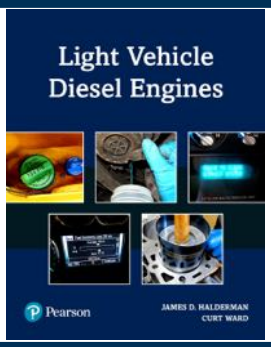
Light Vehicle Diesel Engines

First Edition



Chapter 15
Exhaust and Aftertreatment Systems

LEARNING OBJECTIVES (1 of 1)

15.1 Identify the components of the exhaust and aftertreatment systems.

15.2 Describe the function of each aftertreatment system.

15.3 Explain the differences between active and passive regeneration.

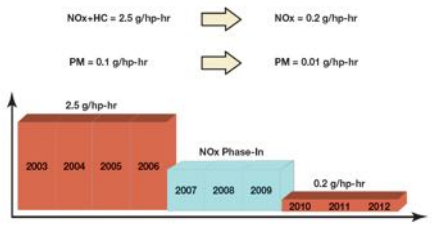
15.4 Explain how temperature sensors are used to monitor component operation.

15.5 Describe the function of the diesel exhaust fluid (DEF) in the selective catalyst reduction (SCR) system.

EXHAUST CHEMISTRY (1 of 4)

- **Emission Standards: FIGURE 15–1**
  - Changes in standards resulted in requirement
  - Reduce PM & NOx emissions by 90%
  - Changes to fuel control strategies helped to achieve

FIGURE 15–1 emission chart shows the mandated reductions in tailpipe emissions, how they have driven changes in way diesel engines operate, and how exhaust aftertreatment is configured.



PEARSON

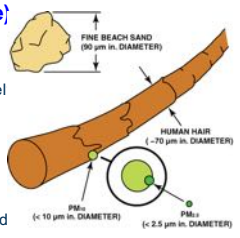
EXHAUST CHEMISTRY (2 of 4)

- **Hydrocarbons (HC)**
  - Unburned diesel fuel measured in PPM
- **Carbon Monoxide (CO)**
  - Partially burned diesel fuel
  - CO combine with O2 to form CO2
- **Oxides Of Nitrogen (NOx)**
  - Colorless, tasteless, odorless gas leaves engine
  - Reaches atmosphere mixes with O2, forms NO2
  - NO & NO2 grouped together and referred to NOx
  - 'x' represents any number of oxygen (O2) atoms
- **Particulate Matter (PM)**
  - Soot, tiny particles of solid/semisolid material

PEARSON

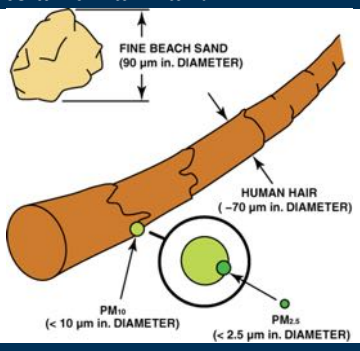
EXHAUST CHEMISTRY (3 of 4)

- **TSP (Total Suspended Particulate)**
  - **Particles 0.1 & 50 microns**
  - **PM10**
    - PM 10 microns or less (approximatel 1/6 the diameter of a human hair).
    - EPA standard for particles based on levels of **PM10.**
  - **PM2.5**
    - PM 2.5 microns or less
    - (1/20 diameter of human hair), called "fine" particles.
    - July 1997, EPA approved **PM2.5**
    - SEE FIGURE 15–2.



PEARSON

FIGURE 15–2 Relative size of particulate matter to a human hair.



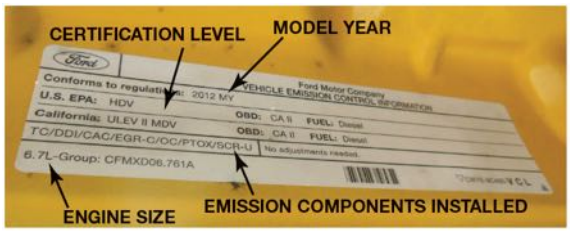
PEARSON

EXHAUST CHEMISTRY (4 of 4)

- Vehicle Emissions Certification: Figure 15-3
  - Exhaust System Function: Page 166
  - Aftertreatment System Consists:
    - Diesel oxidation catalyst (DOC)
    - Particulate filters
    - NOx catalysts

PEARSON

FIGURE 15–3 emissions certification label identifies how the vehicle is certified.



PEARSON

WARNING

Exhaust system components and exhaust air stream can be hot enough to cause damage or personal injury. Do not park or operate vehicle in areas where exhaust might come in contact with anything that can burn. Use extreme caution when working around these components.

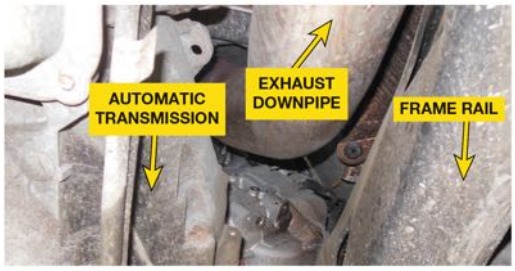
PEARSON

EXHAUST SYSTEM COMPONENTS

- **Exhaust Downpipe: Figure 15-4: Page 167**
- **Exhaust Backpressure Regulators (EBPR) Figure 15-5**
- **Exhaust Tailpipe Figure 15-6**

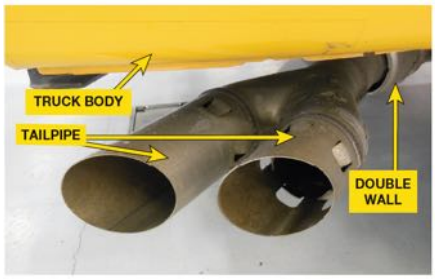
PEARSON

FIGURE 15–4 exhaust downpipe is constructed to retain heat to help the aftertreatment work as designed.



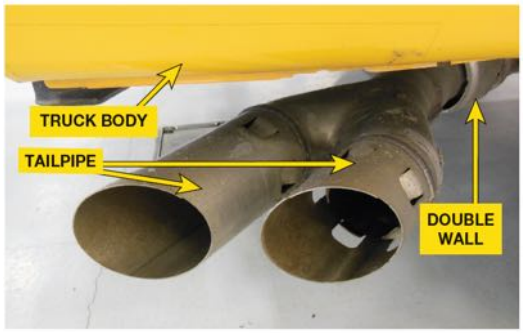
PEARSON

FIGURE 15–5 exhaust backpressure regulator (EBPR) allows engine to warm to operating conditions more quickly.



PEARSON

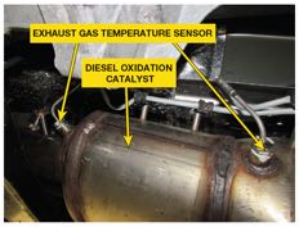
FIGURE 15–6 design of tailpipe allows for cooling of exhaust during regeneration event.



PEARSON

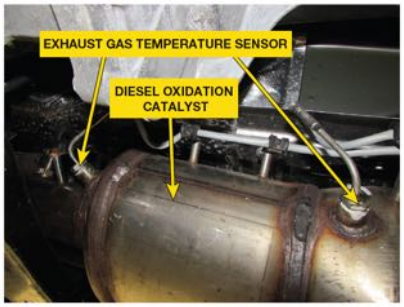
DIESEL OXIDATION CATALYST (DOC)

- **Diesel Oxidation Catalyst (DOC)**
  - Helps to reduce HC & CO **FIGURE 15–7**
  - Helps to reduce level of PM
  - Convert NO to nitrogen dioxide



PEARSON

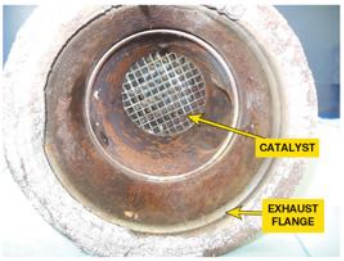
FIGURE 15–7 diesel oxidation catalyst (DOC) reduces hydrocarbons (HC) and carbon monoxide (CO) through oxidation. The heat generated from process is used to reduce particulate matter.



PEARSON

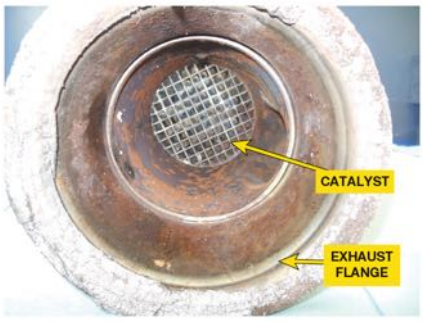
NOx ADSORBER CATALYST

- **NOx Adsorber Catalyst**
  - Maintenance-free strategy for removing NOx emissions
  - Low-temperature, oxygen-rich environment
  - Smaller Diesel Engines
  - Operation **Page 168**



PEARSON

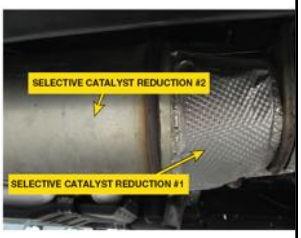
FIGURE 15–8 NOx Adsorber catalyst holds NOx emissions during lean conditions and oxidizes them when operating conditions are rich.



PEARSON

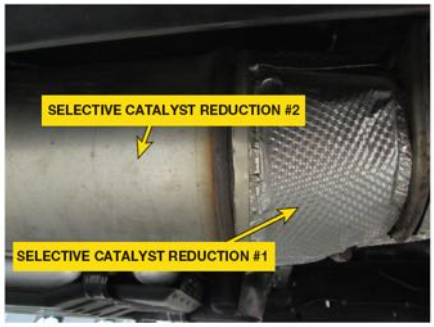
SELECTIVE CATALYST REDUCTION (SCR) (1 of 2)

- **Selective Catalyst Reduction (SCR)**
  - Reduce level of NOx
  - Before or after DPF
  - Ceramic substrate covered W/
    - Washcoat of copper & iron
    - Near inlet of SCR catalyst is reductant dosing module. This module includes injection nozzle, diffuser, mixer
    - Some use 2- stage catalyst
    - Atomize DEF and disperse it evenly onto the substrate



PEARSON

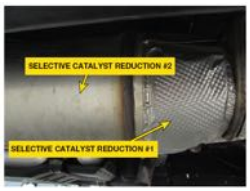
FIGURE 15–9 SCR catalyst reduces level of NOx emissions when diesel exhaust fluid (DEF) is injected onto its substrate.



PEARSON

SELECTIVE CATALYST REDUCTION (SCR) (2 of 2)

- **SCR Operation**
  - AS DEF heats up
  - Separates into carbon dioxide & ammonia
  - When ammonia reacts with NOx
  - Reduction reaction takes place
  - NOx converted to nitrogen dioxide and water
  - SCR catalyst monitored by NOx sensor



PEARSON

DIESEL EXHAUST FLUID

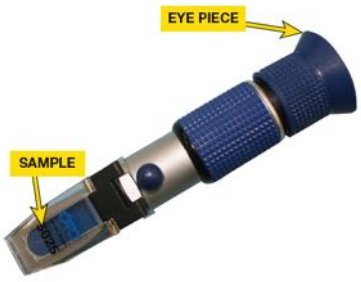
- **Diesel Exhaust Fluid (DEF)**
  - Mixture of 32.5% laboratory grade urea
  - 67.5% deionized water
    - Deionized water deeply demineralized
  - Urea: synthetic ammonia & CO_2
  - Nontoxic & not harmful to handle
  - Injected into exhaust stream upstream of SCR
  - Once inside catalyst, heat causes DEF to decompose into ammonia and CO_2
  - Refractometer measures its density

PEARSON

FIGURE 15–10 Diesel exhaust fluid (DEF) is available in consumer-friendly containers or in bulk.

PEARSON

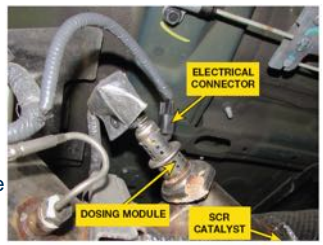
FIGURE 15–11 refractometer is used to measure quality of diesel exhaust fluid (DEF).



PEARSON

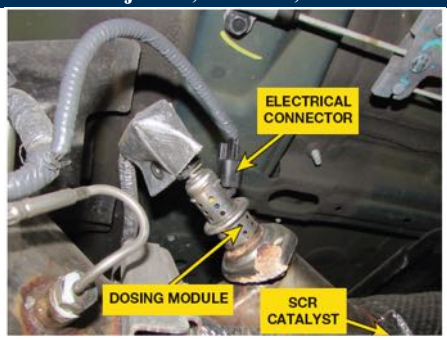
REDUCTANT DOSING MODULE

- **Reductant Dosing Module**
  - Inject DEF
  - Module includes injection, nozzle, diffuser, & mixer
  - Components atomize DEF
  - Disperse it evenly onto substrate



PEARSON

FIGURE 15–12 reductant dosing module contains DEF injector, diffuser, and mixer.



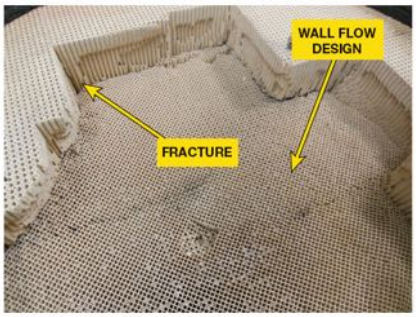
PEARSON

DIESEL PARTICULATE FILTER (DPF)

- **Diesel Particulate Filter (DPF)**
  - Near DOC, Make Exhaust smokeless
  - Closed off wall flow ceramic monolith
  - Forces gasses through porous walls
  - Holds PM too large to pass through
  - Stores PM
  - As PM gathers in filter assembly, exhaust restricts
  - PM oxidized into CO2 by increasing temperature
  - Through regeneration, ash is left

PEARSON

FIGURE 15–13 DPF monolith is responsible for capturing particulate matter and holding it until a regeneration event occurs. DPF pictured failed due to internal fracture.



PEARSON

FIGURE 15–14 DPF warning lamp used to warn driver vehicle needs to be driven in manner that regeneration event can occur.

PEARSON

DIFFERENTIAL PRESSURE SENSOR

- **Differential Pressure Sensor**
  - Determine if restriction exists in DPF
  - Need for service or replacement
  - Compares pressure at inlet and outlet of DPF
  - Uses data to determine if regeneration event needed

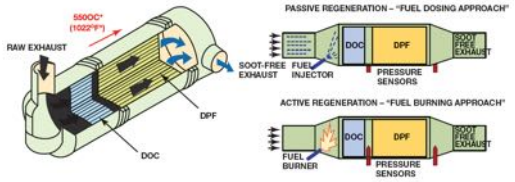
PEARSON

FIGURE 15–15 sequence of drawings shows steps of a regeneration event. SENSOR SHOWN IN FIGURE

DIFFERENTIAL PRESSURE SENSOR

PEARSON

FIGURE 15–16 feedback from the differential pressure sensor is used by the powertrain control module to determine when a regeneration event is needed.



PEARSON

TEMPERATURE SENSORS

- **Exhaust Aftertreatment System**
  - Uses multiple temperature sensors
  - Monitor function of components within system

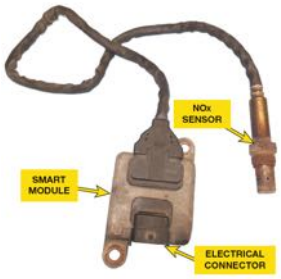
PEARSON

FIGURE 15–17 Temperature sensors are used by PCM to monitor function of various components in aftertreatment system.

PEARSON

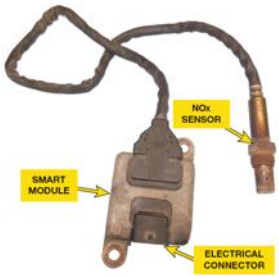
NOx SENSORS

- **NOx Sensors**
  - Part of Smart Module
  - Serviced Together
  - Measure Level of NOx Emissions
    - In Aftertreatment System
    - Determine If DEF Being Delivered To Exhaust
    - Adequate Volume & Quantity



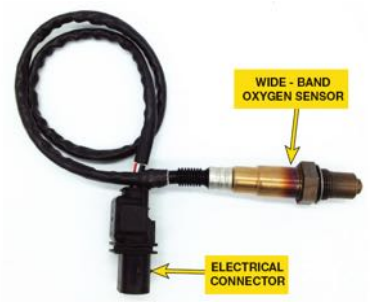
PEARSON

FIGURE 15–18 NOx sensor is used to measure NOx emissions in aftertreatment system.



PEARSON

FIGURE 15–19 oxygen sensor is used to monitor operation of EGR system.



PEARSON

QUESTION? 1

- What is the role of an O_2 sensor (if equipped) in the exhaust aftertreatment system?

PEARSON

ANSWER 1

- Oxygen sensor is used to monitor operation of EGR system.

PEARSON

QUESTION? 2

- What happens if the customer fails to maintain the diesel exhaust fluid (DEF) at a minimum level?

PEARSON

ANSWER 2

- The quality of the diesel exhaust fluid (DEF) is critical for proper catalyst operation. The system is designed to warn the driver when the system fluid level gets low.

PEARSON

QUESTION? 3

- What is the difference between a passive and an active regeneration event?

PEARSON

ANSWER 3

- **Passive Regeneration.** During a passive regeneration event, the engine load is sufficient enough to create the exhaust temperatures needed to eliminate the particulate matter.
- **Active Regeneration.** During active regeneration event, heat is created by **adding fuel to exhaust stream**. This fuel can be added either through a post injection shot at cylinder or through a dosing valve in the exhaust. **Temperature of diesel particulate filter (DPF) is hotter during an active regeneration event than a passive event**.

PEARSON

Summary (1 of 3)

- Tier II diesel emission standards were introduced in 2007 and were phased in until 2010.
- The tailpipe emissions include hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NOx), particulate matter (PM), oxygen (O2), and carbon dioxide (CO2).
- To comply with federally mandated Tier II diesel emission standards, the aftertreatment system consists of following:
  - Diesel oxidation catalyst (DOC)
  - Particulate filters
  - NOx catalysts

PEARSON

Summary (2 of 3)

- On most modern diesel engines, the diesel oxidation catalyst (DOC) is the first major component in the exhaust aftertreatment system after the exhaust downpipe.
- NOx absorber catalyst is a maintenance-free strategy for removing NOx emissions in a low-temperature, oxygen-rich environment.
- The selective catalyst reduction (SCR) system is designed to reduce the level of oxides of nitrogen (NOx) in the exhaust stream.
- DPF is located in a stainless steel housing near diesel oxidation catalyst (DOC). It is responsible for making the exhaust virtually smokeless.

PEARSON

Summary (3 of 3)

- Diesel exhaust fluid (DEF) is a mixture of 32.5% laboratory grade urea and 67.5% deionized water.
- Regeneration events occur automatically throughout course of normal driving when the particulate filter becomes restricted.
- A differential pressure sensor is used to determine if a restriction exists in the DPF, indicating a need for service or replacement.
- The exhaust aftertreatment system uses multiple temperature sensors to monitor the function of components within the system. Some OEMS refer to these sensors as exhaust gas temperature sensors.
- Newer diesel vehicles use a wide-band oxygen sensor that is capable of accurately monitoring the oxygen level in the exhaust stream throughout its broad operating range

PEARSON