APTA STANDARDS DEVELOPMENT PROGRAM
RECOMMENDED PRACTICE
American Public Transportation Association
1300 I Street, NW, Suite 1200 East, Washington, DC 20006

APTA BTS-BMT-RP-007-16
Published: October 6, 2016
APTA Bus Maintenance Training Working Group

Training Syllabus to Instruct Bus Technicians on Hybrid Drive Systems Operations and Maintenance

Abstract: This *Recommended Practice* provides guidelines for establishing a standardized bus maintenance training program related to the theory of operation, maintenance and troubleshooting of bus hybrid drive transmissions and related equipment.

Keywords: AC induction motor, energy storage system (ESS), hybrid drive system, power inverter module, regenerative braking.

Summary: This *Recommended Practice* provides transit bus maintenance training and transit bus maintenance departments with typical information to evaluate, develop or enhance current training programs for the diagnosis, repair and maintenance of transit bus hybrid drive systems. Individual operating agencies should modify these guidelines to specifically teach the coach and transmission manufacturers and modes of operation on their local equipment. The training assumes prerequisite knowledge in several areas of engine, engine diagnostics, transmission/drivetrain, and electrical/electronics training standards through level 300. The depth of module development should be consistent with the operating agency's level of repair requirements as defined by the agency's Vehicle Engineering and Maintenance Department.

Scope and purpose: This *Recommended Practice* reflects the consensus of the APTA Bus Standards Program members in conjunction with transit labor organizations, including ATU and TWU, on the subject material, manuals, textbooks, test equipment, methods and procedures that have provided the best performance record based on the experiences of those present and participating in meetings of the program task forces and working groups. APTA recommends the use of this document by organizations that have a training department or conduct training for the maintenance of transit buses; organizations that contract with others for transit bus maintenance training; and organizations that influence how training for transit bus maintenance is conducted.

Table of Contents

Participants iii

1. Learning environment 1

2. Computer skills 1

3. Course learning objectives 1

4. Exam requirements 1

Related APTA standards ..... **Error! Bookmark not defined.**
Definitions 3
Abbreviations and acronyms 3
Summary of document changes ..... **Error! Bookmark not defined.**
Document history 3

Appendix A: Hybrid bus system learning objectives/training standards 4

Appendix B: Sample curriculum 10

Participants

The American Public Transportation Association greatly appreciates the contributions of the **Bus Maintenance Training Working Group**, which provided the primary effort in the drafting of this document.

At the time this standard was completed, the working group included the following members:

Bob Hykaway, Co-*Chair*
Dennis Cristofaro, *Co-Chair*

Edward Owens, TWU Local 234
Dan Engelkes, Rockford MT
Robert Romaine, TWU
Hector Ramirez, TWU Local 100
John Burke, TWU Local 100
Jack Clark, TLC
Darryl Desjarlais, New Flyer Ind.
Mark Dalton, King County Metro
David Gerber, ATU Local 85
Tony Pilewski, ATU Local 85
Donald Davis, Metro Minn-St. Paul
John Webster, ATU Local 382
James Lindsey, ATU Local 1277
Jeff Hunt, ATU Local 757
Joe Seitz, Maryland Transit
Ken Mall, EDSI

Training Syllabus to Instruct Bus Technicians on Hybrid Drive Systems Operations and Maintenance

1. Learning environment

For best application of this *Recommended Practice*, a combination of classroom lectures, mentoring, practical training and practice tests should be included in the training program.

2. Computer skills

Basic computer skills are now a standard for transit bus technicians. Basic skills and knowledge in the operation of a computer in a Microsoft Windows environment are essential.

3. Course learning objectives

The modules listed below implement the hybrid training standards and learning objectives (see Appendix A) by providing a foundation of theory and safety, introducing the various common components, and providing hands-on exposure to maintenance practices and diagnostics. The underlying learning objectives, organization of the modules, and order of instruction of the various tasks have been developed through a labor-management committee of subject matter experts. When a transit bus mechanic demonstrates proficiency in the learning objectives of these modules, he or she should be capable of demonstrating consistent competence in maintaining hybrid equipment on the particular buses of the local fleet.

- **Module I: Hybrid System Safety:** The objective of this module is to familiarize technicians with all the critical safety considerations for working on a hybrid system. Special tooling, personal protective equipment (PPE) and high-voltage considerations are emphasized.
- **Module II: Hybrid Drive System Theory and Understanding:** The objective of this module is to introduce how hybrid drive systems generate, store and supply power to operate transit vehicles.
- **Module III: Overview of Operations and Components/Three-Phase Power Theory:** The objective of this module is to provide technicians with an overview of the operations of each hybrid system component, including energy storage systems (ESS), inverter modules, power generation equipment, traction motors and control area network equipment, and how all these components work together and communicate with the engine and other bus systems.
- **Module IV: Hybrid Maintenance:** The objective of this module is to provide hands-on practice in the inspection and maintenance of hybrid system components.
- **Module V: Hybrid Troubleshooting:** The objective of this module is to provide extensive hands-on practice in troubleshooting hybrid systems through using OEM software. Technicians will identify common diagnostic troubleshooting codes and work through various troubleshooting steps, perform tests, make adjustments and verify repairs.

4. Exam requirements

The minimum acceptable grade to pass the course and all practical tests is 75 percent. Students must pass written tests with a minimum grade of 80 percent. ASE has not developed tests in this subject area. Delivery

of training should include written pre- and post-training tests and practical demonstrations from the students to confirm that the learning objectives have been achieved.

Definitions

controller area network (CAN): A network for all SAE J1939 communications in a vehicle.

power inverter module: Responsible for AC-DC conversion and motor controls, DPIM in Allison's parallel hybrid system, or as power control module (PCM) in BAE's series hybrid system.

electrically variable (EV) drive: Drive unit for a parallel hybrid system.

energy storage system (ESS): Battery assembly that provides high-voltage DC power to the EP 40/50 system.

electronic control module: The "master" controller that interfaces with the drive system. This is called a TCM in the Allison system.

Abbreviations and acronyms

AC alternating current
ASE Automotive Service Excellence
ATU Amalgamated Transit Union
CAN controller area network
DC direct current
DMM digital multimeter
DTC diagnostic trouble code
ECM engine control module
EDSI Educational Data Systems Inc.
ESS energy storage system
HV high voltage
SDS Safety Data Sheet
NATSA North American Transportation Services Association
OEM original equipment manufacturer
PCM power control module
PM preventive maintenance
PPE personal protective equipment
SAE Society of Automotive Engineers
TWU Transport Workers Union
V volts

Document history

Document Version	Working Group Vote	Public Comment/ Technical Oversight	CEO Approval	Policy & Planning Approval	Publish Date
First published	June 1, 2016	July 7, 2016	Sept. 6, 2016	Sept. 30, 2016	Oct. 6, 2016
First revision					
Second revision					

Appendix A: Hybrid bus system learning objectives/training standards

Explanation of prerequisites

Knowledge of content in the engine, engine diagnostics, transmission/drivetrain and electrical/electronics training standards through level 300 is necessary prior to beginning learning on hybrid systems.

101: Hybrid System Safety

Fulfill local high-voltage electrical safety certification requirements (if applicable).
Demonstrate how to verify that no voltage is present.
Identify what is a safe level of voltage to work with.
Explain the significance of orange cables.
Demonstrate how to use specialized tools for high-voltage testing.
Identify the purpose and use of insulated tools and how to identify unsafe insulated tools.
Identify and demonstrate use of PPE for working on hybrids.
Explain required procedures for fall protection and roof access.
Explain special requirements for using jacking and lifting equipment on hybrid buses.
Explain required procedures for blocking off access to bus or components when work is being performed.
Explain and demonstrate lock-out/tag-out procedures.
Explain use of a shepherd's hook/hot stick and requirements for two-person jobs.
Explain requirements for entering a battery tub/enclosure.
Explain unique precautions and awareness needed when working inside an ESS.
Explain local emergency preparedness and first responder procedures.
Explain precautions and procedures for washing propulsion systems.
Demonstrate battery disconnect procedure.
Isolate and verify safety of energy storage unit.
Review any applicable changes from the manufacturer on hardware used; demonstrate how to find information on updates before service.
Identify a hybrid vehicle from a non-hybrid vehicle at the student's location.

101: Special Tools and Diagnostic Equipment for Hybrid Systems

Use diagnostic tools such as a laptop, software and data-link interface.
Demonstrate how to update software through the Internet.
Use a hi-pot tester/megger.
Use an isolation tester.
Use a digital multimeter with adequate capabilities (1000 V, auto-ranging, Cat 3 or 4).
Explain the gathering and transfer of information from local computers to vendors (uploads, downloads, emails, etc.).

101: Hybrid Drive Systems Theory and Understanding

Explain advantages and history of hybrid technologies.
Explain the effects on emissions (greenhouse gases, particulates) and why capital investments in hybrid technology are being made.
Explain basic differences between parallel and series hybrid systems.
Explain regenerative braking and dissipation of excess power.
Explain function of hybrid cooling system.
Explain high-voltage isolation and how it is implemented.
Explain theory of operation.
Explain driver's perspective, engine and throttle relationship.
Explain unique service line procedures (if applicable).
Explain special towing procedures, if applicable (remove axles or drive shaft).

Identify the system architecture of components, safety precautions for working with, and demonstrate a general knowledge of how these common systems work on hybrid buses at the student's location:

- energy storage system
- power inverter
- power generation
- hybrid electric drive
- data communication networks
- control systems
- high-voltage cables

100: ESS (Energy Storage System): Overview of Operations and Components

Explain what an ESS is and how its design is different from a standard battery system.
Explain capacity and challenges of energy storage, what it is used for, and what applications are best for different types of ESS.
Review safety practices for working with high-voltage equipment.
Explain voltage ranges in hybrid systems.
Describe ESS chemistry at the student's location (e.g., lithium, lead acid, nickel-metal hydride, and voltages and capacities).
Explain how ESS is cooled (forced ambient air or conditioned air from HVAC system) and the function of these components.
Identify the location of all components and safety precautions for working with the ESS.
Explain the function of the control system (internal to ESS).
Explain the function of the disconnect features (shunt disconnects).
Explain the function of the mechanical enclosure.
Explain the function of the isolation system.
Explain the function of the ESS cables.

100: Power Inverter/Power Electronics: Overview of Operations and Components

Identify system architecture of each component and safety precautions for working with the power inverter.
Explain communication among components in the power inverter.
Explain the function of the inverter and how it operates.
Explain the function of the inverter control system and how it operates.
Explain the function of high-voltage cables and how they operate in the power inverter.
Explain the function of the DC-to-DC converter and how it operates.
Explain the function of the cooling system and how it operates.

100: Power Generation: Overview of Operations and Components

Identify the location of components and safety precautions for working with the motor/generator.
Explain the function of the motor/generator and how it operates.
Explain the differences between parallel and series operation.
Explain how motors/generators functionally replace the starter motor.

100: High-Voltage Cables: Overview of Operations and Components

Explain the basic inspection, maintenance, design and function of the AC and DC high-voltage cables.
Explain the function and operation of shielding on high-voltage cables to protect the vehicle control systems from electromagnetic radiation.

100: Hybrid Electric Drive/Traction Motor: Overview of Operations and Components

Explain how the hybrid electric drive works in a parallel system.
Explain how the hybrid electric drive traction motor works in a series system.
Identify the location of components and safety procedures for working with the hybrid electric drive/traction motor.
Explain the function of AC induction motors and how they operate.
Explain the function and operation of wheel motors (if applicable).
Explain how the system captures energy through regenerative braking.
Explain how the cooling system operates.
Explain the function of the cables in the hybrid electric drive.

100: Data Communication Networks: Overview of Operations and Components

Explain the development of data communications standards; SAE 1587/1708 vs. SAE J1939.
Describe how controller area network (CAN)/J1939 works.
Explain CAN architecture (i.e., what components are communicating with what else).
Explain the function and operation of terminating resistors.
Explain the function and operation of gateways.
Explain the differences between public and proprietary J1939 networks on a bus and communication between these networks.
Explain the function and operation of the interface with the engine control module or unit (ECM/ECU).
Explain the function and operation of shielding on data cables to protect from high-voltage cable interference.
Explain the system for communication with the vehicle's 12/24 V system through multiplex/DINEX, etc.

100: Control Systems: Overview of Operations and Components

> **NOTE:** See inverter control system under Power Inverter section. Also see standards for programmable logic controller (PLC) and multiplex operation from electrical standards.

Explain full vehicle communications on a hybrid bus across several systems.
Explain how vehicle control systems interface with hybrid control systems

200: Energy Storage System: Inspection and General Maintenance

> **NOTE:** Classes will be designed around the manufacturer(s) at a given location; can be taught generically as much as possible.

Explain local regulations for removing and replacing components inside enclosures or tubs.
Demonstrate how to use a laptop to identify problems in the ESS.
Inspect and maintain ESS.
Inspect and maintain ESS cooling system.
Inspect and maintain control system (internal to ESS).
Inspect and maintain disconnect features (shunt disconnects).
Inspect, maintain and repair mechanical enclosure.
Inspect and maintain isolation system.
Inspect and maintain cables in the ESS.

200: Power Inverter/Power Electronics: Inspection and General Maintenance

Inspect and maintain inverter.
Inspect and maintain inverter control system.
Inspect and maintain high-voltage cables.
Inspect and maintain DC-to-DC converter.
Inspect and maintain cooling system.
Inspect and maintain communication between components.

200: Power Generation: Inspection and General Maintenance

Inspect and maintain generator/motor.
Apply knowledge about differences in series and parallel operation.

200: High-Voltage Cables: Inspection and General Maintenance

Inspect and maintain shielded and non-shielded cables.

200: Hybrid Electric Drive/Traction Motor: Inspection and General Maintenance

Inspect and maintain AC induction motors.
Inspect and maintain wheel motors (if present).
Inspect and maintain operation of regenerative braking function.
Inspect and maintain cooling system.
Inspect and maintain cables.

200: Data Communication Networks: Inspection and General Maintenance

Verify communication between components on data network.
Inspect and maintain terminating resistors.
Inspect and maintain gateways.
Inspect and maintain the interface with engine control module or unit (ECM/ECU).
Inspect and maintain shielded and non-shielded data cables.
Inspect and maintain communication with vehicle's 12/24 V system.

200: Control Systems: Inspection and General Maintenance

Inspect and maintain hybrid controls' interface with bus multiplex systems.

300: General Troubleshooting and Diagnostic Procedures

NOTE: Classes will be designed around the manufacturer(s) at a given location.

Follow all safety procedures during troubleshooting process.
Verify problem (and write up).
Demonstrate how to approach repeating conditions on a particular bus or fleet.
Demonstrate how to prioritize information from diagnostic trouble codes (DTCs) for diagnosing underlying condition.
Demonstrate how to find DTCs in manufacturer's documentation.
Troubleshoot and diagnose causes of various DTCs using diagnostic tests, troubleshooting trees, vehicle history and/or other information.
Troubleshoot and solve problems when DTCs are not generated.
Demonstrate understanding of using diagnostic software, difference between DTCs on laptop and on touchpad (if applicable) and performing software updates manually if needed.
Follow OEM procedures for repair and replacement of diagnosed defective components.

300: Energy Storage System: Troubleshooting and Repairing

Comply with local regulations when removing and replacing components inside enclosures or tubs.
Demonstrate how to use a laptop to identify problems in the ESS.
Demonstrate ability to identify and repair specific ESS failures.
Troubleshoot and repair ESS cooling system.
Troubleshoot and repair control system (internal to ESS).
Troubleshoot and repair disconnect features (shunt disconnects).
Troubleshoot and repair isolation system.
Troubleshoot and repair ESS cables.

300: Power Inverter/Power Electronics: Troubleshooting and Repairing

Demonstrate ability to identify and repair specific power inverter/power electronics failures.
Troubleshoot and replace inverter.
Troubleshoot and repair inverter control system (VCM, TCM, etc.).
Troubleshoot and repair high-voltage cables.
Troubleshoot and repair DC-to-DC converter.
Troubleshoot and repair cooling system.
Troubleshoot and repair data cables and connectors.

300: Power Generation: Troubleshooting and Repairing

Troubleshoot and repair motor/generator.

300: Hybrid Electric Drive/Traction Motor: Troubleshooting and Repairing

Troubleshoot and repair AC induction motors.
Troubleshoot and repair wheel motors (if present).
Troubleshoot and repair regenerative braking operation.
Troubleshoot and repair exhaust braking operation (if present).
Troubleshoot and repair cooling system.
Troubleshoot and repair cables and connectors.

300: Data Communication Networks: Troubleshooting and Repairing

Demonstrate use of CAN architecture in troubleshooting components.
Troubleshoot and repair terminating resistors.
Troubleshoot and repair gateways.
Troubleshoot and repair the interface with engine control module or unit (ECM/ECU).
Troubleshoot and repair shielding on high-voltage cables.
Troubleshoot and repair communication with vehicle's 12/24 V system.

300: Control Systems: Troubleshooting and Repairing

Troubleshoot and repair hybrid controls' interface with bus multiplex systems.

300: High-Voltage Cables: Troubleshooting and Repairing

Remove and replace high-voltage cables.
Troubleshoot and repair shielded and non-shielded data cables.

400: Rebuilding of Motor/Generator

NOTE: Optional, offered based on what work is done at the agency, must be manufacturer specific.

Remove, rebuild and reinstall motors/generators

400: Rebuilding of Hybrid Electric Drive/Traction Motor

Remove, rebuild and reinstall hybrid electric drive/traction motors.

400: Rebuilding of ESS

Remove, rebuild and reinstall energy storage systems.
Follow proper lifting procedures during removal of the ESS from vehicle.

Appendix B: Sample curriculum

Module I
Hybrid System Safety

Goal: Participants should understand and be able to explain and demonstrate how to comply with all the critical safety considerations for working on a hybrid bus.

Objectives:
Following the completion of this module, the technician should be able to do the following:

- Demonstrate knowledge of critical safety procedures, including but not limited to:
  - identifying whether voltage is present;
  - identifying and using insulated tools;
  - demonstrating lock-out/tag-out procedures;
  - following roof access procedures;
  - explaining and demonstrating unique requirements for working within an energy storage system; and
  - explaining and demonstrating local emergency and first responder procedures.

Related job tasks/OJT checklist: OJT checklists may be used with the learning objectives listed under "101: Hybrid System Safety." All components of high-voltage safety training listed in OSHA.gov 29 CFR 1910 Subpart S should be covered.

Course description: Participants will receive classroom instruction and demonstrations on a bus, where a qualified instructor will familiarize the employee with critical safety practices for high-voltage hybrid vehicles. Participants should leave the course with an understanding of the importance of these safety practices and knowledge of how to comply with them.

Recommended class size: 6:1 or fewer (small group is necessary for productive use of laptop software on the bus as a training tool)

Prerequisites (previous module and/or demonstrated experience): Participants should have basic computer knowledge and an understanding of bus engine operations.

Delivery method (e.g., lecture, hands-on, online, lab): Hands-on and classroom

Course duration: 4-8 hours; the principles of the course should be continuously emphasized through the subsequent modules.

Target audience: All new and existing mechanics, local first responders, or anyone who may need an understanding of subsystems' connections to power from the hybrid system

Classroom equipment and supplies: Notepads, pens/pencils, flip chart or whiteboard (and markers), classroom, laptop, projector, highlighters, note cards and name cards

Course materials, training aids and references: Student workbooks, manuals, handouts, PowerPoint, pre- and post-training questions, laptops with OEM software, buses for use in diagnostic practice. Certification-level training for high-voltage may be necessary. This course should comply with requirements in OSHA.gov 29 CFR 1910 Subpart S and NFPA 70F-2012.

Instructor:

Course developer: Brian Lester, EDSI

Subject matter experts: Contact APTA.

Revision date: 6/18/12

Follow-up: Most recent revision should be sent to committee for feedback.

Instructor and course evaluation: Local course evaluation sheets should be used if present.

Module II

Hybrid Drive Systems Theory and Understanding

Goal: Participants should understand and be able to explain the overall theory of operation of hybrid drive systems, and the general operation and components of the major subsystems. Participants will also learn about special tools for hybrid maintenance.

Objectives:
Following the completion of this module, the technician should be able to do the following:

- Demonstrate understanding of hybrid drive system theory, including:
  - advantages and history of hybrid technologies;
  - advantages and effects on emissions and return on investment;
  - parallel vs. series system differences;
  - role of regenerative braking;
  - hybrid cooling system;
  - high-voltage isolation; and
  - special driving considerations, unique service lines, and special towing procedures (if applicable).
- Demonstrate uses of special tools and diagnostic equipment, including:
  - laptop, software and interface; and
  - hi-pot testers, isolation testers and digital multimeters.
- Identify the system architecture of components, demonstrate safety precautions for working with them, and demonstrate knowledge of how these components work on hybrid buses at the student's location:
  - ESS;
  - power inverter;
  - hybrid electric drive;
  - data communication networks;
  - control systems; and
  - high-voltage cables.

Related job tasks/OJT checklist:
OJT checklists may be used with the learning objectives listed under the following modules in the training standard:

- 101: Theory and Understanding of Hybrid Systems
- 101: Specialized Tools and Test Equipment for Hybrid Systems

Course description: Participants will receive classroom instruction and demonstrations on a bus, where a qualified instructor will teach the general theory of hybrid drive systems, the structure of major subcomponents, and common specialized tools used for hybrid maintenance. Participants should leave the course with an understanding of how a hybrid drive system works on a transit vehicle.

Recommended class size: 6:1 or fewer (small group is necessary for productive use of laptop software on the bus as a training tool)

Prerequisites (previous module and/or demonstrated experience): Participants should have basic computer knowledge and understanding of bus engine operations.

Delivery method (e.g., lecture, hands-on, online, lab): Hands-on and classroom

Course duration: 8 hours

Target audience: All new and existing mechanics

Classroom equipment and supplies: Notepads, pens/pencils, flip chart or whiteboard (and markers), classroom, laptop, projector, highlighters, note cards and name cards

Course materials, training aids and references: Student workbooks, manuals, handouts, PowerPoint, pre- and post-training questions, laptops with OEM software, buses for use in diagnostic practice, Allison.com/OEM software

Instructor:

Course developer: Brian Lester, EDSI

Subject matter experts: Contact APTA.

Revision date: 6/18/12

Follow-up: Most recent revision should be sent to committee for feedback.

Instructor and course evaluation: Local course evaluation sheets should be used if present.

Module III

Overview of Operations and Components/Three-Phase Power

Goal: Participants should develop a deeper understanding of the components and operation of the major subsystems in the hybrid bus and explain how three-phase power is employed in the transit vehicle.

Objectives:
Following the completion of this module, the technician should be able to do the following:

- Identify and explain operations of HV battery, ultracapacitor, ESS cooling system, internal ESS control system, disconnect features, mechanical enclosure, isolation system and cables.
- Identify and explain operations of inverter, inverter control system, high-voltage cables, DC-to-DC converter and cooling system.
- Identify and explain operations of communication between power conversion components.
- Identify and explain operations of generator.
- Understand application of three-phase power in hybrid equipment:
    - Understanding DC power systems
    - Understanding single-phase AC power
    - Understanding three-phase power
    - Common in commercial buildings (check for materials)
    - Bus vehicle specific systems overview
    - Parallel and series circuits/systems
    - Troubleshooting software and equipment—usage and applications
    - How is three-phase power used in hybrid vehicles?
    - Why is three-phase power used in hybrid vehicles?
- Identify and explain operations of AC induction motors, regenerative braking function, traction motor cooling system and related cables.
- Identify and explain operations of CAN architecture and J1939 communication; apply to inspection and maintenance of hybrid buses.
- Identify and explain operations of terminating resistors, gateways, interfaces with ECM or ECU, and communication with vehicle's 12/24 V system.
- Identify and explain operations of multiplex systems and PLCs on a hybrid bus.
- Identify and explain operations of high-voltage cables and shielding on high-voltage cables.

Related job tasks/OJT checklist:
OJT checklists may be used with the learning objectives listed under the following modules in the training standard:

- 100: Energy Storage System: Overview of Operations and Components
- 100: Power Inverter: Overview of Operations and Components
- 100: Power Generation: Overview of Operations and Components
- 100: Final Drive/Traction Motor: Overview of Operations and Components
- 100: Data Communication Networks: Overview of Operations and Components
- 100: Control Systems: Overview of Operations and Components
- 100: High-Voltage Cables: Overview of Operations and Components

Course description: Participants will receive classroom instruction and demonstrations on a bus, where a qualified instructor will familiarize the employee with the operation of hybrid bus subsystem components. This will build the foundation for maintenance and troubleshooting in subsequent modules.

Recommended class size: 6:1 or fewer (small group is necessary for productive use of laptop software on the bus as a training tool)

Prerequisites (previous module and/or demonstrated experience): Participants should have basic computer knowledge and understanding of bus engine operations.

Delivery method (e.g., lecture, hands-on, online, lab): Hands-on and classroom

Course duration: 8-12 hours

Target audience: All new and existing mechanics

Classroom equipment and supplies: Notepads, pens/pencils, flip chart or whiteboard (and markers), classroom, laptop, projector, highlighters, note cards and name cards

Course materials, training aids and references: Student workbooks, manuals, handouts, PowerPoint, pre- and post-training questions, laptops with OEM software, buses for use in diagnostic practice, Allison.com/OEM software

Instructor:

Course developer: Brian Lester, EDSI

Subject matter experts: Contact APTA.

Revision date: 6/18/12

Follow-up: Most recent revision should be sent to committee for feedback.

Instructor and course evaluation: Local course evaluation sheets should be used if present.

Module IV

Hybrid Inspection and Maintenance

Goal: Participants should develop experience inspecting and maintaining subcomponents of the hybrid system and practice performing an overall PM on a hybrid vehicle.

Objectives:
Following the completion of this module, the technician should be able to:

- inspect and maintain the HV battery, ultracapacitor, ESS cooling system, internal ESS control system, disconnect features, mechanical enclosure, isolation system and cables;
- inspect and maintain inverter, inverter control system, high-voltage cables, DC-to-DC converter and cooling system;
- inspect and maintain communication between power conversion components;
- inspect and maintain operations of generator;
- inspect and maintain AC induction motors, regenerative braking function, traction motor cooling system and related cables;
- apply knowledge of CAN architecture and J1939 communication to inspection and maintenance of hybrid buses;
- inspect and maintain terminating resistors, gateways, interfaces with ECM or ECU and communication with vehicle's 12/24 V system;
- inspect high-voltage cables and shielding on high-voltage cables;
- perform a PM inspection on a hybrid bus; and
- perform special repair procedures covered in service bulletins.

Related job tasks/OJT checklist:
OJT checklists may be used with the learning objectives listed under the following modules in the training standard:

- 200: Energy Storage System: Inspection and General Maintenance
- 200: Power Inverter: Inspection and General Maintenance
- 200: Power Generation: Inspection and General Maintenance
- 200: Final Drive/Traction Motor: Inspection and General Maintenance
- 200: Data Communication Networks: Inspection and General Maintenance
- 200: Control Systems: Inspection and General Maintenance
- 200: High-Voltage Cables: Inspection and General Maintenance

Course description: Participants will receive classroom instruction and demonstrations on a bus, where a qualified instructor will demonstrate inspection and maintenance procedures for hybrid components. Students will practice maintenance procedures on a vehicle, including a full PM and any special service bulletin considerations.

Recommended class size: 6:1 or fewer (small group is necessary for productive use of laptop software on the bus as a training tool)

Prerequisites (previous module and/or demonstrated experience): Participants should have basic computer knowledge and understanding of bus engine operations.

Delivery method (e.g., lecture, hands-on, online, lab): Hands-on and classroom

Course duration: 16 hours

Target audience: All new and existing mechanics

Classroom equipment and supplies: Notepads, pens/pencils, flip chart or whiteboard (and markers), classroom, laptop, projector, highlighters, note cards and name cards

Course materials, training aids and references: Student workbooks, manuals, handouts, PowerPoint, pre- and post-training questions, laptops with OEM software, buses for use in diagnostic practice, Allison.com/OEM software

Instructor:

Course developer: Brian Lester, EDSI

Subject matter experts: Contact APTA.

Revision date: 6/18/12

Follow-up: Most recent revision should be sent to committee for feedback.

Instructor and course evaluation: Local course evaluation sheets should be used if present.

Module V
Hybrid Troubleshooting

Goal: Participants should be able to hook up diagnostic software, obtain and evaluate information, and perform appropriate repairs to the hybrid drive system.

Objectives:
Following the completion of this module, the technician should be able to:

- explain how to find codes, interpret codes and follow repair procedures;
- explain methods to approach duplicate problems and repeat conditions;
- explain special advanced troubleshooting techniques for energy storage systems;
- select proper test equipment to diagnose a given set of symptoms;
- demonstrate proficiency in locating information in service manuals and on intranet;
- hook up and use OEM software;
- demonstrate proficiency at navigating menus, identifying codes, performing tests, and following troubleshooting trees;
- troubleshoot ESS problems;
- troubleshoot inverter module problems;
- troubleshoot AC induction motor problems;
- troubleshoot data communication problems; and
- apply knowledge of bus control systems to troubleshooting hybrid drive components.

Related job tasks/OJT checklist:
OJT checklists may be used with the learning objectives listed under the following modules in the training standard:

- 300: General Troubleshooting and Diagnostic Procedures
- 300: Energy Storage System: Troubleshooting and Advanced Diagnostics
- 300: Power Inverter/Power Electronics: Troubleshooting and Advanced Diagnostics
- 300: Power Generation: Troubleshooting and Advanced Diagnostics
- 300: Final Drive/Traction Motor: Troubleshooting and Advanced Diagnostics
- 300: Data Communication Networks: Troubleshooting and Advanced Diagnostics
- 300: Control Systems: Troubleshooting and Advanced Diagnostics
- 300: High-Voltage Cables: Troubleshooting and Advanced Diagnostics

Course description: Participants will receive hands-on instruction and practice diagnosing hybrid drive systems. The course will be taught so each student practices with a laptop OEM software program and explores and repairs a variety of common and critical diagnostic trouble codes. General troubleshooting best practices will be emphasized throughout the course.

Recommended class size: 6:1 or fewer (small group is necessary for productive use of laptop software on the bus as a training tool)

Prerequisites (previous module and/or demonstrated experience): Participants should have basic computer knowledge and understanding of bus engine operations.

Delivery method (e.g., lecture, hands-on, online, lab): Hands-on and classroom

Course duration: 4-8 hours; the principles of the course should be continuously emphasized through the subsequent modules.

Target audience: All new and existing mechanics

Classroom equipment and supplies: Notepads, pens/pencils, flip chart or whiteboard (and markers), classroom, laptop, projector, highlighters, note cards and name cards

Course materials, training aids and references: Student workbooks, manuals, handouts, PowerPoint, pre- and post-training questions, laptops with OEM software, buses for use in diagnostic practice, OEM software and manuals, sufficient laptops, buses and connections for all students to get significant hands-on training time

Instructor:

Course developer: Brian Lester, EDSI

Subject matter experts: Contact APTA.

Revision date: 6/18/12

Follow-up: Most recent revision should be sent to committee for feedback.

Instructor and course evaluation: Local course evaluation sheets should be used if present.

