Last updated 10-29-2020.

Welcome

- Who we are.
- Why this course.
- How we got here.

John Schiavone
Program Director
johnjschiavone@cs.com>

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TRANSPORTATION LEARNING CENTER

Welcome to BEB Familiarization Course & Thanks for Attending

John Schiavone – Transportation Learning Center
Our Mission: Advance frontline worker training on Joint L-M basis

As BEB procurements grow, so does need for increased skills.

Familiarization Course Intended for those with no/limited BEB Experience

Asked OEMs to participate – all volunteered!

BEB Familiarization Course Overview: 3 Sessions

1. BEB Technology Overview
   – June 2020
2. High-Voltage Safety Considerations
   – October 2020
3. Battery Charging Technologies
   - Future date

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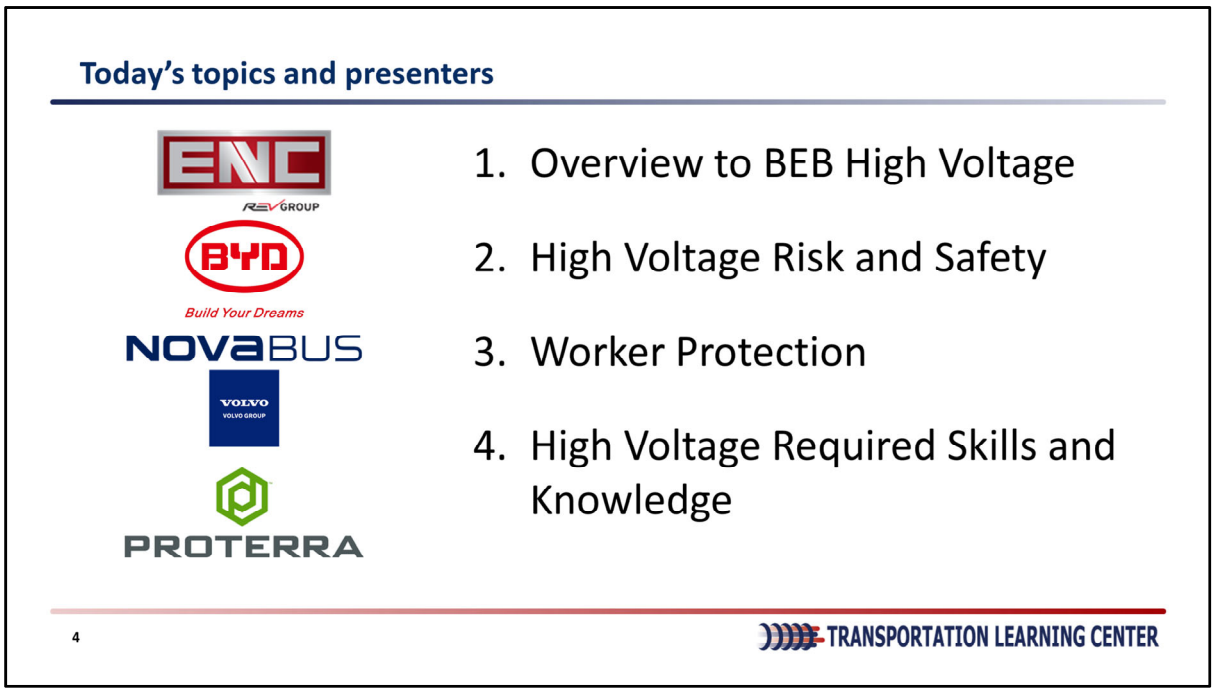
Course being delivered in three sessions:

1. General Technology Overview (June 25, 2020)
2. High-Voltage Safety Considerations Today's session)
3. Various Approaches to Battery Charging (date TBD)

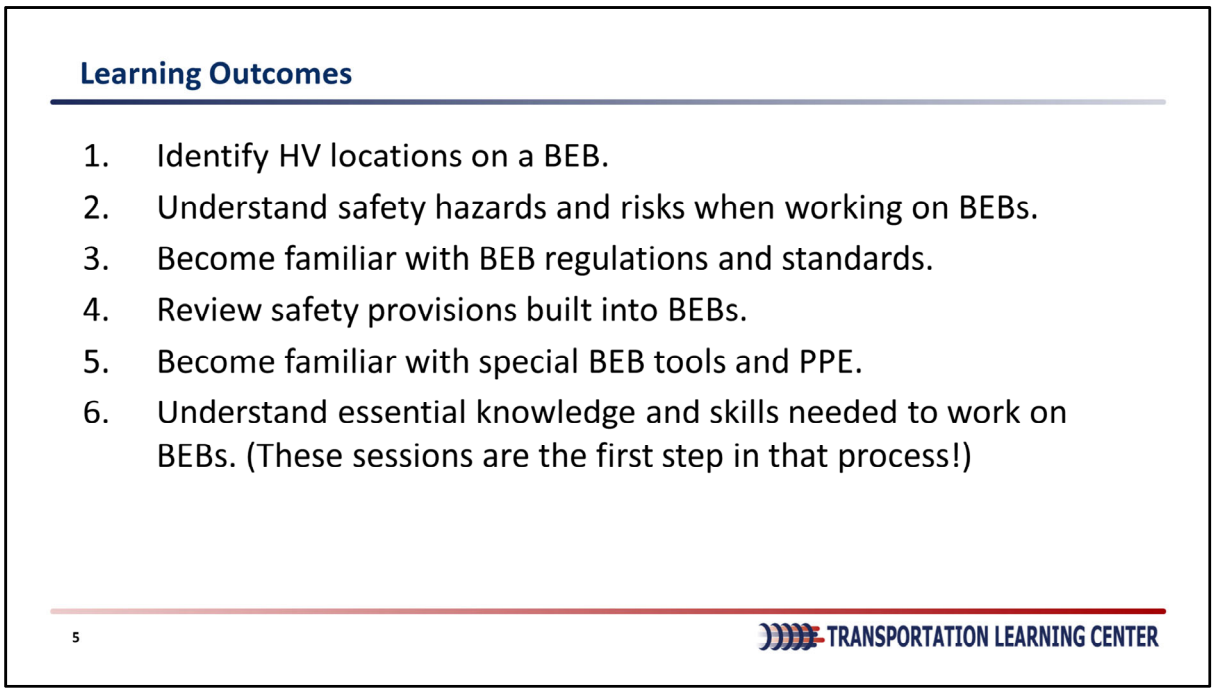
Future sessions will address ways to enhance electrical/electronic training



Today's Presenters

1. Overview to BEB High Voltage
   - Oscar Pardinas, ENC.
2. High Voltage Risk and Safety
   - Randy Premo, BYD.
3. Worker Protection
   - Chris Hossie, Novabus / Volvo Group.
4. Required Skills and Knowledge
   - James Hall or Bill Spaulding, Proterra.

Other BEB OEMs will participate in our third session.

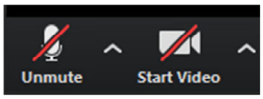


Upon Completion of today's session on BEB High Voltage Safety Considerations, learners will be able to:

1. Identify HV locations on a BEB.
2. Understand safety hazards and risks when working on BEBs.
3. Become familiar with BEB regulations and standards.
4. Review safety provisions built into BEBs.
5. Become familiar with special BEB tools and PPE.
6. Understand essential knowledge and skills needed to work on BEBs. (These sessions are the first step in that process!)

During Today's Presentation

- Attendees are muted and video turned off.



- Attendees send questions via Zoom Q&A.

- Session will be recorded and available on www.TransitTraining.net.

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All Attendees will be muted & web cams turned off .
Attendees submit questions via the "Q&A" in the Zoom webinar controls.

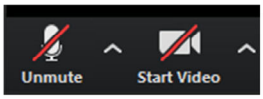
John Schiavone moderates all questions.

Session will be recorded – download from Transportation Learning Center websites: www.TrainsitTraining.net

Download will include audio, slides and presenter's written notes.

During Today's Presentation

- Version downloaded on Center site will include all presenter's notes.
- There will be some repetition.
- We will follow-up with satisfaction survey.



Session 2

High Voltage Safety

Overview to High Voltage

October 2020

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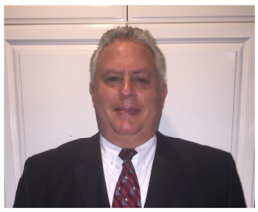
Presenter and Topics

- Define high voltage.
- Identify areas of high voltage on a BEB.
- High voltage risks and safety hazards.



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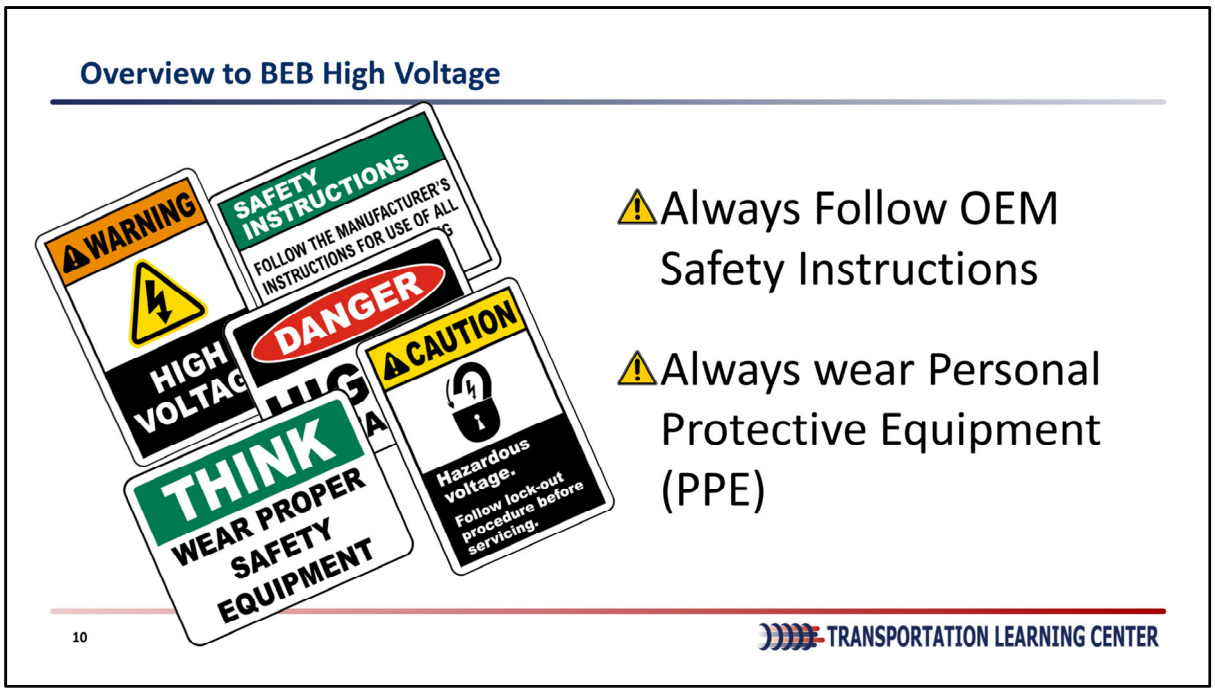
Oscar Pardinas
Regional Sales Manager, ENC (formerly Eldorado).



BEBs vary among their manufacturers or OEMs. This is a generic discussion.

First topic is Safety - We will discuss in detail safety protocols, but these two in red are generic and critical.
We have come together, from various BEB manufacturers, to discuss what it is like to work with BEBs.
In this section, we will discuss what to look out for, when servicing High Voltage (HV) and considerations when dealing with BEBs.

Most of what we are presenting today is generic, general in nature, and non-OEM specific.

It is important that before you are begin working with a specific Manufacturer's BEB HV system, you have familiarized yourself with the Manufacturer's Manual, Safety notifications, bulletins and recommendations, and are aware of all how-to procedures specified by the Manufacturer to ensure your safety.

Definition Of High Voltage

⚠30 – 1000 vAC

⚠60 – 1500 vDC

⚠>50 V = 

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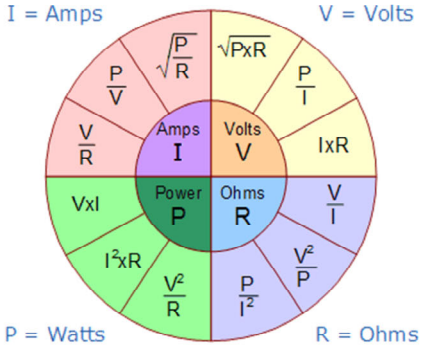
ESSs can store from 100 to 600+ kW of energy at different voltages. The current is a function of the draw placed on the ESS from the components

Our industry identifies HV, (as related to BEBs) with the following characteristics:

- A voltage in range 30 to 1000 VAC or 60 to 1500 VDC
- Keep in mind that voltages above 50 V which can cause heart fibrillation
- Note that if the conductor penetrates the skin, heart fibrillation occurs at lower voltages

When dealing with BEB HV Electric Systems, Current matters!
Current can flows through the body and cause physical damage. The higher the current the more dangerous the effect
To understand the energy stored in the BEB's ESS, the current involved, and potential risks, consider this:

Definition Of High Voltage



- Power (W) = Voltage (V) x Current (I), thus P/V=I
- ESS working at 600 volts has ability to store 300 kW = 300,000 watts!
- 300,00 watts / 600 volts = 500 Amps!
- Current > 0.5 mA AC and 3.0 mA DC CAN CAUSE HARM TO THE HUMAN BODY

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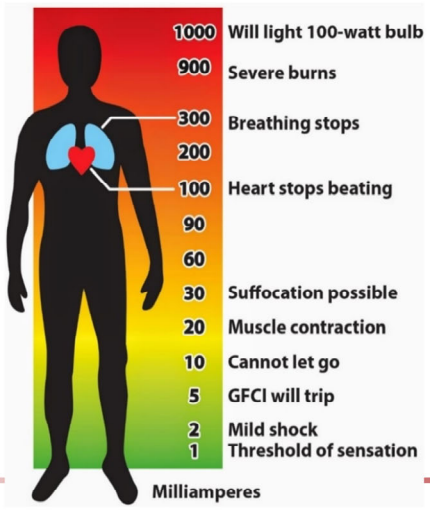
Ohm's Law tells us that Power (W) = Voltage (V) x Current (I) thus P/V = I
A typical ESS, working at 600 volts, has the ability to store 300 kW or more – (that's 300,000 Watts!)
300,000 Watts / 600 volts = **500 Amps**
Current of more than 0.5 mA AC and 2.0 mA DC can cause harm to the human body as noted in the following chart

Effects of High Voltage on Human Body



- ⚠ Current as little as 0.1 Amp traveling across the heart can kill.
- ⚠ Most sensitive organs are heart and brain.
- ⚠ Always assume circuit is energized.

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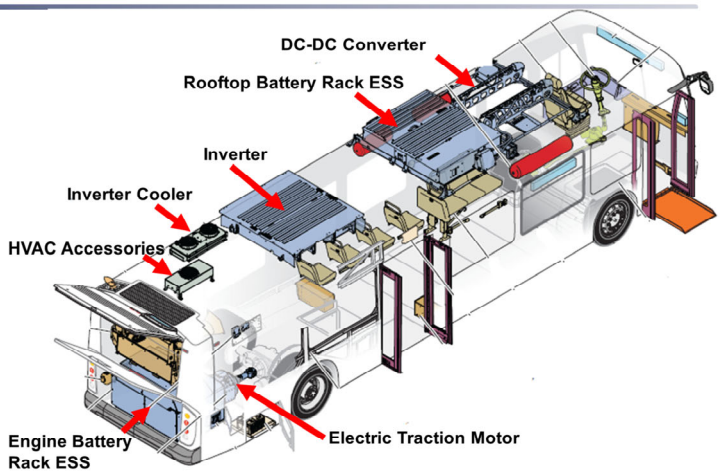
Current Level and Reaction

1 milliamp (one thousandth of an Amp) --- Just a faint tingle.
5 milliamps --- Slight shock felt. Disturbing, but not painful. Most people can "let go." However, strong involuntary movements can cause injuries..
6-30 milliamps --- Painful shock, Muscular control is lost. This is the range where "freezing currents" start. It may not be possible to "let go.."
50-150 milliamps --- Extremely painful shock, respiratory arrest {breathing stops), severe muscle contractions. Reflex muscles may cause holding on; extensor muscles may cause intense pushing away. Death is possible.
1,000-4,300 milliamps - (1-4.3 amps) --- Ventricular fibrillation (heart pumping action not rhythmic) occurs. Muscles contract; nerve damage occurs. Death is likely.
10,000 milliamps (10Amps) --- Cardiac arrest and severe burns occur. Death is probable.

High Voltage Awareness

High Voltage Locations

- Battery Pack
- Inverter
- Electric Traction Motor
- DC-DC Converter
- Power Distribution Node
- Compressor
- HVAC Accessories



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Locations vary by OEM

Like the gun analogy – HV is “always loaded” and should be treated as such. The components are obvious nodes for voltage to be present. All circuitry should be considered “hot”

Where can you encounter HV in a BEB?

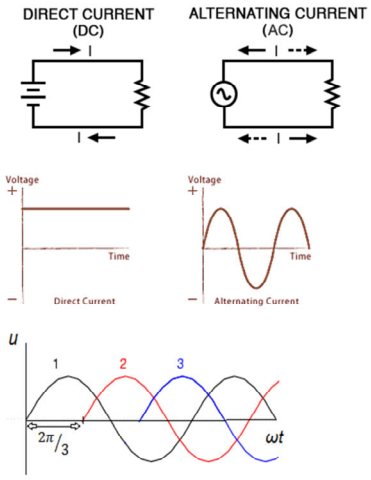
Like with any other potentially dangerous system, one must assume that HV is present anytime you work with any bus or charger circuit
Failure to do so, or relaxing safety protocols can prove deadly!

HV is present in BEBs at least at these locations

Charger
Battery Pack
Inverter
Electric Traction Motor
DC-DC Converter
Power Distribution Node
Compressor
Electric AC Accessories

High Voltage Component – The Inverter

- ESS stores DC
- Inverter changes DC into AC
- AC needed for traction motor, HVAC, etc.
- "Straight line" DC converted to "sine wave" AC.
- Multiple phase AC current.



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Want to discuss the inverter. Found in RVs. Why AC? AC motors are more efficient and less expensive to manufacture. Wiring can be thinner
Modified sine wave – An inverter doesn't create a "clean" sine wave. It makes a "square" or "chopped" wave and takes the value of the height of the square as the DC voltage.

- An inverter is part of modern BEB designs. It is one component that many ICE mechanics may not be familiar with. The inverter's function is to change the DC voltage stored in the ESS into usable AC voltage. The inverter may have both DC and AC voltages present at any time.
- Like all batteries, the ESS stores DC voltage
- The DC voltage stored in the ESS is converted to AC voltage to power components like the traction motor, HVAC, compressors etc.
- The inverter takes the function of changing "straight line" DC energy, and converting it to a cyclical "sine wave" voltage for use on the AC voltage components
- AC voltage is identified by the cyclical reversal in polarity of the potential and the current flow. AC voltages have a frequency , or rate of change, at which potential value changes and polarity reverses. They may also have more than one current profile or "phase". Multiple phase motors can deliver power more efficiently

High Voltage Identification on BEB

- ⚠ Assume high voltage is present.
- ⚠ Wear PPE.
- ⚠ Follow LOTO procedures.
- ⚠ Proceed with caution.

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SAFETY ALERT!

Unless you have secured the system in question, always assume that HV is present. Wear PPE and proceed with caution
Always follow Lock-Out, Tag-Out procedures

High Voltage Identification on BEB

Cables covered with orange insulation or looming.

Components have caution labels.

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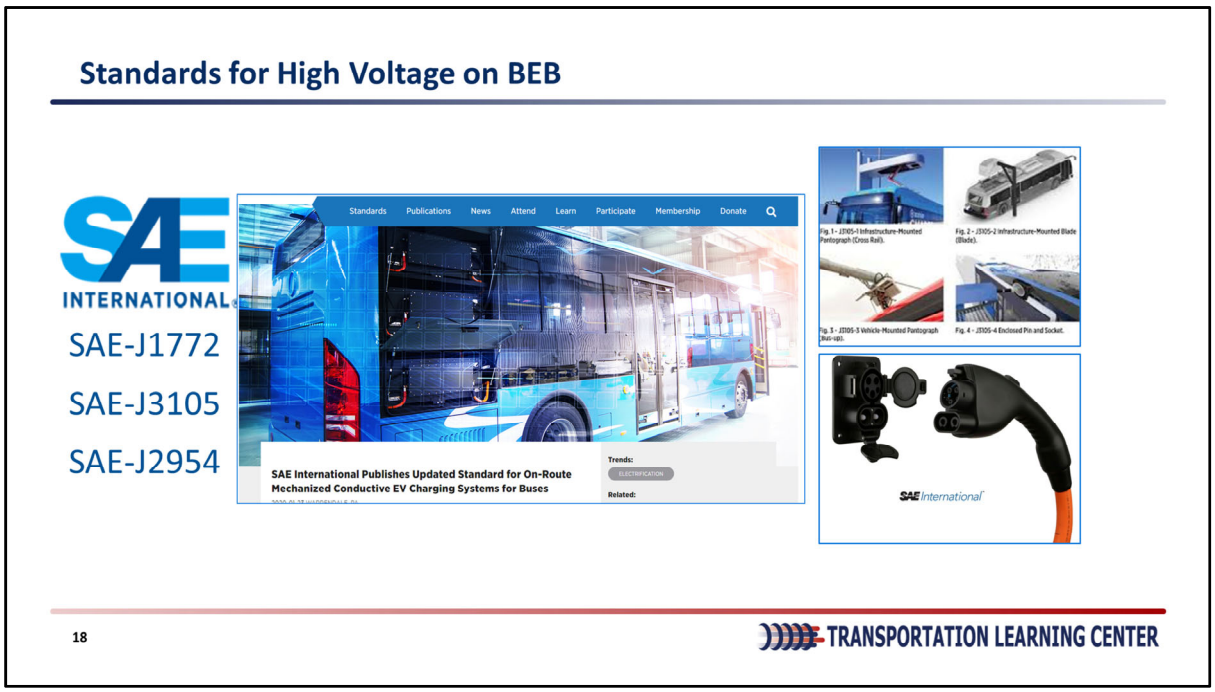
HV cabling in a BEB is recognizable by the heavy girth cabling and the orange colored insulation or protective shielding.

HV equipment like inverters and junction boxes will be typically labeled with a cautionary label

Do not drop your guard!

Use the “one-hand” probing method when testing circuits



SAE International (formerly Society for Automotive Engineers).

Plug-in is used almost 100% in BEB shops. There is on-route charging available using the overhead chargers and the inductive stations

There are a number of standards that come into play when dealing with BEBs. The most commonly quoted standards, are those dealing with “contact” and “plug-in charging.
Standard shop connections are there to allow for mixed OEM fleet deployment

DC Plug-in Standard – SAE-J1772

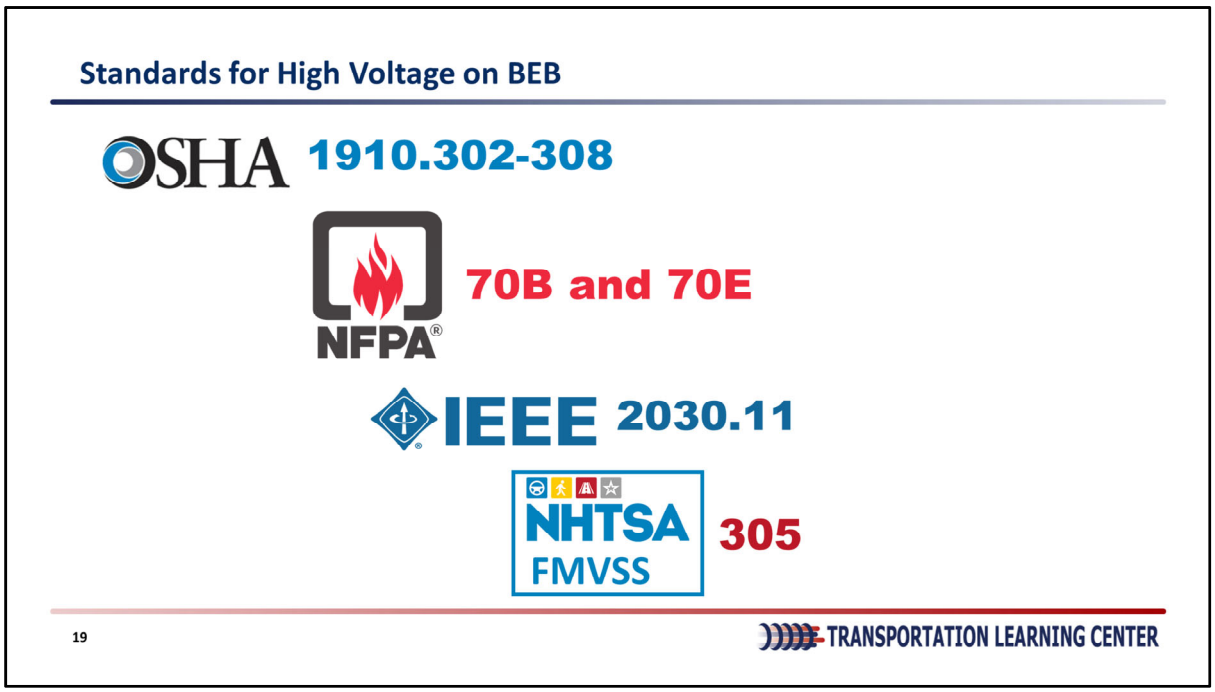
Accepted as the industry standard for plug-in charging
Should be used on generators mounted on service vehicles

Overhead Conductive Charging Standard – SAE J3105

Applies to conductive overhead charging
Typically a fixed charger with a moving arm (pantograph) that couples with the bus

In addition to the 2 contact standards, SAE J2954 covers inductive or “contactless” charging

Contactless charging is typically done with an inductive field from a charger embedded in the street



These standards come from different organizations that look at HV environment with differing interest. They are all complimentary to each other.

In addition to the familiar SAE charging standards, there are many other established industry standards. Standards vary by governing body.
Some examples:

OSHA , Occupational Safety and Health Association, Standards 1910-302-308, deal with electrical systems, not limited to vehicles, and related standards for safety

NFPA , National Fire Protection Association, Standards 70B and 70E are two examples of best practices when dealing with electrical systems. They also provide first responder training

IEEE , Institute of Electric and Electronics Engineers, is the knowledge base for all electrical and continues to develop electric vehicle standards like IEEE 2030.11, which deals with transfer of power between chargers and vehicles

FMVSS , Federal Motor Vehicle Safety Standards, Standard 305, which was established to cover the design of early Hybrid and BEB buses

Questions and Answers

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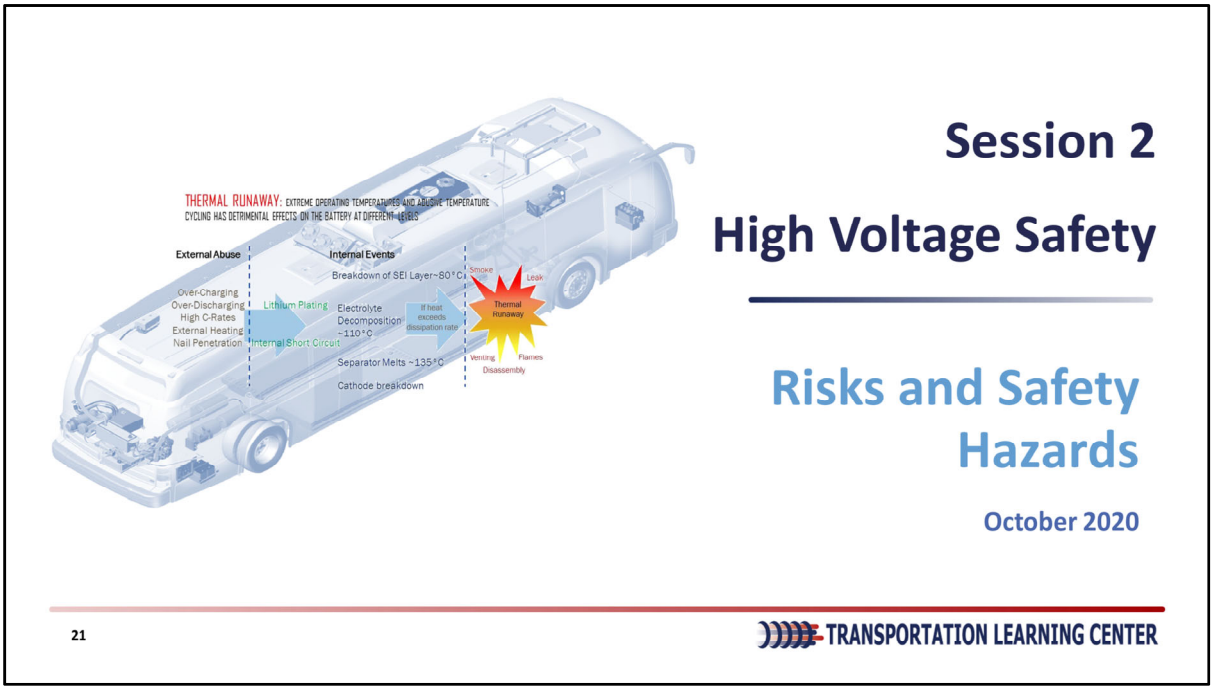
John moderates questions and answers.



Hello all! I will be covering The Risks & Safety concerns associated with High Voltage Battery Electric Buses.

A little background - Prior to joining BYD (late 2018) I was in public transit for almost 26 years (maintenance) and worked my way up through all classifications into management (Supt. Of Fleet Maintenance).

I am glad to be part of this program and thank the TLC Staff (John & Amri), APTA and my esteemed colleagues (Oscar, Chris & James)!

Presenter and topics

- High voltage risks and safety hazards.
- Safety features and preventive measures on the BEB.
- Accident and incident protocols.

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Preface: I just wanted to express that BEB's are not unlike any other vehicle they just have their own new & unique risks and safety concerns. Just like when the gasoline engine came out, there will be new challenges but they will become the "new-norm" and are easily managed and we have added safety features to prevent risks and hazards!

Today we will cover three topics:

1. Overview of HV Risks & Safety Hazards
2. BEB Designed Safety Features & Preventive Measures
3. Accident & Incident Protocols

The Learning Objectives for this presentation are:

- Identifying and understanding risks and safety hazards and those associated with Battery Electric Buses
- Recognizing these risks and safety concerns and avoiding potential incidents/accidents
- To be able to confidently know that these vehicles too are safe but come with specific risks and safety requirements

High voltage risks and hazards

Hazard can cause injury or harm.

Risk is danger that hazard poses.

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First Lets discuss:

- A **hazard** is something that can cause harm. A **risk** 'is the chance, high or low, that any **hazard** will actually cause somebody harm'.

- A risk is defined as; “exposure to danger, harm or loss! – We want to avoid and eliminate Risks!
- Risk Assessments are required (per NFPA 70E – Article 320) and a necessary workplace safety practice – especially when working on HV! These assessments identify the hazards associated with the type of tasks to be performed and assess the risks associated with these tasks which lead to safe work practices and the use/requirement for PPE (gloves, glasses, fall protection, etc.)!
- Hazards – definition of – A danger or Risk!
- Hazard Identification – spotting and identifying hazards; electrical, chemical, etc. These will be identified by placards, labels, etc. and referenced in service and repair manuals as well as operation manuals! Also they will be identified in your operation and servicing of these vehicles!

High voltage risks and safety hazards

- Risk assessment and workplace safety.
- Think before you work.

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OSHA and NIOSH standards.
See https://www.osha.gov/shpguidelines/hazard-Identification.html and https://www.cdc.gov/niosh/topics/hierarchy/default.html

Risk Assessments & Workplace Safety should be a crucial process and part of each properties training and safety goals and objectives. Risk assessments are necessary and will help to prevent risks & hazards and the potential injuries associated with these as well as to help improve tasks and provide the necessary task steps and associated tooling and PPE.

Think before you work, what are the risks, who's responsible for ID risks, techs, safety committee, OEM, (fall protection) agency specific, etc.

High voltage risks and hazards

- ⚠ **Presence of HV systems and components.**
- ⚠ **Stored energy.**
- ⚠ **Heavy component handling & locations.**
- ⚠ **Silent bus operation.**
- ⚠ **Effects on personal medical devices.**
- ⚠ **More batteries = increased hazards.**
- ⚠ **ARC flashing.**
- ⚠ **Thermal runaway.**

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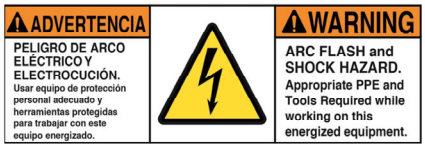
So what are some of the risks and safety hazards associated with HVEV's and BEB's:

- HV, HV Cabling & HV systems & components = Increased risk of electrical hazards and shocks – HV shocks can lead to death! Possible Arc Flashing! Stored Energy – Batteries always have "energy present" - Concern here is "live" energy and potential for fire and explosion (TR)!
- Heavy component handling – With battery packs – very rare! Note; Battery packs may be located on rooftops so there is the potential for injuries due to falls – Fall Protection Required!
- Silent Operation – Everywhere! Garage, in-service, etc. Must be aware of both as an operator and in the operation and vicinity of BEB's. Many buses are now equipped with automated announcements and alarms for this reason (mainly for in-service).
- Effects on personal medical devices – Electrical Systems could have an effect on pacemakers!
- Increased battery packs – increased potential for hazards – electrical, chemical, etc.!
- Arc Flashing – Big concern with HV systems!
- Thermal Runaway – The "Big" concern! Very Rare and can be managed! We will touch on later in the presentation!

High voltage risks and hazards

Arc Flash

- Sudden release of energy generating intense light and heat that radiates at supersonic speed.
- Can occur at high and low voltage environments.
- Severe or fatal burns!
- Follow proper PPE protocols!



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Definition – simple put a “phenomenon” where high voltage “arcs” to a ground or another path

Concerns – explosion, gas, shock wave, personal injury (high impact from blast, heat and possible molten material)!

What to do – Assessments, plans, engineering controls, PPE

Arc Flashing is very rare due to ESS construction and safety design features! An arc flash is an undesired electric discharge that travels through the air between conductors or from a conductor to a ground. The resulting explosion can cause fires and serious harm to equipment and people. The temperature of an arc flash may exceed 35,000 degrees Fahrenheit, which is capable of vaporizing metal and sending a blast of plasma and molten metal in all directions with extreme force. Generally, an electrical system must run at more than 480 V to supply an arc flash; the

higher the voltage, the higher the risk. Damage is caused both by the explosion of the arc flash and by the heat radiating from the blast. Risk Assessments and the 4 P's (Predict-Prevent-Protect-Publish) are crucial in understanding and preventing the potential for and for injuries due to this phenomenon.

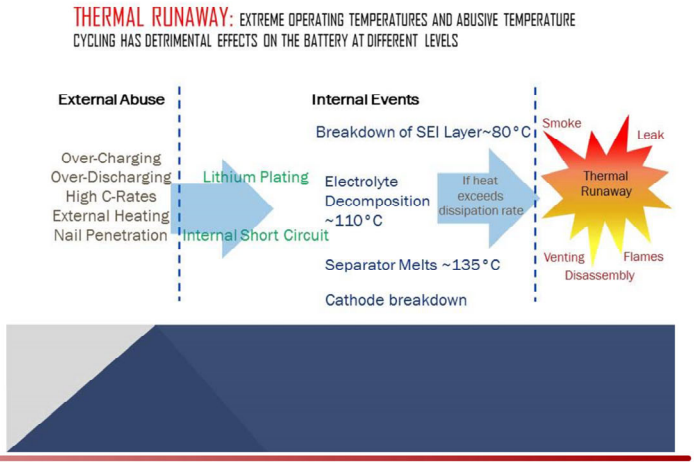
The concerns are; Explosion-personal injury!

What to do; First and foremost are design and engineering controls or safety features. The Four (4) P's -

High voltage risks and hazards

Thermal runaway

- Domino effect of increased heat and temperatures.
- Typically from Abuse (over charging, damage, etc.)
- Fire and explosion hazards.
- Monitor, isolate, evacuate!



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What is a Thermal Runaway Event

- Definition – simple put a domino effect of increased heat and temps

- Concerns – fire & explosion

- What to do – front end – engineering controls, back end – engineering controls, monitor isolate and evacuate/contact emergency personnel (if uncontrollable)

Thermal Runaway can simple be explained as; A condition in battery packs that is created when the heat generated within a battery exceeds the amount of heat that is dissipated to its surroundings, and if not stopped, the condition (increased temperature which causes increased current) will continue and create a domino effect – thus the term Thermal (heat) Runaway. This is very dangerous but also very rare!

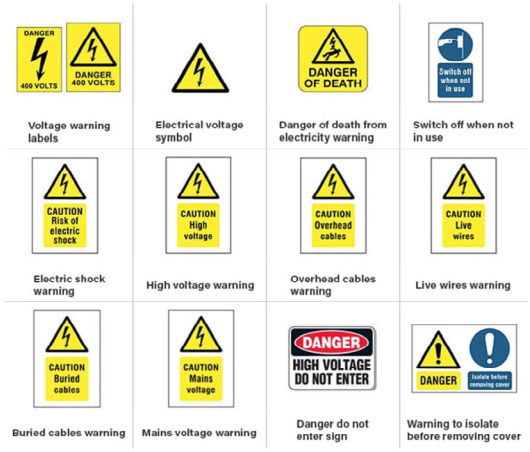
The concerns are; battery explosion and fire!

What to do; First and foremost are design and engineering controls or safety features. Flame retardants, ventilation (thermal release) and monitoring for the beginning signs of thermal runaway. If a Thermal Runaway event does start the best measures are to get away and let safety personnel handle! Monitoring, temperature control and venting are critical as are designs to prevent.

High voltage risks and hazards

HV safety symbols & warnings

- Used both in literature and on components.
- Awareness and warning.
- Different levels
- Clearly Identified
- Always follow warning signs and labels!



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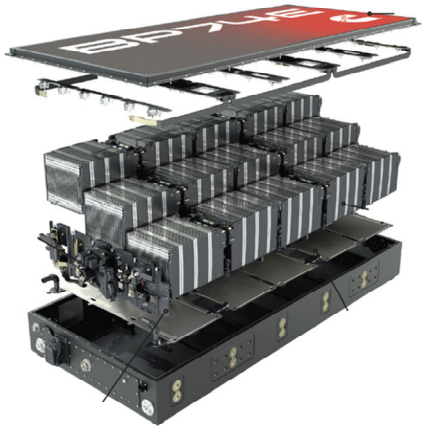
- Pay attention to warning labels and understand their placement and use! They are there for a reason – do not dismiss. You should always heed safety warnings!
- When you see these (manual and on components/vehicle) – you need to follow PPE and safety instructions!

Built-in safety features

Battery pack protection

- Chemistry
- Encased
- Separate posts
- Separate grounding circuit
- Monitoring system
- Extensive testing



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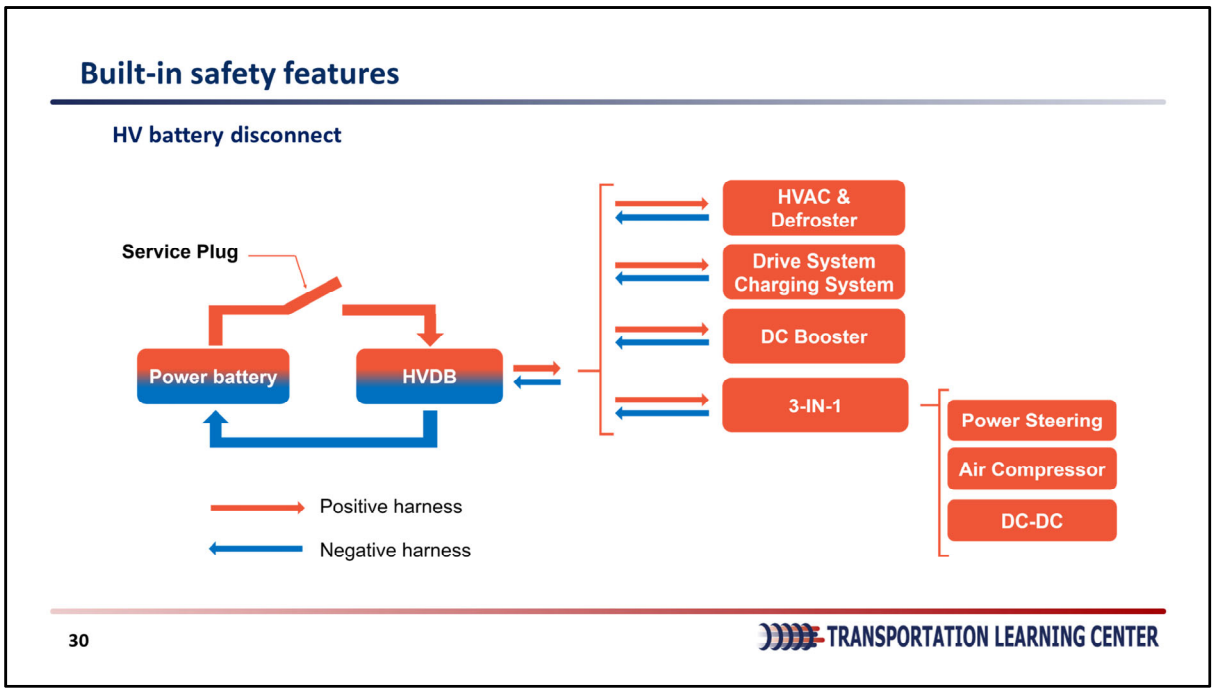
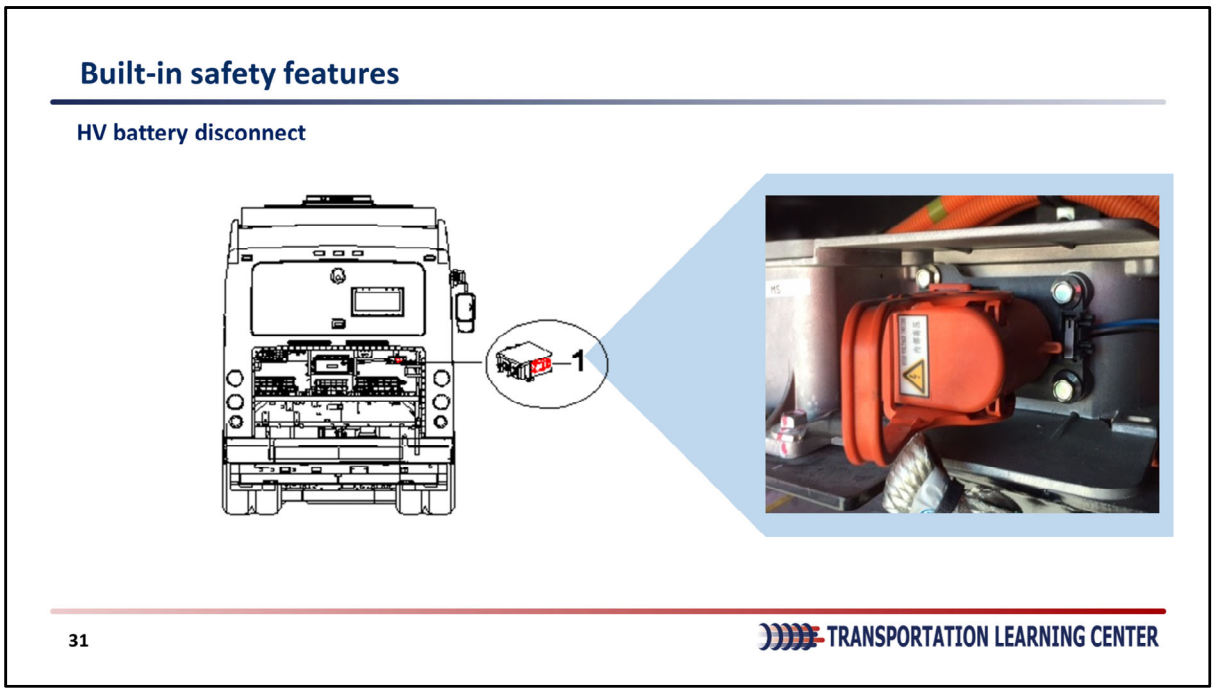
- Chemistry – the battery chemistry determines many factors including safety!
  Types;
  > NMC – Lithium Nickel Manganese Cobalt Oxide
  Benefits – High Specific Energy overall good performance
  Negatives – Less Safe, less life, low specific power and costlier
  > LFP – Lithium Iron Phosphate
  Benefits – Good Electrochemical Performance w/Low Resistance (nano-scale phosphate cathode material), High Current Rating & Long Life Cycle, Good Thermal Stability & Enhanced Safety & Tolerances (from abuse)
  Negatives; Low High Specific Energy and Fair Performance
  >Others; NCA, LCO, etc.
- Encased – for safety and isolation! Locked & non-conductive covers, venting and moisture proof.
- Separate posts – for safety
- Separate grounding circuit
- Monitoring system – for ensuring proper and safe operation and for alarms
- Extensive testing – done on battery packs!

Starts with battery chemistry, continues with ESS construction and safety design features, then testing and then engineering controls and monitoring and finally OEM warnings and guidelines for batteries!



Here is a sample lay-out of a safety feature. Each bus manufacturer may be a little different but there are similarities with safety and components.



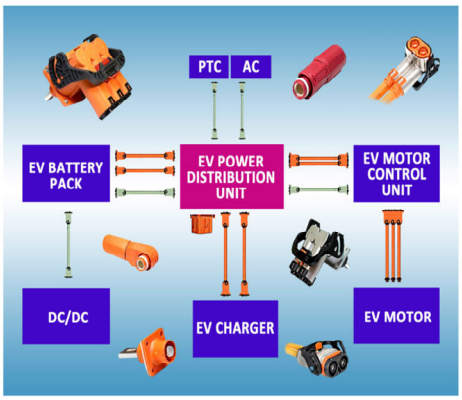
Example of a safety feature to remove/isolate HV. Each OEM has their own.

This manually removed breaker cuts the positive side of the HV power to prevent current flow while the bus is being serviced. Before removing, insure that the low voltage is completely off. ***Although it is extremely and highly unlikely to come into contact with any high voltage doing a PM, it is recommended to remove the Service Plug to prevent any possible current flow.***
Once the lock is released it can be used as a handle to pull the plug from its receptacle.
Pull out on the handle to open the micro switch. Once the switch opens, wait 5 seconds for the HV contactors to open isolating the HV power. Now the plug is safe to remove.
Never disconnect this plug without switching off the Battery Disconnect Switch first, **EXCEPT** for emergencies.
There is no need for special PPE in relation to HV during a routine PM inspection. If exposed cabling or components are reported, some level of PPE maybe required to make the repair

Built-in safety features

HVIL

- High voltage interlock loop and control strategies.
- Used for safety and operations.
- Varies by manufacturer.



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A High Voltage Interlock Loop (HVIL) system and ***Control Strategy*** is **provided for an alternative fuel vehicle including an electric**, a **hybrid electric**, or a **fuel cell vehicle**.

Generally, the HVIL system having associated logic including an HVIL circuit is provided to allow the vehicle to operate in either a high voltage (HV) or power mode powered by a power source or a HVIL interrupt mode based on an operational state of the HVIL system.

The High Voltage Interlock Loop (HVIL) is a single low voltage circuit which passes in series through high voltage connection point on the vehicle.

The HVIL system starts and ends inside a low voltage controller. The responsible controller outputs a low voltage signal onto HVIL circuit and looks for the signal to be returned to the controller after going through the loop.

If a high voltage connection to a high voltage component is removed, the HVIL loop will be broken. The controller will measure an open circuit, and the high voltage contactors in the system will be opened, isolating all high voltage to the ESS battery packs.

Impact on safety systems – The HVIL loop serves to ensure that the high voltage contactors within the ESS battery packs will be opened and high voltage will be contained within the ESS whenever someone tries to access high voltage

The HVIL system loop is always active whenever the bus low voltage system is on. Removing power to the low voltage system will automatically ensure that the contactors within the ESS battery packs are open and there is no high voltage present outside the ESS battery packs.

All OEM's handle HVIL slightly different. Please refer to the electrical schematic manual supplied with the bus for correct operation and wiring of the HVIL circuit.

Accident and incident protocols

Protocols

- Vehicle operator.
- Dispatcher and road supervisors.
- Maintenance road call crew.
- First responders.

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So what happens when we need to respond to an accident or incident in-service? We need to ensure everyone is aware of the risks & hazards (concerns) associated with BEB's.

Prior to any of this the training departments of the company/property will have put together Hazardous Communications and Protocols to deal with any potential issues related to these buses and will have worked closely with local municipalities to go over these response protocols and requirements. For example the local police and fire departments will be made aware of the HV systems on these buses and the controls in place on the bus as well as the make-up of these systems and what is needed in the worst case scenarios (TR, Fire, etc.). Much of these protocols and communications are already in place and should only require updating to the new equipment and standards.

The operator plays the largest and initial role in responding to in-service accidents & incidents. This because they are operating the vehicle and should know the vehicles operating controls and parameters and are responsible for identifying and reacting to issues and concerns.

Every company will have a process in place for safely getting the vehicle over and secured. These are (not all inclusive):

- As soon as possible safely get over/off the road
- Secure the vehicle (Park-Parking Brake On-Four Ways On-Vehicle Off if necessary)
- Assess the situation and contact dispatch and relay issue/concern (canned message)
- If a safety issue (fire, smoke, etc.) – get passengers off of the vehicle and a safe distance from the vehicle

The dispatchers & road supervisors are the first line of communication. They will receive feedback from the operators and will need to listen and respond accordingly. They will be responsible for:

- Listening to what is going on and questioning where necessary (for assessment & response)
- Instructions & keeping the operator calm and focused
- Communicating to the road supervision team, maintenance and possible emergency personnel
- They will stay on top of the situation until the situation is under control

The Road Supervisors are the "Leads" on the scene. They will be responsible for communications, interactions and ensuring protocols are being followed. They are the liaison between the company, departments and the emergency response personnel. They will be instrumental in assessing, reporting and following-up on the accident/incident.
Maintenance will be called for support and where able, repair, tow and clean-up. They will likely be consulted where needed for mechanical/technical experience and expertise.

However they should never by pass protocols and safety measures or put themselves or the vehicle in harms way!

Follow protocols and heed safety requirements and warnings!
First Responders are contacted for emergency situations and/or for safety concerns!

Police for traffic controls, EMT's for passengers needs (injuries, etc.), Fire and Emergency Response Personnel for fires and safety concerns (smoke, etc.)!

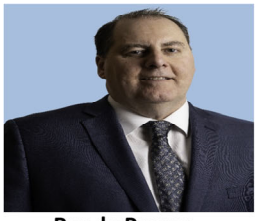
These buses are designed with many safety features to warn of issues and to prevent issues! Coupled with the engineered controls and emergency service protocols there should be no major issues.

Attention, procedures (protocols), actions and communications should allow all

situations to be managed.

The last important detail is; Follow-up! A review and learning from all incidents/accidents go a long way in ensuring risks and hazards are minimal and safe operations!

BYD – HV Risks & Safety Hazards



Randy Premo
NE - Regional Sales Manager
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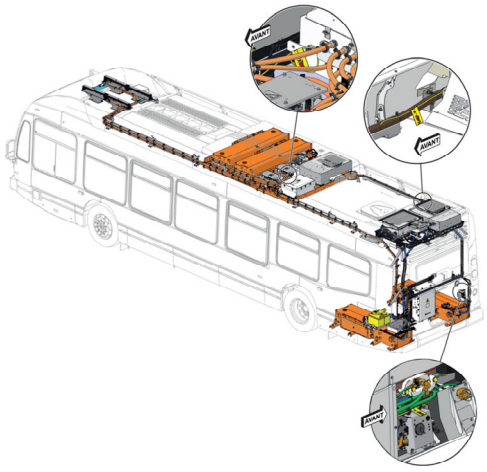
I want to close by saying, that just as gasoline engines became the norm and the safety concerns were managed so is the case with BEV's & BEB's! BEV's are the vehicle of today and tomorrow and will help us as we work towards a brighter, cleaner, and sustainable future!



High Voltage Safety Considerations

Worker Safety

October 2020

TRANSPORTATION LEARNING CENTER

Presenter and Topics

- Safely Work near HV equipment
- PPE and Tools
- Overview of HVIL Safety Loops
- Generic Lock out/Tag Out Procedures
- Worker Considerations

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Chris Hossie
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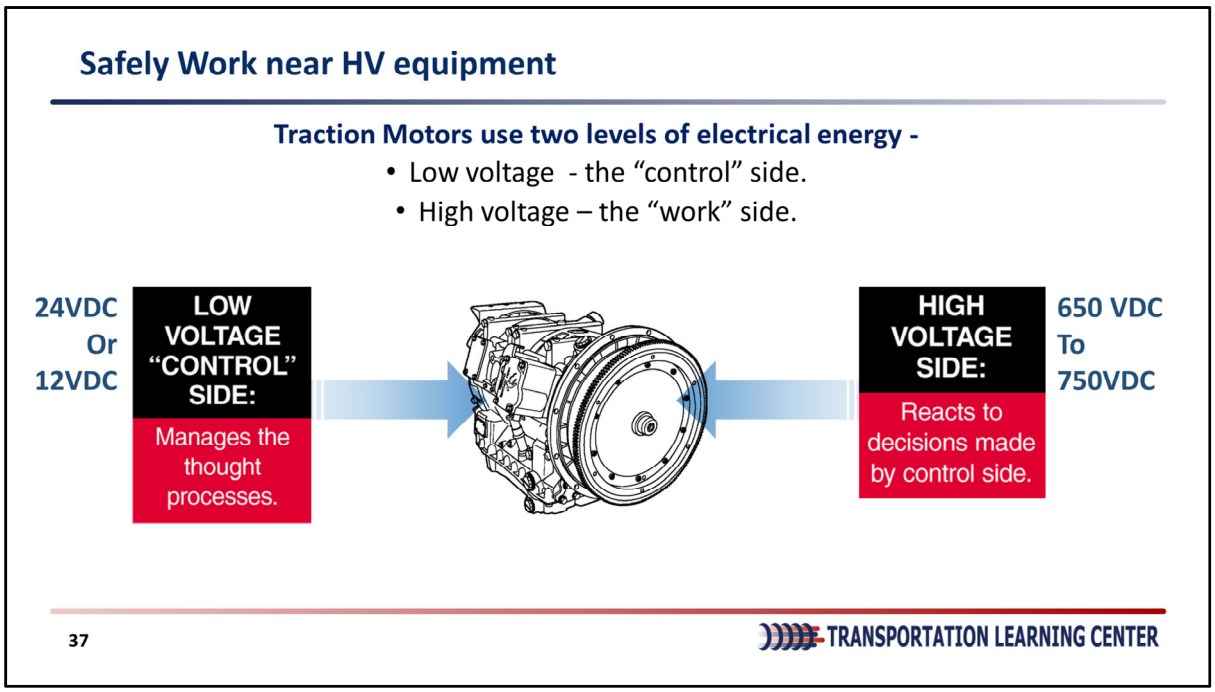
Thank you, participants, for joining this session and the TLC for hosting us today.

As bus techs you already experts on diesel engines, but you may you now be being asked to work on hybrid buses, and in the not distant future you'll be asked to work on fully electric buses.

It's perfectly normal to have concerns. DC voltages run as high as 750VDVC, and there are multiple sources of energy. The buses may look the same but this is very different setup from our standard 24VDC starter batteries and diesel engine.

Today's session is not intended to be a replacement for a full-course on HV safety, but instead it should act as introduction to worker safety for when working on and around battery electric buses.

And I hope it will re-assure you that worker and passenger safety is built-into the designs of all battery electric buses so you can and will be able to work safely.



What moves a BEB forward? In general, it's a traction motor connected by a drive shaft into the rear axle differential.

- Traction Motors Use Two Levels Of Electrical Energy
  - ***Low Voltage***
  - ***High Voltage***
- Two Separate Systems Connected and Working Together
  - *–Low voltage is the "control" side – manages thought processes*
  - *–High voltage is the "work" side – reacts to control side decisions*

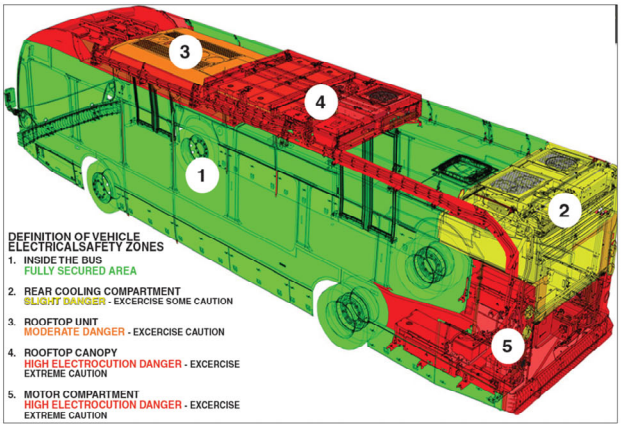
Low-voltage on a transit vehicle is generally 24VDC, or 12VDC. It will be powered by lead-acid or AGM batteries to get your 24V system voltage.

High-voltage on a transit vehicle is generally in the 650 to 750VDC range at the battery, before being converted to multi-phase AC High Voltage used to **turn** the traction motor and do work.

Identifying HV components, such as the traction motor, is critical to working safely and managing risk.

Safely Work near HV equipment

1. Inside the bus – no risk
2. Rear cooling compartment – low risk
3. Heating/HVAC unit – potential risk
4. Rooftop ESS unit – high risk
5. Engine compartment – high risk



Full Electric 40' Bus

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It is important to understand where high voltage is present and how to identify it.

And, many areas on a BEB do not have any risk of High-voltage and can be safely worked on or near. Eg:

- Passenger Area
- Driver Area
- Front Axle / Rear Axle.
- You can safely do a brake job or grease the axle without HV

concerns.

High Risk (shown in Red):
Important to understand that a BEB will have multiple sources of energy.

- Batteries, between 1 and 4 of them. Located in engine bay and/or roof top or built-into the floor.
- Junction Boxes. Bringing batteries together with devices like the inverter or an Accessories converter .
- Pantograph rails (front of the bus).

Medium Risk (shown in Orange) Still HV but at a lower potential.
Accessories

- Air Compressor
- HVAC
- Steering

Low Risk or No Risk

- Low voltage. 12/24 VDC systems.

Check with your vendor-specific training or maintenance manual.

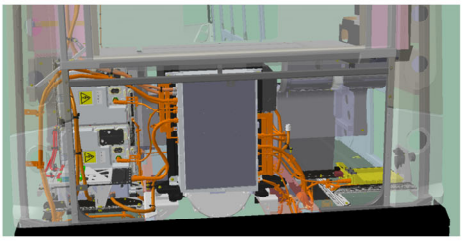
Safely Work near HV equipment

- Unless confirmed safe, assume hazardous voltage is present.
- Follow safety polices and guidelines.
- Always wear appropriate PPE.

All components containing HV will have a warning label on the box. These are boxes are high-risk and precautions need to be taken as listed in the slide.

Safely Work near HV equipment

- HV cables identified with orange sheathing.
- HV and vehicle 12/24V systems are separate.
- High voltage is **never** grounded through the chassis.
- Isolation between HV and chassis ground is **always** monitored. Loss of isolation between these will immediately shut down all systems.
- Replace, **never** repair, high voltage cables.



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Interconnecting the boxes, are the cables themselves which are also at high voltage and can be identified by their orange sheathing.

- All high-voltage cables are identified with orange sheathing.
- High Voltage is NEVER grounded through the chassis. Each component will have a Positive (+) and a Negative (-) HV Cable.
- High Voltage System and Vehicle 12/24V Systems are Separate
- Isolation between High Voltage and chassis ground is **ALWAYS monitored by ECMs** and if there was ever a loss of isolation between the two, all systems are immediately shut down (within milliseconds).

The HV cables themselves are well protected.

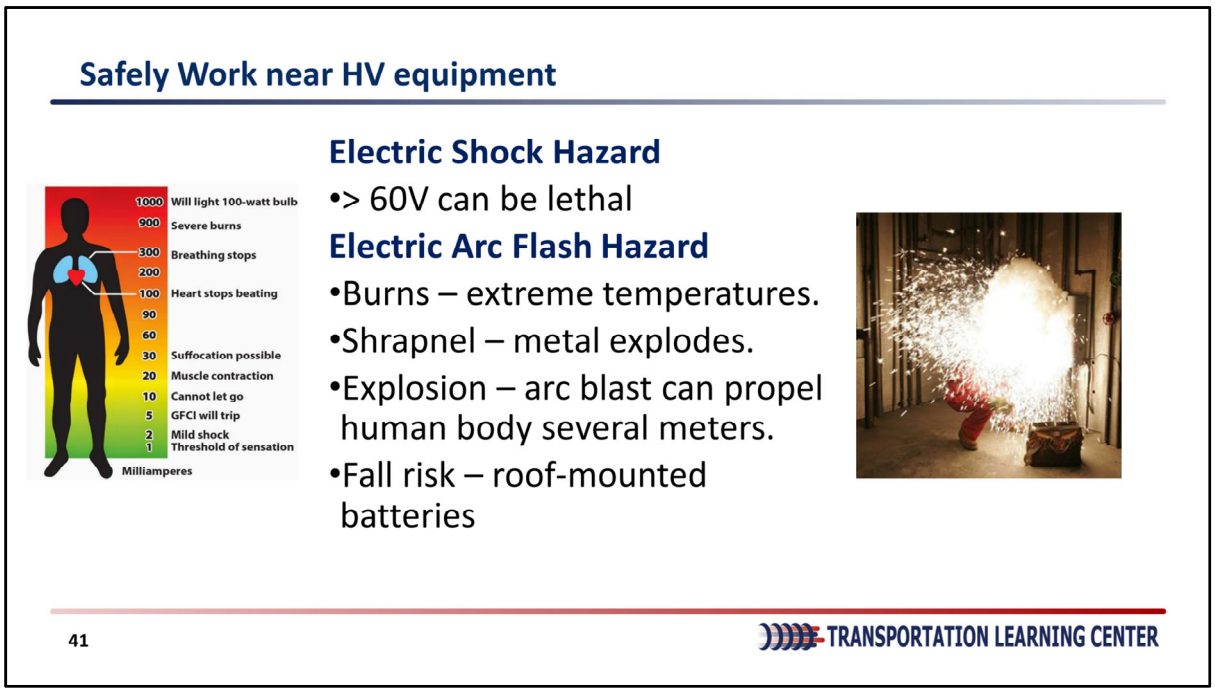
Layers include the middle conductor (copper), protective sheathing, stainless steel braiding, then another external layer of protective sheathing.

But, never repair.

Chassis Ground

High voltage on a BEB is NEVER grounded through the chassis.
Instead, the return path of any component is through an orange-cable.

HV Cables are identified with cable tags as POS, NEG or +,- as these designations can vary between manufacturers. Refer to your vendor specific materials



What are the risks from High Voltage equipment?

There is a lot of potential energy in battery electrical buses, and it is present everywhere in the HV systems of the bus. Bus manufacturers are now building 600kwHr buses. This is 6x the energy of the longest-range Tesla.

ELECTRIC SHOCK HAZARD

- Any voltage above 60 V could be lethal.
- First step is protect oneself from this hazard. PPE
- Second step is to eliminate it. Lock out/ Tag Out

ELECTRIC ARC HAZARD

There are several risks associated with electric arcs:

- Burns: When an electric arc occurs, it generates immediate extreme temperature. Risk of severe burns.
- Metal projections: Metal explodes when an electric arc occurs. Super-heated shrapnel

can be projected in every direction.

- Explosion: The electric arc blast can propel you several meters.
- Fall from Height: In many installations, the HV batteries are mounted on the vehicle roof.
    - Human instinct is to recoil from an arc flash, which could cause a fall from height >10'.
    - Must take precautions around working from height. That could mean fall-protection harnesses, and lanyards. It could mean ladders and work platforms. These are investments in keeping employees safe.

PPE and Tools

- Always wear appropriate PPE.
- Make vehicle safe – isolate HV equipment.
- Confirm isolation.

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Now, that we have gone over the risks of working with or near HV components, it's important to understand how we can and **do work safely**.

Important to keep in mind, that these battery-electrical vehicles do have maintenance issues and parts do need changing and this work is performed **safely** every day.

How?

1) Make the vehicle safe by isolating the HV sources of energy. Common industry terms are vehicle de-energization or de-commissioning, and subsequent to we lockout/tag-out.
2) Wear your protective equipment while isolating the equipment.
3) Confirm isolation.

Don't trust any computer or system to keep you safe. Physically disconnect each potential energy source, verify that there is no voltage present afterwards, then lock it out so no person can re-connect that source of energy while you are working on or near HV equipment.

To perform these 3 steps, certain PPE and tools are required namely;

1) Gloves
2) DMM
3) Hand tools for accessing HV components.

Analysis of the exact PPE required for different jobs on a vehicle will be vendor specific and will be dependent an arc-flash potential risk analysis as described in NFPA 70E.

PPE and Tools

ASTM Labeling Chart
Natural Rubber Electrical Insulating Gloves

Class Color	Proof Test Voltage AC/DC	Max. Use Voltage AC/DC	Insulating Rubber Glove Label
00 Beige	2,500 / 10,000	500 / 750	10
0 Red	5,000 / 20,000	1,000 / 1,500	10
1 White	10,000 / 40,000	7,500 / 11,250	10
2 Yellow	20,000 / 50,000	17,000 / 25,500	10
3 Green	30,000 / 60,000	26,500 / 39,750	10
4 Orange	40,000 / 70,000	36,000 / 54,000	10

Class 0 gloves with a **RED** label required.

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Gloves and leathers (not shown here) are the foundational piece for keeping yourself safe when working near HV equipment or when in the act of locking out and confirming lock out.

In choosing gloves, there are two considerations to make

1) Fit . Example given here is a size 10 glove.
2) Rating for maximum voltage. On BEV, class 0 with a red label gloves are specified.

Notes

- Color of the rubber can wary but the color on the label is specified by the ASTM standard.
- Leathers are worn over the rubber gloves to protect them from nicks and scratches.
- Rubber gloves are hot and not always comfortable. Some technicians choose to wear cotton gloves underneath the rubber gloves. Not necessary from safety perspective but can improve comfort.

PPE and Tools

- PPE – replace, do not repair.
- Fit, form, function.
- Perform air test – roll tight. If air gets out electricity can get in.
- Inspect and test periodically.
- Gloves are imprinted with an initial di-electric test date.
- Always wear your gloves and the leathers that protect them.

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Agencies need to start thinking about processes for maintaining and testing gloves. Similar to the thinking around torque wrenches. Labelling, dates, cals, etc.

Different levels of inspections of gloves.

1) A visual inspection seeks to detect

- Holes, perforations, tears, cuts, cracks, burn marks, air bubbles, encrusted or bonded material
- Users can roll gloves in their hands or inflate them manually to better expose imperfections and air leaks.

2) Periodic inspections

- The usual frequency for periodic inspections is between 30 and 90 days.
- It involves inflating gloves, inspecting them visually. The inspection procedure involves inflating each glove manually or using an inflation device (do not stretch gloves beyond limits set by the manufacturer);
  - Checking for air leaks, for example by listening for escaping air or bringing gloves to your chin to feel the air escaping;
  - A visual examination of the palm, back, fingers, wrist, and sleeve when gloves are inflated;

3) Dielectric tests (send away).

- To make sure gloves maintain their insulating properties, dielectric testing by a recognized, qualified laboratory is required

- The date of dielectric testing must be logged or printed on each glove.
- For Class O gloves, there isn't a mandated testing period, but good practice would be on a yearly basis.

For the technician, in the shop, you are going to inspect your gloves visually and roll test them before every job involving HV, ie lock-out/tag out or decommissioning the vehicle. It will be job of the supervisor or similar person who looks after shop tools, like torque wrenches, to maintain the gloves.

PPE and Tools

- CAT III 1000VDC rated Digital Multi Meter (DVM) required..
- DVM and test leads must be rated for at least 1000 VDC

Verify – Test - Verify

1. Verify DMM – check a known source such as a 9V battery.
2. Measure BEB component you are servicing.
3. Re-measure the known source ensuring meter is functioning correctly.

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After gloves, the next most important tool is a Digital Multi-Meter.

Must be CAT III rated, for both the meter and test leads. This means, they are rated for voltages up to 1000VDC. It's important to check, both the DMM, and the leads, especially if guys start 'borrowing' test leads from a shop's tool crib.

Verify Test Verify

How?

1) Test a 9V battery. Ideally new or near new. Confirm 9V.
2) Test HV component. Wearing your gloves of course. If doing LOTO, you are confirming, there is no voltage present between Pos, and Neg to each other and then each to chassis GND.
3) Test same 9V battery.

Yes, this will mean any job or task will take longer, but someone's life (yours) is reliant on taking your time, and working safely.

PPE and Tools

- Insulated hand tools that follow industry standards and are compliant with OSA and NFPA codes.
- Specific tools may be required by BEB vendors.

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Insulated hand tools follow ASTM F1505-01 and IEC 900 standards. These tools are necessary for compliance with OSHA 1910.333 (c)(2), and NFPA 70E.

Often sold in kits. Kit could include:

Sockets

Pliers

Open End Wrenches

Screwdrivers

Torque Wrenches (3/8,1/4)

Important to have proper, insulated tool sets available in the shop. Personally, I don't think they need to be owned by each technician but more of a shop-level tool. Stored in supervisor's office or locked away so they aren't used as everyday tools.

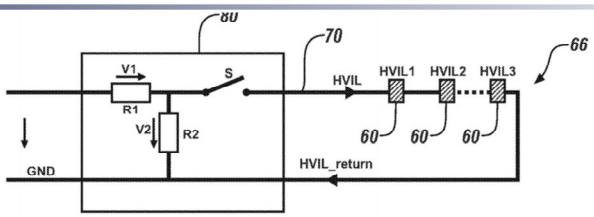
Tools will be insulated, like gloves, and often are double-insulated. Will have been tested and stamped with a test date. Important to have a process for maintaining or re-testing on manufacturers' schedule.

Vendors may (but not always) also require specific tools for measuring voltages at specific locations. Example shown here connects to positive and negative terminals and have an internal resistor to allow safe connection and verification of internal battery voltage.

The right time to purchase these bus-specific tools is at the procurement stage. Negotiated as a part of the bus procurement negotiation as this assures the tools are available, often showing up before the buses do.

High Voltage Interlock Loop (HVIL) Safety

- Reduces risk of arcs and electric shock
- Examples of broken or interrupted loop
  - HV access panel open
  - HV cables disconnected or broken
- Fault created and check indicator display appears.
- Restart denied until HVIL loop restored.
- Design varies by OEM.



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It is important to repeat what was covered in other presentations,

Another foundation of safely working on high-voltage powertrains and accessories is the High-Voltage Interlock Loop.

Each and every access panel and connectors in a high-voltage system will have either a physical switch, or wire-loop all interconnected on a single low-voltage (12/24v) loop that when you physically open the access and place yourself within an air-gap of high-voltage components, this switch will open and that action will shut-down the High-voltage system by opening all contactors at energy sources.

Knifing the bus (low-voltage battery disconnect switch) will open one of the HVIL switches, but in case that switch fails, every other access point has a switch as well.

The design of how these loops will vary between OEMs, but the design premise is always the same. It's a low-voltage loop which is always monitored by every ECU in the bus. Open any portion of the loop and the High-Voltage contactors are all opened.

NB: HVIL loops generally work off either 12V or 24VDC and will see any system voltage below 10.8 or 22.6 V as an open and will shutdown the HV. Crucial to keep 12V batteries in good working order and not to let them drain. Much like a diesel bus, dead 12V batteries means a BEV can't be 'started' or moved.

With BEBs, there will be dozens and dozens of HVIL switch and connectors, which means dozens

and dozens of devices that can go wrong and inadvertently open. This will shutdown the bus, and make it immobile.

It's crucial to always FIX HVIL issues, never to bypass the switches. Even for diagnostic purposes in the shop.

This system is designed and intended to keep both passengers and technicians safe and bypassing it, would be unethical and stupid. No shortcuts.

Lock Out and Tag Out (LOTO) Procedures

LOCKOUT

- Isolates sources of energy making the bus safe.

TAGOUT

- Prominent warning that states that lock only to be removed by lock owner.

Switch

Cable

Charger Receptacle

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What is Lock out / Tag Out

LOTO is a series of steps done in conjunction with de-energizing the bus which makes the bus safe to be worked on, with no HV present. Also it makes the bus safe for anyone else who will work on the bus afterward.

Why do we **lockout**?

To isolate every source or potential source of energy, and be 100% sure that no-one can re-energize a circuit.

Important to note that a Battery Electric bus will have multiple sources of energy and the locking out or decommissioning of the vehicle must always be done to the manufacturer's process.

Why do we **tagout**?

Tagout devices are prominent warning devices that an technician fastens to energy-isolating devices (locks) to warn employees not to reenergize the machine while he or she services or maintains it.

- Could be a warning label or a picture of the technician who locked out the circuit.

Lock-out/tag-out is smart and mandated.

How?

Again, vehicle specific procedures will apply but generally we will locking out switches, cables and various other locations where inputs (even low-voltage) could energize a bus HV circuit. Here we are seeing a depot charger plug receptacle. And a 24V battery disconnect switch.

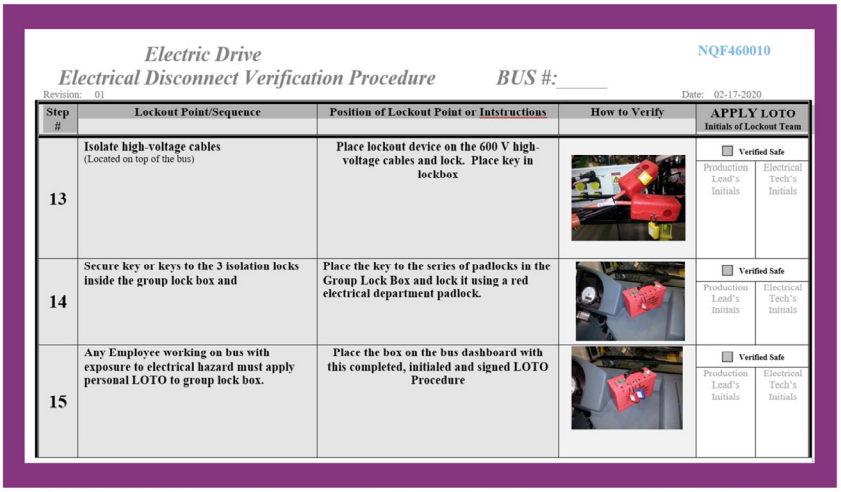
We always follow the procedure specified by the OEM or vendor, in a systematic and orderly fashion.

As part of an energy-control program, employers must:
Establish energy-control procedures for removing the energy supply from machines and for putting appropriate lockout or tagout devices on the energy-isolating devices to prevent unexpected re-energization. This wording comes from the OSHA standard.

Lock Out and Tag Out (LOTO) Procedures

LOTO procedures are vehicle-specific.

Employer responsible for providing training specific to the needs of technicians who will be working on the vehicle.



Electric Drive
Electrical Disconnect Verification Procedure *BUS #:_____*

NQF460010

Revision: 01 Date: 02-17-2020

Step #	Lockout Point/Sequence	Position of Lockout Point or Intstructions	How to Verify	APPLY LOTO Initials of Lockout Team
13	Isolate high-voltage cables (Located on top of the bus)	Place lockout device on the 600 V high-voltage cables and lock. Place key in lockbox		Verified Safe; Production Lead's Initials; Electrical Tech's Initials
14	Secure key or keys to the 3 isolation locks inside the group lock box and	Place the key to the series of padlocks in the Group Lock Box and lock it using a red electrical department padlock.		Verified Safe; Production Lead's Initials; Electrical Tech's Initials
15	Any Employee working on bus with exposure to electrical hazard must apply personal LOTO to group lock box.	Place the box on the bus dashboard with this completed, initialed and signed LOTO Procedure		Verified Safe; Production Lead's Initials; Electrical Tech's Initials

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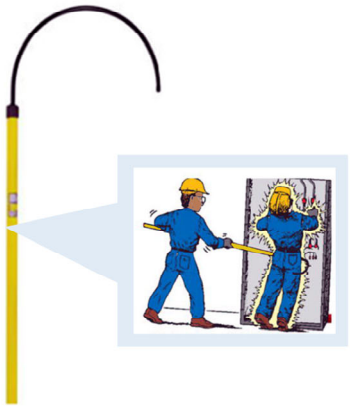
An example of an employer-provided lockout / tagout or as labelled here Electrical Disconnect Verification

In this example, steps must be followed in the prescribed sequence and at each step, two signoffs or stamps required to indicate step verified as complete.

Worker Considerations

- HV Disconnect LOTO procedure is a two-person process.
- Until 100% verified that system is safe to work, it MUST be assumed HV is present.
- Technician performing the job should be watched by a 2nd person.
- Focused only on watching and ready to react if safety incident occurs.
- 2nd person should also be wearing gloves and have electrical rescue hook in hands.



Questions and Answers

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Session 2

High Voltage Safety

High Voltage Skills and Knowledge

October 2020

TRANSPORTATION LEARNING CENTER

Last updated by AHJ 10-19-2020

Presenter and Topics

Following this discussion, you will:

- Examine some background skills of successful BEB technicians.
- Identify where to build the necessary skills to meet the prerequisites.
- List various tasks a trained BEB technician can perform.

James Hall
Manager of Training

PROTERRA

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James Hall
Manager of Training, Proterra

Background skills

Be experienced in performing maintenance on internal combustion engines on vehicles in areas of:

- Suspension / Steering / Brakes
- Pneumatics
- CAN / Multiplexing
- LV Systems

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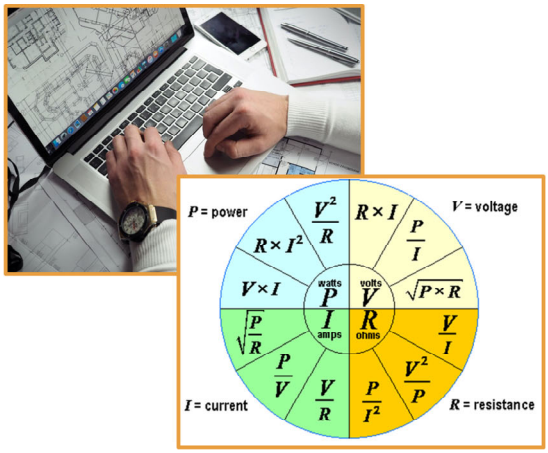
At a minimum, BEB technicians should…

- Have skills or experience related to maintaining and/or troubleshooting ICE/hybrid transit buses, or automotive applications.
    - Suspension / Steering / Brakes
    - Pneumatics
    - CAN / Multiplexing
    - LV Systems

Background skills

- Have a solid understanding of the principles of electricity
  - Voltage
  - Current
  - Resistance
  - Ohm's Law
- Be skilled at interpreting electrical schematics



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In addition to the skills and experience listed in the previous slide, BEB technicians should also:

- Have a solid understanding of the principles of

electricity

- Voltage
  - The **pressure** from an electrical circuit's power source that

pushes charged electrons (current) through a conducting loop enabling them to do

work.

- Current
  - The rate at which electrons **<u>flow</u>** past a point in a complete electrical

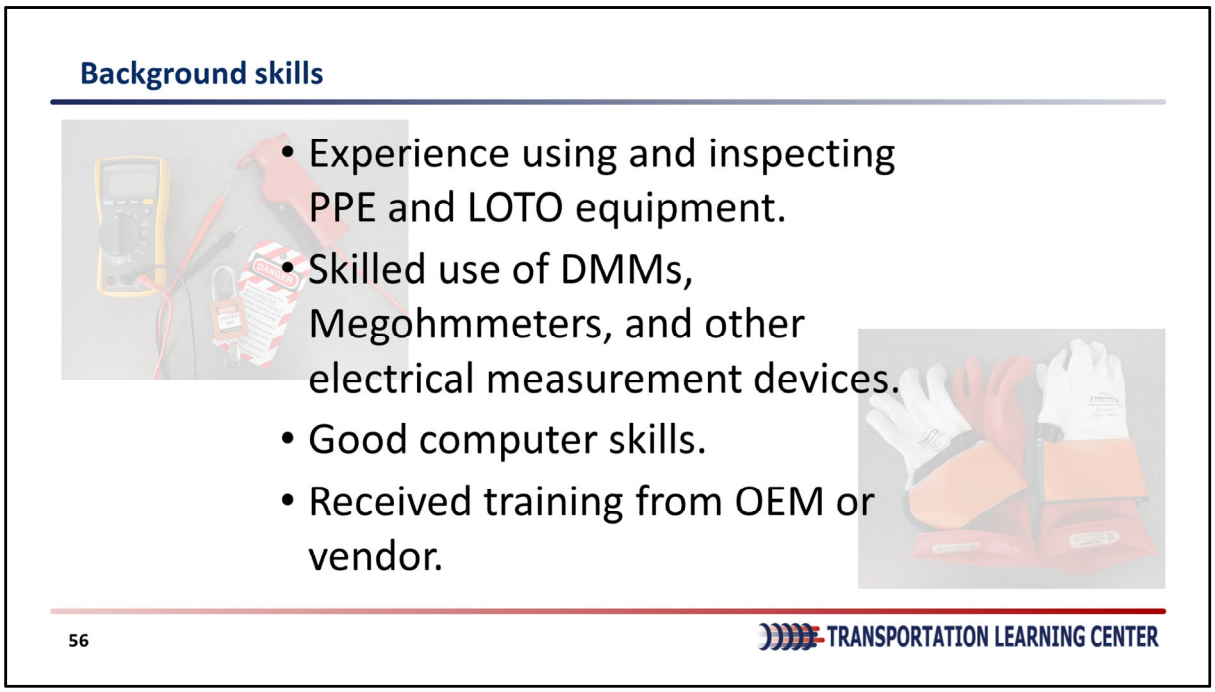
circuit.

- Resistance
  - The **<u>opposition</u>** to current flow in an electrical circuit.
- Ohm’s Law

V=IR.
Ohm's Wheel is pictured to the bottom right, and is used to calculate the

variables in a circuit

- Be skilled at interpreting electrical schematics



Experience with navigating computer QA

- Experience with using and inspecting PPE and LOTO equipment.
- Skilled use of DMMs, Megohmmeters, and other electrical measurement devices.
- Good computer skills.
- Received OEM training.

Amri 10-19-2020 added union and others to list of where to acquire background knowledge and skills.
James: The current picture can be replaced by one that depicts a technical college. Otherwise, this will suffice.

Where can BEB technicians acquire or refresh on these skills?

- OEM's
  - Factory training will include modules on electrical principles, their specific subsystems, and the PPE needed for maintenance activities
- Community Colleges
- Trade Schools
  - Many have partnership programs that will provide in-depth training on the skills needed to be successful
- Employers
  - Continued employee development is crucial for any organization to be successful, so (to the technicians) work with your employer to get the training you need
- Unions
  - Many unions have provisions for training and education, so if you're part of a union reach out for more information.
- Others
  - Websites, non-profits like the transportation learning center, and various consortiums are valuable resources in attaining the skills necessary to safely maintain BEB's.

Maintenance tasks

1. Safely and accurately perform OEM de-energization and LOTO procedures.
2. Measure and troubleshoot high voltage circuits.
3. Utilize troubleshooting software, paired with electrical schematics to troubleshoot and repair BEBs.
4. Accurately follow OEM maintenance and repair procedures.

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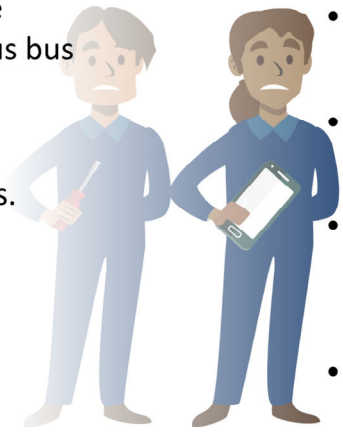
Experienced and recent technicians

- Applied maintenance procedures on various bus technologies.
- "Seen it all".
- Troubleshooting skills.
- Printreading skills.
- Comprehensive job description.



- Computer skills and can troubleshoot software.
- Rely on manuals for maintenance and repair.
- Eager to learn new equipment and technology.
- TBD

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Experienced Technicians

- Experienced with maintenance procedures on previous bus technologies, relevant to BEB's
- Have often "seen it all"
- Skilled in the troubleshooting process, including referencing electrical schematics
- Documentation of job description is often comprehensive

Laptop Technicians

- Skilled with computer systems and quick troubleshooting of software
- Utilizes maintenance and repair manuals for work instructions
- Eager to learn new equipment and technology
- TBD

Experienced and recent technicians

- Both provide best mix of strengths to troubleshoot and maintain BEBs.
- BEB subsystems similar to ICE/hybrid buses.
- Troubleshooting BEBs relies heavily on software from OEM or vendor.

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- Both types of technicians working together provide the best mix of strengths to troubleshoot and maintain BEB's, and ultimately you need technicians who **want** to work on BEB's.
- BEB's utilize many subsystems already found on ICE/Hybrid buses
  - LV systems, pneumatics, axles/suspension, etc.
- Troubleshooting BEB's relies heavily on OEM/vendor-supplied software
  - Skills associate with navigating various types of software are crucial for accurately pinpointing root cause
- The LOTO procedures require a safety observer, so pairing one of each makes sense

Qualifications and certifications

- No BEB-specific certifications in transit industry.
- OEMs approached organizations such as ASE to begin designing certifications.
- Some commercial and residential certifications are available
  - IBEW
  - NFPA 70E

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- No BEB-specific certifications in transit industry.
- OEMs have reached out to organizations such as

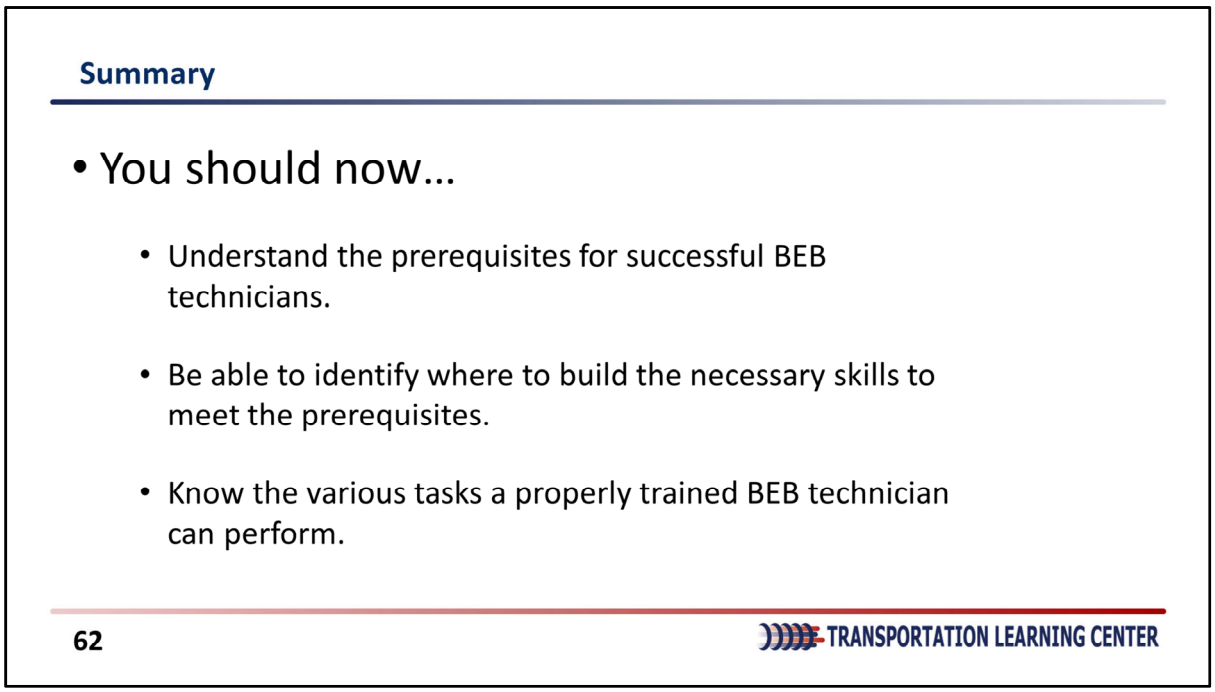
ASE to begin designing certifications

- Needs to be driven by industry demand and market saturation

- Commercial and residential certifications are available, but are only partly relevant
  - IBEW (through local chapters, you can

find certification programs, or lists of relevant certifications they require of their members)

- NFPA 70E – electrical safety



- You should now…
  - Understand the prerequisites for successful BEB technicians.
  - Be able to identify where to build the necessary skills to meet the prerequisites.
  - Know the various tasks a properly trained BEB technician can perform.

Questions and Answers

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PROTERRA

Thank you, I'll take questions now.

Wrap Up

- Session available for download.
- Evaluate today's session.
- Stay tuned for further BEB sessions.

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