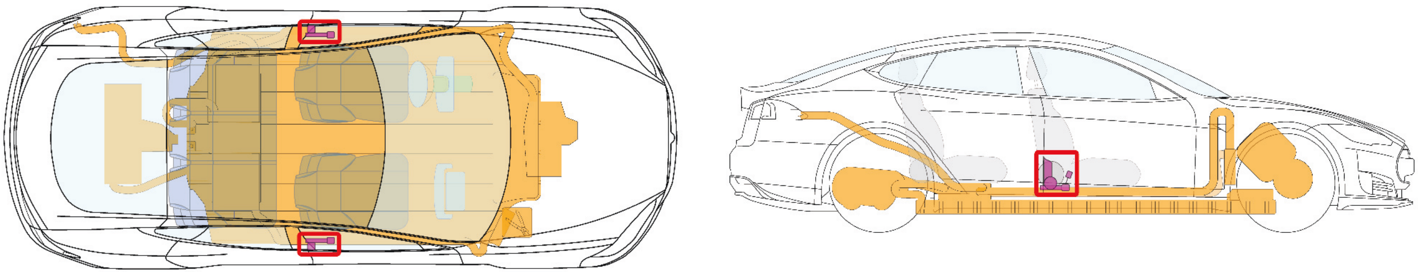


Airbag inflation cylinders are located toward the rear

WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

SEAT BELT PRE-TENSIONERS

Seat belt pre-tensioners are located by the B-pillars, as shown below in red.



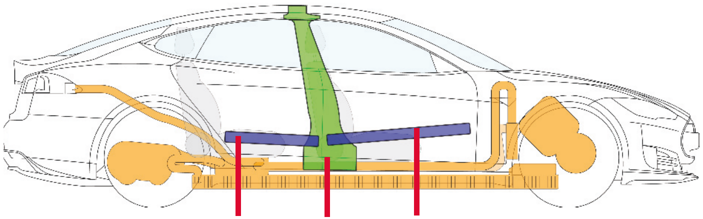
Seat belt pre-tensioners are located by the B-pillars

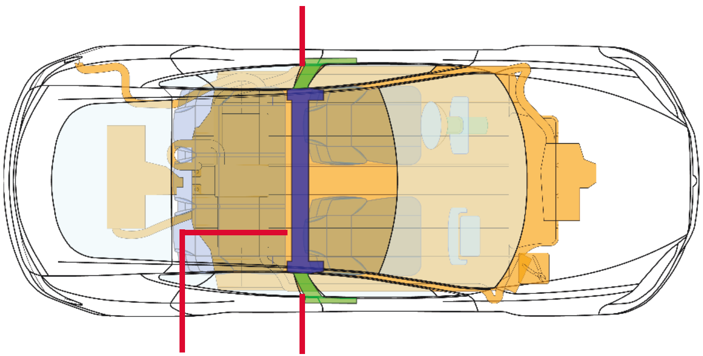
WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

LOCATION OF REINFORCEMENTS AND HIGH STRENGTH STEEL

Model S is reinforced to protect occupants in a collision. Reinforcements are shown below in green (high strength steel) and blue (extruded aluminum).

Depending on the tools used, high strength steel can be challenging or impossible to cut. If necessary, use workaround techniques.





Only the side B-pillars are reinforced with high strength steel

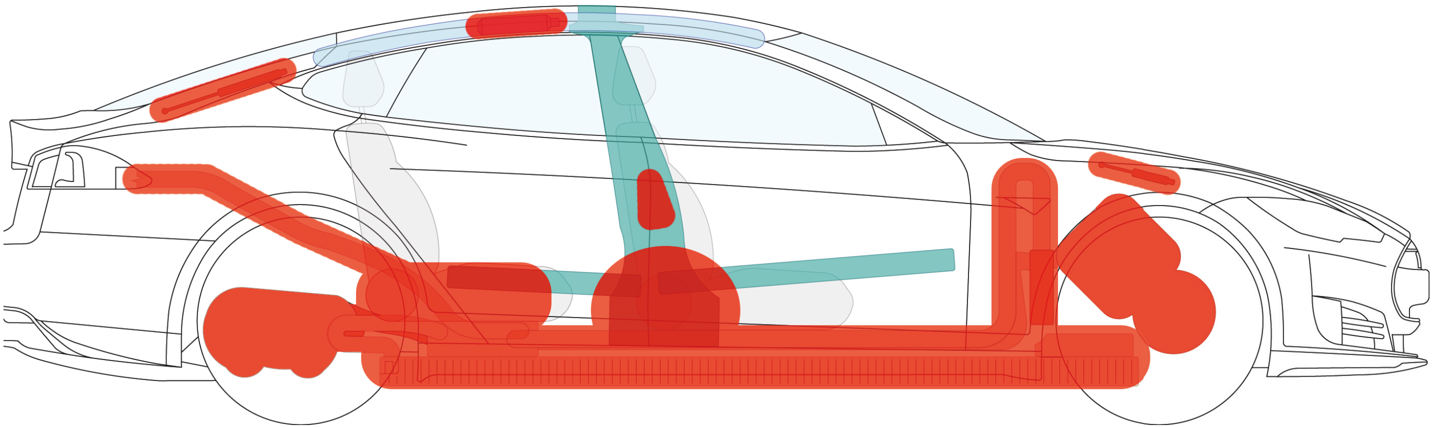
The side doors and roof support are reinforced with extruded aluminum

WARNING: Always use appropriate tools (such as a hydraulic cutter), and always wear appropriate personal protective equipment (PPE) when cutting Model S. Failure to follow these instructions can result in serious injury or death.

WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

NO-CUT ZONES

Model S has areas that are defined as “no-cut zones” due to high voltage, gas struts, and SRS or airbag hazards. Never cut or crush these areas—doing so can result in serious injury or death.



Do not cut through areas shown in red

WARNING: Always use appropriate tools (such as a hydraulic cutter), and always wear appropriate personal protective equipment (PPE) when cutting Model S. Failure to follow these instructions can result in serious injury or death.

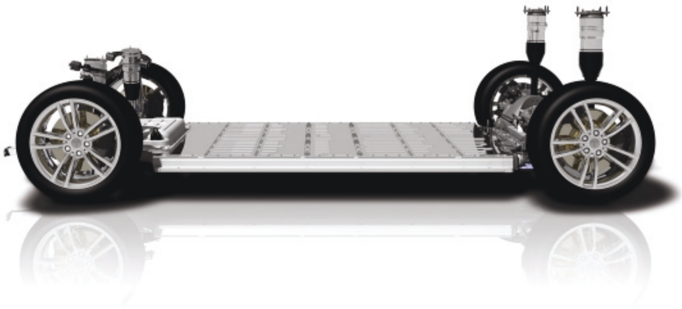
WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

FULLY OR PARTIALLY SUBMERGED VEHICLES

Treat a submerged Model S like any other vehicle. The body of the vehicle does not present a risk of shock in water. However, as a precautionary measure, handle any submerged vehicle while wearing the appropriate personal protective equipment (PPE). Remove the vehicle from the water and continue with normal high voltage disabling.

PUSHING ON THE FLOOR PAN

The high voltage battery is located below the floor pan. Never push down on the floor pan from inside Model S. Doing so can breach the high voltage battery, which can cause serious injury or death.



WARNING: Failure to handle a submerged vehicle without appropriate personal protective equipment (PPE) can result in serious injury or death.

WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

FIREFIGHTING

Extinguish small fires, that do not involve the high voltage battery, using a CO_2 or ABC extinguisher.

During overhaul, do not make contact with any high voltage component. Always use insulated tools for overhaul.

Stored gas inflation cylinders, gas struts, and other components can result in a boiling liquid expanding vapor explosion (BLEVE) in extreme temperatures. Perform an adequate "knock down" on the fire before entering the incident's "hot zone."

If the high voltage battery becomes involved in fire or is bent, twisted, damaged, or breached in any way, or if you suspect that the battery is heating, use large amounts of water to cool the battery. DO NOT extinguish fire with a small amount of water. Always establish or request an additional water supply.

Battery fires can take up to 24 hours to fully extinguish. Consider allowing the vehicle to burn while protecting exposures.

Use a thermal imaging camera to ensure the high voltage battery is completely cooled before leaving the incident. If a thermal imaging camera is not available, you must monitor the battery for re-ignition. Smoke indicates that the battery is still heating. Do not release the vehicle to second responders until there has been no sign of smoke from the battery for at least one hour.

Always advise second responders (law enforcement, tow personnel) that there is a risk of the battery re-igniting. After a Model S has been involved in a submersion, fire, or a collision that has compromised the high voltage battery, always store it in an open area with no exposures within 50 feet.

HIGH VOLTAGE BATTERY - FIRE DAMAGE

A burning or heating battery releases toxic vapors. These vapors include sulfuric acid, oxides of carbon, nickel, aluminum, lithium, copper, and cobalt. Responders should wear full personal protective equipment (PPE), including self-contained breathing apparatus (SCBA), and take appropriate measures to protect civilians downwind from the incident. Use fog streams or positive pressure ventilation (PPV) fans to direct vapors.

The high voltage battery consists of lithium-ion cells. These are considered dry cell batteries. If damaged, only a small amount of battery fluid can leak. Lithium-ion battery fluid is clear in color.

The high voltage battery, the drive unit, the charge controllers, and the DC-DC converter are liquid cooled with typical glycol-based coolant. If damaged, blue fluid can leak out of the battery.

A damaged high voltage battery can cause rapid heating of the battery cells. If you notice smoke coming from the battery area, assume the battery is heating and take appropriate action as described under the heading "FIREFIGHTING" on this page.

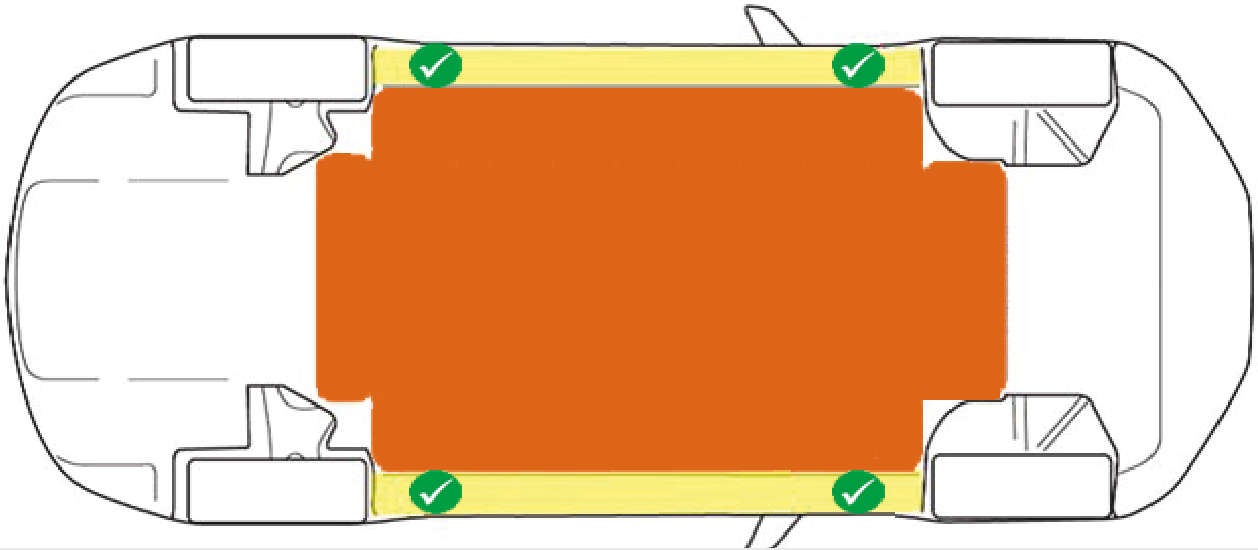
WARNING: When fire is involved, consider the entire vehicle energized and DO NOT TOUCH any part of the vehicle. Always wear full PPE, including SCBA.

WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

LIFT AREAS

The high voltage battery is located below the floor, under a floor pan. A large section of the undercarriage houses this battery. When lifting Model S, do not push on the high voltage battery. When lifting or jacking, use only the designated lifting areas.

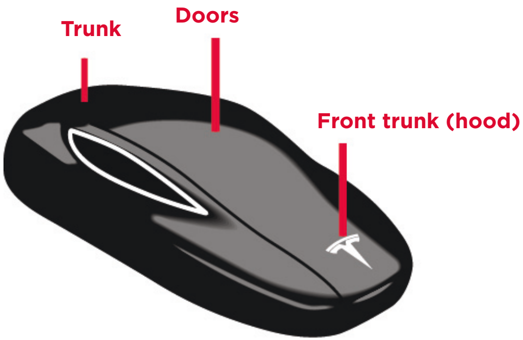
✓	Appropriate lifting locations
Yellow	Safe stabilization points for a side-resting Model S
Orange	High voltage battery. **DO NOT USE THIS AREA TO LIFT OR STABILIZE MODEL S!**



WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

USING THE KEY

Use the key's buttons as shown below.



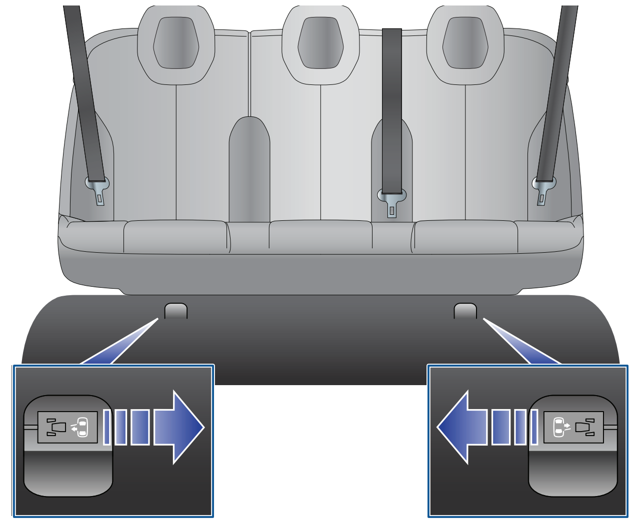
OPENING DOORS

Model S has unique door handles. Under normal conditions, when you press a handle, it extends* to allow you to open the door.

If door handles do not function, open the door manually by reaching inside the window and using the interior handle.

OPENING REAR DOORS WITH NO POWER

Open rear doors from inside by folding back the edge of the carpet below the rear seats to access the mechanical release cable. Pull the mechanical release cable toward the center.

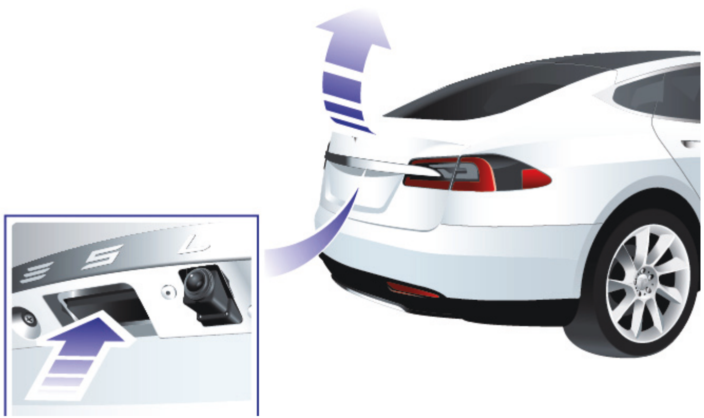


*NOTE: When an airbag inflates, Model S unlocks all doors, unlocks the trunk, and extends all door handles.

OPENING THE TRUNK

Use one of the following methods:

- Press the switch located under the handle.
- Touch Trunk on the touchscreen CONTROLS window.
- Double-click the trunk button on the key.



OPENING THE HOOD (FRONT TRUNK)

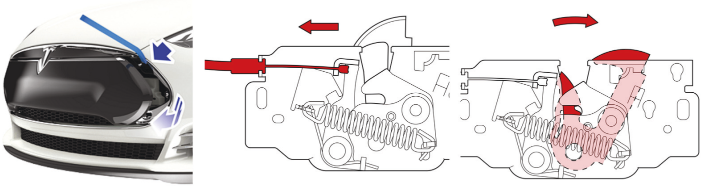
Model S does not have a traditional engine. Therefore, the area that would normally house the engine is used as additional storage space. Tesla calls this area the “Front Trunk” or “Frunk”.

To open the hood electronically, use one of the following methods:

- Touch Front Trunk on the touchscreen.
- Double-click the Front Trunk (hood) button on the key.

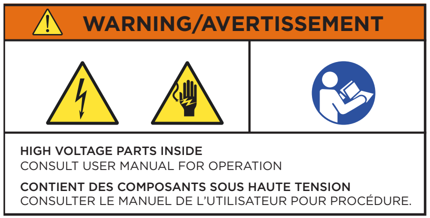
To open the hood manually, perform the following steps:

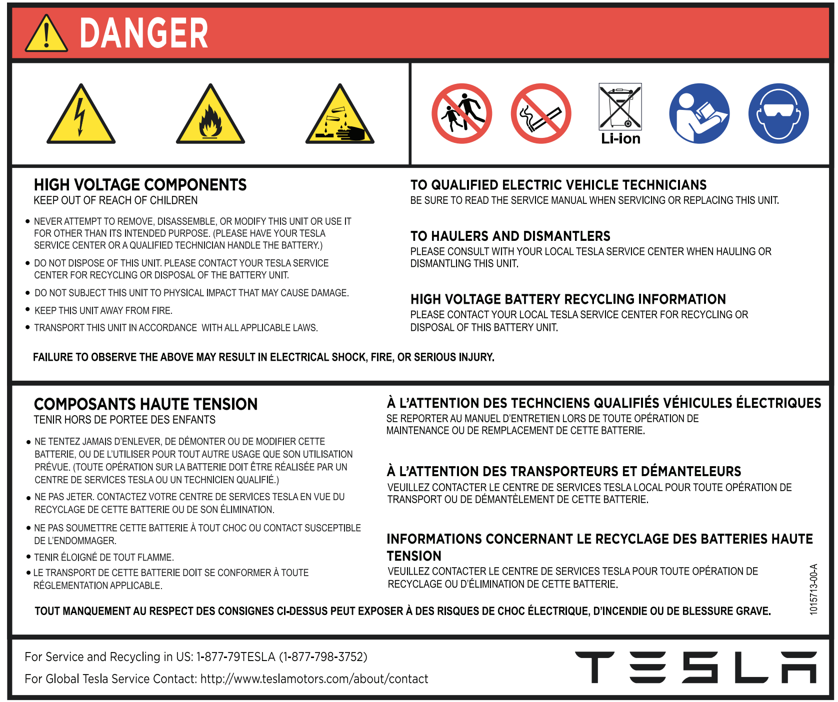
1. Pry the nose cone toward you using a plastic pry tool in the top right corner.
   NOTE: A cable is connected to the rear of the nose cone.
2. Pull the primary release lever under the front middle of the hood to the left.
3. Push the secondary release lever under the front middle of the hood to the right and push up on the hood to open it.



HIGH VOLTAGE LABELS

Vehicle labels associated with high voltage components are shown below. These are examples only. Depending on the region, these labels may be translated into other languages.





WARNING: Regardless of the disabling procedure you use, ALWAYS ASSUME THAT ALL HIGH VOLTAGE COMPONENTS ARE ENERGIZED! Cutting, crushing or touching high voltage components can result in serious injury or death.

TESLA

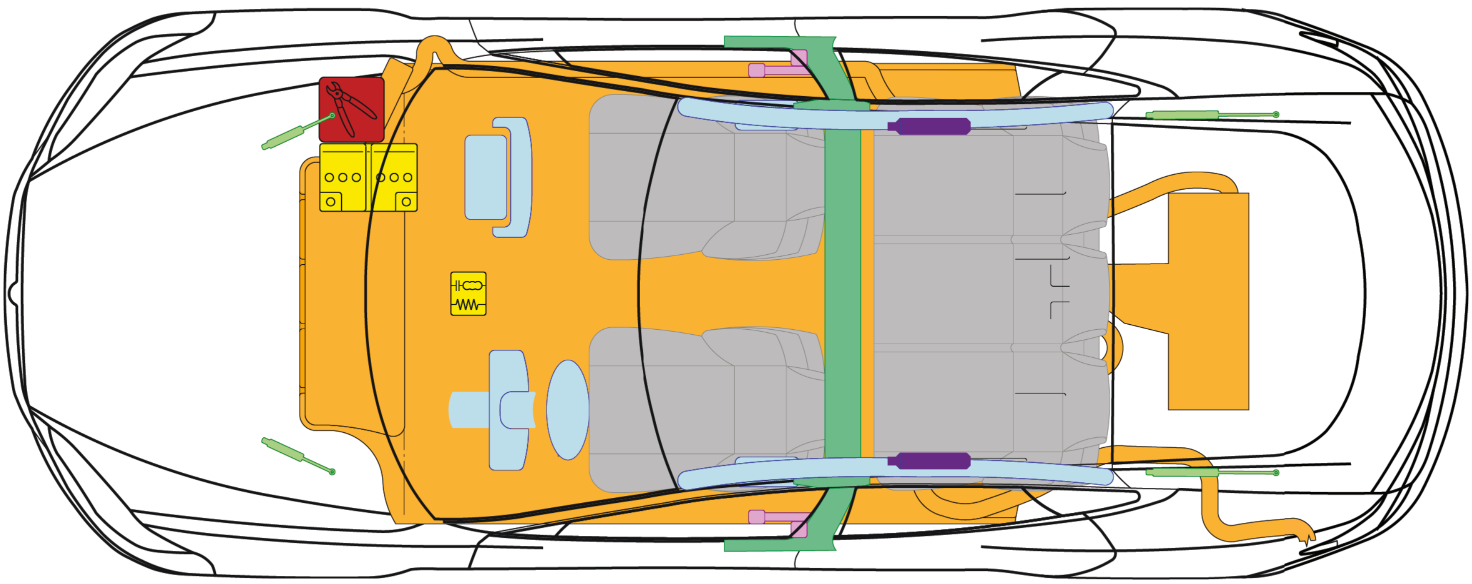
3500 Deer Creek Road
Palo Alto, CA 94304

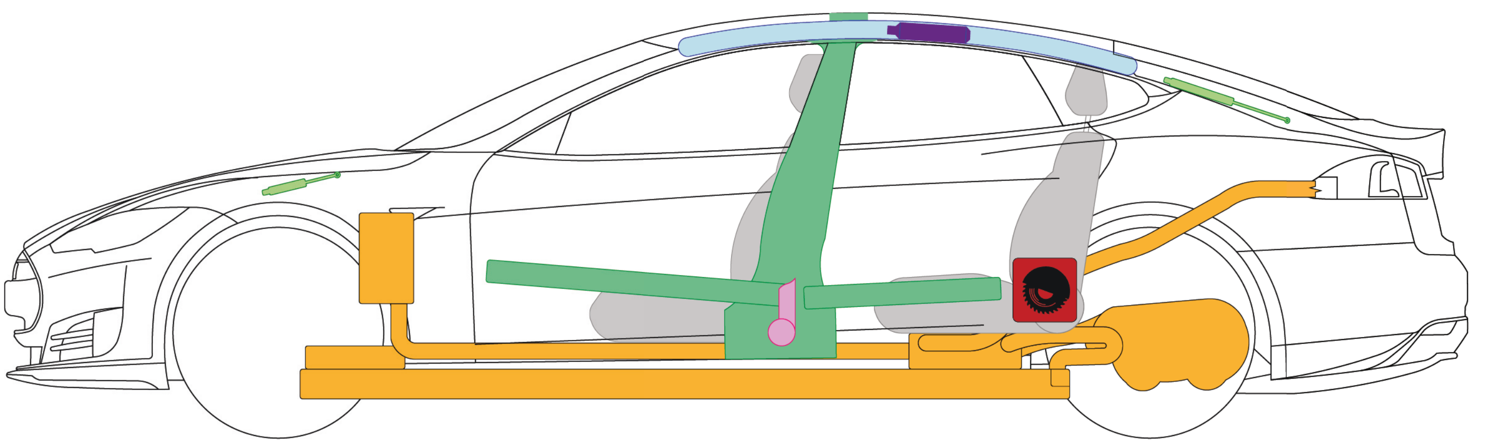
APPENDIX D

2012-2015 Tesla Model S,
Emergency Response Sheet

Model S

2012 - 2013





Legend

- Stored Gas Inflator
- Pressured Gas Cylinder
- HV Cables & Battery
- 12V Battery
- Emergency Disconnect
- Airbags
- SRS Control Unit
- Seat Belt Pre-tensioner
- Reinforcement

GENERAL INSTRUCTIONS

- Always assume the vehicle is powered, even if it is silent!
- Never touch, cut, or open any orange high voltage cable or high voltage component.
- Do not damage the battery pack, even if the propulsion system is deactivated.
- In the event of a collision with pre-tensioner or airbag deployment, the high voltage system should automatically disable.

⚠ WARNING: After deactivation, the high voltage circuit requires two minutes to deplete.

⚠ WARNING: The SRS control unit has a backup power supply with a discharge time of approximately ten seconds.

IMMOBILIZE THE VEHICLE

STEP 1: Chock the wheels.

STEP 2: Set the Parking Brake by pushing in the button on the end of the gearshift stalk.

DEACTIVATE THE VEHICLE

The cut loop is located under the hood on the right side of the vehicle.

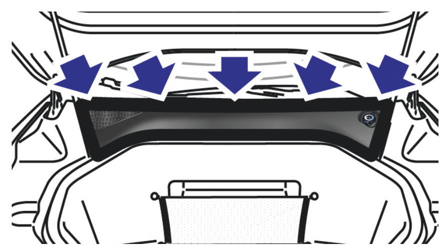
STEP 1: Open the hood using one of these methods:

- Double-click the Front Trunk (hood) button on the key.
- Touch Front Trunk on the touchscreen.
- Pull the release handle located under the glove box, then push down on the secondary catch lever. To release the pressure against the secondary catch, you may need to push the hood down slightly.

3 ways to open the hood

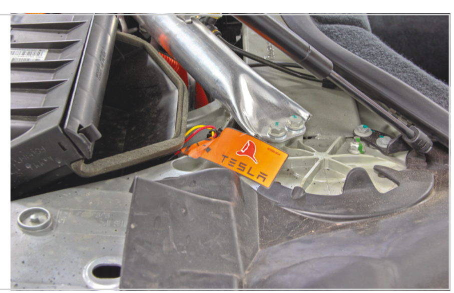
STEP 2: Remove the access panel (cowl screen) by pulling its rear edge upward to release the five clips that hold it in place.

Remove access panel



STEP 3: Double cut a section out of the loop so that the ends cannot reconnect.

Double cut the loop

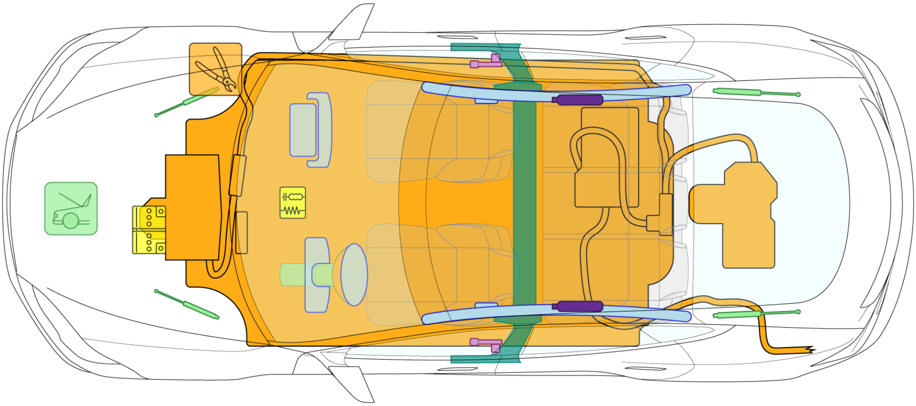


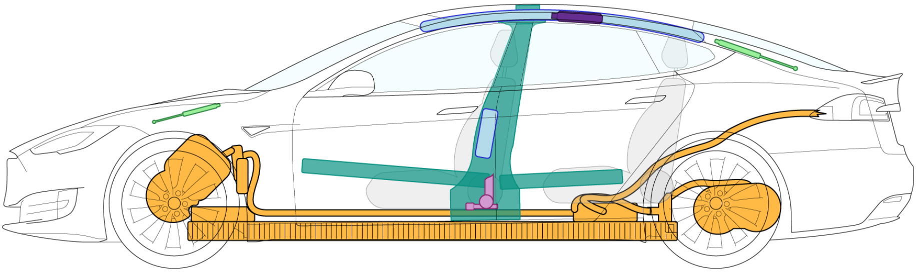
- If you cannot access the front cut loop on vehicles built after June 2013, disable the high voltage by cutting into the second-row door pillar nearest the charge port.
- Use a 12" circular saw to cut 6 in (152 mm) through the label (right) and into the pillar.

APPENDIX E

2016 Tesla Model S,
Emergency Response Sheet

Model S Emergency Response Sheet





12V battery	Emergency disconnect	SRS control unit
Gas cylinder	Airbags	Seat belt pre-tensioners
Gas inflator	High voltage components	Reinforcements

Firefighting

USE WATER TO FIGHT A HIGH VOLTAGE BATTERY FIRE. If the battery catches fire, is exposed to high heat, or is generating heat or gases, use large amounts of water to cool the battery. It can take approximately 3,000 gallons of water (applied directly to the battery); establish sufficient water supply.

Extinguish small fires not involving the battery using typical vehicle firefighting procedures.

Always use insulated tools for overhaul.

Heat and flames can compromise some components, resulting in an unexpected explosion. Perform an adequate knock down before entering a hot zone.

There must not be fire, smoke, or heating present in the battery for at least one hour (consider using a thermal imaging camera to measure the temperature) and the battery must be completely cooled before the vehicle can be released to second responders. Always advise second responders that there is a risk of battery re-ignition.

Warnings and Notes

Warning: Always assume Model S is powered and high voltage (HV) components are energized.

Warning: Always wear full PPE, including a self-contained breathing apparatus.

Warning: Never touch, cut, or open any orange HV cable or component.

Warning: Double cut the first responder loop to remove an entire section. This prevents the wires from reconnecting.

Warning: Do not use the HV battery to lift or stabilize Model S.

Warning: After deactivation, the HV circuit requires 2 minutes to deplete.

Warning: The SRS control unit has a backup power supply with a discharge time of approximately 10 seconds.

Note: Treat a submerged Model S like any other submerged car.

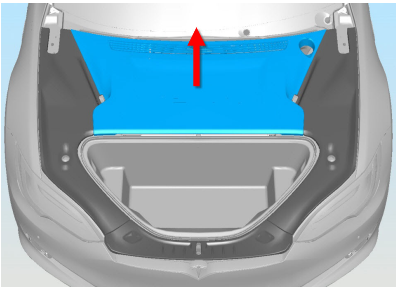
Note: Refer to the relevant Emergency Response Guide for additional information.

Stabilize the Vehicle

1. Chock the wheels.
2. Set the parking brake.

Disable the HV System

1. Open the hood:
   - Touch CONTROLS > FRONT TRUNK on the touchscreen.
   - Double-click the front key button.
   - Pull the release cables located in the front wheel arch liners. You need to release the covers first to expose the straps, and then pull the straps, labeled A (RH wheel arch liner) and B (LH wheel arch liner), in alphabetical order to open the primary and secondary latches.
2. Remove the access panel by pulling it up to release the clips securing it.



3. Double cut the first responder loop to remove an entire section.

APPENDIX F

49 CFR 571.305
Also known as Standard 305

§ 571.305 Standard No. 305; Electric-powered vehicles: electrolyte spillage and electrical shock protection.

S1. *Scope.* This standard specifies requirements for limitation of electrolyte spillage and retention of electric energy storage/conversion devices during and after a crash, and protection from harmful electric shock during and after a crash and during normal vehicle operation.

S2. *Purpose.* The purpose of this standard is to reduce deaths and injuries during and after a crash that occur because of electrolyte spillage from electric energy storage devices, intrusion of electric energy storage/conversion devices into the occupant compartment, and electrical shock, and to reduce deaths and injuries during normal vehicle operation that occur because of electric shock or driver error.

S3. *Application.* This standard applies to passenger cars, and to multipurpose passenger vehicles, trucks and buses with a GVWR of 4,536 kg or less, that use electrical propulsion components with working voltages more than 60 volts direct current (VDC) or 30 volts alternating current (VAC), and whose speed attainable over a distance of 1.6 km on a paved level surface is more than 40 km/h.

S4. *Definitions.*

Automatic disconnect means a device that when triggered, conductively separates a high voltage source from the electric power train or the rest of the electric power train.

Charge connector is a conductive device that, by insertion into a vehicle charge inlet, establishes an electrical connection of the vehicle to the external electric power supply for the purpose of transferring energy and exchanging information.

Connector means a device providing mechanical connection and disconnection of high voltage electrical conductors to a suitable mating component, including its housing.

Direct contact is the contact of persons with high voltage live parts.

Electric energy storage device means a high voltage source that stores energy for vehicle propulsion. This includes, but is not limited to, a high voltage battery or battery pack, rechargeable energy storage device, and capacitor module.

Electric energy storage/conversion device means a high voltage source that stores or converts energy for vehicle propulsion. This includes, but is not limited to, a high voltage battery or battery pack, fuel cell stack, rechargeable energy storage device, and capacitor module.

Electric energy storage/conversion system means an assembly of electrical components that stores or converts electrical energy for vehicle propulsion. This includes, but is not limited to, high voltage batteries or battery packs, fuel cell stacks, rechargeable energy storage systems, capacitor modules, inverters, interconnects, and venting systems.

Electric power train means an assembly of electrically connected components which includes, but is not limited to, electric energy storage/conversion systems and propulsion systems.

Electrical chassis means conductive parts of the vehicle whose electrical potential is taken as reference and which are: (1) conductively linked together, and (2) not high voltage sources during normal vehicle operation.

Electrical isolation of a high voltage source in the vehicle means the electrical resistance between the high voltage source and any of the vehicle's electrical chassis divided by the working voltage of the high voltage source.

Electrical protection barrier is the part providing protection against direct contact with high voltage live parts from any direction of access.

Exposed conductive part is the conductive part that can be touched under the provisions of the IPXXB protection degree and that is not normally energized, but that can become electrically energized under isolation fault conditions. This includes parts under a cover, if the cover can be removed without using tools.

External electric power supply is a power supply external to the vehicle that provides electric power to charge the electric energy storage device in the vehicle through the charge connector.

Fuel cell system is a system containing the fuel cell stack(s), air processing system, fuel flow control system, exhaust system, thermal management system, and water management system.

High voltage source means any electric component which is contained in the electric power train or conductively connected to the electric power train and has a working voltage greater than 30 VAC or 60 VDC.

Indirect contact is the contact of persons with exposed conductive parts.

Live part is a conductive part of the vehicle that is electrically energized under normal vehicle operation.

Luggage compartment is the space in the vehicle for luggage accommodation, separated from the passenger compartment by the front or rear bulkhead and bounded by a roof, hood or trunk lid, floor, and side walls, as well as by electrical protection barriers provided for protecting the occupants from direct contact with high voltage live parts.

Passenger compartment is the space for occupant accommodation that is bounded by the roof, floor, side walls, doors, outside glazing, front bulkhead and rear bulkhead or rear gate, as well as electrical protection barriers provided for protecting the occupants from direct contact with high voltage live parts.

Possible active driving mode is the vehicle mode when application of pressure to the accelerator pedal (or activation of an equivalent control) or release of the brake system causes the electric power train to move the vehicle.

Propulsion system means an assembly of electric or electro-mechanical components or circuits that propel the vehicle using the energy that is supplied by a high voltage source. This includes, but is not limited to, electric motors, inverters/converters, and electronic controllers.

Protection degree IPXXB is protection from contact with high voltage live parts. It is tested by probing electrical protection barriers with the jointed test finger probe, IPXXB, in Figure 7b.

Protection degree IPXXD is protection from contact with high voltage live parts. It is tested by probing electrical protection barriers with the test wire probe, IPXXD, in Figure 7a.

Service disconnect is the device for deactivation of an electrical circuit when conducting checks and services of the vehicle electrical propulsion system.

VAC means volts of alternating current (AC) expressed using the root mean square value.

VDC means volts of direct current (DC).

Vehicle charge inlet is the device on the electric vehicle into which the charge connector is inserted for the purpose of transferring energy and exchanging information from an external electric power supply.

Working Voltage means the highest root mean square voltage of the voltage source, which may occur across its terminals or between its terminals and any conductive parts in open circuit conditions or under normal operating conditions.

S5. *General requirements.* Each vehicle to which this standard applies, must meet the requirements in S5.1, S5.2, and S5.3 when tested according to S6 under the conditions of S7.

S5.1 *Electrolyte spillage from propulsion batteries.* Not more than 5.0 liters of electrolyte from propulsion batteries shall spill outside the passenger compartment, and no visible trace of electrolyte shall spill into the passenger compartment. Spillage is measured from the time the vehicle ceases motion after a barrier impact test until 30 minutes thereafter, and throughout any static rollover after a barrier impact test.

S5.2 *Electric energy storage/conversion device retention.* During and after each test specified in S6 of this standard:

(a) Electric energy storage/conversion devices shall remain attached to the vehicle by at least one component anchorage, bracket, or any structure that transfers loads from the device to the vehicle structure, and

(b) Electric energy storage/conversion devices located outside the occupant compartment shall not enter the occupant compartment.

S5.3 *Electrical safety.* After each test specified in S6 of this standard, each high voltage source in a vehicle must meet one of the following requirements: electrical isolation requirements of subparagraph (a), the voltage level requirements of subparagraph (b), or the physical barrier protection requirements of subparagraph (c).

(a) The electrical isolation of the high voltage source, determined in accordance with the procedure specified in S7.6, must be greater than or equal to one of the following:

(1) 500 ohms/volt for an AC high voltage source; or

(2) 100 ohms/volt for an AC high voltage source if it is conductively connected to a DC high voltage source, but only if the AC high voltage source meets the physical barrier protection requirements specified in S5.3(c)(1) and S5.3(c)(2); or

(3) 100 ohms/volt for a DC high voltage source.

(b) The voltages V1, V2, and Vb of the high voltage source, measured according to the procedure specified in S7.7, must be less than or equal to 30 VAC for AC components or 60 VDC for DC components.

(c) Protection against electric shock by direct and indirect contact (physical barrier protection) shall be demonstrated by meeting the following three conditions:

(1) The high voltage source (AC or DC) meets the protection degree IPXXB when tested according to the procedure specified in S9.1 using the IPXXB test probe shown in Figures 7a and 7b;

(2) The resistance between exposed conductive parts of the electrical protection barrier of the high voltage source and the electrical chassis is less than 0.1 ohms when tested according to the procedures specified in S9.2. In addition, the resistance between an exposed conductive part of the electrical protection barrier of the high voltage source and any other simultaneously reachable exposed conductive parts of electrical protection barriers within 2.5 meters of it must be less than 0.2 ohms when tested using the test procedures specified in S9.2; and

(3) The voltage between exposed conductive parts of the electrical protection barrier of the high voltage source and the electrical chassis is less than or equal to 30 VAC or 60 VDC as measured in accordance with S9.3. In addition, the voltage between an exposed conductive part of the electrical protection barrier of the high voltage source and any other simultaneously reachable exposed conductive parts of electrical protection barriers within 2.5 meters of it must be less than or equal to 30 VAC or 60 VDC as measured in accordance with S9.3.

S5.4 *Electrical safety during normal vehicle operation.*

S5.4.1 *Protection against direct contact.*

S5.4.1.1 *Marking.* The symbol shown in Figure 6 shall be present on or near electric energy storage devices. The symbol in Figure 6 shall also be visible on electrical protection barriers which, when removed, expose live parts of high voltage sources. The symbol shall be yellow and the bordering and the arrow shall be black.

S5.4.1.1.1 The marking is not required for electrical protection barriers that cannot be physically accessed, opened, or removed without the use of tools. Markings are not required for electrical connectors or the vehicle charge inlet.

S5.4.1.2 *High voltage cables.* Cables for high voltage sources which are not located within electrical protection barriers shall be identified by having an outer covering with the color orange.

S5.4.1.3 *Service disconnect.* For a service disconnect which can be opened, disassembled, or removed without tools, protection degree IPXXB shall be provided when tested under procedures specified in S9.1 using the IPXXB test probe shown in Figures 7a and 7b.

S5.4.1.4 *Protection degree of high voltage live parts.*

(a) Protection degree IPXXD shall be provided for high voltage live parts inside the passenger or luggage compartment when tested according to the procedures specified in S9.1 using the IPXXD test probe shown in Figure 7a.

(b) Protection degree IPXXB shall be provided for high voltage live parts in areas other than the passenger or luggage compartment when tested according to the procedures specified in S9.1 using the IPXXB test probe shown in Figures 7a and 7b.

S5.4.1.5 *Connectors.* Direct contact protection for a connector shall be provided by meeting the requirements specified in S5.4.1.4 when the connector is connected to its corresponding mating component, and by meeting at least one of the requirements of subparagraphs (a), (b), or (c).

(a) The connector meets the requirements of S5.4.1.4 when separated from its mating component, if the connector can be separated without the use of tools;

(b) The voltage of the live parts becomes less than or equal to 60 VDC or 30 VAC within one second after the connector is separated from its mating component; or,

(c) The connector is provided with a locking mechanism (at least two distinct actions are needed to separate the connector from its mating component) and there are other components that must be removed in order to separate the connector from its mating component and these cannot be removed without the use of tools.

S5.4.1.6 *Vehicle charge inlet.* Direct contact protection for a vehicle charge inlet shall be provided by meeting the requirements specified in S5.4.1.4 when the charge connector is connected to the vehicle inlet and by meeting at least one of the requirements of subparagraphs (a) or (b).

(a) The vehicle charge inlet meets the requirements of S5.4.1.4 when the charge connector is not connected to it; or

(b) The voltage of the high voltage live parts becomes equal to or less than 60 VDC or equal to or less than 30 VAC within 1 second after the charge connector is separated from the vehicle charge inlet.

S5.4.2 *Protection against indirect contact.*

S5.4.2.1 The resistance between all exposed conductive parts of electrical protection barriers and the electrical chassis shall be less than 0.1 ohms when tested according to the procedures specified in S9.2.

S5.4.2.2 The resistance between any two simultaneously reachable exposed conductive parts of the electrical protection barriers that are less than 2.5 meters from each other shall be less than 0.2 ohms when tested according to the procedures specified in S9.2.

S5.4.3 *Electrical isolation.*

S5.4.3.1 *Electrical isolation of AC and DC high voltage sources.* The electrical isolation of a high voltage source, determined in accordance with the procedure specified in S7.6 must be greater than or equal to one of the following:

(a) 500 ohms/volt for an AC high voltage source;

(b) 100 ohms/volt for an AC high voltage source if it is conductively connected to a DC high voltage source, but only if the AC high voltage source meets the requirements for protection against direct contact in S5.4.1.4 and the protection from indirect contact in S5.4.2; or

(c) 100 ohms/volt for a DC high voltage source.

S5.4.3.2 *Exclusion of high voltage sources from electrical isolation requirements.* A high voltage source that is conductively connected to an electric component which is conductively connected to the electrical chassis and has a working voltage less than or equal to 60 VDC, is not required to meet the electrical isolation requirements in S5.4.3.1 if the voltage between the high voltage source and the electrical chassis is less than or equal to 30 VAC or 60 VDC.

S5.4.3.3 *Electrical isolation of high voltage sources for charging the electric energy storage device.* For the vehicle charge inlet intended to be conductively connected to the AC external electric power supply, the electric isolation between the electrical chassis and the high voltage sources that are conductively connected to the vehicle charge inlet during charging of the electric energy storage device shall be greater than or equal to 500 ohms/volt when the charge connector is disconnected. The electrical isolation is measured at the high voltage live parts of the vehicle charge inlet and determined in accordance with the procedure specified in S7.6. During the measurement, the rechargeable electric energy storage system may be disconnected.

S5.4.4 *Electrical isolation monitoring.* DC high voltage sources of vehicles with a fuel cell system shall be monitored by an electrical isolation monitoring system that displays a warning for loss of isolation when tested according to S8. The system must monitor its own readiness and the warning display must be visible to the driver seated in the driver's designated seating position.

S5.4.5 *Electric shock protection during charging.* For motor vehicles with an electric energy storage device that can be charged through a conductive connection with a grounded external electric power supply, a device to enable conductive connection of the electrical chassis to the earth ground shall be provided. This device shall enable connection to the earth ground before exterior voltage is applied to the vehicle and retain the connection until after the exterior voltage is removed from the vehicle.

S5.4.6 *Mitigating driver error.*

S5.4.6.1 *Indicator of possible active driving mode.* At least a momentary indication shall be given to the driver each time the vehicle is first placed in possible active driving mode after manual activation of the propulsion system. This requirement does not apply under conditions where an internal combustion engine provides directly or indirectly the vehicle's propulsion power when the vehicle is first placed in a possible active driving mode after manual activation of the propulsion system.

S5.4.6.2 *Indicator of possible active driving mode when leaving the vehicle.* When leaving the vehicle, the driver shall be informed by an audible or visual signal if the vehicle is still in the possible active driving mode.

S5.4.6.3 *Prevent drive-away.* If the on-board electric energy storage device can be externally charged, vehicle movement of more than 150 mm by its own propulsion system shall not be possible as long as the charge connector of the external electric power supply is physically connected to the vehicle charge inlet in a manner that would permit charging of the electric energy storage device.

S6. *Test requirements.* Each vehicle to which this standard applies, under the conditions of S7, must be capable of meeting the requirements of any applicable single barrier crash/static rollover test sequence, without alteration of the vehicle during the test sequence. A particular vehicle need not meet further test requirements after having been subjected to a single barrier crash/static rollover test sequence.

S6.1 *Frontal barrier crash.* The vehicle must meet the requirements of S5.1, S5.2 and S5.3 when it is traveling longitudinally forward at any speed, up to and including 48 km/h, and impacts a fixed collision barrier that is perpendicular to the line of travel of the vehicle, or at any angle up to 30 degrees in either direction from the perpendicular to the line of travel of the vehicle.

S6.2 *Rear moving barrier impact.* The vehicle must meet the requirements of S5.1, S5.2, and S5.3 when it is impacted from the rear by a barrier that conforms to S7.3(b) of 571.301 of this chapter and that is moving at any speed up to and including 80 km/h (50 mph) with dummies in accordance with S6.2 of 571.301 of this chapter.

S6.3 *Side moving deformable barrier impact.* The vehicle must meet the requirements of S5.1, S5.2 and S5.3 when it is impacted from the side by a barrier that conforms to part 587 of this chapter that is moving at any speed up to and including 54 km/h, with the appropriate 49 CFR part 572 test dummies specified in 571.214 of this chapter.

S6.4 *Post-impact test static rollover.* The vehicle must meet the requirements of S5.1, S5.2, and S5.3, after being rotated on its longitudinal axis to each successive increment of 90 degrees after each impact test specified in S6.1, S6.2, and S6.3.

S7. *Test conditions.* When the vehicle is tested according to S6, the requirements of S5.1 through S5.3 must be met under the conditions specified in S7.1 through S7.7. All measurements for calculating voltage(s) and electrical isolation are made after a minimum of 5 seconds after the vehicle comes to rest in tests specified in S6. Where a range is specified, the vehicle must be capable of meeting the requirements at all points within the range.

S7.1 *Electric energy storage device state-of-charge.* The electric energy storage device shall be at the state-of-charge specified in either subparagraph (a), (b), or (c):

(a) At the maximum state-of-charge in accordance with the vehicle manufacturer's recommended charging procedures, as stated in the vehicle owner's manual or on a label that is permanently affixed to the vehicle; or

(b) If the manufacturer has made no recommendation for charging procedures in the owner's manual or on a label permanently affixed to the vehicle, at a state-of-charge of not less than 95 percent of the maximum capacity of the electric energy storage device; or

(c) If the electric energy storage device(s) is/are rechargeable only by an energy source on the vehicle, at any state-of-charge within the normal operating voltage defined by the vehicle manufacturer.

S7.2 *Vehicle conditions.* The switch or device that provides power from the electric energy storage/conversion system to the propulsion system is in the activated position or the ready-to-drive position.

S7.2.1 The parking brake is disengaged and the transmission, if any, is in the neutral position. In a test conducted under S6.3, the parking brake is set.

S7.2.2 Tires are inflated to the manufacturer's specifications.

S7.2.3 The vehicle, including test devices and instrumentation, is loaded as follows:

(a) A passenger car is loaded to its unloaded vehicle weight plus its rated cargo and luggage capacity weight, secured in the luggage area, plus the necessary test dummies as specified in S6, restrained only by means that are installed in the vehicle for protection at its seating position.

(b) A multipurpose passenger vehicle, truck, or bus with a GVWR of 4536 kg or less is loaded to its unloaded vehicle weight plus the necessary dummies, as specified in S6, plus 136 kg or its rated cargo and luggage capacity weight, whichever is less. Each dummy is restrained only by means that are installed in the vehicle for protection at its seating position.

S7.3 *Static rollover test conditions.* In addition to the conditions of S7.1 and S7.2, the conditions of S7.4 of Sec. 571.301 of this chapter apply to the conduct of static rollover tests specified in S6.4.

S7.4 *Rear moving barrier impact test conditions.* In addition to the conditions of S7.1 and S7.2, the conditions of S7.3(b) and S7.6 of 571.301 of this chapter apply to the conducting of the rear moving deformable barrier impact test specified in S6.2.

S7.5 *Side moving deformable barrier impact test conditions.* In addition to the conditions of S7.1 and S7.2, the conditions of S8.9, S8.10, and S8.11 of 571.214 of this chapter apply to the conduct of the side moving deformable barrier impact test specified in S6.3.

S7.6 *Electrical isolation test procedure.* In addition to the conditions of S7.1 and S7.2, the conditions in S7.6.1 through S7.6.7 apply to the measuring of electrical isolation specified in S5.3(a).

S7.6.1 Prior to any barrier impact test, the energy storage/conversion system is connected to the vehicle's propulsion system, and the vehicle ignition is in the "on" (propulsion system energized) position. Bypass any devices or systems that do not allow the propulsion system to be energized at the time of impact when the vehicle ignition is on and the vehicle is in neutral. For a high voltage source that has an automatic disconnect that is physically contained within itself, the electrical isolation measurement after the test is made from the side of the automatic disconnect connected to the electric power train or to the rest of the electric power train if the high voltage source is a component contained in the power train. For a high voltage source that has an automatic disconnect that is not physically contained within itself, the electrical isolation measurement after the test is made from both the high voltage source side of the automatic disconnect and from the side of the automatic disconnect connected to the electric power train or to the rest of the electric power train if the high voltage source is a component contained in the power train.

S7.6.2 The voltmeter used in this test has an internal resistance of at least 10 MΩ.

S7.6.3 The voltage(s) is/are measured as shown in Figure 1 and the high voltage source voltage(s) (Vb) is/are recorded. Before any vehicle impact test, Vb is equal to or greater than the nominal operating voltage as specified by the vehicle manufacturer.

S7.6.4 The voltage V1 between the negative side of the high voltage source and the electrical chassis is measured as shown in Figure 2.

S7.6.5 The voltage V2 between the positive side of the high voltage source and the electrical chassis is measured as shown in Figure 3.

S7.6.6 If V1 is greater than or equal to V2, insert a known resistance (Ro) between the negative side of the high voltage source and the electrical chassis. With the Ro installed, measure the voltage (V1′) as shown in Figure 4 between the negative side of the high voltage source and the electrical chassis. Calculate the electrical isolation resistance (Ri) according to the formula shown. Divide Ri (in ohms) by the working voltage of the high voltage source (in volts) to obtain the electrical isolation (in ohms/volt).

S7.6.7 If V2 is greater than V1, insert a known resistance (Ro) between the positive side of the high voltage source and the electrical chassis. With the Ro installed, measure the voltage (V2′) as shown in Figure 5 between the positive side of the high voltage source and the electrical chassis. Calculate the electrical isolation resistance (Ri) according to the formula shown. Divide Ri (in ohms) by the working voltage of the high voltage source (in volts) to obtain the electrical isolation (in ohms/volt).

S7.7 *Voltage measurement.* For the purpose of determining the voltage level of the high voltage source specified in S5.3(b), voltage is measured as shown in Figure 1. Voltage Vb is measured across the two terminals of the voltage source. Voltages V1 and V2 are measured between the source and the electrical chassis. For a high voltage source that has an automatic disconnect that is physically contained within itself, the voltage measurement after the test is made from the side of the automatic disconnect connected to the electric power train or to the rest of the electric power train if the high voltage source is a component contained in the power train. For a high voltage source that has an automatic disconnect that is not physically contained within itself, the voltage measurement after the test is made from both the high voltage source side of the automatic disconnect and from the side of the automatic disconnect connected to the electric power train or to the rest of the electric power train if the high voltage source is a component contained in the power train.

S8. *Test procedure for on-board electrical isolation monitoring system.* Prior to any impact test, the requirements of S5.4 for the on-board electrical isolation monitoring system shall be tested using the following procedure.

(1) The electric energy storage device is at the state-of-charge specified in S7.1.

(2) The switch or device that provides power from the electric energy storage/conversion system to the propulsion system is in the activated position or the ready-to-drive position.

(3) Determine the isolation resistance, Ri, of the high voltage source with the electrical isolation monitoring system using the procedure outlined in S7.6.2 through S7.6.7.

(4) Insert a resistor with resistance Ro equal to or greater than 1/(1/(95 times the working voltage of the high voltage source)−1/Ri) and less than 1/(1/(100 times the working voltage of the high voltage source)−1/Ri) between the positive terminal of the high voltage source and the electrical chassis.

(5) The electrical isolation monitoring system indicator shall display a warning visible to the driver seated in the driver's designated seating position.

S9 *Test methods for physical barrier protection from electric shock due to direct and indirect contact with high voltage sources.*

S9.1 *Test method to evaluate protection from direct contact with high voltage sources.*

(a) Any parts surrounding the high voltage components are opened, disassembled, or removed without the use of tools.

(b) The selected access probe is inserted into any gaps or openings of the electrical protection barrier with a test force of 10 N ± 1 N with the IPXXB probe or 1 to 2 N with the IPXXD probe. If the probe partly or fully penetrates into the electrical protection barrier, it is placed in every possible position to evaluate contact with high voltage live parts. If partial or full penetration into the electrical protection barrier occurs with the IPXXB probe, the IPXXB probe shall be placed as follows: starting from the straight position, both joints of the test finger are rotated progressively through an angle of up to 90 degrees with respect to the axis of the adjoining section of the test finger and are placed in every possible position.

(c) A low voltage supply (of not less than 40 V and not more than 50 V) in series with a suitable lamp may be connected between the access probe and any high voltage live parts inside the electrical protection barrier to indicate whether high voltage live parts were contacted.

(d) A mirror or fiberscope may be used to inspect whether the access probe touches high voltage live parts inside the electrical protection barrier.

(e) Protection degree IPXXD or IPXXB is verified when the following conditions are met:

(i) The access probe does not touch high voltage live parts. The IPXXB access probe may be manipulated as specified in S9.1(b) for evaluating contact with high voltage live parts. The methods specified in S9.1(c) or S9.1(d) may be used to aid the evaluation. If method S9.1(c) is used for verifying protection degree IPXXB or IPXXD, the lamp shall not light up.

(ii) The stop face of the access probe does not fully penetrate into the electrical protection barrier.

S9.2 *Test method to evaluate protection against indirect contact with high voltage sources.* At the option of the manufacturer, protection against indirect contact with high voltage sources shall be determined using the test method in subparagraph (a) or subparagraph (b).

(a) *Test method using a resistance tester.* The resistance tester is connected to the measuring points (the electrical chassis and any exposed conductive part of electrical protection barriers or any two simultaneously reachable exposed conductive parts of electrical protection barriers that are less than 2.5 meters from each other), and the resistance is measured using a resistance tester that can measure current levels of at least 0.2 Amperes with a resolution of 0.01 ohms or less. The resistance between two exposed conductive parts of electrical protection barriers that are less than 2.5 meters from each other may be calculated using the separately measured resistances of the relevant parts of the electric path.

(b) *Test method using a DC power supply, voltmeter and ammeter.*

(1) Connect the DC power supply, voltmeter and ammeter to the measuring points (the electrical chassis and any exposed conductive part or any two simultaneously reachable exposed conductive parts that are less than 2.5 meters from each other) as shown in Figure 8.

(2) Adjust the voltage of the DC power supply so that the current flow becomes more than 0.2 Amperes.

(3) Measure the current I and the voltage V shown in Figure 8.

(4) Calculate the resistance R according to the formula, R=V/I.

(5) The resistance between two simultaneously reachable exposed conductive parts of electrical protection barriers that are less than 2.5 meters from each other may be calculated using the separately measured resistances of the relevant parts of the electric path.

S9.3 *Test method to determine voltage between exposed conductive parts of electrical protection barriers and the electrical chassis and between exposed conductive parts of electrical protection barriers.*

(a) Connect the voltmeter to the measuring points (exposed conductive part of an electrical protection barrier and the electrical chassis or any two simultaneously reachable exposed conductive parts of electrical protection barriers that are less than 2.5 meters from each other).

(b) Measure the voltage.

(c) The voltage between two simultaneously reachable exposed conductive parts of electrical protection barriers that are less than 2.5 meters from each other may be calculated using the separately measured voltages between the relevant electrical protection barriers and the electrical chassis.

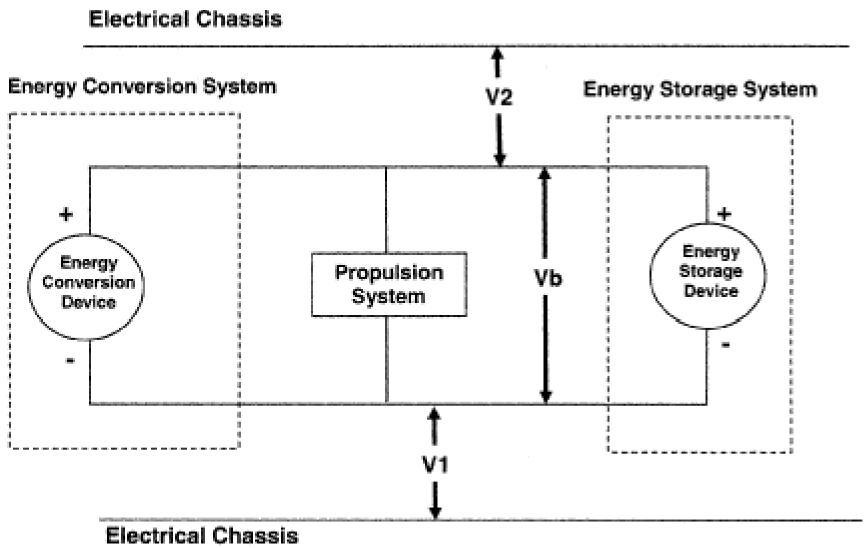


Figure 1. S7.6.3 and S7.7 Voltage Measurements of the High Voltage Source

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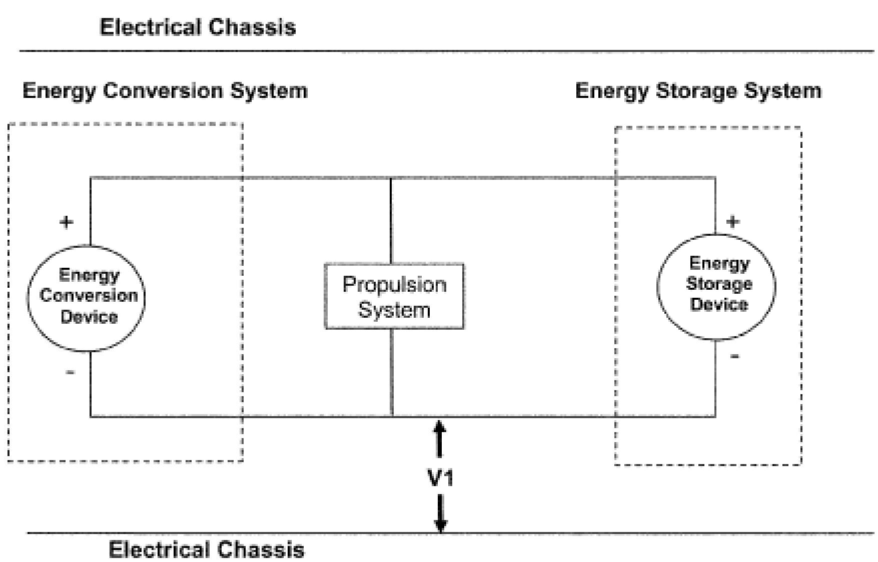

Figure 2. S7.6.4 Measurement for V1 Voltage between the Negative Side of the High Voltage Source and the Electrical Chassis

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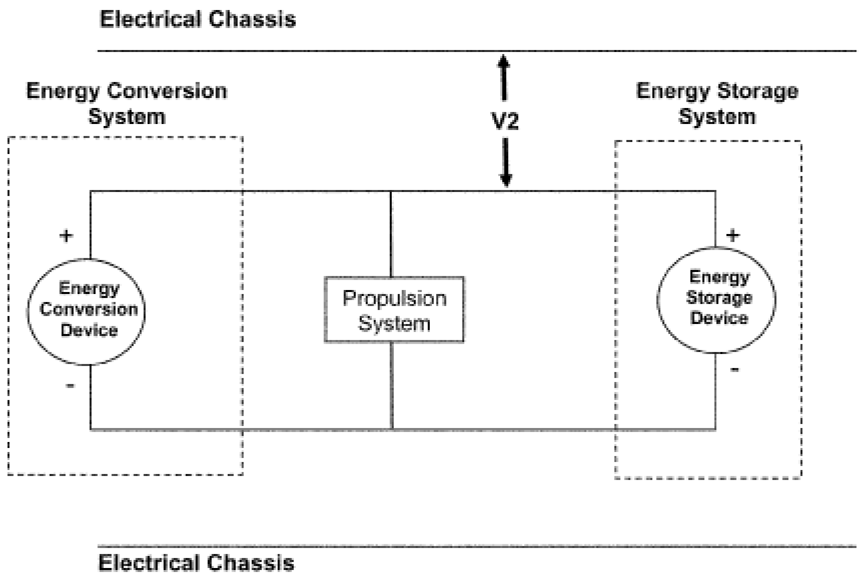

Figure 3. S7.6.5 Measurement for V2 Voltage between the Positive Side of the High Voltage Source and the Electrical Chassis

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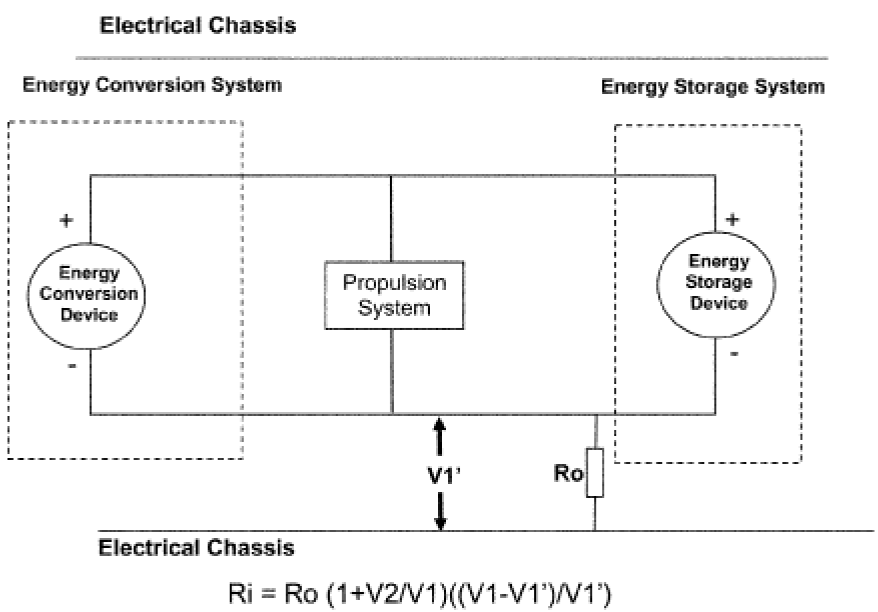

Figure 4. S7.6.6 Measurement for V1' Voltage across Resistor between Negative Side of the High Voltage Source and Electrical Chassis

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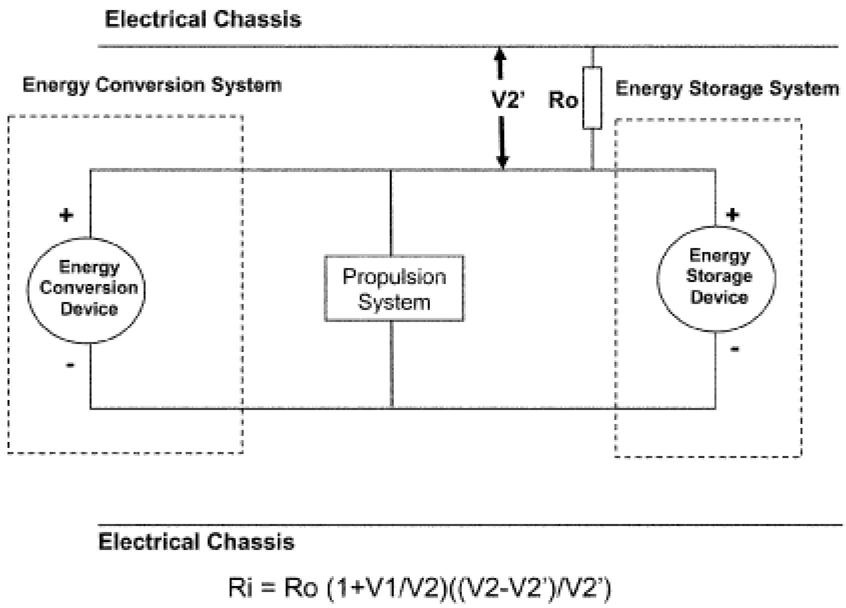

Figure 5. S7.6.7 Measurement for V2' Voltage across Resistor between Positive Side of the High Voltage Source and Electrical Chassis

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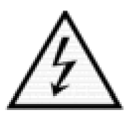

Figure 6. S5.4.1.1 Marking of high voltage equipment.

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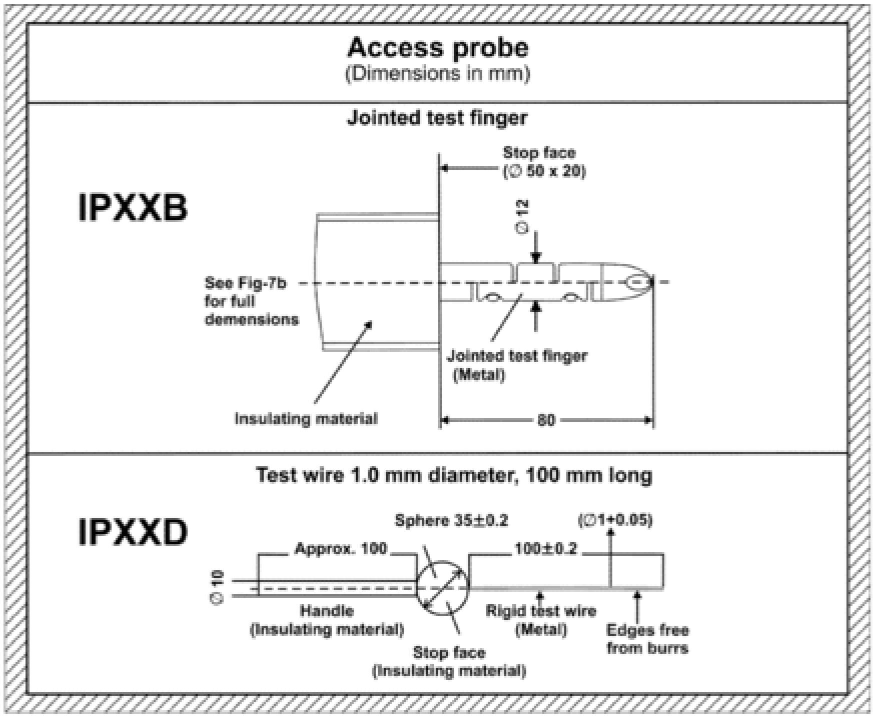

Figure 7a. S4, S5.3, S5.4.1.3, and S5.4.1.4 Access probes for the tests of direct contact protection. Access probe IPXXB (top) and Access probe IPXXD (bottom).

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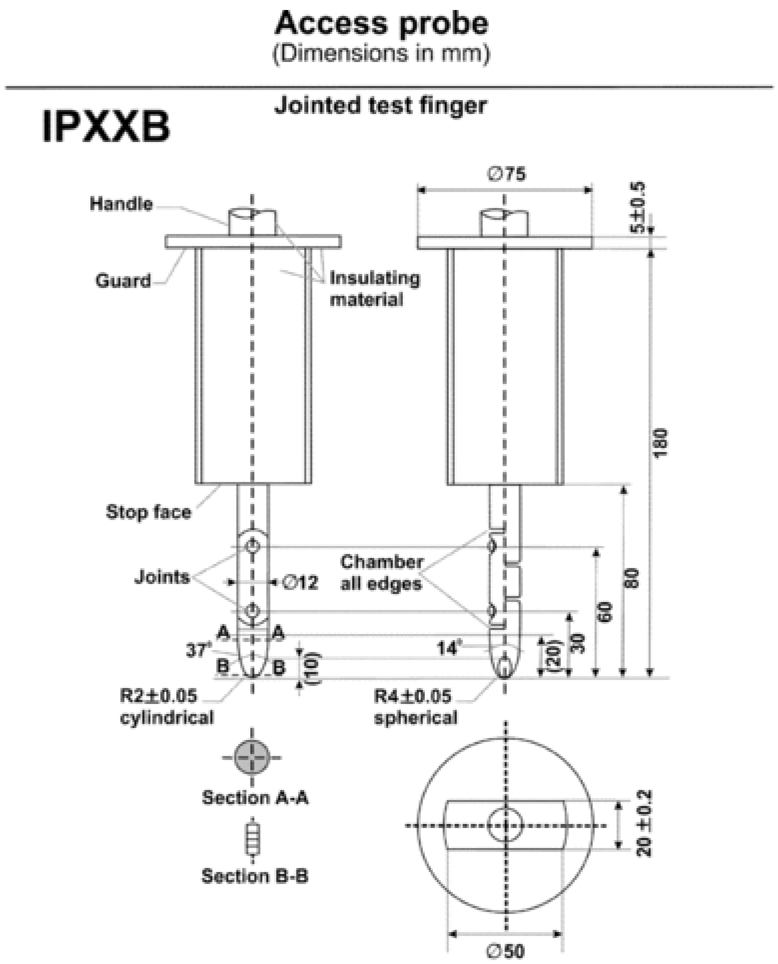

Material: metal, except where otherwise specified
Linear dimensions in millimeters
Tolerances on dimensions without specific tolerance:
on angles, 0/10 degrees
on linear dimensions:
up to 25 mm: 0/-0.05 mm
over 25 mm: ±0.2 mm
Both joints shall permit movement in the same plane and the same direction through an angle of 90° with a 0° to +10° tolerance.

Figure 7b. S4, S5.3, S5.4.1.3, and S5.4.1.4 Jointed test finger IPXXB

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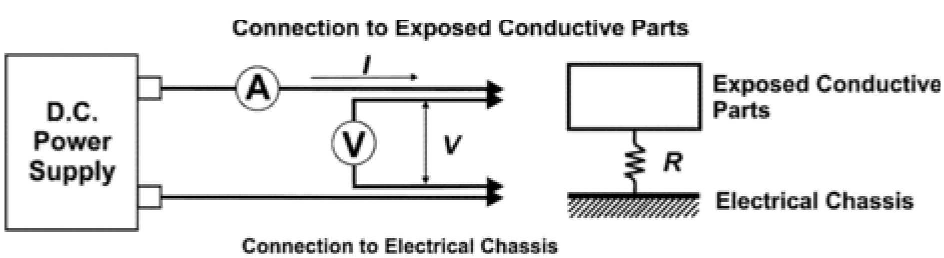

Figure 8. S9.2 Connection to determine resistance between exposed conductive parts of electrical protection barrier and electrical chassis

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[65 FR 57988, Sept. 27, 2000, as amended at 66 FR 60160, Dec. 3, 2001; 69 FR 51399, Aug. 19, 2004; 72 FR 51972, Sept. 11, 2007; 75 FR 12141, Mar. 15, 2010; 75 FR 33527, June 14, 2010; 76 FR 45448, July 29, 2011; 80 FR 2325, Jan. 16, 2015; 82 FR 44960, Sept. 27, 2017]

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