OPTIMAL EV
HIGH VOLTAGE SAFETY TRAINING 101 & OPERATOR'S GUIDE

S1
ELECTRIC LOW-FLOOR BUS

E1
ELECTRIC CUTAWAY CHASSIS

G1
ELECTRIC CUTAWAY CHASSIS

OPTIMAL · EV

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Optimal EV Safety and Operator's Guide
02/24

FOREWORD

Electric Bus and High Voltage Safety

Optimal EV builds battery-powered, electric vehicle-powered chassis and buses. Optimal buses operate like other buses, with the exception of the motor/propulsion system. Battery packs located under the floor provide power to the electric drive motor at the rear of the bus.

During normal driving conditions, the batteries provide energy to the traction motor to turn the wheels on the drive axle. During a “Regenerative Braking” event, this flow of energy is reversed. In this sequence, the traction motor becomes a generator. The motion of the wheels on the drive axle turns the traction motor, which charges the batteries. Providing this additional charge to the batteries will extend the driving range of the electric vehicle.

NOTE: The regenerative braking feature is automatically controlled and is optionally disabled. In the event of slippery conditions, it will automatically deactivate and reactivate. During a regenerative braking event, the bus will undergo a deceleration similar to that of a traditional “retarder” where the vehicle slows down without the use of frictional brakes.

Electrical Shock Hazard

This electric vehicle uses a direct current (DC) energy storage and power distribution system that operates at up to 400 volts. An electrocution hazard exists if humans come in contact with parts of this system.

– WARNING

This bus contains areas of high voltage that should only be accessible by authorized personnel: under the hood, and under the bus. If necessary, get assistance from the maintenance manager for help.

– IMPORTANT

All access and servicing of this vehicle must be performed by properly trained and qualified personnel who are equipped with personal protective equipment (PPE) appropriate to the task at hand.

Table of Contents

Glossary of Terms

AC	Alternating Current; positive and negative swap 60 times a second (in the USA)
A/C	Air Conditioning – reference cabin air conditioning or the cooling loop used by the BMS
ABS	Antilock Braking System
BCM	Body Control Module
BMS	Battery Management System
CAN	Controller Area Network; Communication bus from one controller to another
DC	Direct Current; positive is always positive
DC-DC	Converter that transforms DC power from one voltage potential to another (i.e. 400VDC to 12VDC)
EPU	Export Power Unit
EV	Electric Vehicle
HV	High Voltage
SH	Specialist for High Voltage Systems in Automobiles
VCU	Vehicle Control Unit; The electronic control module that coordinates and commands all of the EV powertrain and auxiliary HV components
SOC	State of Charge; The energy remaining in the battery expressed as a percentage of the total capacity when full.
ZE	Zero Emissions

High Voltage Safety Training

1. Scope of High Voltage 101 (HV101) Safety Training

Reading and understanding the information in this guide will enable you to:

- Gain basic knowledge of High Voltage Systems in the Optimal Electric Bus
- Drive an instrumented series production vehicle containing a High Voltage System
- Drive a pre-series vehicle containing a High Voltage System

It will NOT enable you to:

- Power-down/ power-up any high voltage application
- Perform testing/validation a vehicle containing a high voltage system
- Operate a test bench containing a high voltage system
- Perform any ‘non-HV work’ on any vehicle containing a high voltage system
- Perform any work on automotive high voltage system

2. Driver / Technician Safety Training Roles

Employee Job Classification	HV 101	HV 201	HV 301
Driver production HV Vehicle	✓	✓	✓
Driver of pre-production HV Vehicle	✓	✓	✓
Fleet/ Customer Technician(working HV eVehicle but non-HV Components)		✓	✓
Fleet/ Customer Technician (working HV eVehicle and working on HV Components)			✓
Fleet/ Customer Maintenance Employees not working on eVehicles (Awareness)	✓	✓	✓
Dealer Technician (working HV eVehicle but non-HV Components)		✓	✓
Dealer Technician (working HV eVehicle and working on HV Components)			✓
Dealership Technicians not working on eVehicles (Awareness)	✓	✓	✓
Anyone moving in and around (inside physical safety barriers) a HV eVehicle while maintenance is being performed. Anyone that must go beneath a HV eVehicle for any reason, inspections or other purposes.		✓	✓
HV-System modifications / troubleshooting energized HV eVehicle			

High Voltage Safety training falls into three categories - High Voltage 101; High Voltage 201 (HV201), and High Voltage 301 (HV301).

Each category has specific task and roles the employee is allowed to perform. Reading and understanding this guide is the equivalent of HV101 Training.

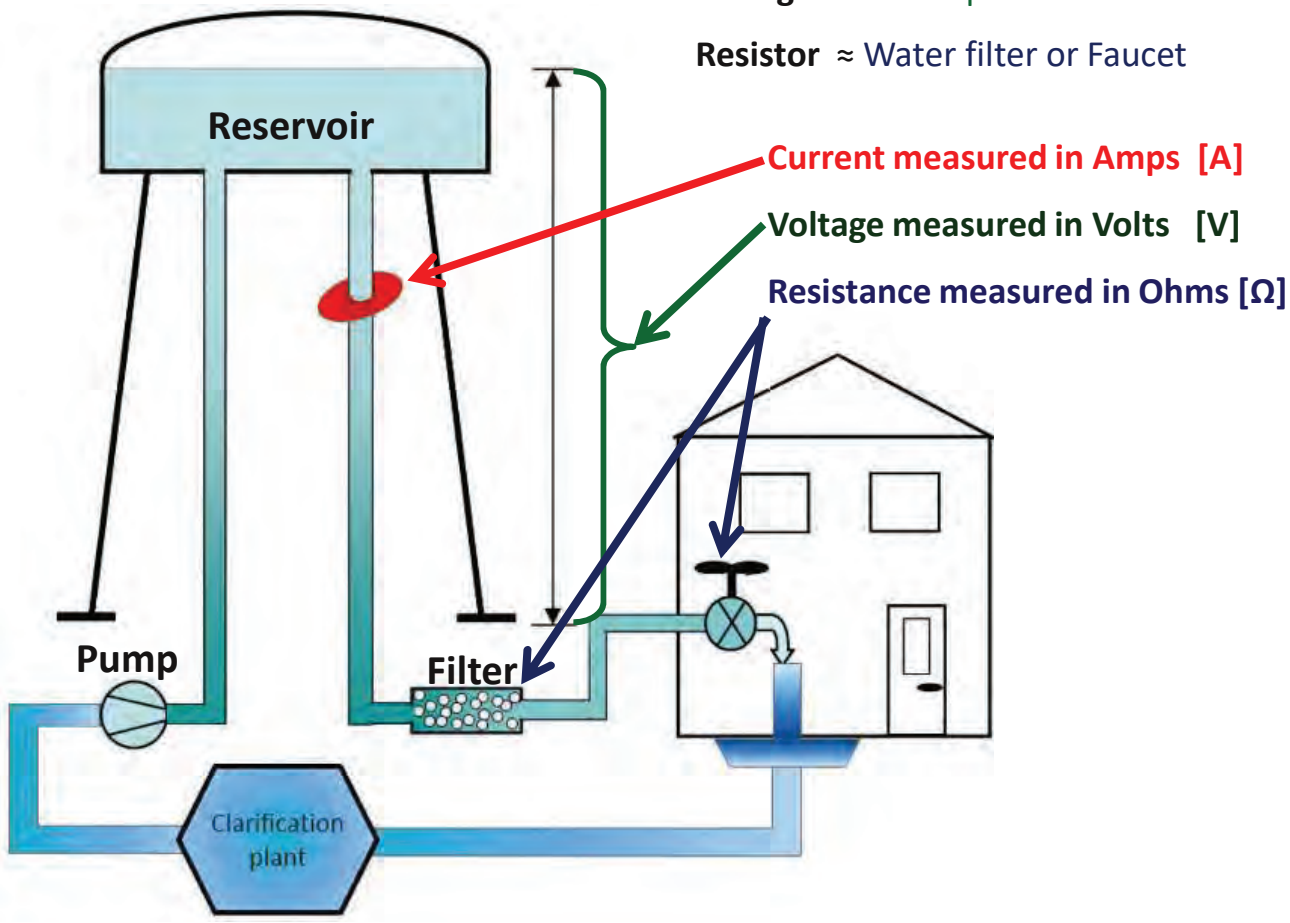
Optimal EV HV101 training is required for drivers, technicians, and any other personnel that will interact with a Optimal Electric Buses.

3. Basics of Electricity

Current ≈ Amount of water / second

Voltage ≈ Water pressure

Resistor ≈ Water filter or Faucet



Current (A)

In this analogy, electric current can be compared to the flow rate of the water. More water flowing equates to more current. Current is measured in Amperes (amps).

Resistance (Ω)

Resistance is the circuit or component's opposition to the flow of electricity. It is represented in our water model by a filter, partially-closed valve, or other flow obstruction. Resistance is measured in Ohms, and represented by the Ω symbol.

Voltage (V)

Electromotive Force (EMF) is measured in Volts (V). In the water analogy, this is represented by water pressure. Higher pressure is equivalent to higher voltage. Higher voltage causes more current (A) to flow if the resistance is kept constant.

4. Defining High Voltage

According to the OSHA, a hazard for humans starts at:
50 V alternating current (AC)
120 V direct current (DC)

OSHA 29 CFR 1910.303(g)(2)(i) / NFPA 70E limit is **50V**, AC or DC.

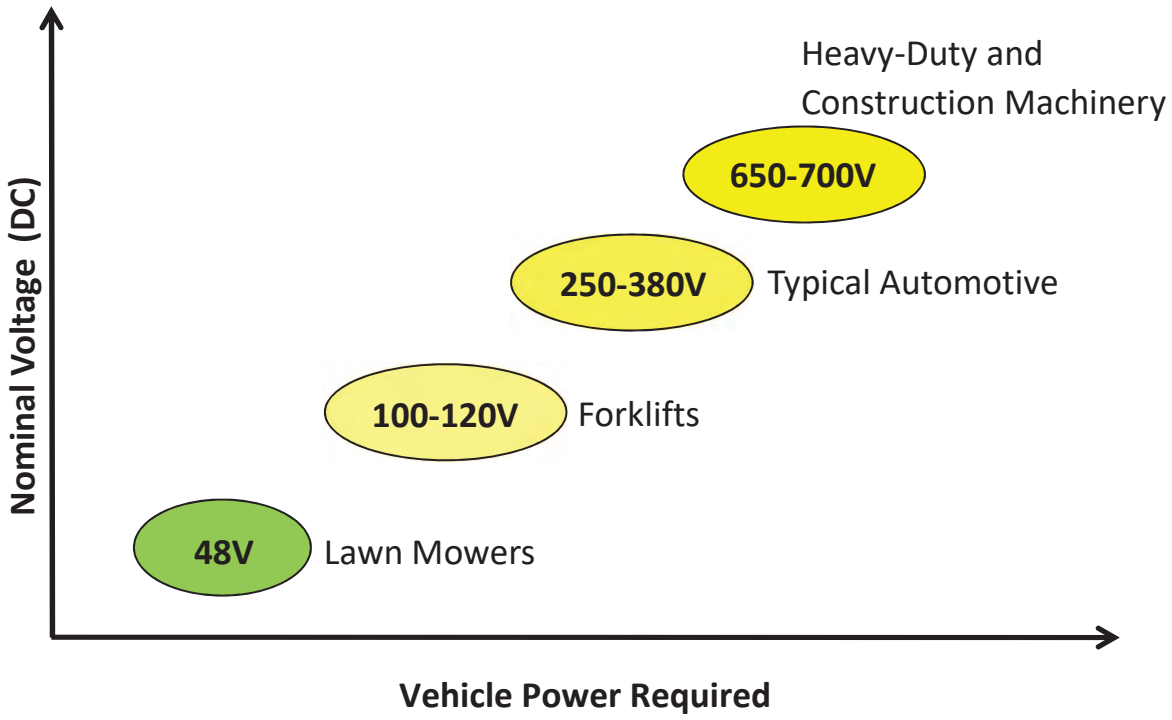
How much voltage is *High* Voltage?

According to the DIN VDE 0100 Part 410 standard, electrical hazard for humans starts at 50 V of alternating current (AC) or 120 V of direct current (DC). The updated/ released OSHA standard 1910.303(g)(2)(i) applies, and specifies that the maximum voltage that can be left unguarded/unshielded as **50 V AC *or* DC**.

5. Electric Vehicle – Why High Voltage?

One equation for electrical power is P = V x A. From this equation, you can see that as power demands rise, voltage, current, or both, must rise proportionally. Raising current is the more problematic of the two because it necessitates larger, heavier electrical components and conductors. Also, raising the current increases electric power losses, which lower overall system efficiency and elevate cooling requirements. To create 600 HP from a 12V electrical system would require over 37,000 amperes!

Of course, raising the voltage to astronomical levels in order to keep the current low is also impractical. This is primarily due to the increasing shock hazards involved and also the physical limitations of insulation, controls, and battery construction materials.



6. Optimal EV Power Specifications

Vehicle:s:	Optimal EV E1, S1 and G1
Battery Capacity::	113 kWh (Proterra)
Traction Motor::	280 kW kW
Range:	125+ miles (estimated)

S1

ELECTRIC LOW-FLOOR BUS

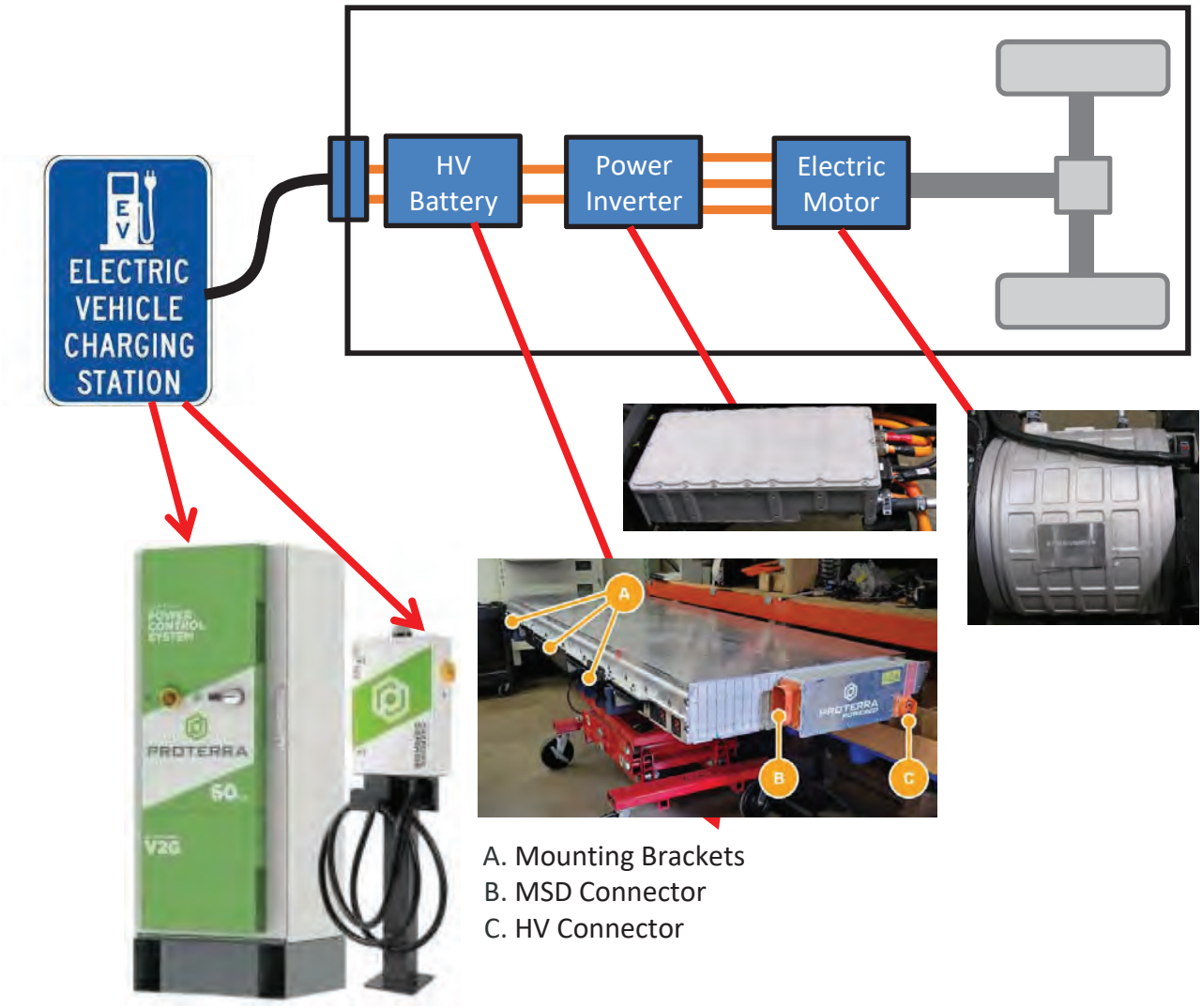
E1

ELECTRIC CUTAWAY CHASSIS

G1

ELECTRIC CUTAWAY CHASSIS

7. Electric Drive Vehicle Basic Layout

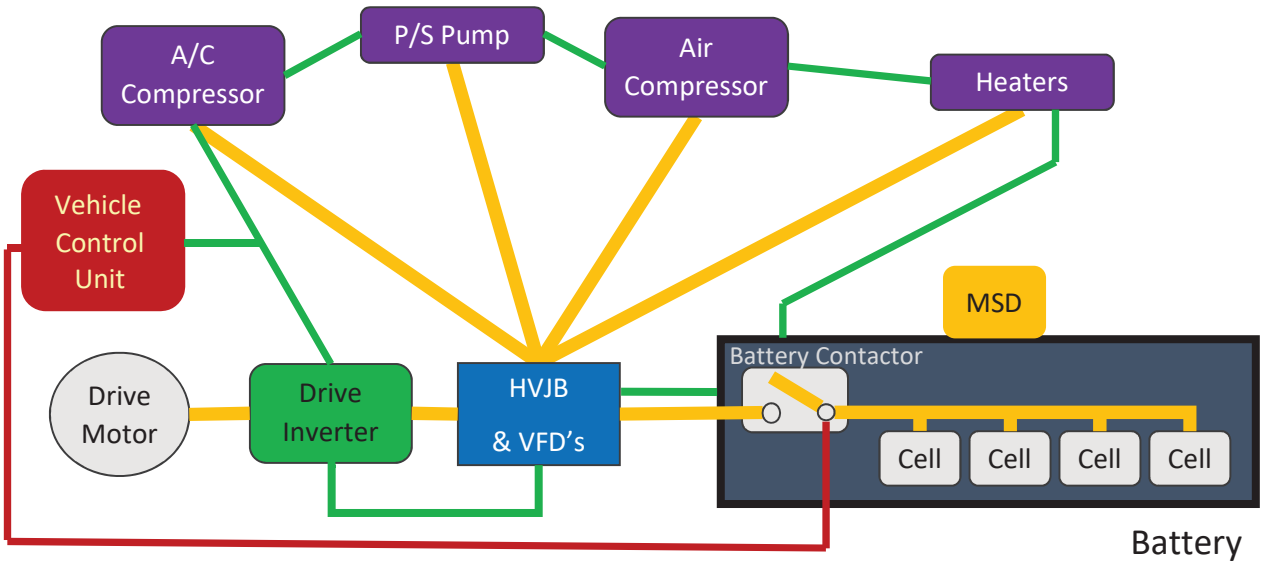


A. Mounting Brackets
B. MSD Connector
C. HV Connector

EV charging stations supply DC power straight to the battery. The HV battery supplies the current that is used to propel the vehicle and maintain the low voltage (12V) features and components. The drive power inverter converts the DC current that is supplied by the battery into AC current that is used by the motor, and controls the motor's speed. When braking,it acts as a rectifier to convert the motor's AC output into DC current in order to charge the battery. The drive motor is a 3-phase AC synchronous motor.

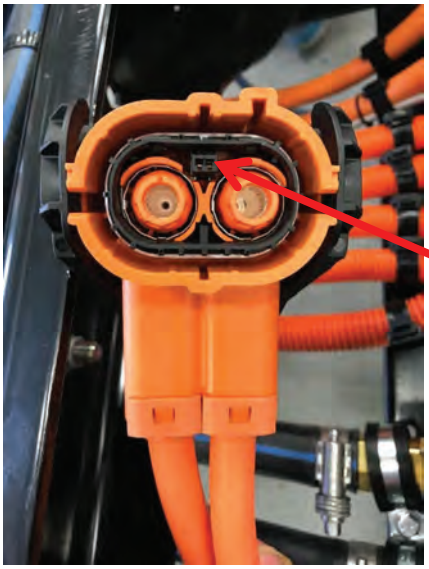
8. High Voltage System Safety Features

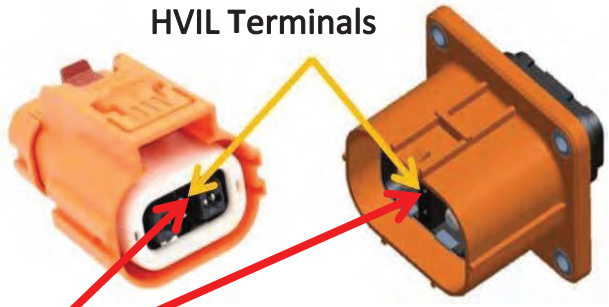
High Voltage Interlock Loop (HVIL)



There are multiple vehicle interlocks that can cause the battery contactor to open, such as a disconnected high-voltage connector or other problems with high-voltage components. The Vehicle Control unit provides a signal to turn off the high-voltage system when a connector or cover is removed and prevents re-starting the high-voltage system if the connector or cover is not properly fastened. It is a continuous series loop that, if continuity is broken, is sensed by the vehicle controller, which in turn signals the battery contactors to open.

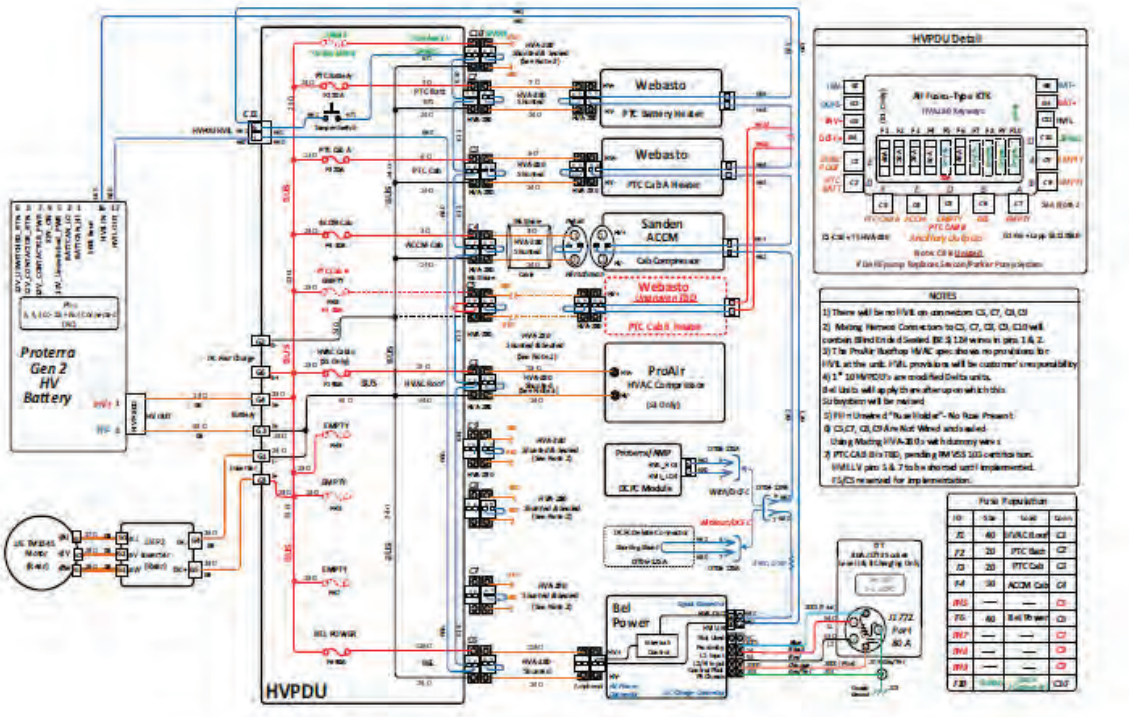
High Voltage Interlock Loop (HVIL) Contacts on High Voltage Power Connector





HVIL terminals are recessed to be the last to make contact when connecting and the first to break contact when disconnecting.

HVIL Wiring Diagram



High Voltage Safety Software features

Primary Function

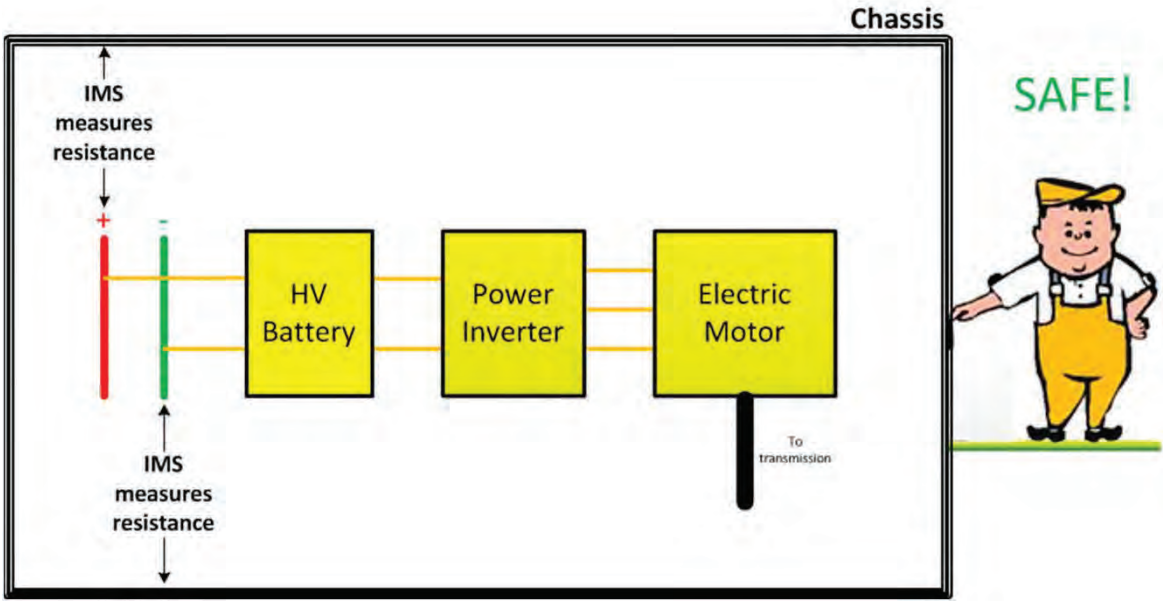
- Prevent energizing the HV system until all the necessary signals are valid

Application

- Provide a signal to turn off the HV circuit when a necessary CAN signal from a critical component is invalid
- The system shall inhibit re-starting the HV circuit until a necessary CAN signal from a critical component is valid.

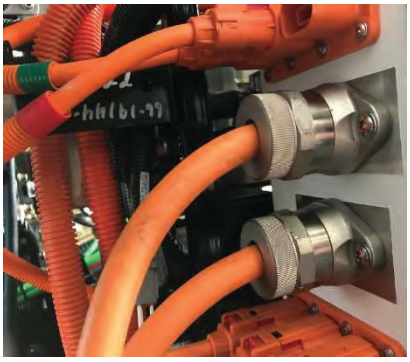
Isolation Monitoring System

The isolation monitoring system constantly measures the resistance between the high voltage conductors and ground. It warns the vehicle operator if the resistance falls below a set threshold.



Safety by Mechanical and Functional Design

- **High Voltage Cables are orange.**
- **High voltage conductors and live components can only be accessed by disassembly tools**.



Discharge of DC Capacitor

Active Discharge

- Discharge of the DC link through permanent discharge resistor
- Requirement: Voltage <60V in <120 seconds

High Voltage Component Labels

All high voltage components are identified with the following labels:

9. Hazards of Electric Current

Electrical ArcFlash

Arc flash is likely the primary hazard present with high voltage vehicles. It is often caused by the interruption of a large electrical current in an inductive circuit (as shown in the example below). This interruption forces electrons through theair heating it and surrounding materials to extremely high temperatures. It can throw sparks and molten material up to 6 feet away. The flash is extremely bright, and can permanently damage your vision.

The Optimal E1 bus is not considered an Arc Flash hazard.

- Electric arc radius ca. 10 in
- Flying sparks up to 6 ft.
- Electric arc temperature 1,000 °C

Electrical Arcs in HV Battery During Short Circuit Test

Electrical Shock

Electric current passing through the human body can cause shock, burns and in extreme cases, death. The body's electrical resistance can be affected by many factors. Skin moisture, body size, and body composition can cause these values to vary. Also, the more voltage that is applied, the lower the body's resistance value.

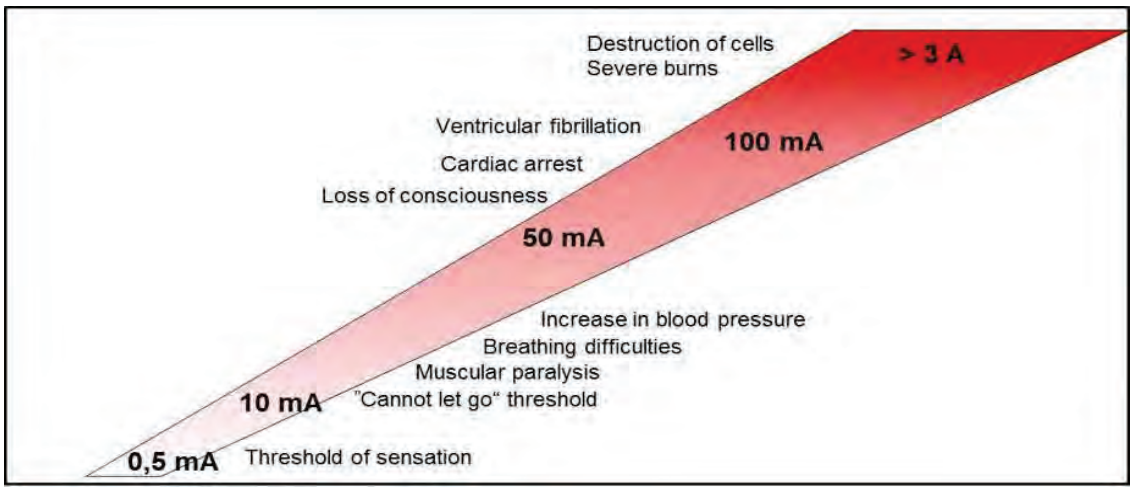
Current Path	Resistance
Hand – to - hand	1000Ω
One hand – two feet	750Ω
Two hands – two feet	500Ω

Typical Electrical Resistance for Different Paths Through the Body

Using the nominal voltage value for a commercial vehicle battery, and the best-case resistance, Ohm's Law shows a 600 mA current.

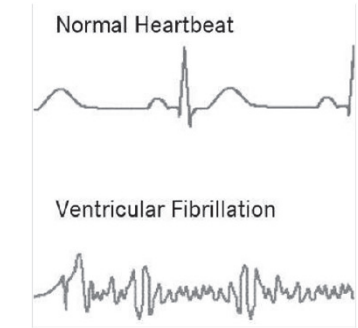
$$I = \frac{V}{R} = \frac{600V}{1000\Omega} = 600\ mA$$

The 600 mA that we calculated above would be in the most dangerous part of this chart.



Effects of Current on the Body - Length of Exposure Increases Severity

Effects of Electric Shock



Alternating current can cause uncoordinated twitching of the heart, resulting in no blood flow.

Current flow can cause severe burns, and bursting of blood vessels.

Current flow (particularly DC) can cause a breakdown of the cell chemistry. This effect is toxic, and can manifest days after the shock.

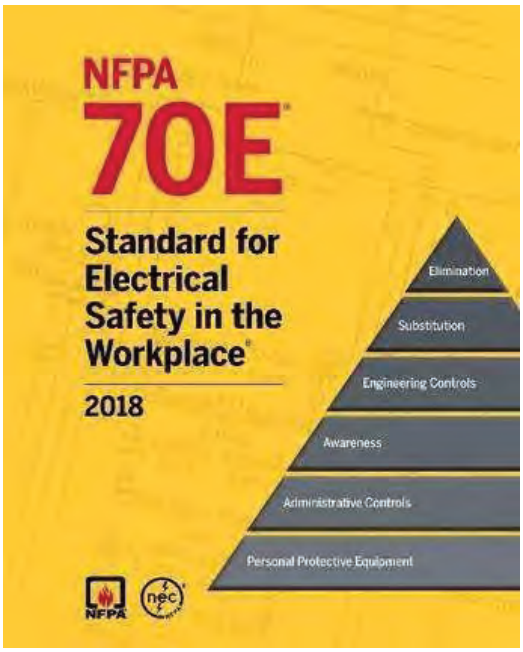
Secondary Hazards

These hazards can be caused due to electric shock, electric arcs, etc. For example, falling down from a ladder due to electric shock.

10. Safety Regulations

NFPA 70E

The NFPA 70E lists requirements for safe work practices that protect personnel by reducing exposure to electrical hazards. Originally developed at OSHA's request, NFPA70E helps companies and employees avoid workplace injuries and fatalities due to shock, electrocution, arc flash, and arc blast, and assists in complying with OSHA 1910 Subpart S and OSHA 1926 Subpart.



Some NFPA 70E Topics

- Guidelines for electrical safety in the workplace
- Electric safety related work practices
- Hazard identification and assessment
- Selection of appropriate of Personal Protective Equipment (PPE)
- Requirements for special equipment

The important basic rule that serve the goal of avoiding accidents at work:
Never perform work on live parts.

Before performing any work on the above mentioned live parts, the voltage-free condition has to be tested by approved means and has to be safeguarded while at work. NFPA 70E also complies with IEC EN60903, an International Standard for safety.

11. Work on Electrical Installations and Equipment

Strategies Used to Ensure Electrical Safety

Remove the Danger

The Specialist for High Voltage Systems (SH) will remove power from a high voltage vehicle before it is worked-on. There are five steps to this procedure.

1. Disconnect the source of high voltage to the vehicle. This generally consists of ensuring that the battery contactors are open.
2. Secure the electrical system against reconnection to high voltage. Follow lock-out/ tag-out procedures to prevent the vehicle from being inadvertently re-started.
3. Verify that the high-voltage system is shut off. Before performing any work involving the high-voltage system, it must be verified voltage free by use of a dual-pole voltage tester.
4. Grounding and short-circuiting - this step must be carried out only if the system's nominal rated voltage exceeds 1000 VAC or 1500 VCD. It can be skipped if the first three steps are carried out successfully.
5. Provide protection from adjacent live parts - this step will likely not be necessary as when the vehicle is shut off, there will be no adjacent live parts. However, you must still protect workers from other hazards that might be present, such as rotating equipment, hot surfaces, etc.

Safety by Design

As discussed earlier in the course, the vehicle is designed and constructed to provide the maximum safety to the operator and service technician through use of safety interlocks, component guards, and electrical insulation.

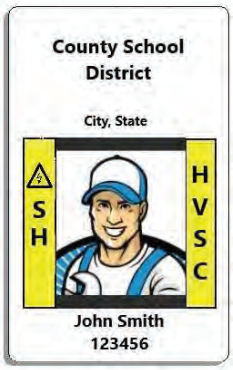
Safety by Organization

When working on a high voltage vehicle, access to these high voltage systems is restricted to personnel that are properly trained, and are actually performing maintenance or repair.

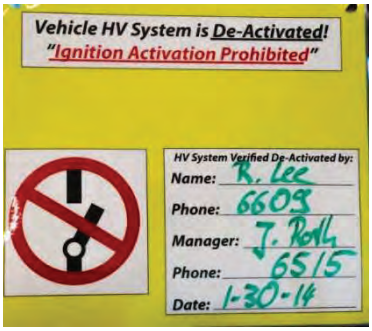
Electrical Safety Area

Temporary Barrier Around Work Area

Marking of HV Vehicle in the Workshop



Marking Employee's HV Training on Badge



Marking of a De-energized Vehicle

Personal Protective Equipment (PPE)

In addition to the PPE that is normally worn in a shop environment, PPE that protects the wearer against high-voltage contact or arc flash must also be worn when appropriate.



Shop Safety

OSHA requires shops to provide safety equipment, work perimeters, disposal of safety equipment, and training. Refer to your shop's OSHA-compliant safety program for training, PPE, and operational requirements. When working on electrical vehicles, special tools are required for working whenever high voltage is present.



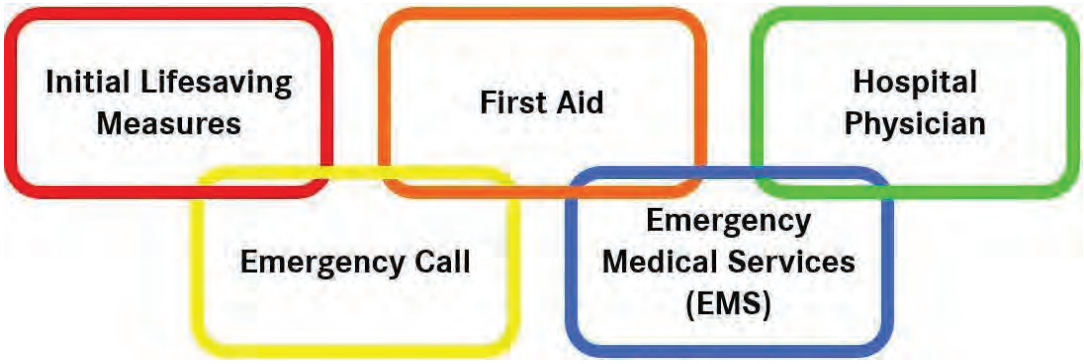
Insulated Tools, Class D Fire Extinguisher and Optional Hot Stick Shown

Behavior-Related Measure

High voltage work must be conducted by trained personnel according to approved, risk-assessed work instructions. The shop must have a culture of safe work habits. Shop personnel must know first aid.sonnel must know first aid.

12. First Aid

The Rescue Chain

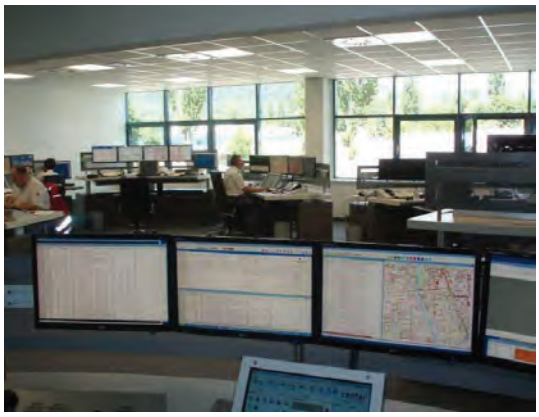


When there is a mishap at the workplace, having a strategic plan to quickly move from one end of one chain to the other can greatly enhance your ability to contribute to a positive outcome for the victim. These steps are only a suggestion. Please follow your company's/ location safety processes.

Initial Lifesaving Measures

This step involves getting the victim out of danger and preventing further injuries. If a person is in contact with a live electrical conductor, shutting off the power is the easiest, quickest, and safest way of preventing further injury. If this is not possible, a rescue hook could be used, if available, to separate the victim from the conductor, but you could also don electrical safety gloves and accomplish something with more control. The most important thing to remember is do not become a casualty yourself. Relocate the victim to a safe space for evaluation (away from fire, traffic, etc.).

Emergency Call



Know the address of your building, or where to find it. A great place to post the address is above the exit doors, especially in shop areas. Give the emergency operator all of the information they ask for, and wait for them to hang-up at the completion of the call. The next call you should make is to corporate security (if applicable). They will help first responders quickly find the area where you are located.

First Aid

Determine if the victim has a pulse and respiration. If not, have an assistant retrieve an AED while you perform. Remember that the AED may still require you to continue CPR after it has stopped any heart fibrillation. Use cool water on burns to stop the heat damage of to tissue. Cover any burns with a clean, dry gauze dressing. The purpose of this dressing is only to prevent the burn from getting dirty.

Emergency Medical Services (EMS)

Open any necessary doors to allow EMS access. Don't get in their way, but render any assistance that they ask for.

Hospital Physician

This step is performed at a hospital or other medical care facility.

Summary

The key to effectively providing aid to a person who has been involved in a workplace mishap is preparation. Know the locations of first aid and firefighting equipment in your building, and get first aid training when available. Calm, determined action will provide the most help to a colleague in need.

Operators Guide

1. Optimal EV Electric Bus Component Overview

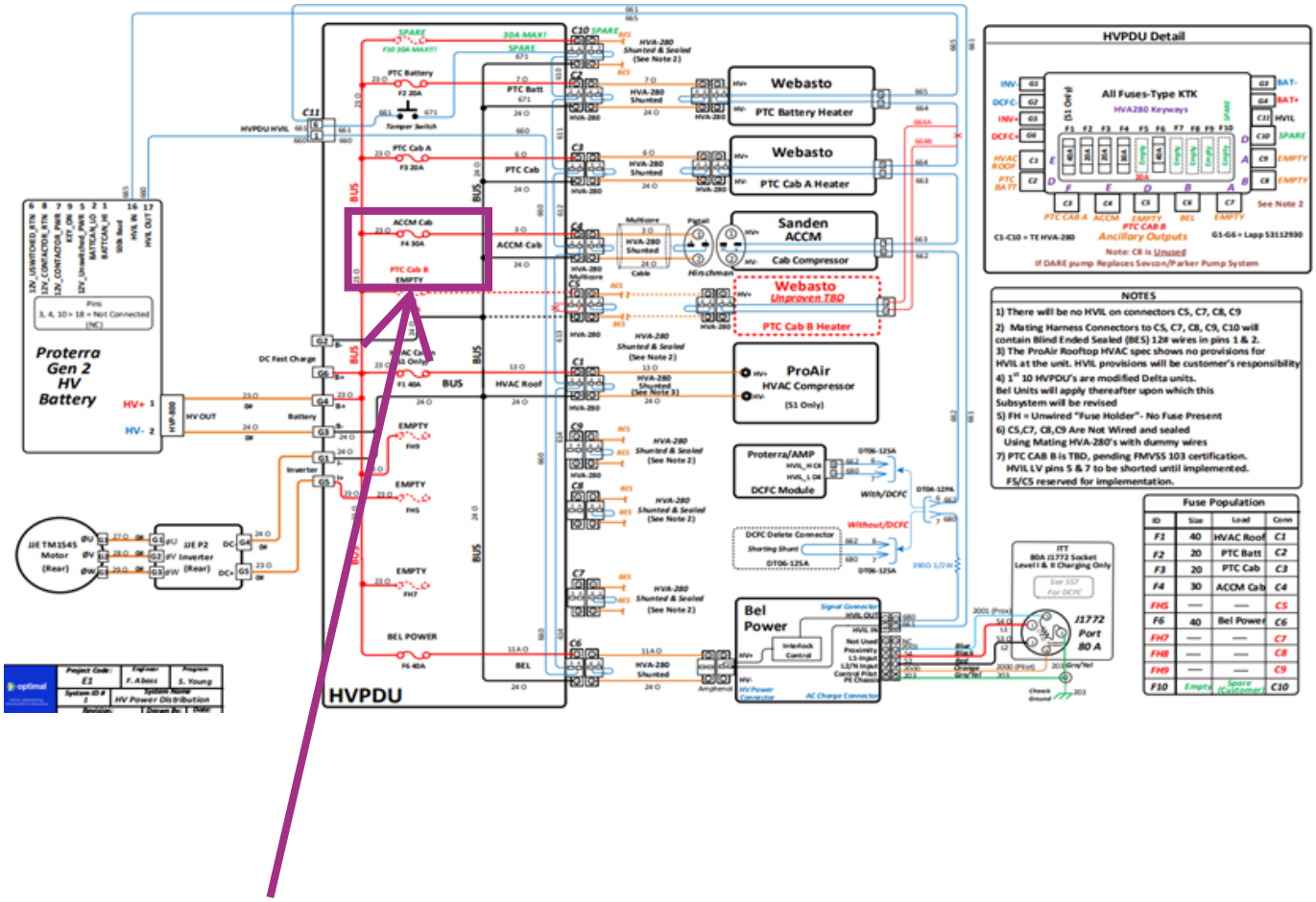
High Voltage Battery Packs

- Sealed lithium-ion battery from Proterra
- 6-year or 175,000-kWh warranty
- 113 kWh, 326V nominal voltage
- Water/Glycol mixture temperature control
- High Voltage coolant heater A/C compressor cooled
- Temperature range: -22 F to +133 F (-30 C to +56 C)
- Installed between the frame rails for added protection

The high-voltage system powers all high-power systems on the vehicle. Primary energy is stored in the high-voltage battery pack located below the floor. When the vehicle is started, contactors close within the battery pack and energize the high-voltage buss. This powers the high-voltage components and the low-voltage 12-volt (12V) system through a DC-to-DC converter. The battery packs are cooled by an internal heat exchanger and are connected to an external heat exchanger and HVAC chill plates by a dedicated cooling loop. The batteries have vents to relieve any high atmospheric pressure. Manual Service Disconnects (MSD) are located on the driver's side forward end of each pack to isolate power within the battery. Various controllers on the vehicle work together to manage the safety and power flow of the high-voltage system. The high-voltage system is continuously monitored for safety during operation.

High Voltage Battery Pack

HVIL High Voltage Interlock Loop



The purple line in the Schematic is the HVIL circuit. It originates at the battery and continues through the modules to complete the circuit. With “Shunts” in place of modules not installed. Notice the Tamper Switch inside the HVPDU. This switch is open anytime the cover is removed. What is not shown here is the contactor. When in the “OFF” position, the contactor inside the battery opens, the HVIL is now an open circuit. Disconnecting the High Voltage on the circuits and modules.

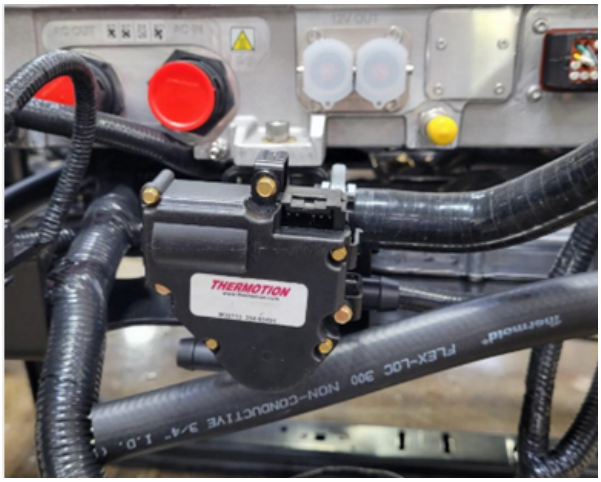
Thermal Management System

Optimal buses use four coolant pumps to circulate coolant through the thermal management system. Coolant capacity is approximately seven gallons of premix Ford coolant. The 4-way valve is controlled by the VCU B and regulates the flow of coolant through the system.

The three of the four coolant pumps and the PTC heaters are shown in the photo below. Three pumps are used for the battery management side of the system. The fourth pump, (not shown) is used to heat the cab heater core, using the second PTC heater.

Coolant Pumps (3) and PTC Heaters (2)

The 4-way valve is located on the back side of the center stack. The valve is controlled by the VCU "B".



VCU "B" also controls the coolant pumps and the radiator cooling fan operation.

Thermal Management System (cont.)

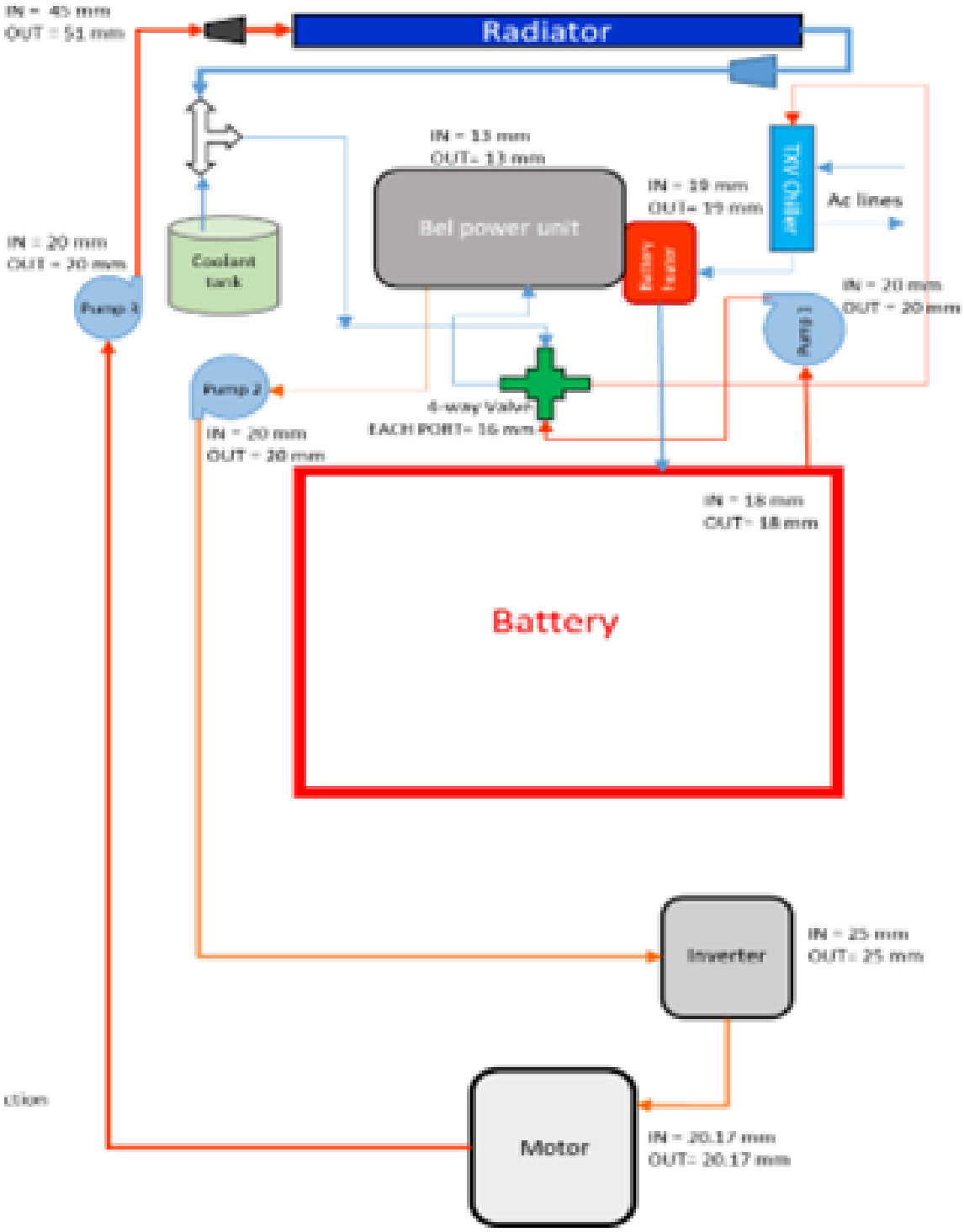
The photo below shows the fourth coolant pump, AC compressor, TXV heat exchanger, a vacuum pump, and the power steering pump. The TXV heat exchanger (yellow cap, on the far right) is used to cool the coolant. The AC compressor does double duty by cooling the coolant for the Thermal Management System and the evaporator core for the cab. This assembly is mounted in the cradle as a unit.

Cradle with Coolant Pump, AC Compressor, TXV Heat Exchanger, Vacuum Pump, and the Power Steering Pump

Vacuum System Pump

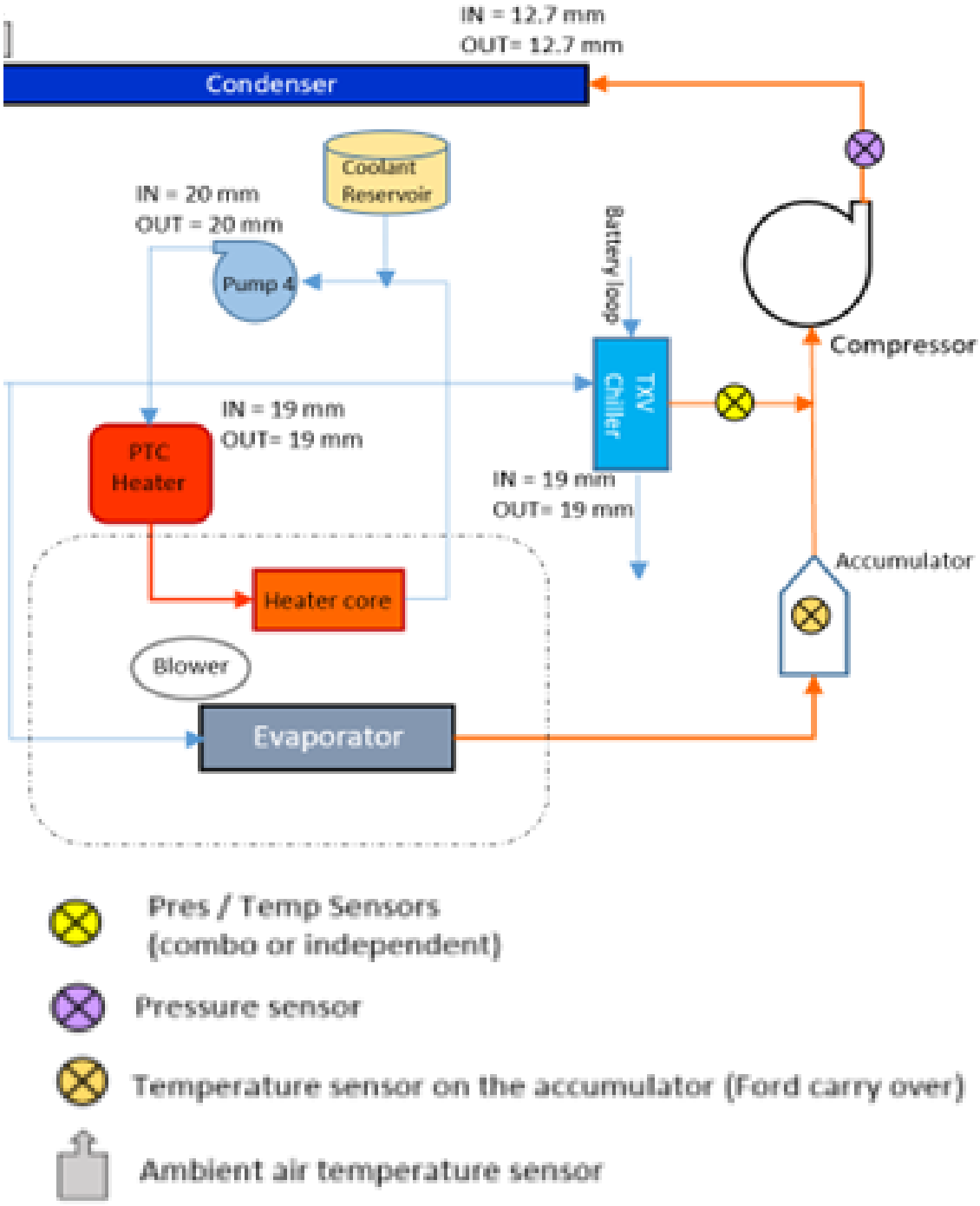
The vacuum pump is mounted in the cradle area, next to the AC compressor. You can also see in this photo the coolant/ refrigerant TXV heat exchanger. This heat exchanger is used to cool the coolant in the Thermal Management System.

Coolant and AC System – Schematics



The system is managed by controlling its temperature. We accomplish this by heating and cooling the Water/Glycol mixture.

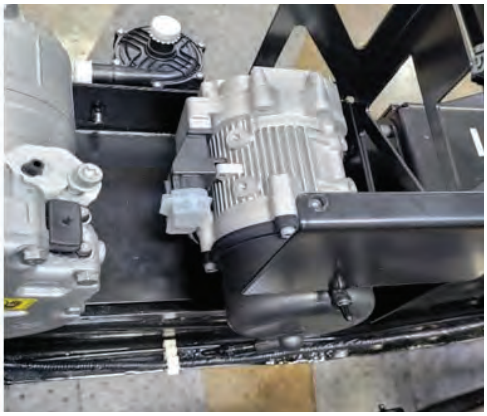
Coolant and AC System – Schematics



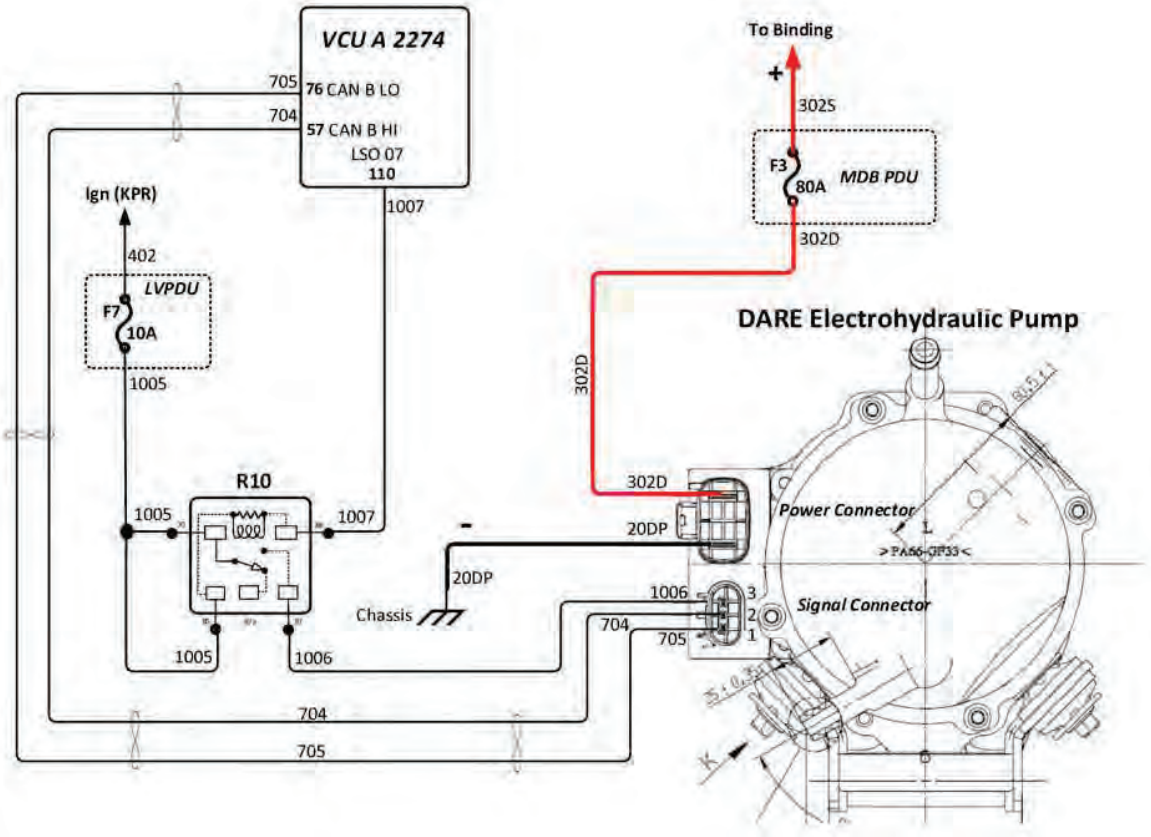
Using 134A refrigerant, AC compressor, along with a TXV heat exchanger. We can maintain optimal coolant and component temperatures.

Hydraulic System

The DARE pump provides hydraulic pressure for the power steering system. The DARE pump also supplies hydraulic pressure for the factory “Hydro Boost” brake system. The pump creates a familiar steering and braking experience for drivers that is similar to the sensation of a belt-driven pump. The pump Is controlled by the VCU A, based on the RPM signal received via CAN lines.



DARE Pump



DARE Pump Circuit Diagram

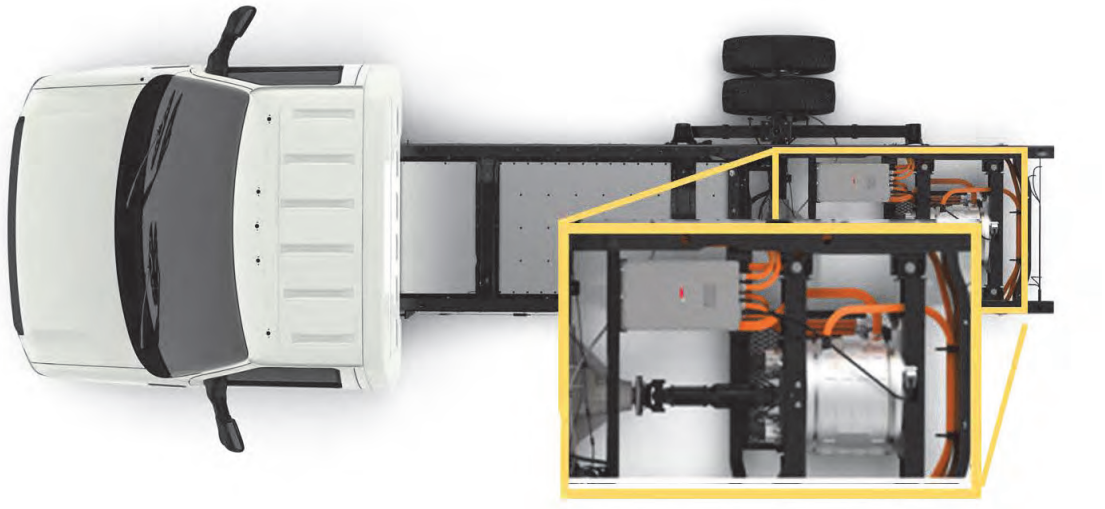
Traction Motor and Motor Controller/Inverter

The drive train consists of the motor controller, traction motor, driveshaft, and rear axle assembly.

The Traction Motor, or Drive motor, is a 3 phase AC, permanent-magnet, liquid cooled motor. The Traction Motor is connected to a liquid cooled Motor Controller / Inverter (inverter) with three-phase, HV power cables and a data cable. The Inverter converts HV DC from the main battery into variable frequency, variable current, three-phase power to turn the traction motor at the desired speed and power level.

Power flow through the inverter is bidirectional. When accelerating, power flows from the main battery pack to the inverter and then to the traction motor. When decelerating, the traction motor generates electricity which flows to the inverter, gets converted to DC, and recharges the main battery. Regenerative braking significantly improves vehicle energy efficiency.

The traction motor drives a driveshaft attached to the rear axle. To go in reverse, the traction motor rotates the driveshaft in the opposite direction. Parking is provided by the Wilwood braking system. The system is controlled by the VCU A based on inputs from the PRND switches. Electronic controlled calipers clamp onto disc mounted on the front of the motor.



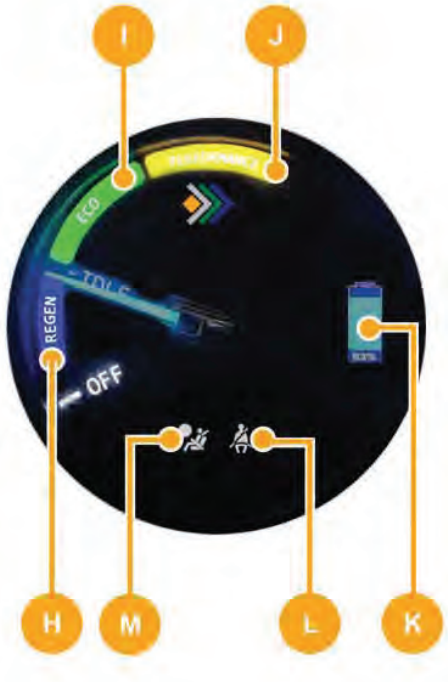
Detail Shows Inverter, Traction Motor and Driveshaft

Traction Motor Specs

- Continuous/Peak Torque – 1000/1700 Nm (737/1254 lb-ft)
- Continuous Peak Power – 170/280 kW (227/375 hp)
- Voltage Range – 300-750 vdc
- Top speed – 70 MPH (112 KPH)
- Gradeability – 30% (Equivalent to OEM E450)
- Rear axle is rotated, motor mounted in rear.
- The 2 Wilwood brake calipers serve as a Park. Controller is mounted right kick area of the cab.

2. Instrument Panel

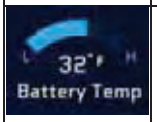
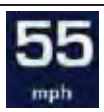
A. Drive Voltage
B. 12V Battery Voltage
C. HV Battery Temperature
D. Motor Temperature
E. Speedometer
F. Message Center
G. Performance Gauge
H. Regenerative Braking
I. Eco Mode
J. Performance Mode
K. Battery State of Charge
L. Air Bag Warning Light
M. Seatbelt Warning Light



Performance Gauge Detail

3. Message Center

Message Center Descriptions

Image	Indicator	Notes
	Drive Battery Voltage Gauge	Normal drive battery voltage ranges from 250 to 370V. The gauge changes color to red when the drive battery voltage goes too low or high.
	12V Battery Gauge	Vehicle 12V voltage gauge ranges from 0 to 16V. The gauge changes color to red when the 12V battery voltage goes too low or high.
	Vehicle Battery Temperature	Vehicle battery temperature gauge ranges from -40° to 176° F. The gauge changes color to red when the battery temperature goes too low or high.
	Motor Temperature	Vehicle motor temperature ranges from -40° to 302°F The gauge changes color to red when the motor temperature goes too low or high.
	Turn Signal (Left)	Flashes when left hand turn signal light is flashing.
	Turn Signal (Right)	Flashes when right hand turn signal light is flashing.
	Low 12V Voltage Indicator	Illuminates when 12V (auxiliary) battery charge is low.
	Coolant Temperature Indicator	Illuminates when coolant temperature exceeds normal operating temperature.
	Speedometer Digital Number	Vehicle speed in miles per hour.

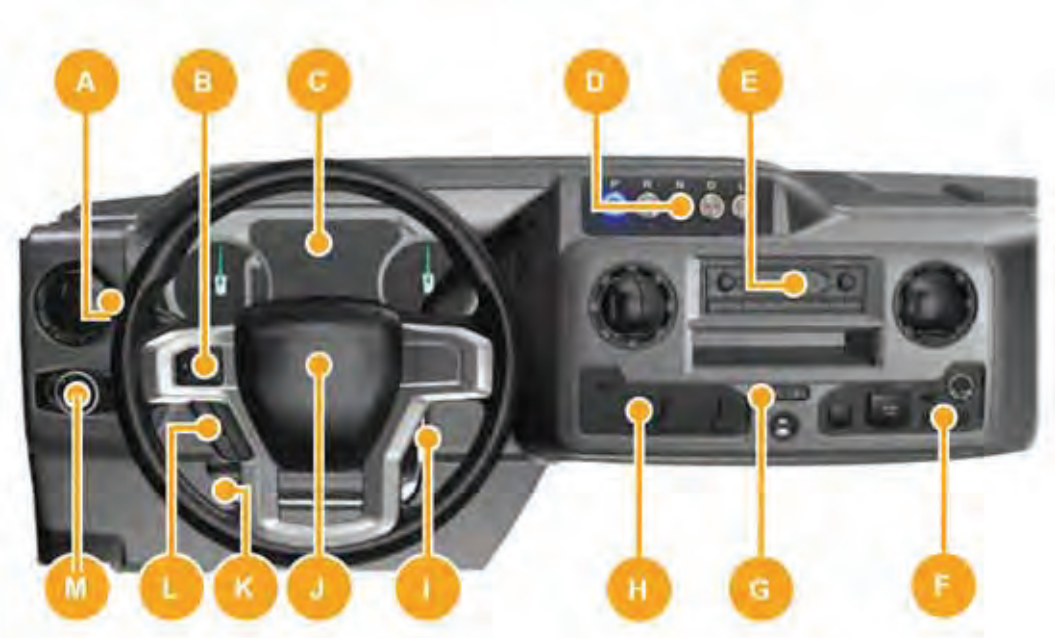
Message Center Descriptions

Image	Indicator	Notes
	Headlight Indicator	Illuminates when the vehicle headlights are on.
	Low Beam Indicator	Illuminates when the vehicle headlights are dipped (i.e. when low beam headlights are on).
	High Beam Indicator	Illuminates when the vehicle headlights are on full beam (i.e. when high beam headlights are on).
	Fog Light Indicator	Illuminates when the vehicle fog lights are on.
	Traction Control Indicator	This indicator will turn on when the traction control is activated. When the traction control is off, this indicator will show traction off indicator as well.
	Motor Problem Indicator	Illuminates when there is a problem with the vehicle drive train. Seek vehicle service immediately,
	Brake Pedal Indicator	Illuminates when the brake pedal is engaged.
	Low vehicle battery indicator	This indicator will turn on when the high-voltage traction battery charge is below 20%.
	Door Open Indicator	When driver or passengers of doors are open, this icon will indicate the door open statues.
	Regen Brake Indicator	This indicator will turn on when the regen brake is on. Avoid hard braking when regen is active.
	Hazard Warning Indicator	Flashes when the vehicle hazard lights are on.
	Battery SOC Indicator	Battery state-of-charge (SOC) indicator ranges from 0 - 100%. The gauge color changes to red when the battery SOC goes below 20%. When the vehicle is charging, the gauge color changes to green.
	BMS Malfunction Indicator	Illuminates when there is a problem with the Battery Management System. Seek vehicle service immediately,
	OBC Malfunction Indicator	Illuminates when there is a problem with the On-Board Charging System. Seek vehicle service immediately,
	PTC Malfunction Indicator	Illuminates when there is a problem with the Pressure Temperature Current switch. Seek vehicle service immediately,
	DCDC Malfunction Indicator	Illuminates when there is a problem with the DC-to-DC Converter. Seek vehicle service immediately,
	ACCM Malfunction Indicator	Illuminates when there is a problem with the Air Conditioning Control Module. Seek vehicle service immediately,
	SWP Malfunction Indicator	Illuminates when there is a problem with the Steering Wheel Pump. Seek vehicle service immediately,

Message Center Descriptions

Image	Indicator	Notes
	J1939 DM1 Red Stop Lamp	This lamp indicates serious faults that require the vehicle to stop. The lamp will flash slowly, quickly, or remain ON depending on the severity of the fault.
	J1939 DM1 Malfunction Indicator	Malfunction Indicator Lamp (MIL) shows malfunctions related to electric drivetrain. The lamp will flash slowly, quickly, or remain ON depending on the severity of the fault.
	J1939 DM1 Amber Warning Indicator	This lamp signals less critical faults and vehicles need not be immediately stopped. The lamp will flash slowly, quickly, or remain ON depending on the severity of the fault.
	J1939 DM1 Protection Indicator	This lamp indicates faults in non-electrical systems (e.g., high hydraulic fluid temperature) The lamp will flash slowly, quickly, or remain ON depending on the severity of the fault.

4. Instruments and Controls



A. Turn Signal, Windshield Wiper and Washer Control Lever
B. Information Display Control
C. Instrument Cluster
D. Gear Selector Buttons
E. Audio unit
F. Passenger Airbag Deactivation Indicator
G. Hazard Flasher Switch
H. Cab Climate Control
I. Ignition
J. Horn
K. Steering Wheel Adjustment
L. Cruise Control
M. Lighting Controls

5. Important Driving Guidelines

The following operational limits **must** be adhered to unless in a controlled situation, such as during a test with a Proterra Customer Service Representative present:

- Although allowing the bus to coast and progressively slow down during a stop regenerates electricity into the batteries, using the brake pedal during stops should NEVER be discouraged.
- **DO NOT** accelerate and decelerate often in an attempt to “regenerate” more power into the batteries. Smooth operation during acceleration and deceleration provides the highest driving efficiency.
- When at 100% SOC, regenerative braking will be limited to prevent overcharge of the batteries.
- Full throttle at 50% SOC has a slight torque decrease from full throttle at 100% SOC.
- Driving in Reverse – Limited to 8 mph and decreased torque. (It requires more throttle travel / input to move in reverse.)
- Turn Temp Dial from “Red” to “Blue” zone when heaters are not in use. The “Red” zone activates HV coolant heaters regardless of heater blower activation. This practice will help gain the full mileage potential of the HV batteries.
- If “Low Voltage” appears in the Instrument Panel Message Center, all auxiliary components should be shut down immediately, including all heaters, AC, and body fans. The bus should be moved to a safe location off of the road to park until the message clears, or proper troubleshooting is completed.

6. Operations

Before Starting

1. Remove the charging cord from the vehicle charge port and return the cord to the charging station.
2. Close and latch charging inlet port cover and close charging door.
3. Walk around the vehicle to make a visual inspection to ensure that tires are inflated, doors are properly closed, there is no unexpected damage, and the vehicle is clear of people and obstructions.
4. Make sure the wheelchair ramp (if equipped) is properly stowed.
5. Adjust the seat and mirrors.
6. Fasten your seatbelt.
7. Engage the parking brake.

Shutting Down

1. Make sure the vehicle comes to a complete stop.
2. Put the vehicle in Park by pressing "P" on PRNDL controls. Wait until the P button is illuminated.
3. Engage the parking brake.
4. Turn the key to the "Off" position and remove the key from the ignition.
5. If the vehicle has shut down properly, the cluster screen will be turned off in a few seconds.

7. Charging

1. Remove the charging cord from the charging station. Only J1772 level 1&2 AC charger or CCS type 1 combined charger is accepted.
2. Visually inspect the cord and charging head for signs of damage. DO NOT use the charger if the cord or charging head is cut, damaged, or broken.
3. Open the charging door on the vehicle's front grille.
4. Release the lever on the charging inlet port cover to expose the charging inlet plug.
5. Plug the charging head into the charging inlet port on the vehicle. For a J1772 AC charger, make sure the charging head is fully inserted with a clicking sound.
6. Press "Start" on the charging station if required to begin charging. For a CCS type 1 charger, a locking motor sound indicates the charger is engaged properly.
7. Check Message Center. The green battery icon should be illuminated.



Estimated Charing Times:

- Standard Level 1 & 2 AC Charging (J1772) – < 8 Hours
- Optional Level 3 DC fast Charge – < 2 Hours

8. Shutting Down the High Voltage System

Always disconnect the HV battery before performing any work on the High Voltage side of the system.

The Proterra battery disconnect is located in the front of battery. It is accessible by removing the doghouse or from underneath the vehicle. As an added safety precaution, you should be removing the keys from the vehicle and placing them in a secure location (toolbox drawer, etc.)

The Proterra battery is a sealed unit. Do not break the seal on the battery case.

The disconnect opens 2 different circuits:

- High Voltage Circuit – large terminals
- High Voltage Interlock loop (HVIL) – small terminals

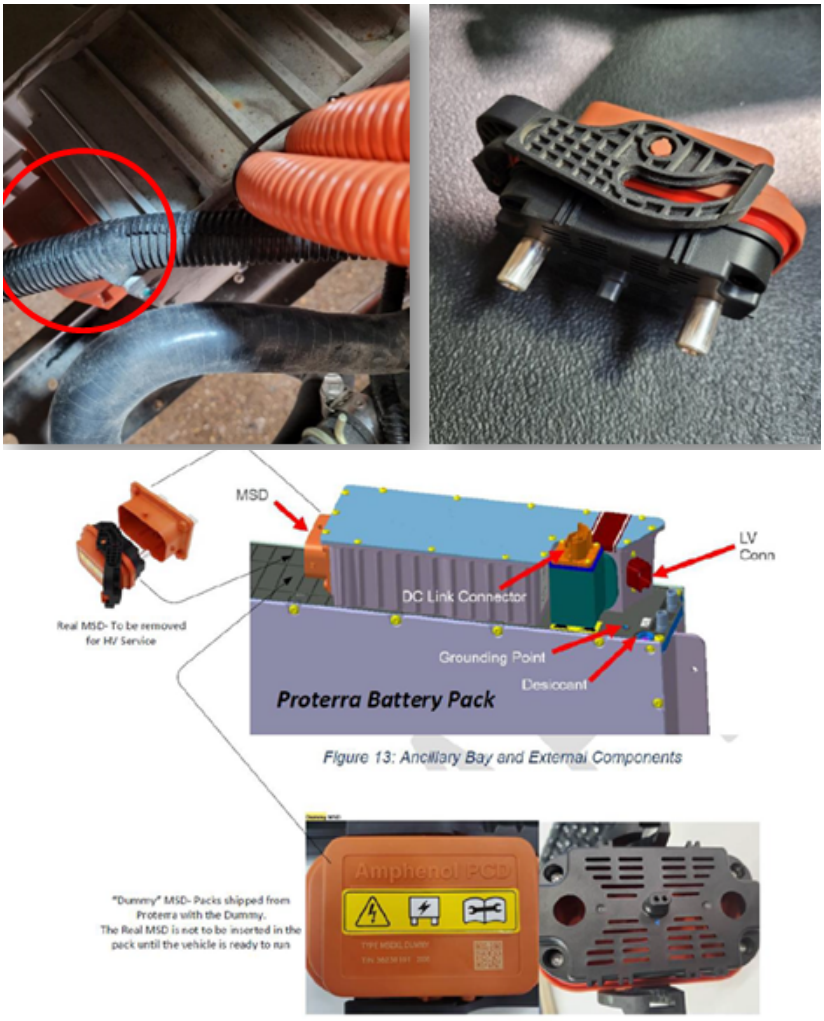
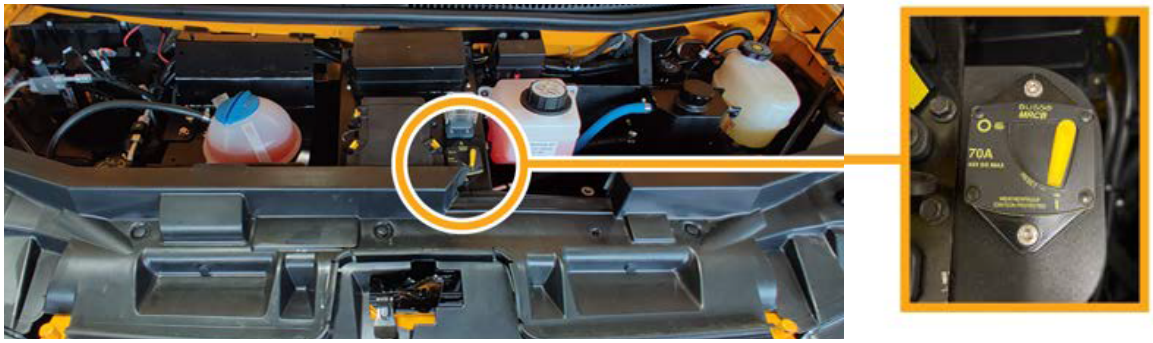


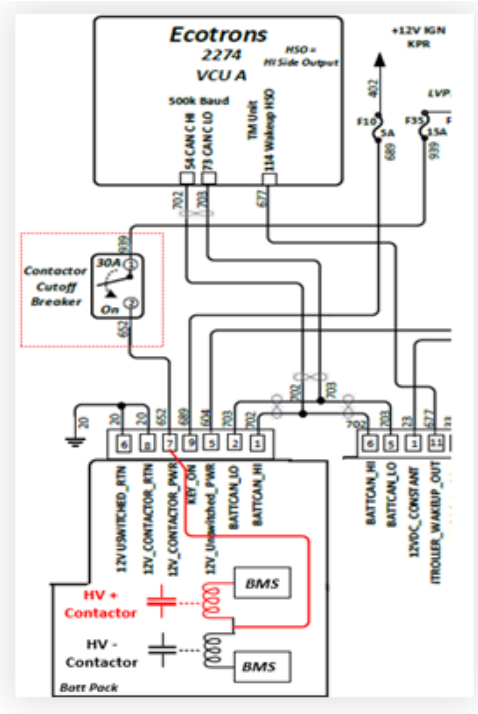
Figure 13: Ancillary Bay and External Components

Shutting Down the High Voltage System

1. Turn HV system contractor switch to "0" (off). The contractor switch is located behind the charge port door on S1/E1 and under the hood on G1 vehicles.
2. Put on your Safety Gloves. (When ever working around the battery, use precautions).
3. Remove the MSD on the front of the battery.
4. If battery is to be disconnected for any length of time. Install the “Dummy” plug that came with vehicle to protect the Battery connections and contacts.

The contactor switch is located under the hood on the G1 and inside the charging panel below the charge port on the S1 and E1.





Contactor Circuit to HV Battery

9. Towing

⚠ – WARNING

Do not tow an unbraked vehicle if the combined weight of both vehicles is more than the sum of the gross axle weight ratings (GAWR) of the towing vehicle. Otherwise brake capacity will be inadequate, which could result in personal injury or death.

⚠ – IMPORTANT

When it is necessary to tow the vehicle, make sure the instructions below are closely followed to prevent damage to the vehicle. When towing or pushing the vehicle, regardless of the distance or speed traveled, either disconnect the driveshaft at the rear axle and support it as necessary, or remove the axle shafts.

NOTE: Towing rules and regulations vary from federal, state, local, and transit authority. These laws must be followed when towing the bus.

Prior to towing, shut off the contactor to disable the high voltage (HV) system. The contactor switch is located inside the charging panel velow the charge port on the S1 and E1. It is located under the hood on the G1.

Turn Lever Clockwise to Switch Contractor Off

Tow Vehicle Capacity

Optimal has determined the curb weight of the Optimal S1 Low Floor Bus to be 12,000 lbs. and 14,000 lbs. for the G1. Optimal suggests that the towing equipment has a minimum 20% safety margin. Tow trucks should have the capacity to tow 14,400 lbs. for the S1 and 16,800 lbs. for the G1.

· WARNING

Incorrect towing may cause damage not covered by the vehicle warranty.
the vehicle warranty.

- WARNING

DO NOT TOW FROM THE FRONT. Severe damage may occur to the electric traction motor that drives the rear wheels. Towing with the rear wheels on the ground may cause an unintended generation of high voltage throughout the system.

The vehicle warranty does not cover damage to the traction motor, battery, or other components caused by incorrect towing.

Tow with Rear Wheels Off the Ground

A flatbed truck is the recommended method for transporting a disabled bus. If towing is necessary, the rear wheels must be off the ground--either towed from the rear or with the rear wheels on a dolly.

Towing from the front is not recommended and may cause severe damage to the traction motor. When towing the Optimal electric bus, the tow truck lifting device must contact only the frame rails or the rear wheels.

If the bus is towed or hauled with the rear of the bus forward, secure the primary dual-panel entrance door to prevent it from opening. A strong strap or bungee cord is sufficient. Otherwise, towing the bus backward, rushing air can catch the front door leaf and pull the door open, likely causing damage to the door panels or the opening mechanism. Also, secure the charging port door with masking tape to prevent wind damage.

NOTE: If questions arise regarding proper and acceptable towing methods or if you need recommendations for moving your Optimal vehicle, please call Optimal EV Customer Relationship at the toll-free number: +1 (888) 304-4205.

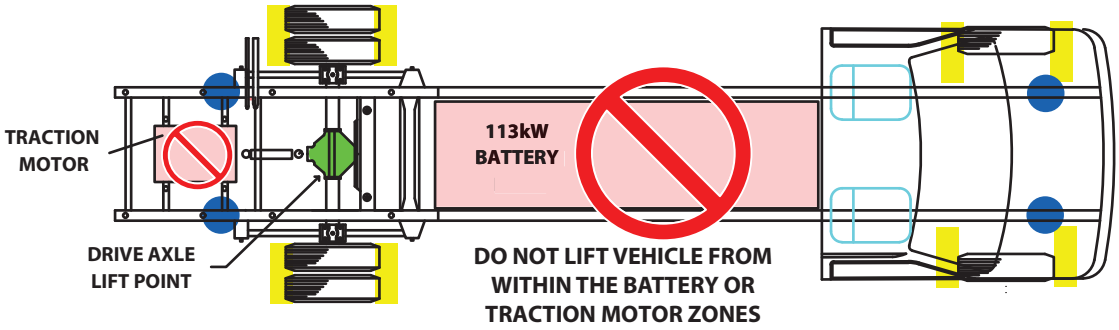
10. Lifting and Hoisting

⚠ – WARNING

To avoid damage to the vehicle battery pack and traction motor, do not position any lifting equipment under either of these critical components.

When servicing the vehicle, refer to the figure below to identify acceptable lifting points.

Yellow areas represent lift locations for mobile column lift system (four-post style). Blue areas indicate locations under the chassis rail where jacks can be positioned for lifting the vehicle. The green area indicates the location under the drive axle for lifting with a portable floor jack.



Lift Locations for the Optimal EV

Lifting Points and Jack Stands

Place jack under the frame rails at the locations identified by the blue circles in the illustration above.

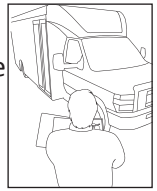
Notes

QUICKSTART GUIDE

OPTIMAL·EV

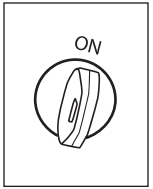
BEFORE STARTING

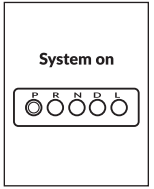
1. Remove charging cord from vehicle charge port and return cord to charging station.
2. Close and latch charging inlet port cover and close charging door.
3. Walk around vehicle to make a visual inspection to ensure that tires are inflated, doors are properly closed, there is no unexpected damage, and vehicle is clear of people and obstructions.
4. Make sure wheelchair ramp (if equipped) is properly stowed.
5. Adjust seat and mirrors.
6. Fasten seatbelt.
7. Engage parking brake.

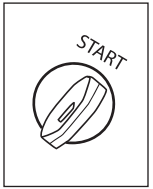


STARTING THE VEHICLE

1. Insert key into ignition.
2. Turn key to “On” position
3. Wait for Message Center to turn on and display vehicle status. If vehicle has started properly, Message Center will read “System on” and no warning light will be illuminated.
4. Ensure that vehicle is in park and the “P” button is illuminated in PRNDL settings on vehicle dashboard.
5. Press brake pedal and turn key to “Start” to engage drive. Message Center will read “Ready to Drive.
6. Press brake pedal and release parking brake.
7. Press brake pedal while shifting vehicle into Reverse, Neutral or Drive using PRNDL controls. Wait until R/N/D button is illuminated before pressing drive pedal.







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QUICKSTART GUIDE

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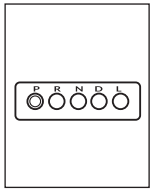
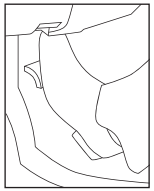
SHUTTING DOWN

1. Make sure vehicle comes to a complete stop.
2. Put vehicle in park by pressing “P” on PRNDL controls. Wait until P button is illuminated.

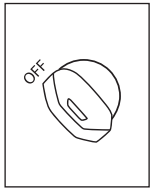


3. Engage parking brake.
4. Turn key to “Off” position and remove key from ignition. If vehicle has shut down properly, cluster screen will be turned off in a few seconds.

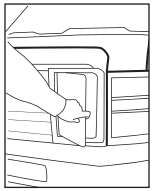


CHARGING THE VEHICLE

1. Remove charging cord from charging station. Only J1772 level 1 & 2 AC charger or CCS type 1 combined charger is accepted.

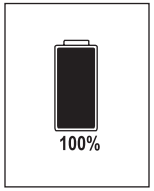


2. Visually inspect cord and charging head for signs of damage. DO NOT use charger if the cord or charging head is cut, damaged or broken.
3. Open charging door on vehicle front grille.



4. Release lever on charging inlet port cover to expose charging inlet plug.
5. Plug charging head into the charging inlet port on vehicle. For a J1772 AC charger, make sure the charging head is fully inserted with a clicking sound.

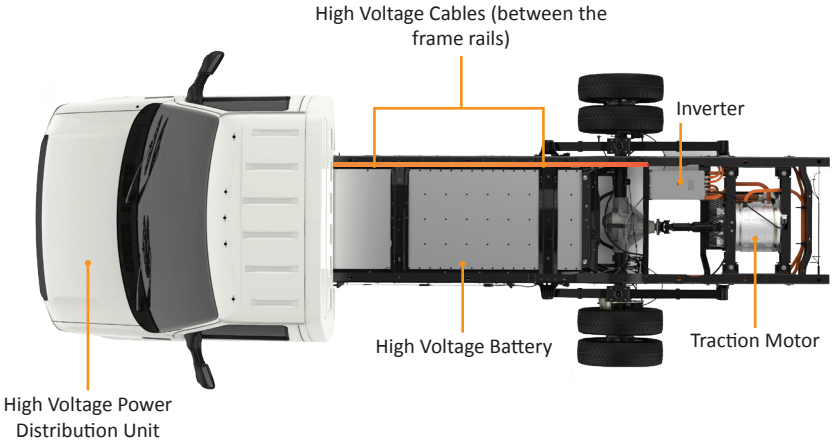
6. Press “Start” on charging station if required to begin charging. For a CCS type 1 charger, a locking motor sound indicates charger is engaged properly.
7. Check Message Center. Green battery icon should be illuninated.



OPTIMAL EV EMERGENCY RESPONSE GUIDE

Optimal EV is a manufacture of high-voltage electric buses and cutaway chassis. Optimal EV buses and chassis can be identified by the Vehicle Safety Standard Certifications label affixed to the driver's door or the charging port door located on the grille of the vehicle. Major components of the high-voltage system are identified below.

Charge Port and High Voltage



High-Voltage cabling is **ORANGE** in color. Never cut into orange high-voltage cables or high-voltage components.

- Always assume an orange cable is energized.
- Cutting an energized orange cable can be lethal!
- Do NOT assume that a "thin" orange cable is less dangerous than a "thick" one
- Always wear appropriate personal protective equipment including.

WARNINGS

- Allow 2 minutes for the high-voltage system to de-energize after disabling the high-voltage disconnect switch.
- Always assume that all high-voltage components are energized. Cutting, crushing, or touching high-voltage components can result in serious injury or death.
- Failure to disable the low-voltage system prior to occupant extraction may cause supplemental restraint system (i.e airbags) to deploy causing injury or death.
- When fire is involved, consider the entire vehicle energized and do not touch any part of the vehicle.
- Always wear appropriate PPE including high-voltage, Class 0 (1000V) rubber insulated safety gloves and self-contained breathing apparatus (SCBA)
- When handling a submerged vehicle, failure to wear proper PPE could result in serious injury or death.
- Hot metals may be ejected during high-voltage lithium battery fires, failure to wear proper PPE could result in serious injury or death.

IN THE CASE OF A BATTERY FIRE:

- Establish a 20-foot radius "safety zone" around the vehicle.
- Battery fires can take up to 24 hours to burn out. Use abundant amounts of water to extinguish a battery fire and establish an additional water source. Do not attempt to put out a battery fire with an ABC fire extinguisher.
- Extinguishing efforts should be focused at the battery enclosure for maximum effectiveness.
- Use a thermal imaging camera to ensure all heat sources are extinguished and monitor the battery for at least one hour after cooling, The presence of smoke or steam indicates that the battery is still heating.
- Do not release the vehicle to a second responder such as law enforcement or towing service provider until no heating is detected for one hour. Advise second responders that there is a risk of battery re-ignition.

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EMERGENCY PROCEDURES

OPTIMAL·EV

WARNING! ELECTRIC VEHICLES MAY BE ON WHEN SILENT AND APPEAR TO BE OFF. NEVER ASSUME AN ELECTRIC VEHICLE IS OFF UNTIL IT IS POWERED OFF.

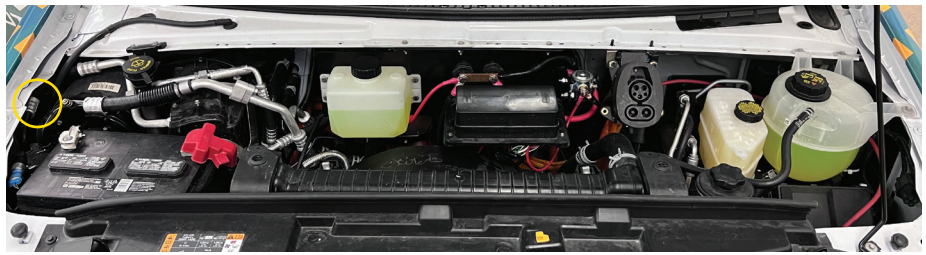
1. Chock the wheels to ensure the vehicle does not move while disabling power to the vehicle.

2. Engage the parking brake and put the vehicle into Park by pushing down on the foot pedal and pushing the “P” button on the PRNDL.

3. Remove the key from the starter.

4. Locate the high-voltage disconnect switch behind the charge port and rotate the yellow bat handle on the disconnect switch to the 0/off position.

5. Cut the 12V battery cable on the negative terminal to disconnect power to the low-voltage system, which powers airbags among other systems.



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Optimal EV Safety and Operator's Guide
02/24

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