**Intermountain Transit Career Ladder Inc.**



**Transit Bus Emissions Control Systems**

*Instructor’s Manual*

Prepared by:

EDSI Consulting

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# REVISION INDEX

Any additions, deletions, or revisions are to be listed below.

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| **Revision No.** | **Date** | **Section** | **Description of Change** | **Revision Author** |
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Transit Bus Emissions Control Systems

Instructor’s Manual

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# Course Information Summary Sheet

**Purpose**

This purpose of this course is to deepen bus technicians’ understanding of the operation and maintenance of transit bus emission control systems. The content covers a review of intake and exhaust systems in general, the technology involved in modern emission controls systems, the operation and components of UTA’s emissions control system, and the diagnoses and repair of all components.

The following content areas will be explored through classroom presentations and hands-on activities in this training:

* Review of Servicing Intake and Exhaust Systems
* Operations of EGR / Crankcase Ventilation Systems (2005/06 Buses, 04,08,09 Fords)
* Diagnostics and Best Practices of EGR / DOC Systems
* Operations of DOC with DPF Emissions Control Systems (2007/2009 Buses)
* Diagnostics and Best Practices of DOC with DPF systems
* Operations of DEF/DPF with Selective Catalyst Reduction Emissions Control Systems (2010 Buses)
* Diagnostics and Best Practices of DEF/DPF with SCR Systems

**Duration**

3 full days of training

**Recommended Class Size and Target Audience**

This course is designed for incumbent bus mechanics in all UTA Business units.

**Prerequisite Knowledge**

Requires foundation understanding of engine operation, repair and maintenance.

**Instructional Materials**

|  |  |
| --- | --- |
| Courseware – printed material for students and instructor, files for instructor (see list below) | Multimeters ? Other test equipment? |
| Computer | Laptops (if applicable), various terminals, cables and adaptors; current versions of Cummins INSITE and DDDL |
| Projector (test before class) | PPE / Safety Equipment |
| Colored pencils, rulers |  |

**Courseware Files**

|  |  |  |
| --- | --- | --- |
| **Day** | **Item** | **Filename / Location** |
| All | Instructor Manual | Bus Emissions Controls Instructor Manual v1.2.docx |
| All | Technician’s Guide | Bus Emissions Controls Student Guide.docx |
| 1 | Power Point Presentation | Day 1.pptx |
| 1 |  |  |
| 2 | Power Point Presentation | Day 2.pptx |
| 2 |  |  |
| 3 | Power Point Presentation | Day 3.pptx |
| 3 |  |  |

# Day 1 Lesson Plan – Intro to Servicing Intake and Exhaust Systems / EGR and DOC Operations, Service and Troubleshooting

## Overview and Purpose

The first day of the course is designed to familiarize or re-familiarize students with the operation and servicing of Intake and Exhaust systems, and the emissions control technology of engines with emissions gas recirculation and diesel oxidation catalysts. Students will also practice connection and using Cummins INSITE and Detroit Diesel Diagnostic Link

## Objectives

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

* Explain theory of operation of engine intake and exhaust systems
* Identify and explain purpose of common components such as wastegate, exhaust manifolds, turbo charger and related components, and air restriction indicators or other sensors
* Perform common diagnosis and repair tasks such as diagnosing temperature, back pressure, or air flow restriction problems; perform boost tests with laptop, VGT (starting in 05).
* 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.
* Explain the inverse relationship that exists between PM and NOx when reducing emissions in a diesel engine
* Identify common acronyms associated with emission control technologies
* Identify and explain operation of variable vane turbochargers. (VGT) Explain the differences between Cummins and Detroit styles of VGT.
* 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 differential pressure sensor (delta p) and NOx sensor Identify all components and explain full operation of EGR with DOC system

## Preparation

Print all required technician’s handbooks and supplementary material as needed for the three day class. Arrange ahead of time for the buses needed for hands-on scenario practice on each day. (See daily lesson plans for specifics)

## Instructional Flow

*Please note times are approximate, and can be adjusted by the instructor based on the needs and skills of a particular class. The schedule assumes 7 hours of instructional time in an 8.5 hour day with 1.5 hours for lunch and breaks.*

|  |  |
| --- | --- |
| **Activity / Objectives Covered** | **Courseware Reference / Notes** |
| **Introduction Activities (1 hour)** | |
| *Logistics:* Pass out sign-in sheet. Ensure everyone has student workbooks, supplementary courseware, and other materials.  Instructor and class introductions. Use an ice breaker such as: “what do you hope to get from this training?”.  Go over all classroom ground rules and expectations. |  |
| Administer short Pre-Test and questionnaire, which will be designed to identify student’s locations, their desires for the class. Instructor can emphasize certain points in the course based on the interest established by the questionnaire | Note: Review results during 1st break |
| *Topic Introduction:* Go over very broadly the topics that will be covered in the next three days, and the main learning objectives. Lead an informal discussion: Why is controlling emissions important? Why is understanding and maintaining the emissions systems critical? What time and money can be saved from a better understanding of these systems? What separates a great technician from a good or average technician? | Day 1, Slide #2 |
| **Review of general operations and servicing of intake and exhaust systems (1-2 hours)** | |
| Explain overall theory of engine intake and exhaust systems | Slide 3 |
| Explain evolving technology for emissions controls, and the technologies in place at UTA. What is an aftertreatment system? Discuss role of EPA and its requirements. | Slide 4 |
| **Operations of EGR/Crankcase Ventilation Emission Control Systems (2 hours)** | |
| Show engine diagram from Quickserve for 2006 Engine (#46573883). Emphasize engine sensor locations that are important for emissions. Explain operation of delta p sensor and NOx sensor. | Slide 5-6 |
| Show flow diagrams of air intake and exhaust systems. Explain role of turbocharger (VGT), charge air cooler, EGR mixer, EGR valve, and EGR cooler. Explain and discuss overall operations. Explain crankcase ventilation and how it works. | Slide 7-9 |
| Emphasize the safety considerations of high pressure common rail system | Aftertreatmenttraining.pdf |
| Discuss other engines (other Cummins models, Detroit models) with similar technology. Explain that the class will primarily follow Cummins models, but troubleshooting concepts learned will apply in other areas. | Slide 10 |
| **Diagnostics and Best Service Practices for EGR/Crankcase Ventilation Emission Control Systems (2-3 hours)** | |
| Discuss service procedures and solicit input on which maintenance tasks have given the class difficulty. Review the processes for:   * EGR cleaning procedures * EGR cooler * Cleaning out delta p sensor * EGR valves * EGR pipes | Slides 11-23 |
| Discuss the common diagnostic problems, and what students have seen on these engines. Review the troubleshooting trees for:   * Intake Manifold pressure (boost) low * Intake Air Temperature Above Specification * Turbocharger Leaks Engine oil or Fuel | Slides 24-29 |
| Demonstrate hook up and navigation process for Cummins INSITE | Slides 30-46 |
| Demonstrate hook up and navigation process for Detroit Diesel Diagnostic Link | Slides 47-54 |
| On Bus Practice:   * Demonstrate, and give students and opportunity to demonstrate, the Cummins INSITE hookup process. * Demonstrate process of responding to and overtemp code. Perform tests to watch EGR valves open and close * Perform flow and isolations tests on EGR valves and look at performance. Discuss use of INSITE for items without specific codes, such as turbo boost, air inlet temperature, and other items that can be monitored * Click on codes within INSITE, demonstrate how to create a custom data list | Slides 55 |
| Review and wrap up:   * Discuss importance of using INSITE (or DDDL) early in the diagnostic process, and for service and troubleshooting manual references, not just for finding codes. * Discuss Cummins field reps and tech as a resource, and access to technical forums |  |

# Day 2 Lesson Plan – Servicing and Troubleshooting DOC with DPF Emissions Control Systems

## Overview and Purpose

The second day of the course provides a detailed overview of the intake, exhaust, and aftertreatment components of 2007 and 2009 coaches at UTA. Technicians will learn the role of diesel particulate filters and how and why to perform regens, as well as other critical servicing and common troubleshooting tasks. Continued practice using Cummins INSITE for hands-on diagnostics will be emphasized.

## Objectives

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

* Explain the role of exhaust after-treatment in reducing emissions in diesel engines
* Identify and explain operation of dosing valve injector and active regeneration injectors (on ISM 07/09 Buses)
* Identify and explain operation of VGT on 07/09 buses
* Identify and explain operation of differential pressure sensor (delta p) and NOx sensor
* Identify and explain operation of DPF (catalyst filters)
* Explain purpose and process of performing a regen and describe the difference between active and passive methods.
* Diagnose faults related to DPF 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 backpressure. Check fuel injection system associated with active PM filters including injectors and fuel line.
* Inspect control system associated with active PM filter including wiring harness and functionality.
* Clean DPF dosers
* Demonstrate proficient use of Cummins INSITE for Diagnosing 07/09 buses

## Preparation

Arrange ahead of time for a 2009 Coach with a Cummins ISL engine to be available to hands-on practice. If a 2009 Coach is not available, obtain a 2007 with a Cummins engine. If available, a second Coach with Detroit Diesel engine can also be obtained. The selection of coaches may depend on composition of the class.

## Instructional Flow

*Please note times are approximate, and can be adjusted by the instructor based on the needs and skills of a particular class. The schedule assumes 7 hours of instructional time in an 8.5 hour day with 1.5 hours for lunch and breaks.*

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| --- | --- |
| **Activity / Objectives Covered** | **Courseware Reference / Notes** |
| **Review Day 1 (20-30 minutes)** | |
| *Logistics:* Pass out sign-in sheet. Ensure everyone has student workbooks, supplementary courseware, and other materials.  Administer a short quiz or worksheet, or lead general discussion on previous days material | Slides 1-4 |
| **Operations of DOC with DPF Emissions Control Systems (2007/2009 Coaches) (3 hours)** | |
| Show engine diagram from Quickserve for 2009 ISL engine (#46957564), emphasize sensor locations important for emissions. Explain operation of various sensors. | Slides 5-9 |
| Show flow diagrams of air intake and exhaust systems. Explain role of turbocharger (VGT) and its differences in operation from the 2005/06 Coaches. Discuss the differences between the Detroit and Cummins Turbocharger. | Slides 10-24 |
| Explain the role of charge air cooler, exhaust manifold and seal, EGR valve, EGR cooler, exhaust pressure sensor and mounting. Explain and discuss overall operation. |
| Explain role of aftertreatment. Discuss flow of exhaust through DPF and DOC. Discuss role of dosing valves and injector and DPF sensors. |
| Spend time with bus in training area viewing the various components. |  |
| **Diagnostics and Best Practices of DOC with DPF Emissions Control Systems (3.5 hours)** | |
| Provide familiarization with service manual processes.  Student guide will include nearly all service manual processes. Discuss with students which ones to review, and/or select certain ones ahead of time. Focus on service of parts introduced with the 2007 emissions control technology.  The list includes:   * 1. Dry Exhaust manifold   2. Exhaust restriction   3. EGR Cooler, Valve and Connection Tubes   4. Exhaust Gas Pressure Sensor Tube   5. EGR Cooler Coolant Lines   6. Aftertreatment DPF   7. DPF Differential Pressure   8. Aftertreatment Inlet and Outlet   9. Aftertreatment DOC   10. Aftertreatment system   11. Exhaust System Diagnostics   12. Air Inlet Connection   13. Air Intake Manifold   14. Air Leaks, Air Intake and Exhaust Systems   15. Charge Air Cooler   16. Air Intake restriction   17. Turbocharger   18. Turbocharger Coolant Hoses   19. Turbocharger Oil Drain Line   20. Turbocharger Oil Supply Line   21. Intake Manifold Pressure   22. Air Intake Connection   23. Turbocharger Compressor Outlet Connection   24. VGT Turbocharger Actuator (Electric) | Slide 27 |
| Demonstrate performing flow tests on dosers. This is a required process before installing dosers cleaned by the machine shop | Slide 28 – placeholder. Training doesn’t have the equipment available to teach this. Look into how important this is. |
| Discuss common faults related to the DPF injection system: clogged filter, onboard warning system, and excessive temperatures. Provide familiarization with troubleshooting procedures from the Quickserve manual for these conditions:   * + Intake Manifold Temperature High   + Turbocharger leaks engine oil or fuel   + Stationary Regeneration will not Activate   + Stationary Regeneration will not complete   + DPF excessive automatic or stationary regeneration | Slides 28-40 |
| Discuss process of responding to engine struggling to complete a regen and the difference between active and passive methods. Emphasize not simply clearing a code to force a regen. This may sometimes be necessary to get the bus back in the shop, but actually finding the problem is critical. Discuss active vs. passive regens | When discussing, go back to slides for relevant troubleshooting processes. |
| If possible, demonstrate the use of DDDL on 2007/09 coaches |  |
| On Bus Practice:  Demonstrate a manual regen on bus for the class, communicating with and telling the computer what to perform. Use INSITE to explore various codes. |  |
| Discuss these items that may cause regens without throwing a code:   * + VGT module timing can be off without throwing a code   + Cooling fan module (when it fails it will turn all the time, so engine coolant may not obtain temperature   + VGT can develop carbon and not stroke fully   + Bad temperature sensor   + Plugged filters   + Replacing sensors may require further calibration   + Cleaning dosers is sometimes just a band-aid and doesn’t solve an underlying problem   + INSITE can be told a new DPF has been put in even if it hasn’t. This will sometimes achieve the regen   + Clearing | Slides 42-46 |
| Discuss regen best practices compiled at Timp, including:   * Engine codes 2639, 1921 and 1922 are codes that should require a simple regen to be run * Engine codes 2637, 2638, and 1691 are codes that require the DOC and DPF be checked for damage or soot on the face and a flow test be performed on the diesel injector/doser**.** | Slide 43 |
| Review and wrap up:   * Review various aftertreatment features for an overall understanding of their purpose * Discuss again the importance of using INSITE (or DDDL) early in the diagnostic process, and for service and troubleshooting manual references, not just for finding codes. | Slide 46 |

# Day 3 Lesson Plan – Servicing and Troubleshooting DEF/DPF with SCR Emissions Control Systems

## Overview and Purpose

The third day of the course provides a detailed overview of the intake, exhaust, and aftertreatment components on 2010 coaches at UTA. Technicians will learn the role of Diesel Exhaust Fluid and Selective Catalyst Reduction, performing regens on these coaches, as well as other critical servicing and common troubleshooting tasks. Continued practice using Cummins INSITE for hands-on diagnostics will be emphasized.

## Objectives

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

* Explain the operation and major functions and components for UTA’s 2010 emission control system, and why additional engine cooling capacity is needed to meet EPA 2010 regulations.
* Explain safe handling procedures for Diesel Exhaust Fluid (DEF).
* Identify and explain operation of VGT (on 2010 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, inspect brackets and piping Inspect diesel exhaust fluid (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
* Developing skills in interpreting information provided by software Identify when a system is vulnerable to coding (proactive diagnosis)
* Use of Cummins Quickserve and INSITE for Diagnosing 2010 buses
* Demonstrate Aftertreatment dosing injector cleaning

## Preparation

Arrange ahead of time for a 2010 Coach with a Cummins ISB engine to be available to hands-on practice.

## Instructional Flow

*Please note times are approximate, and can be adjusted by the instructor based on the needs and skills of a particular class. The schedule assumes 7 hours of instructional time in an 8.5 hour day with 1.5 hours for lunch and breaks.*

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| --- | --- |
| **Activity / Objectives Covered** | **Courseware Reference / Notes** |
| **Review Day 2 (20-30 minutes)** | |
| *Logistics:* Pass out sign-in sheet. Ensure everyone has student workbooks, supplementary courseware, and other materials.  Administer a short quiz or worksheet, or lead general discussion on previous days material | If needed, can spend a bit more time on 07/09 Technology on Day 3, reducing time for 2010s.\  Slides 1-3 |
| **Operations of DEF/DPF with SCR Emissions Control Systems (2010 Coaches) (2.5 hours)** | |
| Show engine diagrams from Quickserve for 2010 ISB engine (#73087097), emphasizing engine sensor locations important for emissions. Explain operation of various sensors. | Slides 5-9 |
| Show flow diagrams and overviews of air intake and exhaust systems. Explain differences in crankcase ventilation compared to 07/09 engines. | Slides 10-27 |
| Explain role of charge air cooler, exhaust manifold and seal, EGR valve, EGR cooler, exhaust pressure sensor and mounting. Explain and discuss the overall operation | Slides 10-27 |
| Explain role of aftertreatment processing 2010s. Discuss flow of exhaust through DPF and DOC. Discuss role of active regeneration injectors (instead of dosing valve injectors on 07/09 engines). Discuss the flow from DEF dosing valves and intake to the SCR. | Slides 22-24, 26-27 |
| **Diagnostics and Best Practices of DEF/DPF with SCR Systems (3.5 hours)** | |
| Provide familiarization with service manual processes. Discuss considerations for working with DEF during service.  Student guide will include nearly all service manual processes. Discuss with students which ones to review, and/or select certain ones ahead of time. Focus on service of parts introduced with the 2010 emissions control technology.  The list includes:   * Dry Exhaust manifold * Exhaust restriction * EGR Cooler, Valve and Connection Tubes * Exhaust Gas Pressure Sensor Tube * EGR Cooler Coolant Lines * Aftertreatment SCR Catalyst * Aftertreatment DPF * DPF Differential Pressure Sensor Tubes * Aftertreatment DOC * Aftertreatment system * Exhaust System Diagnostics * Aftertreatment DEF Fluid Controller * Aftertreatment DEF Fluid Dosing Unit, and Dosing Unit Override Test * Aftertreatment DEF Fluid Dosing Valve * Aftertreatment DEF Fluid Dosing Unit Filter * Aftertreatment Decomposition Tube * Aftertreatment Outlet * Air in DEF * Aftertreatment DEF Controller Calibration Code * Aftertreatment DEF System Leak Test * Air Inlet Connection * Air Intake Manifold * Air Leaks, Air Intake and Exhaust Systems * Charge Air Cooler * Air Intake restriction * Turbocharger * Turbocharger Coolant Hoses * Turbocharger Oil Drain Line * Turbocharger Oil Supply Line * Intake Manifold Pressure * Air Intake Connection * Turbocharger Compressor Outlet Connection * VGT Turbocharger Actuator (Electric) * Air Intake System Diagnostics | Slides 30-33 |
| Discuss common faults related to DEF injection system and SCR. Level sensors are a common failure on Gilligs, discuss troubleshooting process for these. Provide familiarization with Cummins troubleshooting trees for the following problems:   * Aftertreatment DPF – excessive ash cleaning * Intake Manifold Air Temp Above Specification * Turbocharger Leaks Engine Oil or Fuel * DEF usage Abnormal * Stationary Regen will not activate * Aftertreatment DPF Excessive Automatic and/or Stationary Regen * Stationary Regen will not complete * DEF Contamination   Discuss process of responding to engine struggling to complete a regen and the difference between active and passive methods. Emphasize not simply clearing a code to force a regen. This may sometimes be necessary to get the bus back in the shop, but actually finding the problem is critical. Discuss active vs. passive regens | Slides 33-46 |
| On-Bus Practice:  Discuss or demonstrate if possible the servicing of:   * DEF supply module and DEF tank and hoses, cleaning the DEF nozzle thoroughly is very important * DEF flow tester * Removal of fluid lines in 2010s * Decomposition reactor and DEF dosing valve * SCR, inspecting brackets and piping * DEF injection system associated with SCR including injector, pump, dispenser and DEF lines   Use INSITE to explore various codes. Emphasize the additional INSITE screens for DEF and SCR temperature for the 2010s. Discuss items that may cause regens without throwing a code. | Slides 48-49 |
| Course Summary (30 minutes – 1 hour) | |
| * Reemphasize troubleshooting best practices: How to approach a problem. * Encourage students to continue practice using INSTIE and DDDL for tests, codes, manuals and troubleshooting procedures * Encourage students to provide feedback to improve the course | Slide 52 |