# Automotive Technology 6th Edition
# Chapter 80 Fuel-Injection Components & Operation
## Opening Your Class

| KEY ELEMENT | EXAMPLES |
|---|---|
| **Introduce Content** | This Automotive Technology 6th text provides complete coverage of automotive components, operation, design, and troubleshooting. It correlates material to task lists specified by ASE and ASEEducation (NATEF) and emphasizes a problem-solving approach. Chapter features include Tech Tips, Frequently Asked Questions, Case Studies, Videos, Animations, and ASEEducation (NATEF) Task Sheets. |
| **Motivate Learners** | Explain how the knowledge of how something works translates into the ability to use that knowledge to figure why the engine does not work correctly and how this saves diagnosis time, which translates into more money. |
| **State the learning objectives for the chapter or course you are about to cover and explain this is what they should be able to do as a result of attending this session or class.** | Explain learning objectives to students as listed below:<br>1. List components of electronic fuel-injection systems.<br>2. Explain how air intake is measured in fuel-injection systems.<br>3. Describe how throttle-body injection and port fuel-injection<br>4. Systems work.<br>5. Discuss the function of the fuel-pressure regulator and describe a vacuum-biased fuel-pressure regulator.<br>6. Describe returnless fuel systems.<br>7. Describe how fuel injectors function and describe central port injection.<br>8. Explain modes of fuel-injection system operation.<br>9. Explain how idle speed is controlled.<br>10. This chapter will help prepare for Engine Repair (A8) ASE certification test content area “C” (Fuel, Air Induction, and Exhaust Systems Diagnosis and Repair). |
| **Establish the Mood or Climate** | Provide a ***WELCOME***, Avoid put downs and bad jokes. |
| **Complete Essentials** | Restrooms, breaks, registration, tests, etc. |
| **Clarify and Establish Knowledge Base** | Do a round robin of the class by going around the room and having each student give their backgrounds, years of experience, family, hobbies, career goals, or anything they want to share. |

**NOTE: Lesson plan is based on 6th Edition Chapter Images found on Jim’s web site @ www.jameshalderman.com**

**DOWNLOAD Chapter 80 Chapter Images: From**

**http://www.jameshalderman.com/automotive_principles.html**

**NOTE: You can use Chapter Images or possibly Power Point files:**

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1. **SLIDE 1 CH80 FUEL-INJECTION COMPONENTS & OPERATION**

**Check for ADDITIONAL VIDEOS & ANIMATIONS @ http://www.jameshalderman.com/**

**WEB SITE IS CONSTANTLY UPDATED**

**http://www.jameshalderman.com/automotive_principles.html**

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**Crossword Puzzle (Microsoft Word) (PDF)**

**Word Search Puzzle (Microsoft Word) (PDF**

## Videos

**EXPLAIN TECH TIP:** ***"Two Must-Do's"***

***For long service life of fuel system, always do following:***

1. **Avoid operating vehicle on a near-empty tank of fuel. The water or alcohol becomes more concentrated when fuel level is low. Dirt that settles near bottom of fuel tank can be drawn through fuel system and cause damage to pump and injector nozzles.**
2. **Replace fuel filter at regular service intervals (if applicable).**

2. **SLIDE 2** EXPLAIN **FIGURE 80–1** Typical port fuel-injection system, indicating the location of various components. Notice that the fuel-pressure regulator is located on fuel-return side of system. The computer does not control fuel pressure, but does control the operation of the electric fuel pump (on most systems) and the pulsing on and off of injectors.

**DISCUSSION: Have the students discuss how the PCM controls fuel injection system. What are some common components of an electronic fuel-injection system? FIGURE 80-1**

**DISCUSS CASE STUDY:**

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**DISCUSSION:** **Have the students discuss the two types of electronic fuel-injection systems. Which type is more efficient?** **Discuss diagram shown in FIGURE 80–1**. **Why is the pressure regulator positioned after the injectors?**

3. **SLIDE 3 EXPLAIN FIGURE 80–2** A dual-nozzle TBI unit on a Chevrolet 5.0 L V-8 engine. The fuel is squirted above the throttle plate where fuel mixes with air before entering the intake manifold..
4. **SLIDE 4 EXPLAIN FIGURE 80-3** typical port fuel-injection system squirts fuel into the low pressure (vacuum) of the intake manifold, about 2 to 3 in. (70 to 100 mm) from the intake valve

**DEMONSTRATION:** **Show examples of fuel injectors. Show them injectors for a port-injection system and throttle-body injection. Discuss similarity of injectors.**

**DISCUSSION:** **Discuss Speed-Density Fuel-Injection Systems. Ask them to discuss the importance of coolant temperature & ambient air temperature on these systems.**

**DISCUSSION:** **Have the students talk about the Mass Airflow Fuel-Injection System & how it works. How is it different from speed-density system?**

5. **SLIDE 5 EXPLAIN FIGURE 80-4** tension of spring in the fuel-pressure regulator determines the operating pressure on a throttle-body fuel-injection unit

6. **SLIDE 6 EXPLAIN FIGURE 80–5** injectors receive fuel and are supported by fuel rail. A pulse damper is used to help reduce noise caused by pressure changes in the fuel rail during injector pulsing operation.
7. **SLIDE 7 EXPLAIN FIGURE 80-6** Cross-section of a typical port fuel-injection nozzle assembly. These injectors are serviced as an assembly only; no part replacement or service is possible except for replacement of external O-ring seals

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**DEMONSTRATION:** **Show 2 vehicles, one with port fuel injection & other with throttle-body fuel injection. Ask students to explain differences between the 2 systems.**

**DISCUSS FREQUENTLY ASKED QUESTION:**

**H*ow Do the Sensors Affect the Pulse Width?***

**The base pulse width of a fuel-injection system is primarily determined by value of MAF or MAP sensor and engine speed (RPM). However, PCM relies on input from many other sensors, such as following, to modify base pulse width:**

- **TP Sensor. This sensor causes the PCM to command up to 500% (five times) the base pulse width if accelerator pedal is depressed rapidly to the floor. It can also reduce pulse width by about 70% if throttle is rapidly closed.**
- **ECT. value of this sensor determines Temperature of engine coolant, helps determine base pulse width, and can account for up to 60% of determining factors.**
- **BARO. compensates for altitude and adds up to about 10% under high-pressure conditions and subtracts as much as 50% from base pulse width at high altitudes.**
- **IAT. The intake air temperature is used to modify base pulse width based on temperature of air entering the engine. It is usually capable of adding as much as 20% if very cold air is entering engine or reducing pulse width by up to 20% if very hot air is entering engine.**
- **O2S. This is one of main modifiers to base pulse width and can add or subtract up to about 20% to 25% or more, depending on oxygen sensor activity.**

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8. **SLIDE 8** **EXPLAIN** **Figure 80-7** Port fuel injectors spray atomized fuel into the intake manifold about 3 inches (75 mm) from the intake valve
9. **SLIDE 9** **EXPLAIN** **Figure 80-8** port fuel-injected engine that is equipped with long, tuned intake manifold runners

**DISCUSSION:** **Have the students talk about the firing order of a sequential fuel injection system. Can fuel injector firing time be adjusted like ignition timing?**

**DEMONSTRATION:** **Show intake manifolds on port fuel-injected vehicles. Allow them to see lengths of the runners. Point out that all the runners can be the same length and can be tuned for optimum performance. FIGURE 80-8**

**4-cylinder ENGINES are good examples for an intake manifold demonstration. These vehicles usually have manifold runners that are easier to view.**

**DISCUSSION:** **Have the students talk about the sensors that affect fuel pulse width. What can happen if a sensor gives a false reading?**

**DEMONSTRATION:** **Show the students a car with Sequential Fuel Injection. Point out difference in the color of wires to injectors.**

**DISCUSSION:** **Have the students discuss the grouped double-fire, simultaneous double-fire, & sequential injection firing characteristics. Which one is the most efficient?**

10. **SLIDE 10** **EXPLAIN** **Figure 80-9** A typical port fuel-injected system showing a vacuum-controlled fuel-pressure regulator.
11. **SLIDE 11** **EXPLAIN** **Figure 80-10** typical fuel-pressure regulator that has a spring that exerts 46 pounds of force against fuel. If 20 inches of vacuum are applied above the spring, the vacuum reduces the force exerted by the spring on the fuel, allowing the fuel to return to the tank at a lower pressure.

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**DEMONSTRATION:** Show examples of fuel pressure regulators for throttle-body and port fuel injection. Point out vacuum hose fitting on the port fuel injection regulator.

**DISCUSSION:** discuss differences between fuel-pressure regulators and vacuum biased fuel-pressure regulators. Why is a secondary control source (vacuum) used with port injection?

**DEMONSTRATION:** Explain how a leaking diaphragm can allow fuel to enter the engine & cause a rich condition. Show how to remove vacuum lid to check for presence of fuel.

**DISCUSS FREQUENTLY ASKED QUESTION:** ***How Can It Be Determined If the Injection System Is Sequential?*** Look at the color of the wires at the injectors. If a sequentially fired injector is used, then one wire color (pulse wire) is a different color for each injector. The other wire is usually same color because all injectors receive voltage from some source. If a group- or batch-fired injection system is being used, then the wire colors are 3 same for injectors that are group fired. For example, a V-6 group-fired engine has 3 injectors with a pink and blue wire (power and pulse), and the other three have pink and green wires.

**EXPLAIN TECH TIP:** ***Don't Forget the Regulator*** Some fuel-pressure regulators contain a 10 micron filter. If this filter becomes clogged, a lack of fuel flow results. • **SEE FIGURE 80–11.**

12. **SLIDE 12 EXPLAIN FIGURE 80-11** A lack of fuel flow could be due to a restricted fuel-pressure regulator
13. **SLIDE 13 EXPLAIN FIGURE 80–12** fuel pressure sensor and fuel temperature sensor are often constructed together in one assembly to help give PCM needed data to control fuel-pump speed.
14. **SLIDE 14 EXPLAIN FIGURE 80-13** mechanical returnless fuel system. Bypass regulator in fuel filter controls fuel line pressure.

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|  | **DISCUSSION:** **talk about mechanical returnless fuel systems FIGURE 80-13. How are these systems different from electronic returnless systems? What are their limitations? Discuss why there is no pressure regulator in an electronic returnless fuel system. What takes its place?** |
|  | 15. SLIDE 15 EXPLAIN **Figure 80-14** A demand delivery system uses a fuel pressure regulator attached to the fuel pump assembly |
|  | **DISCUSSION: Discuss Demand Delivery System of fuel delivery. How does it differ from other systems of fuel delivery? FIGURE 80-14** |
|  | **DEMONSTRATION: Show examples of round & rectangular cross-section fuel rails. Explain how rectangular-shaped fuel rail can help control pulsations and noise: FIGURE 80-15** |
|  | **DEMONSTRATION: Show the students how to use a stethoscope to listen for noises.** |
|  | **HANDS-ON TASK: Have them use stethoscope to listen to fuel injectors on running engine.** |
|  | **DISCUSS FREQUENTLY ASKED QUESTION:** ***Why Are Some Fuel Rails Rectangular Shaped?*** **A port fuel-injection system uses a pipe or tubes to deliver fuel from fuel line to intended fuel injectors. This pipe or tube is called fuel rail. Some vehicle manufacturers construct fuel rail in a rectangular cross section. • SEE FIGURE 80–15. The sides of fuel rail are able to move in and out slightly, thereby acting as a fuel pulsator evening out the pressure pulses created by opening and closing of injectors to reduce underhood noise. A round cross-sectional fuel rail is not able to deform and, as a result, some OEMS have had to use a separate dampener** |

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16. **SLIDE 16 EXPLAIN FIGURE 80-15** rectangular-shaped fuel rail is used to help dampen fuel system pulsations and noise caused by injectors opening and closing
17. **SLIDE 17 EXPLAIN FIGURE 80-16** multiport fuel injector. Notice that the fuel flows straight through and does not come in contact with the coil windings**.**
18. **SLIDE 18 EXPLAIN FIGURE 80-17** Each of 8 injectors shown are producing a correct spray pattern for the applications. While all throttle-body injectors spray a conical pattern, most port fuel injections do not.

Electronic Fuel Injection, EFI 1 (View) (Download)
Electronic Fuel Injection, EFI 2 (View) (Download)
Electronic Fuel Injection, EFI 1 (View) (Download)
Electronic Fuel Injection, EFI 2 (View) (Download)

**DEMONSTRATION: Show Examples of fuel injectors, having them note the strainer screen, the seals, and the fuel discharge nozzle. Show the students a central port-injection assembly from a GM vehicle & point out central injector, Fuel distribution tubes, & poppet valves in each tube nozzle.**

**DISCUSSION: Have students discuss fuel injectors design. Do injectors that have distinctive spray patterns have to be installed in a specific way? Why are deposit-resistant fuel injectors used in some applications?**

**DEMONSTRATION: Show how to calculate injector size required for an engine. Work through calculations with them.**

**DISCUSS FREQUENTLY ASKED QUESTION:** ***How Can the Proper Injector Size Be Determined?:*** **Most people want to increase the output of fuel to increase engine performance. Injector sizing can sometimes be a challenge, especially if size of injector is not known. In most cases, OEMS publish rating of injectors, in pounds of fuel per hour (lb/hr). The rate is figured with the injector held open at 3 bars (43.5 PSI). An important consideration is**

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**that larger flow injectors have a higher minimum flow rating. Here is a formula to calculate injector sizing when changing mechanical characteristics of an engine.**

**Flow rate = hp × BSFC/number of cylinders × maximum duty cycle (% of on-time of the injectors)**

- **HP is projected horsepower. Be realistic!**
- **BSFC is brake-specific fuel consumption in pounds per horsepower-hour. Calculated values are used for this, 0.4 to 0.8 lb. In most cases, start on the low side for naturally aspirated engines and high side for engines with forced induction.**
- **Number of cylinders is actually number of injectors being used.**
- **Maximum duty cycle is considered at 0.8 (80%).**
- **Above this, the injector may overheat, lose consistency,o r not work at all. For example: 5.7 liter V-8 · 240 hp · 0.65/8 cylinders · 8· 24.37 lb/hr injectors required**

19. **SLIDE 19** EXPLAIN **FIGURE 80-18** central port fuel-injection system.
20. **SLIDE 20** EXPLAIN **Figure 80-19** factory replacement unit for a CSFI unit that has individual injectors at ends that go into the intake manifold instead of poppet valves

**EGR & crankcase ventilation vapors are usually introduced near throttle blade to be distributed equally among all the cylinders. This combination of hot exhaust and oily vapor can create deposits on fuel injectors, altering or restricting fuel flow.**

**DISCUSS FREQUENTLY ASKED QUESTION:** ***What Is Battery Voltage Correction?*** **Battery voltage correction is a program built into PCM**

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| | **that causes the injector pulse width to increase if there is a drop in electrical system voltage. Lower battery voltage causes fuel injectors to open slower than normal and fuel pump to run slower. Both of these conditions can cause engine to run leaner than normal, if battery voltage is low. Because a lean air–fuel mixture can cause engine to overheat, PCM compensates for lower voltage by adding a percentage to injector pulse width. This richer condition helps prevent serious engine damage. The idle speed is also increased to turn the generator (alternator) faster if low battery voltage is detected.** |
| | **DISCUSSION: Have the students discuss Fuel Injector Modes Of Operation. What actually controls these modes of operation?** |
| | **DEMONSTRATION: Demonstrate clear flood mode operation to the students. Try this before class to make sure the vehicle will comply.** |
| | Idle Air Control, IAC (View) (Download)<br>Idle Air Control, IAC (View) (Download) |
| | 21. **SLIDE 21** **EXPLAIN** **Figure 78-20** The small arrows indicate the air bypassing the throttle plate in the closed throttle position. This air is called minimum air. The air flowing through the IAC (blue arrows) is the airflow that determines the idle speed |
| | **DISCUSSION: Have the students talk about the need for an idle control system on fuel-injected engine. What other function can this control perform? Discuss stepper motors & solenoids used for idle air control. Which of these is more accurate? FIGURE 80-20** |

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22. **SLIDE 22 EXPLAIN Figure 80-21** Most stepper motors use four wires, which are pulsed by the computer to rotate the armature in steps

**DISCUSS FREQUENTLY ASKED QUESTION:** ***Why Does the Idle Air Control Valve Use Milliamperes?*** **Some Chrysler vehicles, such as the Dodge minivan, use linear solenoid idle air control valves (LSIAC). The PCM uses regulated current flow through solenoid to control idle speed and scan tool display is in milliamperes (mA).**

- **Closed position = 180–200 mA**
- **Idle = 300–450 mA**
- **Light cruise = 500–700 mA**
- **Fully open = 900–950 mA**

**DEMONSTRATION: While monitoring data on a scan tool, start engine & allow students to see steps or percentage of idle air control performed by PCM. Show examples of idle air control valves or stepper motors used on fuel-injected engines.**