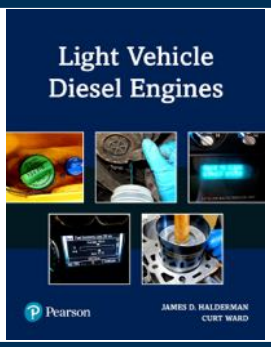
Light Vehicle Diesel Engines

First Edition



Chapter 9
Turbocharger systems

LEARNING OBJECTIVES (1 of 1)

9.1 Prepare for the Light Vehicle Diesel Engine (A9) ASE certification test content area • "E" (Air Induction and Exhaust Systems Diagnosis and Repair).

9.2 Discuss airflow requirements and volumetric efficiency of engines.

9.3 Explain forced induction principles.

9.4 Discuss turbochargers.

9.5 Explain boost control.

INTRODUCTION (1 of 2)

- 4-stroke engine can take in only so much air
  - How much fuel it needs for proper combustion
  - Depends on how much air it takes in.
  - Engineers calculate engine airflow requirements
    - using 3 factors:
      - **Engine Displacement**
      - **Engine Revolutions Per Minute (RPM)**
      - **Volumetric Efficiency**

FIGURE 9–1 turbocharger on a Cummins inline six-cylinder diesel engine. Engine oil is fed to the center of the turbocharger to lubricate the bushings and returns to the oil pan through a return line.

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INTRODUCTION (1 of 1)

- **Volumetric Efficiency**
  - Measure of how well an engine breathes
  - Comparison of actual volume of air-fuel mixture
  - Drawn into an engine to Theoretical maximum
    - Volume that could be drawn in
  - Volumetric efficiency is expressed as a percentage

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QUESTION 1: ?

What is volumetric efficiency?

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ANSWER 1:

Measure of how well an engine breathes and the comparison of actual volume of air-fuel mixture drawn into an engine to the theoretical maximum volume that could be drawn into the engine. Volumetric efficiency is expressed as a percentage. It could be called mass efficiency because it is the weight the of the air that counts.

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TURBOCHARGER PURPOSE AND FUNCTION (1 of 2)

- Amount of force an air-fuel charge produces
- When ignited; largely a function of charge density.
  - **Charge Density** is a term used to define
    - Amount of air-fuel charge introduced into cylinders
  - Density is mass of substance in given space

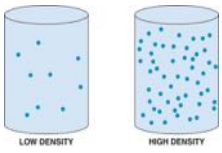

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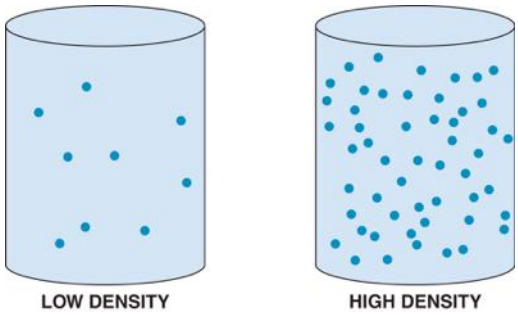
FIGURE 9–2 The more air that can be packed in a cylinder, the greater the density of the air and the greater the efficiency of the engine.



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TURBOCHARGER PURPOSE AND FUNCTION (2 of 2)

- Forced induction systems use an air pump
- Pack a denser air-fuel charge into cylinders
- Because density of air-fuel charge is greater
- Following occurs:
  - Weight of air-fuel charge higher
  - **Power is increased**
    - Because it is directly related to weight of
    - Air-fuel charge consumed within a given time period

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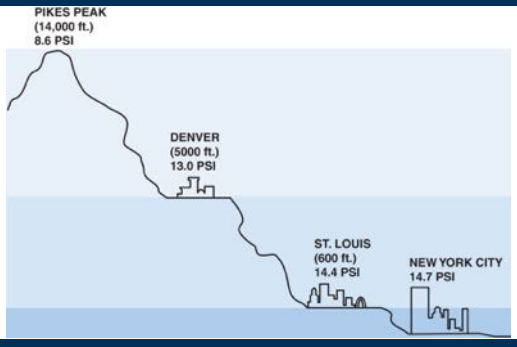
FIGURE 9–3 Atmospheric pressure decreases with increases in altitude.



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QUESTION 2: ?

What is charge density?

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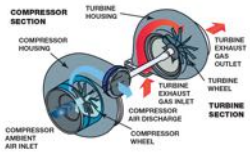
ANSWER 2:

Charge Density is a term used to define Amount of air-fuel charge introduced into the cylinder. Density is mass of substance in given space.

TURBOCHARGERS (1 of 4)

- **Turbocharger**
  - Uses heat of exhaust to power a turbine wheel
  - Does not directly reduce engine power.
    - In NA engine, about ½ heat energy contained in fuel goes out exhaust system.
  - Operation
  - Turbocharger Operation
  - Turbocharger Size and Response Time



TURBOCHARGERS (2 of 4)

- **Turbocharger: Page 108**
  - **Advantages**
  - **Disadvantages**

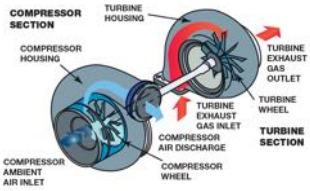


FIGURE 9–4 Turbine wheel is turned by the expanding exhaust gases.

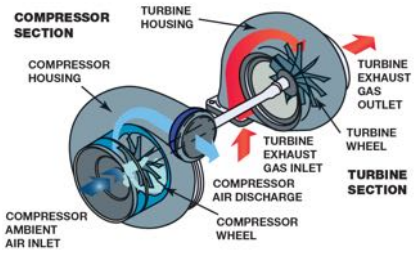


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FIGURE 9–5 The exhaust drives the turbine wheel on the left, which is connected to the impeller wheel on the right through a shaft. Bushings that support the shaft are lubricated with engine oil under pressure.

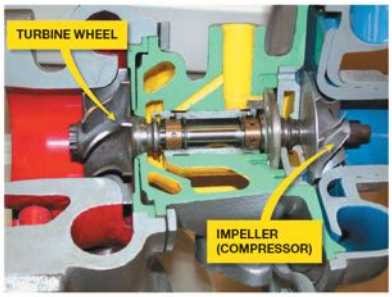

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FIGURE 1–2 The extra heat required to change a standard amount of water at its boiling point to vapor is called latent heat of vaporization.

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TURBOCHARGERS (3 of 4)

- **Text Pages 109-110**
  - Turbocharger Operation At Idle Speed
  - Turbocharger Operation Under Boost Conditions
  - Importance Of Engine Oil
  - Turbocharger Cooling

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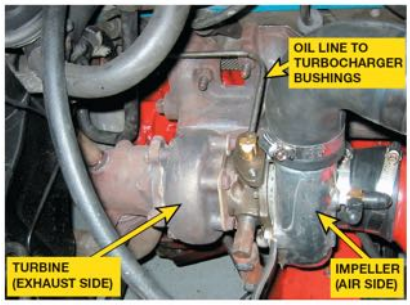
FIGURE 9–6 Engine oil is fed to the center of the turbocharger to lubricate the bushings and returns to the oil pan through a return line.



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TURBOCHARGERS (4 of 4)

- **Text Pages 109-110**
  - Cool Down Idling
  - Turbocharger Size & Response Time

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CHART 9-1

- Estimated time that the engine should be allowed to idle to cool the turbocharger before shutting off the engine is based on vehicle speed and load

VEHICLE OPERATION	ENGINE LOAD	IDLE TIME NEEDED BEFORE SHUT DOWN
Stop and Go City-Type Driving	Light-Vehicle Empty	Less than One Minute
Stop and Go City-Type Driving	Medium Load	One Minute
Highway Speeds	Medium Load	Two Minutes
Stop and Go City-Type Driving	Heavy Load	Three Minutes
Highway Speeds	Heavy Load	Four Minutes

CHART 9–1

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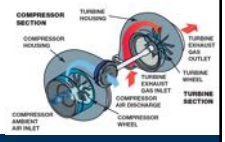
BOOST CONTROL (1 of 2)

- **Boost Control Factors**
  - **Provide pressure > atmospheric pressure**
  - **In intake manifold**
    - **Increased pressure forces additional amounts of air**
    - **Into combustion chamber**
    - **Increased charge increases engine power**
    - **Boost (or pressure in intake manifold)**
    - **Measured**
      - **Pounds per square inch (PSI)**
      - **Inches of mercury (inch Hg)**
      - **Atmospheres**



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BOOST CONTROL (2 of 2)

- **Wastegate**
  - Valve can open and close
  - Bypass valve at exhaust inlet turbine
  - Allows all of exhaust into turbine
  - Can route part of exhaust past turbine to exhaust system

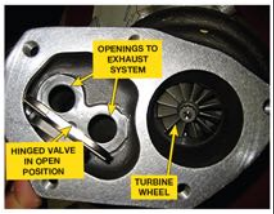

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FIGURE 9–7 wastegate is a hinged door usually with two exists for the exhaust to flow through bypassing the turbine blade of the turbocharger.

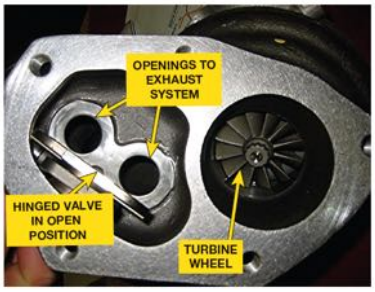

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Chart 9-2

	POUNDS PER SQUARE INCH (PSI)	INCHES OF MERCURY (INCH HG)	BAR	ATMOSPHERE
I PSI	1	2.04	0.069	0.070
1 Bar	14.50	29.53	1	1.019
I in. Hg	0.49	1	0.034	0.034
1 Atmosphere	14.22	29.92	0.986	1

CHART 9–2

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VARIABLE GEOMETRY TURBOCHARGER (1 of 2)

- **Variable Geometry Turbocharger (VGT)**
  - Boost pressure controlled independently of engine speed
  - Wastegate not needed
  - Match turbocharger boost levels to power demands
  - Without overboosting
  - Less lag time compared to wastegate system
- **Parts & Operation Text Page 111**
- **Sequential Turbochargers**

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FIGURE 9–8 Variable vane turbocharger allows the boost to be controlled without the need of a wastegate.

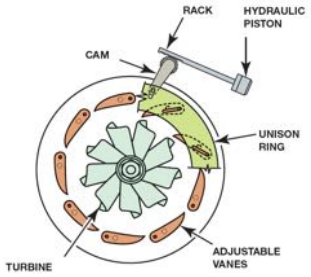

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FIGURE 9–9 (a) the variable vane turbocharger from a Duramax diesel engine, showing the vanes in the extended position. This position creates a higher velocity exhaust stream being applied to the turbine blades when the engine speed is low.

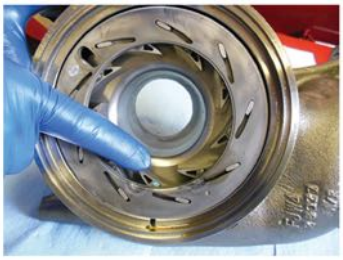

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FIGURE 9–9 (B) This shows the position of three variable vanes at higher engine speed where the greater volume of exhaust gases can be applied to the turbine blades.

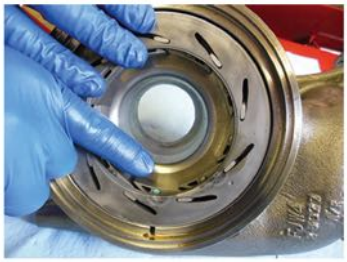

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FIGURE 9–10 The vane position sensor is an input signal to the PCM to provide feedback data for control of turbocharger boost levels.

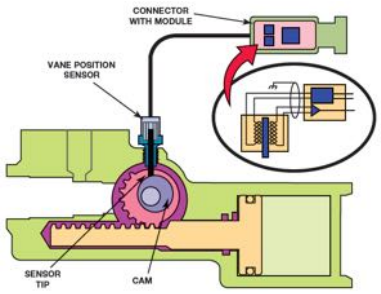

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FIGURE 9–11 The low-pressure turbocharger compresses the air and sends the air through the extension tube and the crossover tube prior to entering the high-pressure turbocharger.

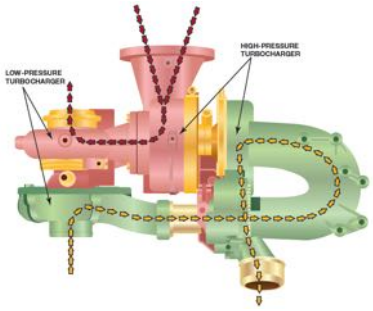

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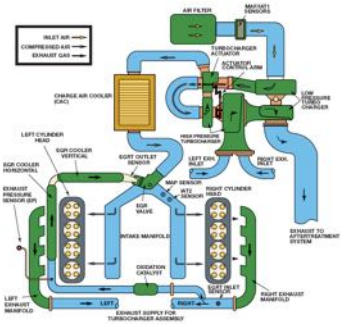
FIGURE 9–12 6.4-Liter power stroke diesel engine air management system, showing a low-pressure and a high-pressure turbocharger, plus the sensors and arrows showing the airflow.



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VARIABLE GEOMETRY TURBOCHARGER (2 of 2)

- **Ford 6.4-liter Power Stroke**
  - Uses 2 turbochargers
  - One feeding air to other
    - Low-pressure, high-volume turbocharger
    - High-pressure, low-volume turbocharger
      - FIGURE 9–11.

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AIR CHARGE COOLER (1 of 1)

- **Cooler Air Entering Engine**
  - Means more power can be produced
  - Cooler air is denser than hot air
  - Power can be increased about 1% per 10°F (–12°C)
    - **Air Charge Cooler, An Intercooler, Or Charge Air Cooler**
    - Similar to radiator
  - Cooling pressurized heated air that is moving through cooler
  - Some intercoolers use engine coolant to cool hot compressed air

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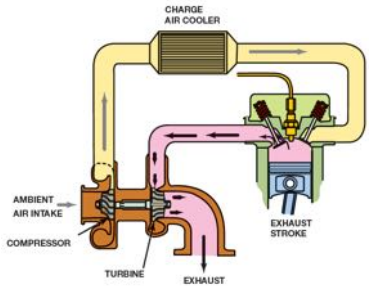
FIGURE 9–13 air charge cooler is used to cool the compressed air.



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TURBOCHARGER DIAGNOSIS (1 of 1)

- **Verify Customer Concern**
  - **Diagnosis Trouble Codes**
    - Possible causes of a P0229 DTC include
      - Faulty or damaged turbocharger
      - Low oil pressure in the engine
      - Fault in the EGR system
      - Air intake leak or restriction
      - Defective or out-of-range boost pressure sensor
      - Variable geometry turbocharger **(VGT) actuator**

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TURBOCHARGER DIAGNOSIS

- **Visual Inspection**
- **Symptoms of Failure**
  - When turbochargers fail to function correctly
  - Noticeable drop in power occurs

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FIGURE 9–14 A turbocharger with damaged impeller blades. Small black plastic pieces were found around area indicating that air filter housing had been damaged when owner replaced air filter. Pieces from broken housing causes damage to turbocharger.

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QUESTION 3: ?

What is the first sign that a turbocharger is not working?

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ANSWER 3:

Loss of power or a low power concern.

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Summary (1 of 2)

- A turbocharger uses the normally wasted heat energy of the exhaust gases to turn an impeller at high speed. The impeller is linked to a turbine wheel on the same shaft and is used to force air into the engine.
- An intercooler is used on many turbocharged engines to reduce the temperature of air entering the engine for increased power.

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Summary (2 of 2)

- A wastegate is used on most turbocharger systems to limit and control boost pressures.
- A variable-vane turbocharger is used on many diesel engines for boost control.
- Turbocharger diagnosis includes performing a thorough visual inspection and using a scan tool to retrieve any stored diagnostic trouble codes.

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