

BEB Familiarization Course
Learning Objectives and Course Outline

Pre-Course

Pre-Course Outline

1. Pre-assessment
 - a. Pre-Assessment - 20 minutes
2. Pre-Course
 - a. Disclaimer
 - b. How to Use the Participant Guide
 - i. Purpose of the Course
 - ii. Approach of the Course
 - c. Tables of Contents
 - d. Table of Figures

Module 1 – Battery Electric Bus Overview: Fundamentals

M1 Learning Objectives

- 1-1 BEBs vs. ICE vs. Hybrid Buses
 - 1) Compare and contrast differences and similarities between BEBs and other current bus types
 - 2) Explain the general advantages and disadvantages of each propulsion type
- 1-2 Details of BEB Systems and Components
 - 1) Describe the process of power flow on a BEB
 - 2) Identify the components and subsystems that make up a standard BEB
 - 3) Describe the primary function(s) of each subsystem and component in the overall process of BEB operation
- 1-3 BEB High-Voltage, System Cooling, and Data Communications
 - 1) Identify the areas of high voltage risk associated with each subsystem of a BEB
 - 2) List the BEB subsystems that utilize a coolant loop
 - 3) Explain why various subsystems utilize a coolant loop
 - 4) Describe the data communication protocols on a BEB
- 1-4 Battery Management & Cooling
 - 1) Describe ESS/battery makeup and how to identify them
 - 2) List the battery safety systems and devices
 - 3) Describe the purpose and operation of Battery Thermal Management System [BTMS]
- 1-5 Maintenance
 - 1) Identify the purpose of preventive maintenance
 - 2) List the typical tasks and maintenance intervals for BEBs
 - 3) Differentiate between maintenance tasks on BEBs vs. traditional buses
 - 4) Identify typical diagnostic equipment and their functions
- 1-6 Summary

M1 Course Outline

1. Overview

- a. Brief History of Electric Vehicles
- b. What is a Battery Electric Bus?
- c. Terminology

2. BEBs vs. ICE vs Hybrid Buses

- a. Vehicle Characteristics & Operations
- b. Standards & Charging
 - i. Plug-In Charging
 - ii. Overhead Charging
 - iii. Inductive Charging
 - iv. **LEARNING EXERCISE 1A – Compare and contrast bus types**

3. Details of BEB Systems and Components

- c. Vehicle-Specific Electrical Systems
- d. Major Components
 - i. External (Manual) Charge Port
 - ii. Energy Storage System [ESS]
 - iii. High Voltage Junction Box [HVJB]
 - iv. Inverters
 - v. DC/DC Converter
 - vi. Electronic Controllers & Contactors/Electrical Switching Devices
 - vii. High Voltage Cables
 - viii. Electric Drive Accessories/Subsystems (those that utilize HV energy)
 - ix. Traction Motors
- e. **LEARNING EXERCISE 1B – Match components and fill out table for functions [should be done at bus when possible] – can be done in conjunction with Learning Exercises 1C and 1D**
- f. Theory of Operation: Power Flow
 - i. Inverters & Traction Motors for Power Flow
 - ii. Overall Power Flow
 - iii. Regenerative Braking
- g. **LEARNING EXERCISE 1C – Fill in the Bank to describe Power Flow activity [can be conducted at bus with 1B]**

4. BEB High Voltage Identification & Risks, System Cooling and Data Communications

- h. High Voltage Awareness & Identification
 - i. **LEARNING EXERCISE 1D – Identify areas on the bus of HIGH, MEDIUM AND LOW voltage risk [should be done at bus when possible]; have instructor point out areas on actual bus – follow a checklist**
- i. Temperature/Cooling Systems and Management
 - i. Battery Coolant Loop
 - ii. Power Electronics Coolant Loop
 - iii. Expansion Tanks
 - iv. Coolant Temp Sensors
 - v. Coolant Loop Filters
- j. Data Communications Systems Basics
 - i. CAN System for Communication
 - ii. Multiplexing System [MUX]
 - iii. MUX Theory of Operation

5. Battery Management & Cooling

- k. Basics on the High Voltage Battery [ESS] Construction
 - i. High Voltage Battery Configuration

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- ii. Handling High Voltage Batteries
 - iii. Battery Management Controller (BMC)
 - iv. **LEARNING EXERCISE 1E – Fill in the blank for theory of MUX operation activity**
 - I. ESS and Batteries
 - i. ESS Battery Chemistry
 - ii. High Voltage Isolation Safety & Detection
 - iii. High Voltage Interlock Loop [HVIL] & Driver Display
 - m. ESS Thermal Management
 - 6. Preventive Maintenance**
 - n. PM Schedule Intervals
 - i. Intervals
 - o. Diagnostic Troubleshooting
 - i. Diagnostic Software
 - ii. Diagnostic Tools
 - iii. **LEARNING EXERCISE 1F – Match the correct term/location for ESS construction**
- Break for Lunch – instructor and participants will determine prior**
- 7. Summary**

Additional Notes, Resources or Hands-on learning:

- Optional – Walkthrough of PM inspection process and procedures
 - Identify what to look for – under bus, rooftop, street or curb side

Module 2 – Electrical Safety & Personal Protective Equipment

M2 Learning Objectives

- 2-1 Overview
- 2-2 Safety Considerations
 - 1) Recall the formula for calculating voltage
 - 2) Define high voltage risk and shop safety conditions
 - 3) Recall the SAE standards pertaining to BEBs
 - 4) Identify primary built-in safety features and recall their function
- 2-3 Personal Protective Equipment [PPE]
 - 1) Identify typical PPE involved with BEB maintenance under NFPA70E Category ratings
 - 2) Recall the primary functions of each PPE introduced
 - 3) Recall the procedures for testing and inspecting HV gloves
- 2-4 Safety & Testing Equipment
 - 1) Explain the purpose of the appropriate safety and testing equipment
 - 2) Identify when to use the appropriate safety and testing equipment
- 2-5 De-Energizing or LOTO [Lock-Out/Tag-Out] of BEB Electrical Systems
 - 1) Recall the proper de-energization procedure for an 800-volt Proterra bus
 - 2) Demonstrate the ability to perform a LOTO on an 800-volt Proterra bus (only applicable to in-person training with qualified personnel)
 - 3) Recall the proper de-energization procedure for a New Flyer bus
 - 4) Demonstrate the ability to perform a LOTO on a New Flyer bus (only applicable to in-person training with qualified personnel)

2-6 Summary

M2 Course Outline

1. Overview

2. Fundamentals & Safety Considerations

- a. Electrical Fundamentals & Laws
 - i. Ohm's Law
 - ii. Watt's Law
 - iii. Electrical Schematic Basics
 - iv. **LEARNING EXERCISE 2A – Use the Ohm's Law formula to calculate voltage [can this be done with voltmeter at bus]**
- b. Safety Considerations, Hazards and Risks
 - i. Definition of High Voltage
 - ii. Effects of High Voltage on the Human Body
 - iii. Safety Considerations
 - iv. High Voltage Safety Hazards and Risks
 - 1. Increased risks of electrical shock hazards
 - 2. Arc Flashing
 - a. HV & Arc Flash Safety
 - b. Limits of Approach
 - c. Arc Flash Warning Labels
 - 3. Thermal Runaway Event
 - 4. Limits of Approach
 - 5. Arc Flash Warning Labels
 - v. Additional Safety Hazards and Concerns
 - vi. **LEARNING EXERCISE 2B – Use the space to identify and recall key safety considerations for the 3 primary sources of safety hazards and risks – Ask the participants how they would identify and assess the risks**
- c. Integral BEB Safety Features
 - i. Manual Service Disconnect [MSD]
 - ii. High Voltage Interlock Loop [HVIL]
 - iii. Additional notes on HVIL safety
 - iv. Passive Propagation Resistance
- d. Shop Safety Practices
 - i. Lock-out/Tag-out
 - ii. First-Aid & CPR
 - 1. Releasing victim from HV
 - iii. **LEARNING EXERCISE 2C - Use the space to identify and recall the primary functions of the integral BEB safety features reviewed**
 - iv. Shutting Down HV Quickly
 - v. Emergency Response Procedures

END OF DAY 1

3. Personal Protective Equipment [PPE]

- a. **Learning Exercise 2D– have students put on PPE; Instructors will need at least 2 sets of PPE (one in best conditions, one with known defect for students to identify when putting on)**
- b. NFPA PPE Category Ratings
- c. High Voltage and Leather Gloves [Class 0]
- d. Electrical Hazard-Rated Safety Shoes
- e. HV Glove Inspection & Testing

4. Safety & Testing Equipment

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- a. Meters & Digital Multimeter
 - i. Verify Test Verify
 - ii. Taking measurements using a meter
 1. Learning exercise 2E– have instructor with meter and known voltage source present; have instructor use meter to perform “test verify test” with students and allow time for students to take their own measurements on a separate electrical equipment
- b. Current Probe [1000 V Category III/600V Category IV]
- c. Insulated Rescue Hook
- d. Fire Extinguisher
- e. Phase Rotation Meter
- f. Safety Barricade
- g. Insulated Tools
 - i. HV insulated Mat

Break for Lunch – instructor and participants will determine prior - Head to bus location after lunch

5. De-energizing [Lock-out/Tag-out] of BEB Electrical Systems

- a. Proterra Catalyst Demonstration
 - i. LEARNING EXERCISE 2F –
 1. At vehicle LOTO demonstration with qualified agency technician
 2. If # 1 is not an option, use the video review of LOTO demo and answering related questions
- b. New Flyer Charge Demonstration
 - i. LEARNING EXERCISE 2G
 1. At vehicle LOTO demonstration with qualified agency technician
 2. If # 1 is not an option, use the video review of LOTO demo and answering related questions

6. Summary

Additional Notes, Resources or Hands-on learning:

- Additional resource/exercise – Video review of glove inspection and answering questions in Guide
- Additional resource – video of results of thermal runaway event
<https://vimeo.com/852691674/984974430a>

Module 3 – Battery Charging Technologies

M3 Learning Objectives

- 3-1 Overview
- 3-2 Charging Overview
 - 1) Describe the three primary charging methods for BEBs
 - 2) Calculate an anticipated charge time for each method of charging
- 3-3 Electric Vehicle Charging Standards
 - 1) Explain the purpose of standards SAE J1772, SAE J3105 and SAE J2954-2
- 3-4 Details of Charging Technologies
 - 1) Explain the general process of how a charger and battery communicate
 - 2) Identify the purpose of a switchgear
 - 3) Define smart charging

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- 3-5 Charging Equipment Maintenance & Safety Precautions
 - 1) Describe safety precautions for charging equipment
- 3-6 Summary

M3 Course Outline

- 1. Overview**
- 2. Charging Overview**
 - a. Various Charging Options
 - i. Transit Bus Charger Suppliers
 - ii. Charging Options
 - b. Charging Times
 - c. **LEARNING EXERCISE 3A – Calculate the approximate charging time for each scenario**
- 3. Electric Vehicle Charging Standards**
 - a. Standard J772 (Plug-In Charging)
 - b. Standard J3105 (Overhead Charging)
 - c. Standard J2954-2 (Inductive Charging)
 - d. **Additional Exercise 3B – After students go through the content for communication sequence, go to bus and ask students to follow the full battery charger connect-disconnect sequence (checklist)**
- 4. Details of Charging Technologies**
 - a. Battery and Charger Communications
 - b. Transformers and Switchgears
 - c. Emerging Charging Technology
 - i. Smart Charging
 - ii. Simultaneous vs Sequential Charging
 - iii. Other Emerging Charging Technologies & Opportunities
 - iv. **LEARNING EXERCISE 3C – Fill in the blanks for the process of how a charger and battery communication sequence**
- 5. Brief Overview of Charging Maintenance & Safety Precautions**
 - a. Charging Equipment Maintenance & Safety Precautions
- 6. Summary**

END OF DAY 2

Additional Notes, Resources or Hands-on learning:

Post-Course

Post-Course Outline

- 1. Post-assessment
 - a. Post-Assessment – 45 to 60 minutes
- 2. Have participants fill out the Participant course survey
- 3. When able, fill out the Instructor survey
- 4. When able, fill out the Instructor edit log Word or Excel version(s)