APTA STANDARDS DEVELOPMENT PROGRAM
RECOMMENDED PRACTICE
American Public Transportation Association
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APTA Bus Maintenance Training Working Group

Training Syllabus to Instruct Bus Technicians on EPA Emissions Standards and Treatment Technologies

Abstract: This *Recommended Practice* provides guidelines for establishing a standardized bus maintenance training program related to the maintenance and troubleshooting of bus engine and after treatment components used to achieve applicable EPA emission standards.

Keywords: crankcase ventilation, diesel exhaust fluid (DEF), diesel oxidation catalyst (DOC), diesel particulate filter (DPF), Environmental Protection Agency (EPA), exhaust gas recirculation (EGR), NOx, selective catalytic reduction (SCR), regen, variable geometry turbocharger (VGT)

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 emissions control systems. Individual operating agencies should modify these guidelines to specifically teach the coach and engine manufacturers and modes of operation on their local equipment. Instructors should be familiar with local and state emission requirements for transit busses. Note that California has multiple emissions regulations in various jurisdictions within the state, plus statewide requirements.

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.

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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.

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Training Syllabus to Instruct Bus Technicians on EPA Emissions Standards and Treatment Technologies

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 emissions training standards and learning objectives (see Appendix A) by providing a foundation of theory and safety, and introducing technology and equipment as it was developed to achieve successive EPA standards. 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 competence in maintaining emissions control equipment on the engines and aftertreatment components of the local fleet.

- **Module I: Emissions Control Theory:** The objective of this module is to familiarize the employee with the basics of servicing intake and exhaust systems of an engine; identifying various common components; identifying the emissions regulated by the EPA; and understanding the purpose of low-sulfur fuel, types of and effects of particulate matter, and safety considerations.
- **Module II: Operations, Diagnostics and Best Practices for EGR/DOC Systems:** The objective of this module is to familiarize students with the emissions control technology of engines with exhaust gas recirculation and diesel oxidation catalysts, and to practice connecting OEM equipment and using OEM software for these engines.
- **Module III: Operations, Diagnostics and Best Practices for DOC with DPF Systems:** The objective of this module is to familiarize students with the intake, exhaust and aftertreatment components used to achieve applicable EPA standards. Technicians will learn the role of diesel particulate filters, how and why to perform regens, as well as other critical servicing and common troubleshooting tasks. Continued practice with using OEM software for hands-on diagnosis is emphasized.
- **Module IV: Operations, Diagnostics and Best Practices for DPF with SCR Systems:** The objective of this module is to familiarize students with additional intake, exhaust and aftertreatment components not covered in Module III. Technicians will learn the role of diesel exhaust fluid and selective catalyst reduction, performing regens for these newer engines, as well as other critical

servicing and common troubleshooting tasks. Continued practice with using OEM software for hands-on diagnosis is emphasized.

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. A standalone emissions test for the transit bus (H series) has not been developed by ASE. However, ASE L-2 (Diesel Electronic Engine Diagnostics) and H-2 (Transit Bus Diesel Engine) will cover emissions-related material. Separate *Recommended Practices* have been or are being developed in these areas. 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.

Abbreviations and acronyms

ASE National Institute for Automotive Service Excellence
ATU Amalgamated Transit Union
DTC diagnostic trouble code
DEF diesel exhaust fluid
DOC diesel oxidation catalyst
DPF diesel particulate filter
EDSI Educational Data Systems Inc.
EGR exhaust gas recirculation
EPA Environmental Protection Agency
ECU electronic control units
MSDS material safety data sheet
NATSA North American Transit Services Association
NOx oxides of nitrogen
OBD on-board diagnostics
OEM original equipment manufacturer
OJT on-the-job training
ppm parts per million
PM particulate matter
PPE personal protective equipment
R&R remove and replace
SCR selective catalytic reduction
TWU Transport Workers Union
VGT variable-geometry turbocharger

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: Transit bus emissions learning objectives

Training Topic	Learning Objective
Safety	Explain common rail pressure precautions that must be followed when working with pressurized fuel lines (i.e., when diagnosing leaks, changing injectors or changing lines).
	Explain safety precautions related to fumes and dust, etc., released when working on diesel particulate filters (DPFs).
	Demonstrate ability to properly operate lifting tools when servicing and lifting heavy exhaust aftertreatment devices.
	Demonstrate ability to refer to material safety data sheet (MSDS) to safely handle diesel exhaust fluid (DEF) and apply first aid for exposure to DEF.
	Explain fire safety considerations of exhaust aftertreatment devices given high exhaust temperatures and proximity of components to other vulnerable systems.
Theory and understanding	Describe the role of the EPA relative to the transit bus industry's diesel emissions.
	Explain the inverse relationship that exists between particulate matter (PM) and NOx when reducing those emissions in a diesel engine.
	Explain the role of exhaust aftertreatment in reducing emissions in diesel engines.
	Demonstrate basic knowledge and purpose of major emission reduction components of an engine and exhaust aftertreatment system: **Engine:** • Role of exhaust gas recirculation (EGR) and related components • Role of crankcase ventilation • Role of turbocharger (variable vane and water-cooled features) and how it relates to exhaust treatment in engine **Aftertreatment system:** • Oxidation catalyst • DPF, including active and passive regeneration • Selective catalytic reduction (SCR) including DEF dispensing system • Decomposition tube • Pressure and temperature sensors • NOx sensors
	Identify emission reduction components fitted to engine and those included in exhaust aftertreatment system (see component listing above).
	Explain why ultra-low sulfur (15 ppm) diesel fuel is needed to reduce exhaust emissions.
	Describe the emissions reduction equipment added to meet EPA 2010 regulations and why that equipment is needed.
	Explain the process of regeneration, and describe the difference between active and passive methods.
	Explain the procedures available for cleaning DPF.
	Explain the function and benefit of cooled EGR.
	Explain the function and benefit of variable vane turbochargers including different styles and different OEM approaches.
	Explain why additional engine cooling capacity is needed to meet EPA 2010 regulations.
	Explain associated engine derates and fault lights for after treatment failures.
	Explain the role coalescent crankcase ventilation plays in reducing diesel emissions.

Training Topic	Learning Objective
Maintenance and repair procedures	Refer to local safety and environmental procedures for correct safety procedures and personal protective equipment (PPE) usage.
	Remove and replace all emissions-related components.
	Service and clean EGR valves and pipes (or exhaust ports).
	Inspect engine fault warning and diagnostic lights (onboard diagnostics).
	Inspect DPF support brackets, piping and clamps.
	Manually clean DPF and remove ash.
	Use DPF cleaning machine and flow testing on dosers (if applicable).
	Check DPF temperature and back-pressure.
	Check fuel injection system associated with active DPF, including injectors and fuel line.
	Inspect control system associated with active DPF, including wiring harness and functionality.
	Inspect SCR support brackets and piping.
	Inspect DEF injection system associated with SCR, including injector, pump, dispenser and DEF lines.
	Check DEF for proper concentration using refractometer.
	Clean DEF injection system.
	Change crankcase ventilation filter.
	Replace variable-geometry turbocharger (VGT) and calibrate actuator.
	Replace diesel oxidation catalyst (DOC) sensors.
	Replace DPF.
	Replace DPF high-temperature seal.
Testing, diagnostics and troubleshooting	Diagnose emissions-related diagnostic trouble codes (DTCs) and diagnostic lights.
	Diagnose faulty EGR valve and other system components.
	Diagnose faults related to DEF injection system, including clogged filter, fuel injection (if applicable), onboard warning system and excessive temperatures.
	Diagnose faults related to DPF system, including clogged filter, fuel injection (if applicable), onboard warning system and excessive temperatures.
	Diagnose cause of engine not completing regen.
	Utilize software to test and diagnose: • EGR; • crankcase ventilation; • turbocharger (variable vane and water cooled); • oxidation catalyst; • DPF, including active and passive regeneration; and • SCR with DEF dispensing system and other emission control equipment.

Appendix B: Sample curriculum

Module I
Emissions Control Theory

Goal: Participants should understand emissions control theory and EPA regulations and identify the equipment used to achieve these regulations.

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

- explain safety considerations and PPE requirements;
- explain theory of operation of engine intake and exhaust systems;
- identify and explain purpose of common components, such as wastegate, exhaust manifolds, turbocharger and related components, and air restriction indicators or other sensors;
- explain how engine timing relates to emissions;
- explain why low-sulfur diesel fuel is needed to reduce exhaust emissions;
- explain theory of new technologies to better control emissions;
- identify the heavy-duty diesel emissions regulated by the EPA, history of EPA standards and OBD standards pending for 2013;
- explain the inverse relationship that exists between PM and NOx when reducing emissions in a diesel engine; and
- identify common acronyms associated with emission control technologies.

Related job tasks/OJT checklist: OJT checklists may be used with the learning objectives listed under the "Safety" and "Theory and understanding" sections of the learning objectives (Appendix A).

Course description: Participants will receive classroom instruction in which a qualified instructor will familiarize the employee with the basics of servicing intake and exhaust systems of an engine, identify various common components, identify the emissions regulated by the EPA, and convey how the engine operations affect these emissions. Participants should leave the course with a strong understanding of how the exhaust and intake systems affect emissions.

Recommended class size: 12:1 or fewer (subsequent modules will have smaller ratios)

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: 4-6 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 test questions, laptops with OEM software, buses for use in diagnostic practice

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

Operations, Diagnostics and Best Practices for EGR/DOC Systems

Goal: Participants should understand and be able to service and diagnose equipment used to achieve the 2004 EPA emission regulations, especially EGR and DOC components.

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

- perform common diagnosis and repair tasks such as diagnosing temperature, back-pressure or air-flow restriction problems;
- perform boost tests with laptop;
- identify and explain operation of VGT;
- explain the differences between OEM styles of VGTs;
- explain the function and benefit of a cooled EGR system;
- explain the role crankcase ventilation plays in reducing diesel emissions;
- identify and explain operation of a differential pressure sensor (Delta-P) and NOx sensor; and
- identify all components and explain full operation of EGR with DOC system.

Related job tasks/OJT checklist: OJT checklists may be used with the learning objectives listed under the "Maintenance and repair" and "Testing, diagnostics and troubleshooting" sections of the learning objectives related to 2004 emissions equipment (Appendix A).

Course description: Participants will receive classroom instruction in which a qualified instructor will familiarize the employee with the core components of engines designed to meet the 2004 EPA emissions standards. Participants should leave the course with an understanding of the operation of and an ability to service and diagnose the engine and aftertreatment components.

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 test questions, laptops with OEM software, buses for use in diagnostic practice

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

Operations, Diagnostics and Best Practices for DOC with DPF Systems

Goal: Participants should understand and be able to service and diagnose equipment used to achieve the 2007 EPA emission regulations, diesel particulate filters and other aftertreatment components.

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

- explain the role of exhaust aftertreatment in reducing emissions in diesel engines;
- identify and explain operation of dosing valve injector and active regeneration injectors;
- identify and explain operation of VGT on 2007 and later buses;
- identify and explain operation of differential pressure sensor (Delta-P) and NOx sensor;
- identify and explain operation of DPF;
- explain purpose and process of performing a regen, and describe the difference between active and passive methods;
- diagnose faults related to DEF injection system, including clogged filter, fuel injection, onboard warning system and excessive temperatures;
- interpret information and respond to engine struggling to complete a regen;
- inspect PM filter support brackets, piping and clamps;
- manually clean PM filter and remove ash;
- check PM filter temperature and back-pressure;
- check fuel injection system associated with active PM filters, including injectors and fuel line;
- inspect control system associated with active PM filters, including wiring harness and functionality;
- clean DEF dosers (injector); and
- demonstrate proficient use of OEM software for diagnosing 2007-2009 buses.

Related job tasks/OJT checklist: OJT checklists may be used with the learning objectives listed under the "Maintenance and repair" and "Testing, diagnostics and troubleshooting" sections of the learning objectives related to 2007 emissions equipment (Appendix A).

Course description: Participants will receive classroom instruction in which a qualified instructor will familiarize the employee with the core components of engines designed to meet the 2007 EPA emissions standards. Participants should leave the course with an understanding of the operation of and an ability to service and diagnose the engine and aftertreatment components.

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

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

Operations, Diagnostics and Best Practices for DPF with SCR Systems

Goal: Participants should understand and be able to service and diagnose equipment used to achieve the 2010 EPA emission regulations, especially the selective catalyst reduction components, and use of diesel exhaust fluid and the associated injection system.

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

- explain the operation and major functions and components for 2010 emission control system, and why additional engine cooling capacity is needed to meet EPA 2010 regulations;
- explain safe handling procedures for DEF;
- identify and explain operation of VGT on 2010 and later buses;
- identify and explain operation of active regeneration injectors, differential pressure sensor (Delta-P) and NOx sensor;
- identify and explain operation of DEF supply module and DEF tank, DEF hoses, decomposition reactor/tube (crossover pipe) and DEF dosing valve;
- identify and explain operation of SCR and inspect brackets and piping;
- inspect DEF injection system associated with SCR, including injector, pump, dispenser and DEF lines;
- diagnose faults related to DEF injection system, including injector, pump, dispenser and distribution lines, and DEF supply module;
- diagnose, maintain and replace operation of differential pressure sensor and NOx sensor;
- diagnose, maintain and replace DEF tank, including checking filtration, heater elements, pump and fluid level sensors, and DEF hoses;
- diagnose, maintain and replace operation of SCR;
- diagnose, maintain and replace operation of decomposition reactor, including checking clamps and seals when needed;
- diagnose, maintain and replace operation of dosing valve injector and active regeneration injectors;
- diagnose, maintain and replace operation of VGT, including checking leaks, pipes and clamps;
- develop skills in interpreting information provided by software;
- identify when a system is vulnerable to coding (proactive diagnosis);
- use OEM software for diagnosing 2010 buses; and
- demonstrate aftertreatment dosing injector cleaning.

Related job tasks/OJT checklist: OJT checklists may be used with the learning objectives listed under the "Maintenance and repair" and "Testing, diagnostics and troubleshooting" sections of the learning objectives related to 2010 emissions equipment (Appendix A).

Course description: Participants will receive classroom instruction in which a qualified instructor will familiarize the employee with the core components of engines designed to meet the 2010 EPA emissions standards. Participants should leave the course with an understanding of the operation and ability to service and diagnose the engine and aftertreatment components.

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

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.

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