STT- SMART TECH TRAINING: SAN LUIS OBISPO, CA (805) 543-3582

LEVEL-I TRAINING

SECTIONS 28-35

FUEL INJECTION & CARBURETION

1

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FUEL INJECTION: SECTIONS 28-31

- ❑ BASIC KNOWLEDGE OF FUEL INJECTION SYSTEMS THEORY, DESIGN, & OPERATION
- ❑ KNOW HOW A MALFUNCTIONING SYSTEM AFFECTS EMISSIONS (SMOG CHECK)
- ❑ IDENTIFY FUEL INJECTION SYSTEM TYPES AND SYSTEM COMPONENTS
- ❑ IDENTIFY DIESEL FUEL INJECTION SYSTEM COMPONENTS

2

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LEVEL-I TRAINING SECTIONS 28-35 FUEL INJECTION & CARBURETION

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- ❑ IDENTIFY DIESEL FUEL INJECTION SYSTEM COMPONENTS

CARBURETION: SECTIONS 32-35

- ❑ **BASIC KNOWLEDGE OF CARBURETOR THEORY, DESIGN, & OPERATION**
- ❑ **KNOW HOW THE CARBURETOR CAN AFFECT EMISSIONS (SMOG CHECK)**
- ❑ **VISUALLY INSPECT A CARBURETION SYSTEM AND RELATED SYSTEMS (TAC, EFE, ETC)**
- ❑ **CHECK / ADJUST ENGINE IDLE SPEED PER SPECIFICATIONS**

3

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LEVEL-I TRAINING SECTIONS 28-35 FUEL INJECTION & CARBURETION

BASIC KNOWLEDGE OF FUEL INJECTION SYSTEMS THEORY, DESIGN, & OPERATION

- ❑ **FUEL STORAGE SYSTEM**
- ❑ **FUEL SUPPLY SYSTEM**
- ❑ **FUEL DISTRIBUTION**
- ❑ **METHOD OF INJECTION**
- ❑ **“SELF-TESTING” = FEEDBACK**
- ❑ **MUST HAPPEN VERY FAST!**

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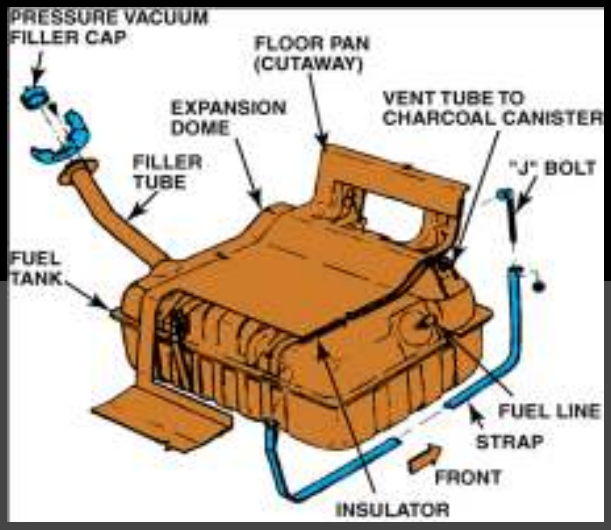
LEVEL-I TRAINING SECTIONS 28-35 FUEL INJECTION & CARBURETION

FUEL STORAGE SYSTEM:

- ❑ FUEL CAP & FILLER NECK
- ❑ TANK: METAL OR PLASTIC COMPOSITE
- ❑ IN-TANK PUMP OR PICK-UP TUBE/SOCK
- ❑ LINES/HOSES TO EXIT TANK
- ❑ "EVAP" SYSTEM TO CONTROL VAPORS
- ❑ "VENTING" SYSTEM



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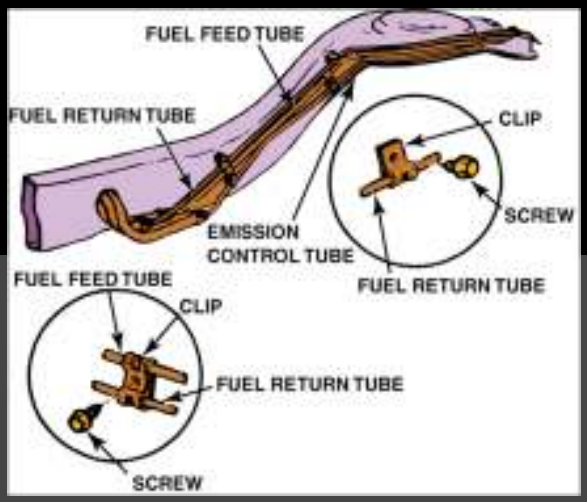
LEVEL-I TRAINING SECTIONS 28-35 FUEL INJECTION & CARBURETION

FUEL SUPPLY SYSTEM:

- ❑ FUEL PUMP (MORE LATER)
- ❑ FUEL LINES/TUBES (HARD)
- ❑ FUEL HOSES (SOFT/FLEXIBLE)
- ❑ FILTER (IN-TANK & IN-LINE)
- ❑ PRESSURE REGULATION
  - ➢ IN TANK
  - ➢ IN FILTER
  - ➢ ON FUEL LINE
  - ➢ AT ENGINE



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LEVEL-I TRAINING SECTIONS 28-35 FUEL INJECTION & CARBURETION

FUEL SUPPLY SYSTEM: FUEL PUMP

- ❑ DIFFERENT TYPES
  - ➢ POSITIVE DISPLACEMENT
  - ➢ NON-POSITIVE TYPE
- ❑ DIFFERENT LOCATIONS
  - ➢ IN THE FUEL TANK
  - ➢ BETWEEN TANK AND ENGINE
  - ➢ ON THE ENGINE (CARB/GDI/DIESEL)

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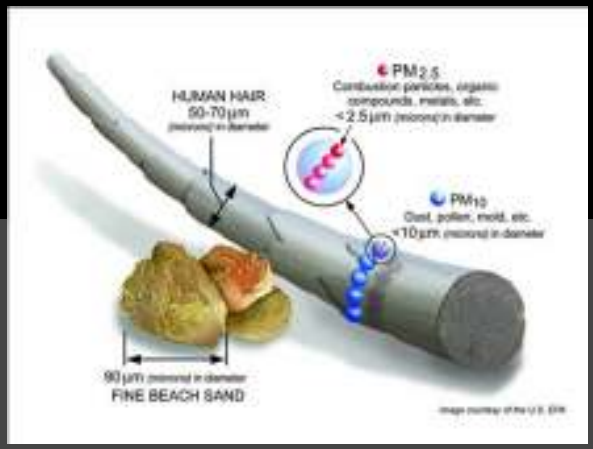
LEVEL-I TRAINING SECTIONS 28-35 FUEL INJECTION & CARBURETION

FUEL DISTRIBUTION

- ❑ FUEL FILTER
  - ➢ IN-TANK "SOCK" TYPICALLY FILTERS 80-100 MICRON SIZED PARTICLES AND LARGER
  - ➢ MAIN/PRIMARY FILTER USUALLY DESIGNED TO STOP 10-20 MICRONS FROM MAKING IT TO INJECTORS



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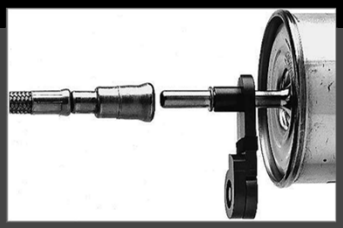
LEVEL-I TRAINING SECTIONS 28-35 FUEL INJECTION & CARBURETION

FUEL DISTRIBUTION

- ❑ **FUEL LINES & CONNECTIONS**
  - ➢ **"QUICK" DISCONNECT TYPE**
  - ➢ **SPECIAL TOOLS**
  - ➢ **READ SERVICE INFO!**



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LEVEL-I TRAINING SECTIONS 28-35 FUEL INJECTION & CARBURETION

FUEL DISTRIBUTION

- ❑ **FUEL RAIL (CDI/GDI/PFI)**
  - ➢ **ODD SHAPES TO REDUCE NOISE**
  - ➢ **EQUAL DISTRIBUTION OF FUEL**
- ❑ **THROTTLE BODY (TBI)**
  - ➢ **NOT A CARBURETOR!**
  - ➢ **EQUAL AMOUNT TO INJECTORS**

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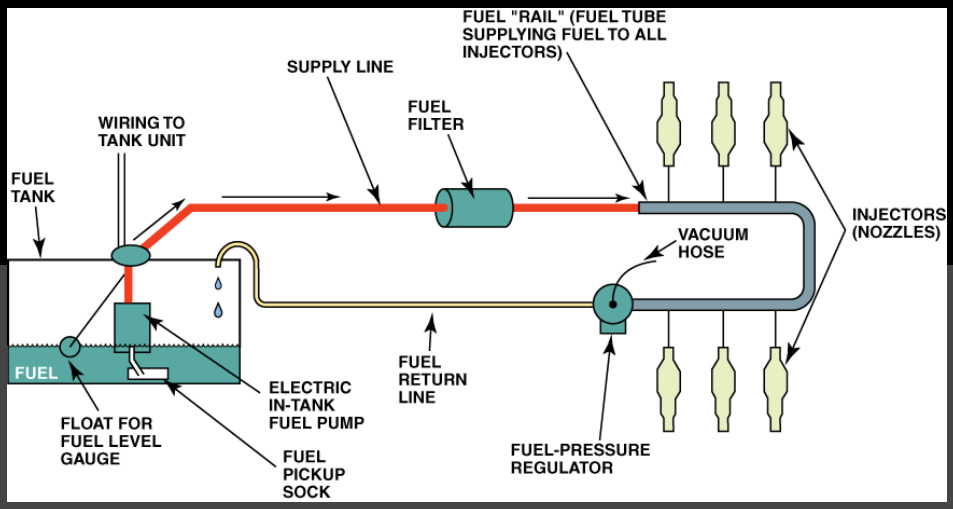
LEVEL-I TRAINING SECTIONS 28-35 FUEL INJECTION & CARBURETION



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LEVEL-I TRAINING SECTIONS 28-35 FUEL INJECTION & CARBURETION

"METHOD OF INJECTION"

- ❑ **"DIRECT"**
- ❑ **"INDIRECT"**

THIS IS A KEY POINT TO UNDERSTAND ABOUT FUEL INJECTIONS SYSTEMS!

DIRECT = FUEL DIRECTLY INTO THE COMBUSTION CHAMBER / CYLINDER

INDIRECT = INTO MANIFOLD, CYLINDER HEAD PORT, OR PRE-CHAMBER

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LEVEL-I TRAINING SECTIONS 28-35 FUEL INJECTION & CARBURETION

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DIRECT = FUEL DIRECTLY INTO THE COMBUSTION CHAMBER / CYLINDER
INDIRECT = INTO MANIFOLD, CYLINDER HEAD PORT, OR PRE-CHAMBER

- ❑ "DIRECT"
  - ➢ GASOLINE: "GDI" = GASOLINE DIRECT INJECTION
  - ➢ DIESEL: "DI" = DIESEL INJECTION
- ❑ "INDIRECT"
  - ➢ GASOLINE: CARBURETION, THROTTLE BODY, & PORT FUEL INJECTION
  - ➢ DIESEL: "IDI" = INDIRECT DIESEL INJECTION (PRECHAMBER DESIGN TYPE)

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LEVEL-I TRAINING SECTIONS 28-35 FUEL INJECTION & CARBURETION

"METHOD OF INJECTION"

BASIC TYPES:

- ❑ MECHANICAL / PRESSURE
  - ➢ INJECTION SYSTEM USES PRESSURE TO OPEN INJECTORS AND DISPENSE FUEL

- ❑ ELECTRONIC
  - ➢ INJECTION SYSTEM USES ELECTRICITY TO OPEN THE INJECTOR
  - ➢ "ELECTRO-MECHANICAL" INJECTOR
  - ➢ "PIEZO-ELECTRICAL" INJECTOR

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LEVEL-I TRAINING SECTIONS 28-35 FUEL INJECTION & CARBURETION

FUELS:

WHAT TYPE OF COMPOUND IS GASOLINE?

A. HYDROCARBON COMPOUND (HYDROGEN AND CARBON ATOMS BOUND TOGETHER).

B. HYDROXIDE COMPOUND (HYDROGEN AND OXYGEN ATOMS BOUND TOGETHER).

C. CARBON OXIDE COMPOUND (CARBON AND OXYGEN ATOMS BOUND TOGETHER).

D. OXIDES OF NITROGEN COMPOUND (NITROGEN AND OXYGEN ATOMS BOUND TOGETHER).

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LEVEL-I TRAINING SECTIONS 28-35 FUEL INJECTION & CARBURETION

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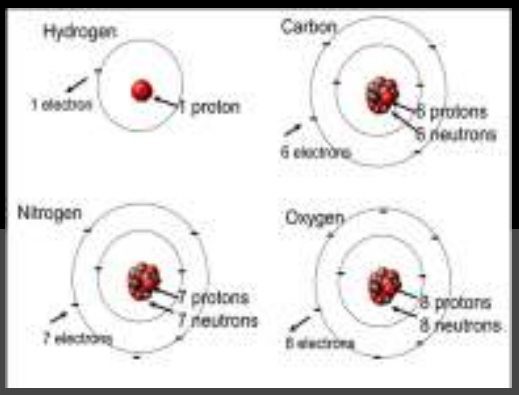
LEVEL-I TRAINING SECTIONS 28-35 FUEL INJECTION & CARBURETION

FUELS:

WHAT TYPE OF COMPOUND IS GASOLINE?

- **HYDROCARBON COMPOUND = C_8H_{18}**
- **V.O.C. = VOLATILE ORGANIC COMPOUND**
- **BONDED CARBON-HYDROGEN MOLECULES**
- **HYDROGEN PRODUCES WATER WHEN BURNED**
- **H_2O = 2 HYDROGEN AND 1 OXYGEN ATOM**



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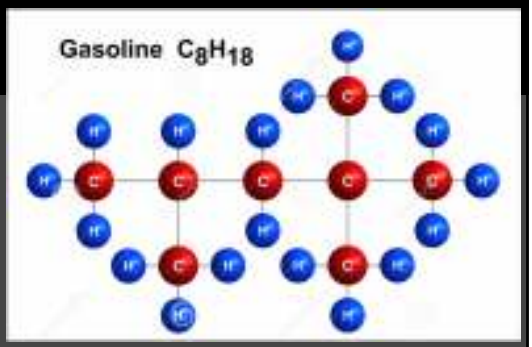
LEVEL-I TRAINING SECTIONS 28-35 FUEL INJECTION & CARBURETION

- **This is the atomic breakdown of gasoline.**
- **It can be helpful for us auto techs to have a basic understanding of HC compounds!**

Just remember that gasoline is a Hydrocarbon compound!



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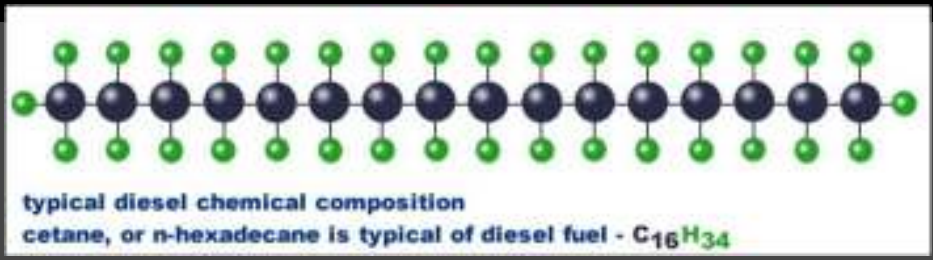
Gasoline: C8-H18

Diesel Fuel; C16-H34

- NEARLY TWICE THE POTENTIAL AMOUNT OF ENERGY
- WE BURN FUELS TO CREATE HEAT-ENERGY



typical diesel chemical composition
cetane, or n-hexadecane is typical of diesel fuel - $C_{16}H_{34}$

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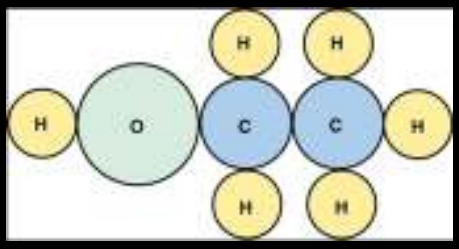
LEVEL-I TRAINING SECTIONS 28-35 FUEL INJECTION & CARBURETION

Gasoline: C8-H18

Diesel Fuel: C16-H34



Ethanol: C2-H5-O-H

- Added to gasoline that is:
- "Oxygenated"
- "Reformulated"
- Contains an Oxygen Atom

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Gasoline: C8-H18

Diesel Fuel: C16-H34

Ethanol: C2-H5-O-H

Methanol: C-H3-O-H

- Different type of injectors for gaseous fuels (not liquid)

Propane: C3-H8

CNG: C-H4

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Diesel Fuel: C16-H34

- Dyed RED for off-highway use.
- Same compound structure.

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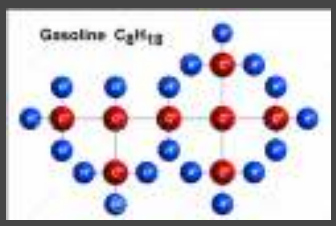
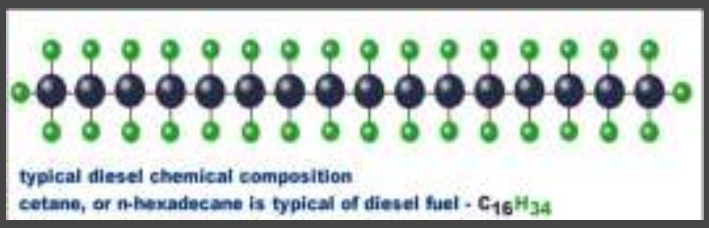
LEVEL-I TRAINING SECTIONS 28-35 FUEL INJECTION & CARBURETION

So, why should we learn about fuel?

- **To better understand how it is utilized in an ICE fuel injection system.**
- **So we can speak intelligently with our coworkers and customers.**
- **So we can "read" a Smog Check VIR and understand the data.**





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LEVEL-I TRAINING SECTIONS 28-35 FUEL INJECTION & CARBURETION

Source of measured tailpipe emissions gasses:

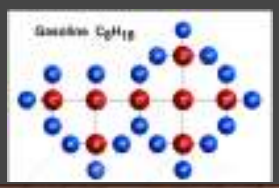
HC = Hydrocarbons = Unburned Fuel

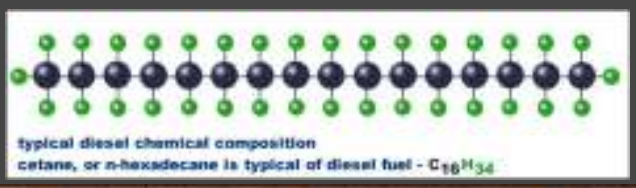
CO = Carbon Monoxide = Partially Burnt Fuel

CO2 = Carbon Dioxide = Complete Combustion

O2 = Oxygen = "Air"

NOx = Oxides of Nitrogen = High Combustion Temperature





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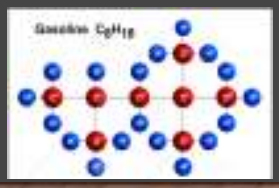
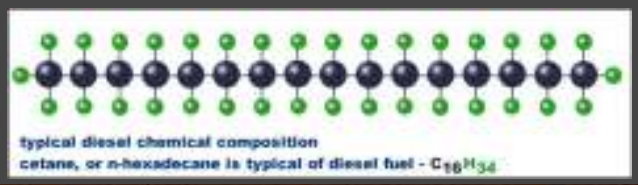
SAMPLE #1	SAMPLE #2	SAMPLE#3	SAMPLE #4
HC 10 PPM	HC 50 PPM	HC 150 PPM	HC 500 PPM
CO .15%	CO .35%	CO 1.2%	CO .10%
CO2 15%	CO2 13%	CO2 10%	CO2 12%
O2 .5%	O2 1.5%	O2 .1%	O2 4%





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Review Question #1:

What two types of fuel pumps are used in automotive applications?

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Review Question #1:

What two types of fuel pumps are used in automotive applications?

- ❑ Different types
  - ➢ Positive displacement
  - ➢ Non-positive type

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Review Question #2:

What are the two types of injection methods?

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Review Question #2:

What are the two types of injection methods?

"Method of injection"

- ❑"Direct"
- ❑"Indirect"

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LEVEL-I TRAINING SECTIONS 28-35 FUEL INJECTION & CARBURETION

Review Question #3:

What two factors were presented that engineers must consider when designing the fuel rail for an injection system?

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Review Question #3:

What two factors were presented that engineers must consider when designing the fuel rail for an injection system?

- Odd shapes to reduce noise
- Equal distribution of fuel

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Review Question #4:

What type of compound were ALL of the fuels?

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Review Question #4:

What type of compound were ALL of the fuels?

HYDROCARBON

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Review Question #5:

Would a restricted fuel injector cause high HC tailpipe emission readings?

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Review Question #5:

Would a restricted fuel injector cause high HC tailpipe emission readings?

No. HC is unburned fuel.

Oxygen would be high.

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Now that we have a common, basic understanding of fuel storage, fuel supply, fuel distribution, and the fuels...

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Now that we have a common, basic understanding of fuel storage, fuel supply, fuel distribution, and the fuels...
We need to be able to identify systems
We need to test & diagnose systems

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LEVEL-I TRAINING SECTIONS 28-35 FUEL INJECTION & CARBURETION

- TBI = THROTTLE BODY
- PFI = PORT FUEL
- K-JET = MECHANICAL
- GDI = GASOLINE DIRECT INJECTION
- DI = DIESEL INJECTION
- SFI = SEQUENTIAL INJ
- CDI = COMMON RAIL
- CARBURETION

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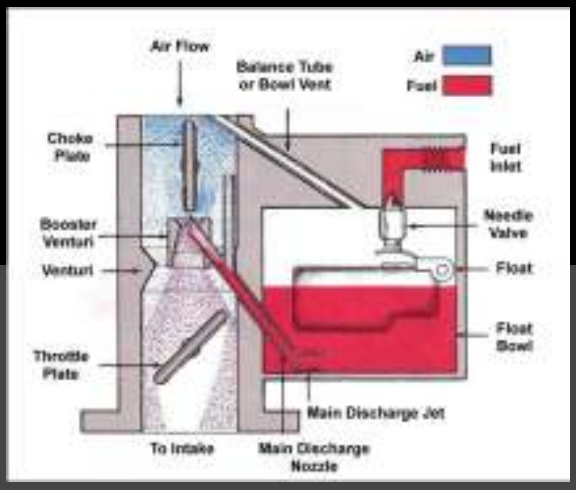
- CARBURETION
- Airflow dispenses fuel
- Venturi
- Circuits
- Mixture-control
- Choke

40

CARBURETION

- "Throat" or Barrel
- Venturi – Narrow to increase speed of air and draw fuel from bowl
- Butterfly Valve or Throttle Valve is rotating disc that blocks air flow.
- Throttle is opened to increase airflow which increases fuel flow.



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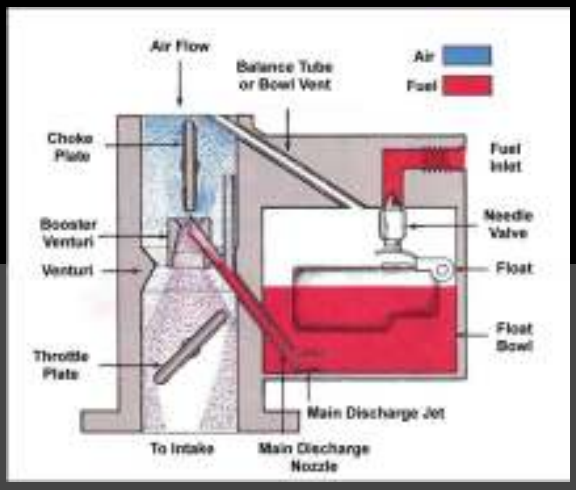
LEVEL-I TRAINING SECTIONS 28-35 FUEL INJECTION & CARBURETION

CARBURETION

- Throttle is opened to increase airflow which increases fuel flow <u>at RPM</u>.
- No fuel through venturi at idle speed.
- SIX (6) circuits are needed to get fuel into the engine during all of the different "modes of operation.
- Circuits: Float, Idle, Main, Power, Accel, and Choke.



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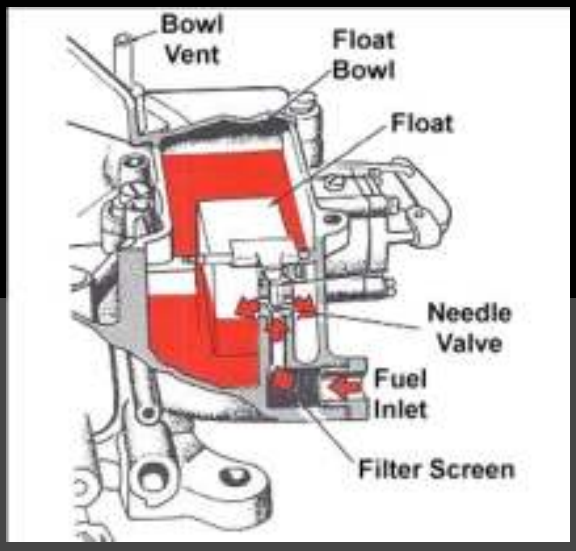
CARBURETION

- **Float Circuit: The float chamber holds a quantity of ready-to-use fuel at atmospheric pressure. Its supply is refilled by a float driven valve; as the level drops, the float drops too and opens an inlet, which allows the fuel pump to deliver more fuel to the float chamber.**



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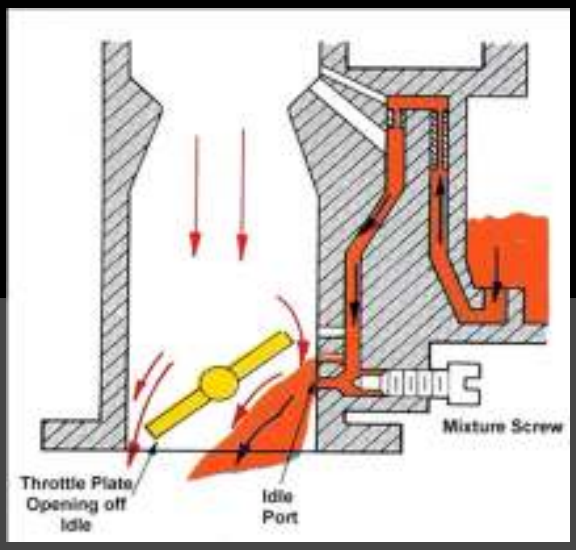
CARBURETION

- **Idle and Off-Idle Circuits: When the throttle valve is closed or nearly closed, the manifold vacuum created behind the throttle is sufficient to pull a small amount of fuel and air through small openings located after the butterfly valve. As the throttle valve opens slightly, the manifold vacuum is reduced, so additional small openings are revealed to compensate for this. This design is the "off-idle" circuit.**



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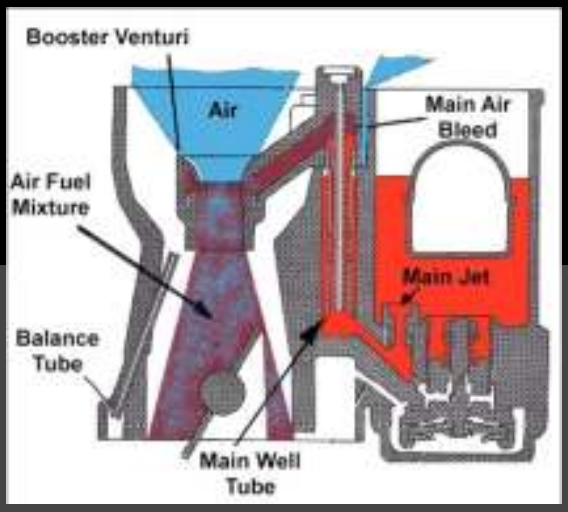
CARBURETION

- **Main Metering Circuit**
- **As airflow through the venturi increases, a main metering jet in the float bowl meters fuel passing into the discharge nozzle.**
- **As the throttle opens, and airflow increases, more and more fuel is drawn from the discharge nozzle.**



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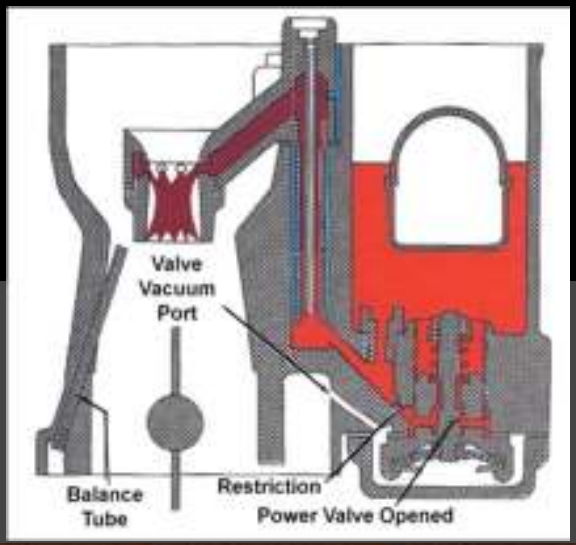
CARBURETION

- **Power Circuit: The size of the main jet is selected to provide the best mixture for economy under cruising conditions. When the throttle is open wide for maximum power, a richer mixture is required. The extra fuel is provided by a power valve, with a vacuum diaphragm and a calibrated spring. At low speeds, manifold vacuum keeps the power valve closed. With the throttle valve fully open for full engine power, the vacuum in the intake manifold falls opening the valve.**



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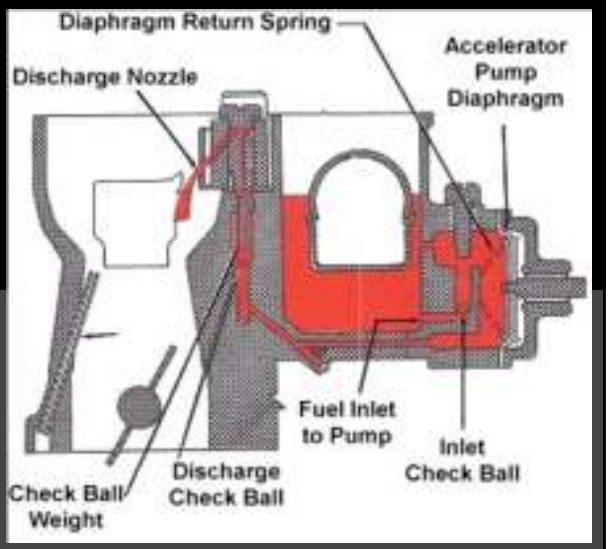
CARBURETION

- **Accelerator Pump Circuit**
- **Extra fuel is also needed for accelerating. Suddenly opening the throttle increases the airflow, but fuel cannot flow from the discharge nozzle quickly enough to match it. An extra squirt of fuel is needed, which is where the accelerator pump circuit comes into play. Thus, whenever the throttle is opened, the accelerator pump discharges a small amount of fuel into the throat of the carburetor.**



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CARBURETION

- **"Choke" Function**
- **The choke restricts the amount of air that can enter a carburetor barrel. In doing so, it causes the idle, off-idle, and main circuits to be placed under a vacuum (from the air trying to enter the engine).**
- **The float circuit (fuel bowl) is still exposed to barometric pressure, so more fuel is pushed out of the fuel bowl and through the jets.**

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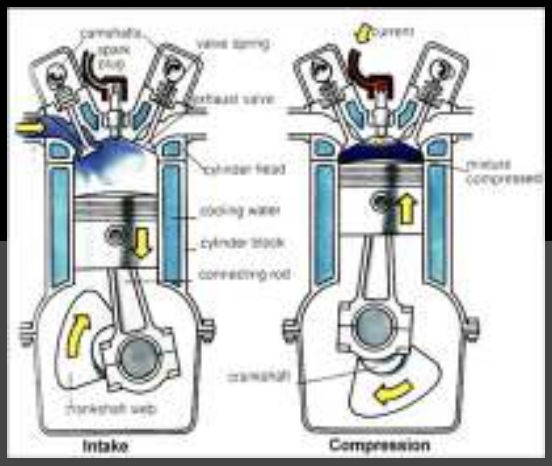
CARBURETION

- **"Vacuum" – Now is a good time to start thinking about what "engine vacuum" really is and how it is created in an internal combustion engine (ICE).**

Vacuum is relative to barometric pressure.

- **BARO is 14.7 PSI (29.92"Hg) at sea level.**
- **We all have air pressure pushing against us now.**
- **Take a deep breath now…**



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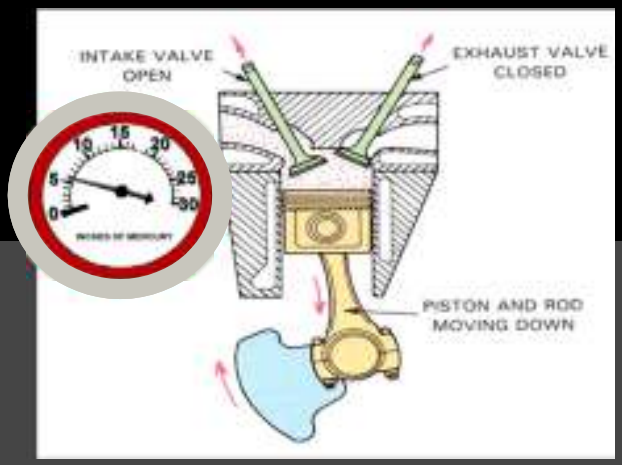
CARBURETION

- **Vacuum is relative to barometric pressure.**
- **BARO is 14.7 PSI (29.92"Hg) at sea level.**
- **What you just did was to expand your chest cavity and open the airway in your throat.**
- **Barometric pressure PUSHED the air into your lungs because you created a "void".**
- **Your lungs/chest muscles are the piston**
- **Your airway is the intake valve**



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CARBURETION

- Vacuum is relative to barometric pressure.
- BARO is 29.92"Hg at sea level (inches of mercury).
- This vacuum gauge is indicating 6"Hg (low)
- 29.92 minus 6 = 23.92"Hg of PRESSURE that is in the intake manifold.
- ALL automotive vacuum gauges are calibrated to read "0" – Zero at 29.92"Hg of pressure.

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CARBURETION

- Vacuum is relative to barometric pressure.
- Vacuum is "created" by the piston being drawn down in the cylinder.
- This creates a "Void" that air tries to enter.
- If anything restricts the air – Vacuum is created!
- Only GDI/DI/IDI fuel systems can get fuel into the cylinder without airflow.
- Carburetion MUST have vacuum to dispense fuel.
- TBI/PFI must have some sort of airflow to get the fuel into the cylinder.

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Computer Controlled Carburetion:

- Demand for cleaner burning engines required more precise fuel control.
- Computer controls Mixture Control Solenoid (M/C), Mixture Control Valve, Electronic Bleed Control Valve (EBCV), etc.
- Typically referred to as Feed Back Carburetors.
- Sensor inputs allows the computer to determine Solenoid on-off time.
- Fuel flow Circuits are virtually the same as conventional Carburetion.

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Computer Controlled Carburetion:

- Computer controls Mixture Control Solenoid (M/C), Mixture Control Valve, Electronic Bleed Control Valve (EBCV), etc.
- "Feedback" to ECM/PCM from Oxygen Sensor.
- O2 Sensor measures OXYGEN (not HC's)!
- Typically, a solenoid (shown in blue) is pulsed by the ECM to "lean" the fuel mixture (default rich).
- Longer "On Time" results is a leaner fuel mixture.

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Review Question #1:

What are the SIX (6) carburetor circuits?

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Review Question #1:

What are the SIX (6) carburetor circuits?

1. FLOAT – HOLDS FUEL IN A BOWL FOR USE BY OTHER CIRCUITS
2. IDLE / OFF-IDLE – DISPENSE FUEL WHEN OTHER CIRCUITS CANNOT
3. MAIN – FOR NORMAL ENGINE SPEEDS AND MODERATE LOAD
4. ACCELERATION – SQUIRT OF FUEL ON QUICK THROTTLE OPENING
5. POWER – FOR WIDE-OPEN THROTTLE OPERATION
6. CHOKE – INCREASE FUEL FLOW DURING ENGINE WARM-UP

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Review Question #2:

How is engine vacuum created?

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Review Question #2:

How is engine vacuum created?

By restricting barometric pressure from entering the cylinder when the piston lowers.

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Review Question #3:

At sea level, how much actual air pressure is in the engine's intake manifold if your vacuum gauge reads 19.92"Hg?

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Review Question #3:

At sea level, how much actual air pressure is in the engine's intake manifold if your vacuum gauge reads 19.92"Hg?

10"Hg of pressure (29.92 – 19.92 = 10.00)

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TBI – Throttle Body Injection

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TBI – Throttle Body Injection

- NOT a Carburetor!
- Only similarity is a "Wet Intake"
- Means that fuel travels and mixes in the intake manifold.
- All other modern fuel injection systems do NOT have fuel in the intake manifold.

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TBI – Throttle Body Injection

- TBI - Throttle Body Injection has pressurized fuel supplied by a pump to the TBI assembly.
- Fuel is released by an electro-mechanical injector into the air charge entering the engine.
- The ECM/PCM triggers the injector(s) to open and determines the duration necessary for the amount of fuel needed.
- Use a "Peak & Hold" control circuit (more later).
- Use Speed-Density method (not MAF).

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TBI – Throttle Body Injection

Main Components:

- **Injectors (1 or 2)**
- **Throttle Valve**
- **Throttle Position Sensor (TPS)**
- **Idle Air Control (IAC)**
- **Fuel Pressure Regulator (Return Type)**
- **Vacuum Connections**
- **Attached Air Cleaner (mostly)**

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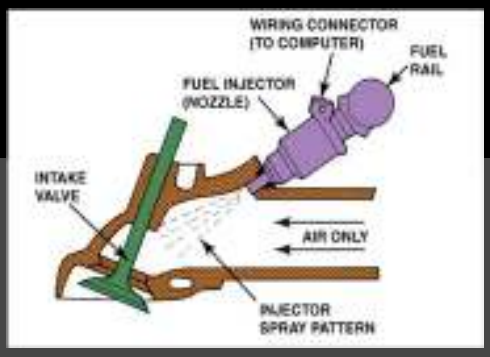
PFI – Port Fuel Injection



66

PFI – Port Fuel Injection

- No fuel in intake manifold.
- Fuel is dispensed into cylinder head PORT.
- Higher supply pressure than TBI.
- "Return" or "Return-less" supply system.
- Usually a "Saturated Switch" control circuit.
- Can use Airflow or Speed-Density methods.
- Can be "SFI" – Sequential Fuel Injection.
- Can be mechanical or electronic types.
- Can be combined with GDI.
- Can have multiple injectors per cylinder.

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PFI – Port Fuel Injection

Main Components:

- An injector located at every cylinder head intake port (can be in manifold and aimed at the intake port).
- "Fuel Rail" to equally distribute fuel to each injector (or a fuel distributor).
- MAP or MAF Sensor to calculate needed amount of fuel based on engine speed, engine load, and temperature.

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Jetronic (CIS) – Mechanical Port Fuel Injection

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Jetronic (CIS) – Mechanical Port Injection

- Uses fuel pressure to open injectors.
- VERY dependent on vacuum and fuel pressure being correct.
- Airflow causes deflector plate to move which then causes more fuel pressure to be dispensed out of fuel distributor.
- Individual line from fuel distributor to each fuel injector.
- K-Jetronic does have a computer to modify mixture based on O2 feedback.

70

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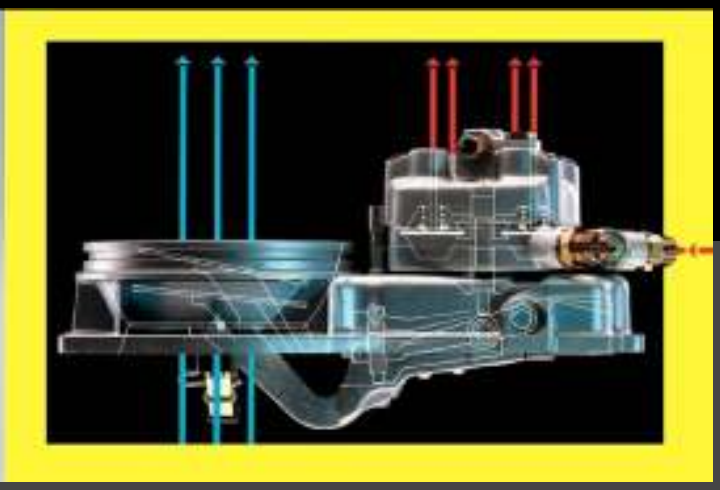

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Jetronic – <u>Mechanical</u> Port Fuel Injection

- **Almost ALL issues with Bosch Jetronic are caused by vacuum leaks or incorrect fuel supply pressure.**
- **Low intake vacuum will not provide enough "suction" on the airflow plate – so then there will not be a correct amount of fuel dispensed.**
- **Low/High fuel supply pressure will throw off all the internal pressures inside the fuel distributor.**
- **The injectors also need to be calibrated equally so they will open the same amount.**

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GDI – Gasoline Direct Injection

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GDI – Gasoline Direct Injection

- **Fuel is injected directly into the combustion chamber / cylinder.**
- **"Piston-Guided" or "Wall-Guided"**
- **The difference is the injector location and the design of the top of the piston (spray-guided shown).**
- **Only gasoline EFI system capable of injecting fuel during stroke <u>other than</u> the intake stroke.**

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GDI – Gasoline Direct Injection

- Fuel is supplied from tank via LPSP.
- HPP increases pressure on demand.
- Amount of fuel is determined by pressure.
- PFI must open injector for a longer time.
- Capable of 6-7 injections per 4-cycles.
- Capable of "Stratified Mode".
- Can run engine a MUCH leaner than 14.7:1
- Some engines also have a PFI system.

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Review Question #1:

Which fuel injection system presented is NOT (EFI) Electronic Fuel Injection?

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Review Question #1:

Which fuel injection system presented is NOT (EFI) Electronic Fuel Injection?

Bosch CIS Jetronic

77

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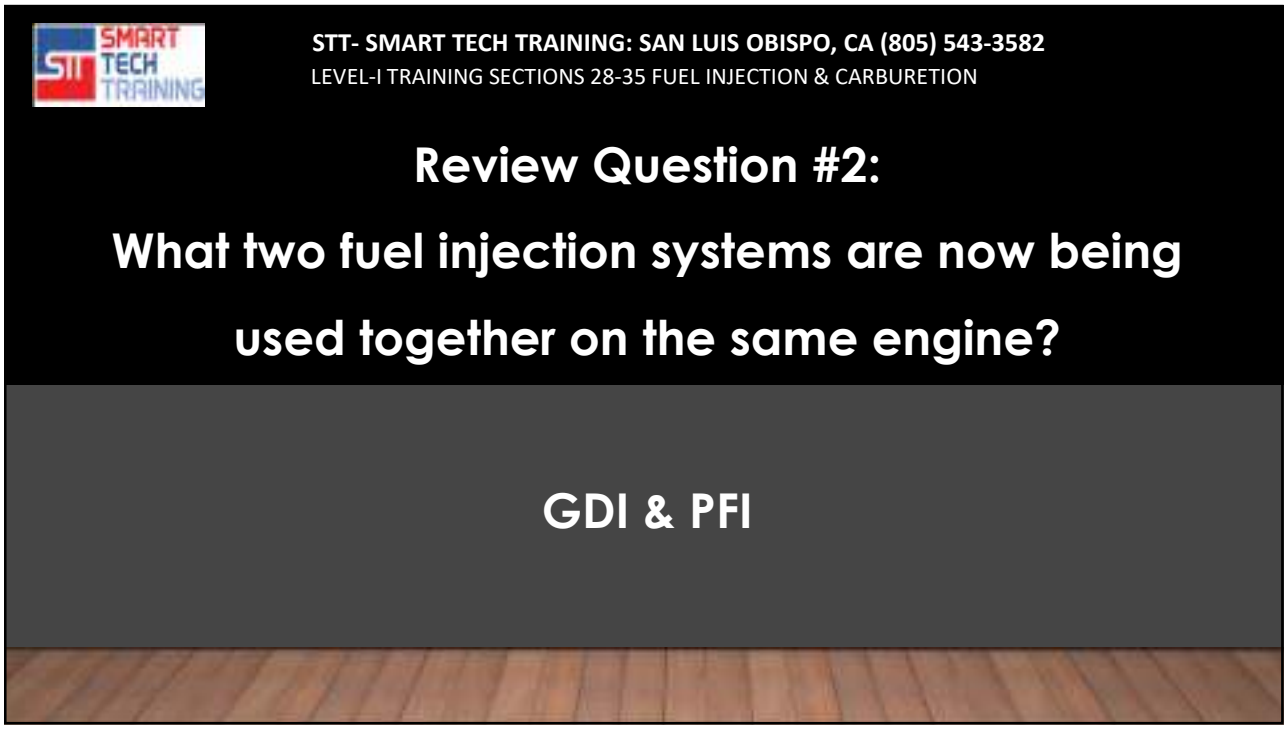
Review Question #2:

What two fuel injection systems are now being used together on the same engine?

78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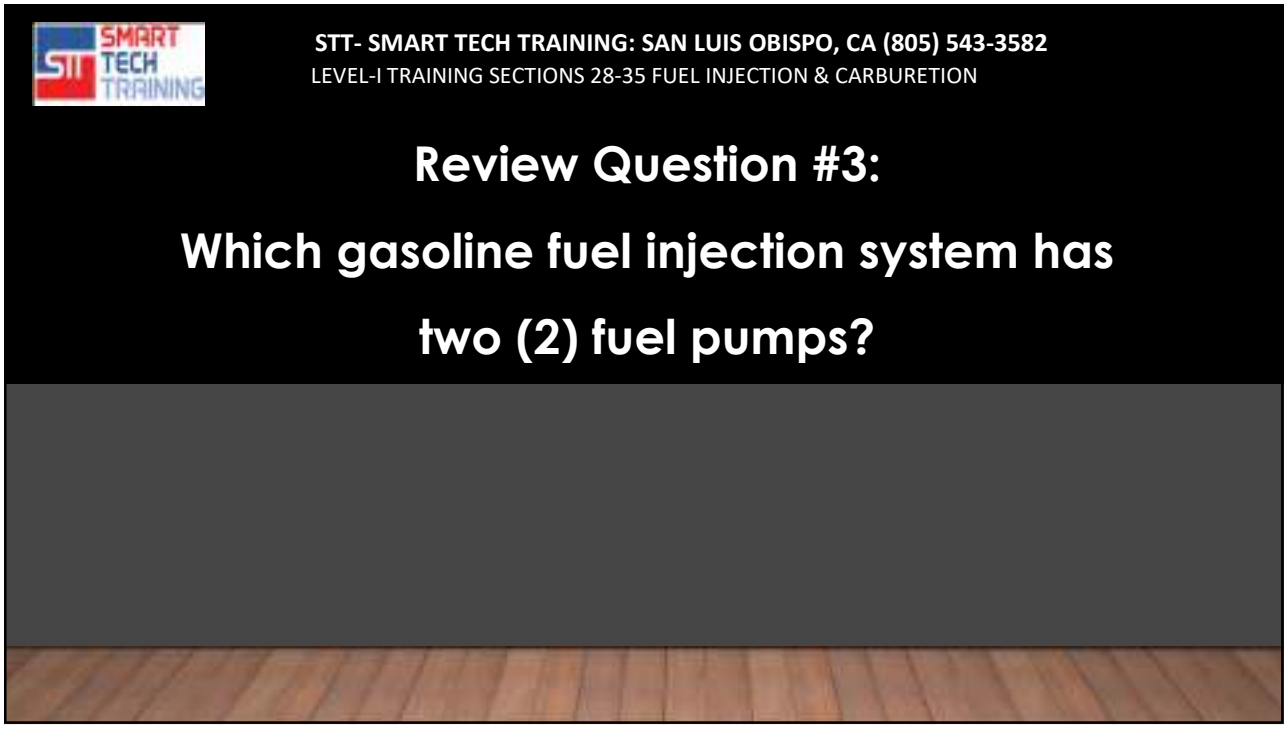
Review Question #2:
What two fuel injection systems are now being used together on the same engine?
GDI & PFI

79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Review Question #3:
Which gasoline fuel injection system has two (2) fuel pumps?

80

Review Question #3:

Which gasoline fuel injection system has two (2) fuel pumps?

GDI – LPSP & HPP

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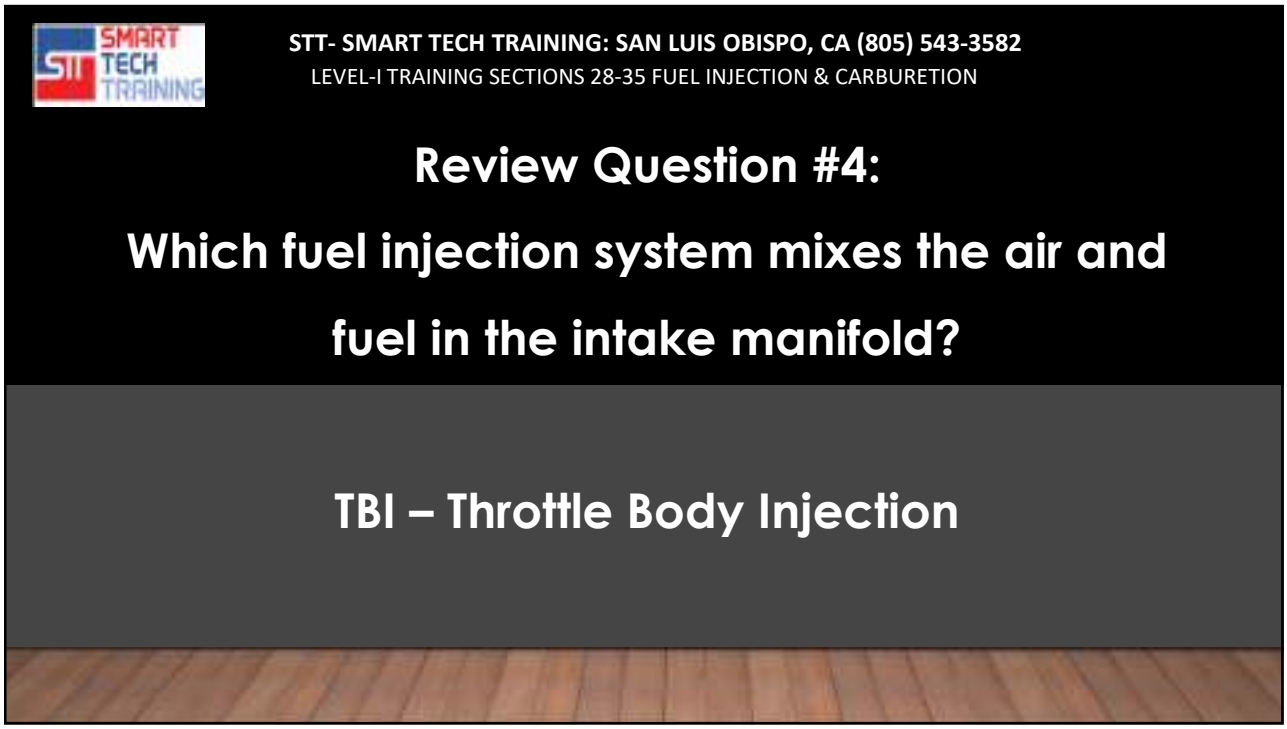
Review Question #4:

Which fuel injection system mixes the air and fuel in the intake manifold?

82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Review Question #4:
Which fuel injection system mixes the air and fuel in the intake manifold?
TBI – Throttle Body Injection

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Operation of fuel injection systems:

ALL fuel injection systems need a sensor or method of knowing the engine temperature.

All systems also need a method of determining how fast the engine is turning and how much load is on the engine.

85

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Temperature:

To know how much fuel to add during warm-up.

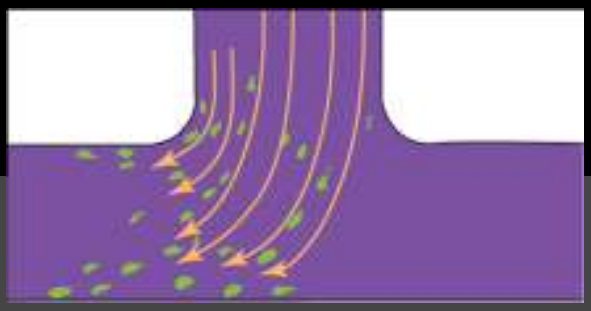
- **To know when the emission systems should be at a warm enough temp to operate.**

86

Temperature:

To know how much fuel to add during warm-up.

Cold fuel likes to form droplets and collect on cool engine parts, so more is needed until the engine is warmed up.



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I-P-O Input – Process – Output

Whether you're working on a mechanical or electronic fuel system – there is something that is sensing an "input", processing the info, and then creating an "output".

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I-P-O Input – Process – Output

"Open Loop"

When the I-P-O process happens based ONLY on the basic programming in the ECM and the primary sensor inputs: ECT – CKP - MAP/MAF

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I-P-O Input – Process – Output

"Closed Loop"

When the I-P-O process ADDS info from other sensors to "fine tune" the process for the best economy or performance AND to minimize emissions output.

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I-P-O Input – Process – Output

Economy, Performance, and Emissions output.

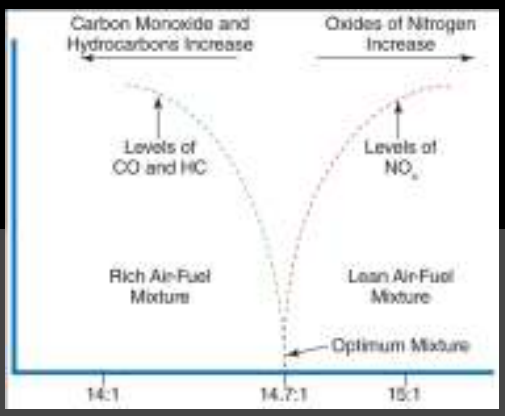
14:7 is the ideal A/F mixture.

Calculated by weight (not volume).

"Rich" is a lower ratio (14.6:1)

"Lean" is a higher ratio (14.8:1)

The exhaust catalyst needs oxygen, so the mixture is made rich/lean.



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I-P-O Input – Process – Output

The ECM uses these same inputs and outputs to perform "self tests" that can result in DTCs

DTC = Diagnostic Trouble Code

Also called "Fault Codes" or just "Codes" by many technicians.

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I-P-O Input – Process – Output

OBD I Codes

- Two- or three-digit code
- Indicate defect in specific component

OBD II Codes

- Five-digit alphanumeric code
- Standardized format

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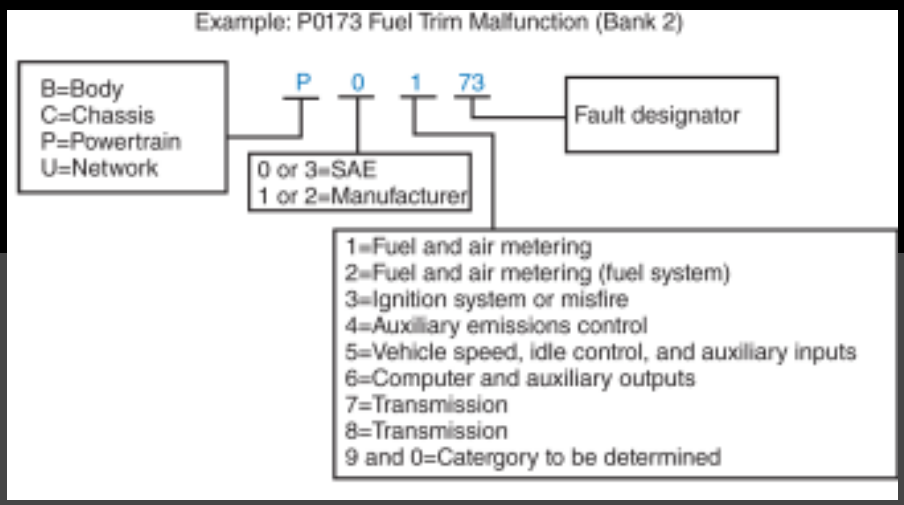
OBD-II DTCs



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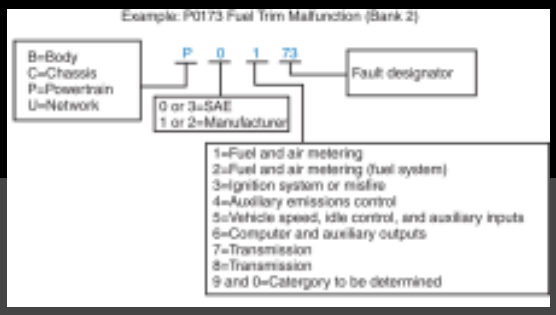
OBD-II DTCs

A fault code is the STARTING POINT of diagnosis – NOT the part that needs to be replaced.

P0173 = Fuel Trim Bank 2



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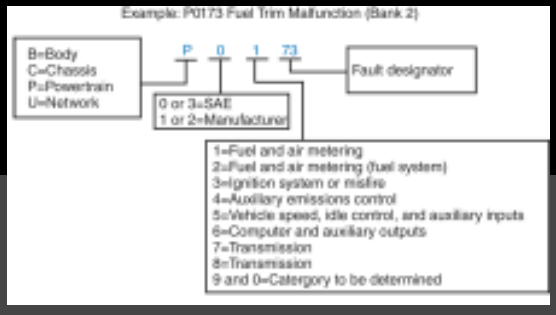
Fuel Trim:

The long-term and short-term "fuel trims" are indicators of how much a f/inj system is having to "adjust itself" away from the basic programming in its memory.

+ or – Percentage



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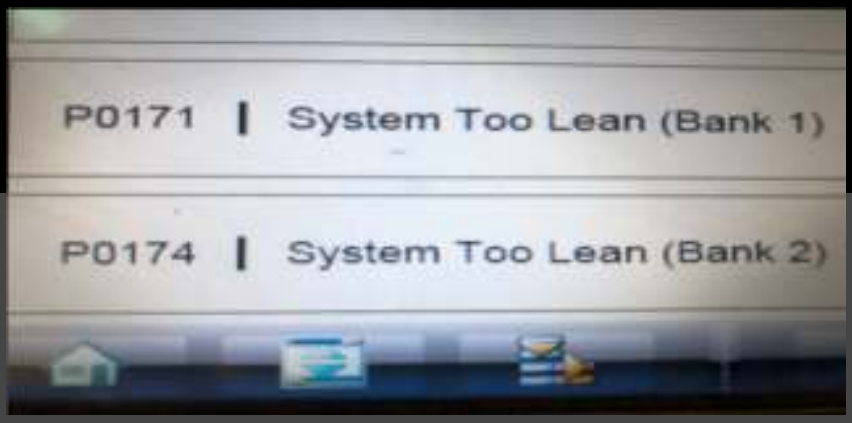
P0171 & P0174 = Fuel Trim Lean Bank 1 & 2



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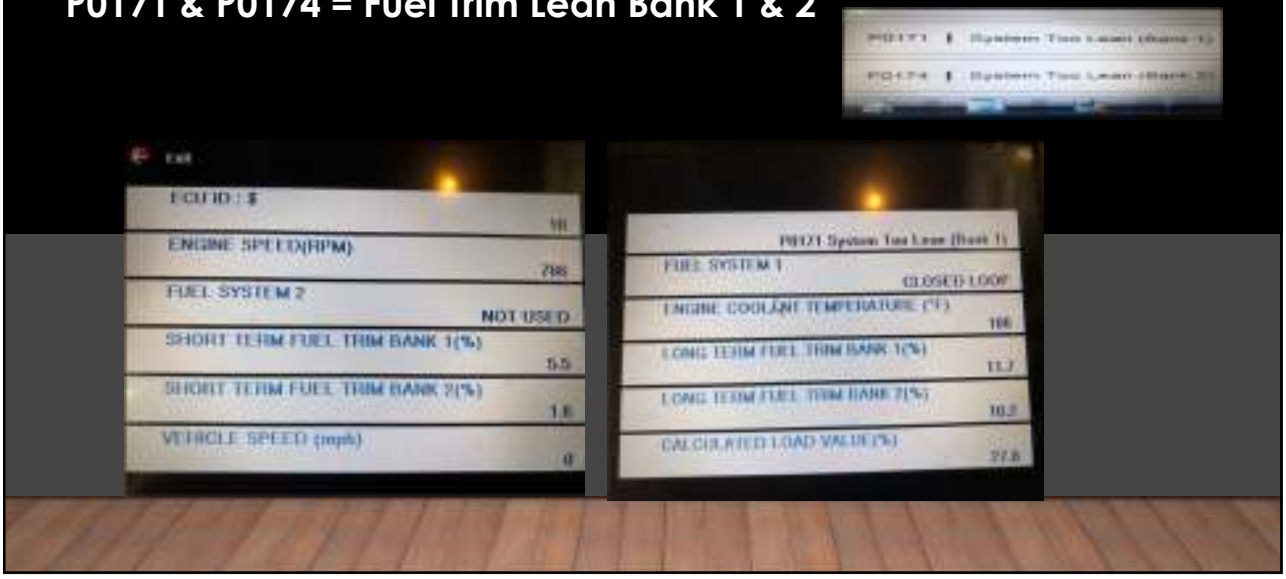
P0171 & P0174 = Fuel Trim Lean Bank 1 & 2



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P0171 & P0174 = Fuel Trim Lean Bank 1 & 2

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P0171 & P0174 = Fuel Trim Lean Bank 1 & 2

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P0171 & P0174 = Fuel Trim Lean Bank 1 & 2




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Fuel Trim Data = Now within acceptable range – Yeah!

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Review Question #1:

What type of sensor does every fuel injection system have?

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Review Question #1:

What type of sensor does every fuel injection system have?

Engine Temperature

Some are Electronic / Some are Mechanical

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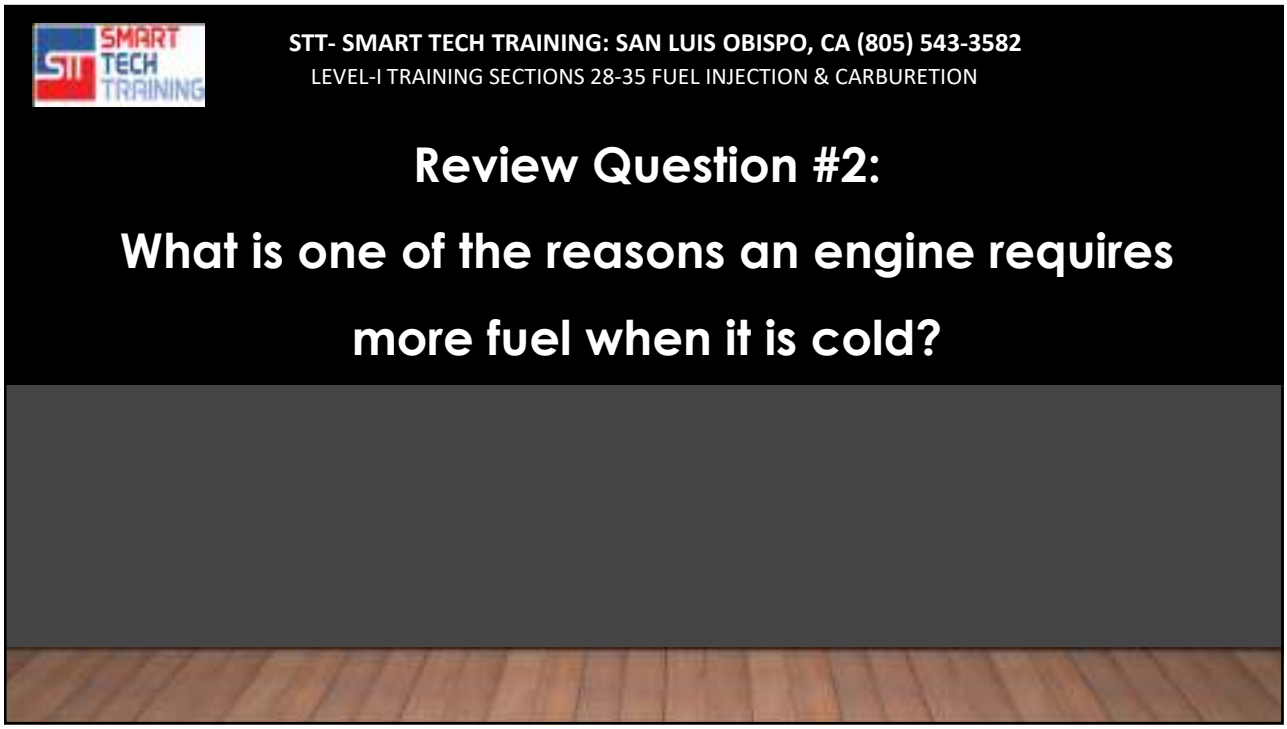
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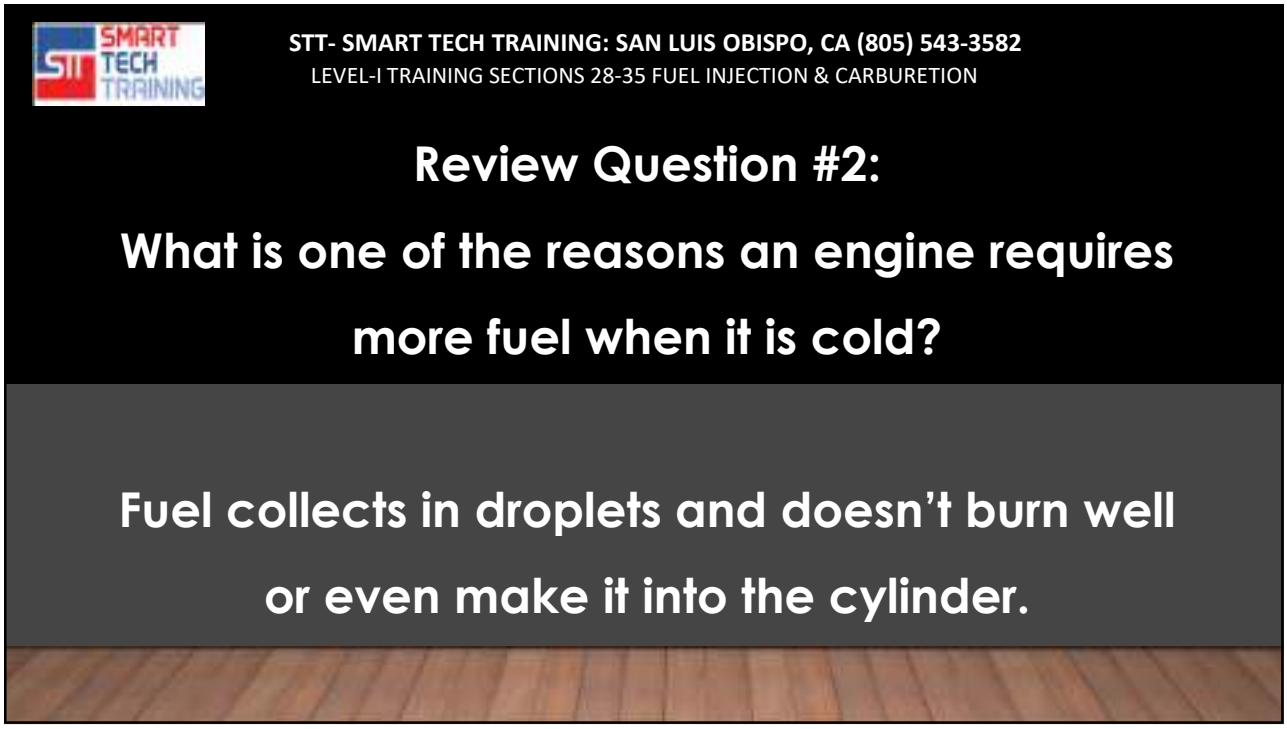
Review Question #2:
What is one of the reasons an engine requires more fuel when it is cold?

107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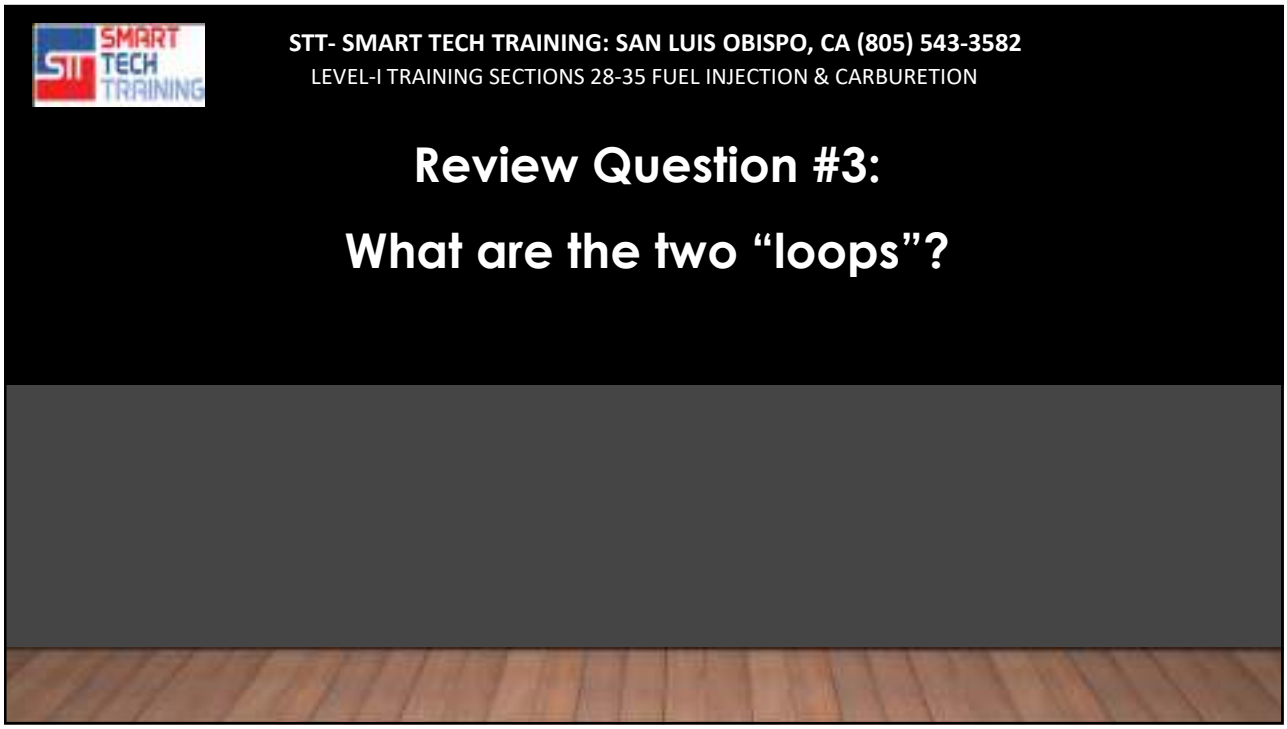
LEVEL-I TRAINING SECTIONS 28-35 FUEL INJECTION & CARBURETION
Review Question #2:
What is one of the reasons an engine requires more fuel when it is cold?
Fuel collects in droplets and doesn't burn well or even make it into the cylinder.

108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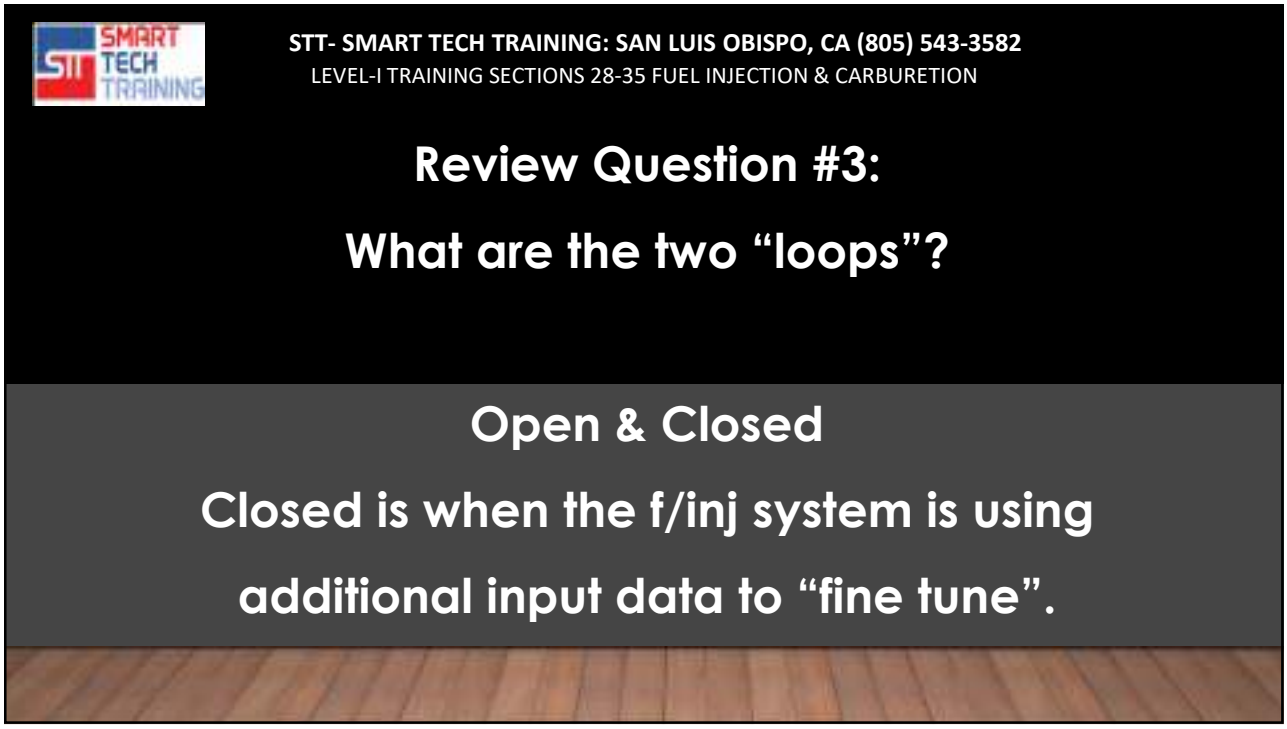
LEVEL-I TRAINING SECTIONS 28-35 FUEL INJECTION & CARBURETION
Review Question #3:
What are the two “loops”?

109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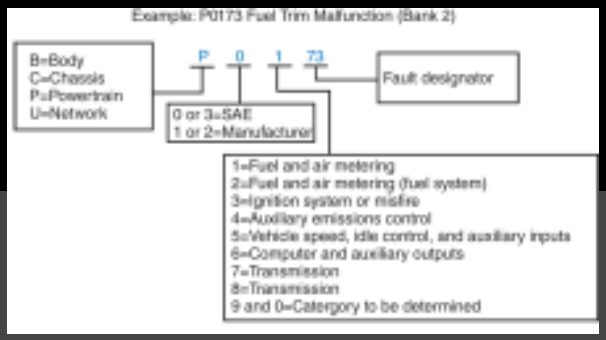
Review Question #3:
What are the two “loops”?
Open & Closed
Closed is when the f/inj system is using additional input data to “fine tune”.

110

Review Question #4:

What 4 things can you learn from an OBD-II DTC before you even look up the service info?



111

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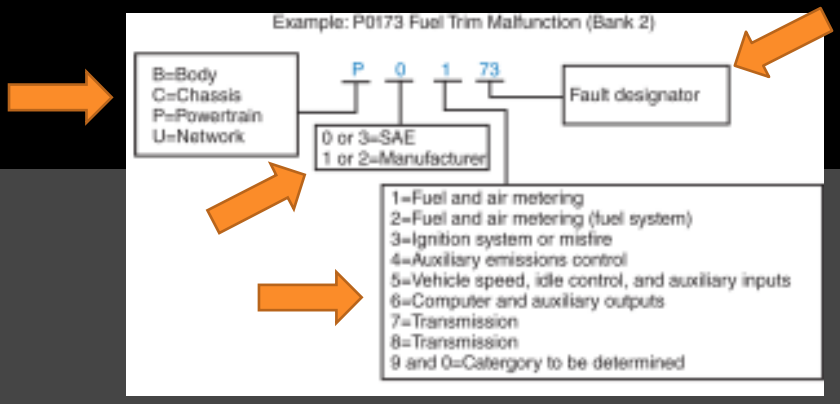
Review Question #4:



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I-P-O Diagnosis

If you know:

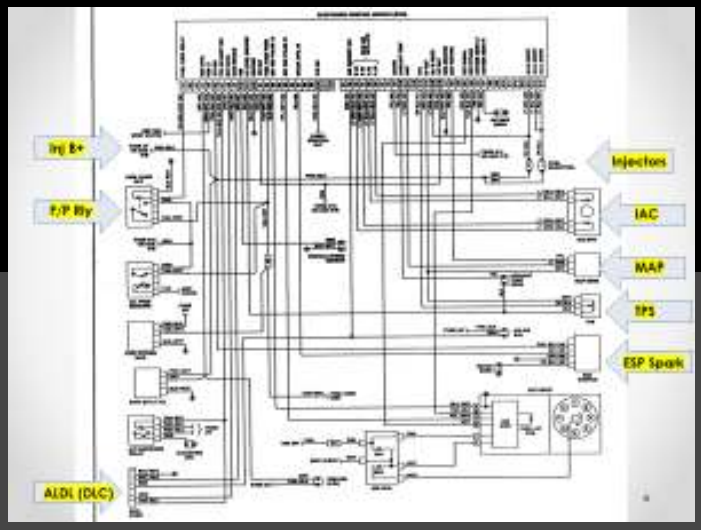
What it is...

Where it is...

How it works...

How it's connected...

YOU CAN TEST IT



114

MAP/MAF Diagnosis

Both send a signal to the PCM to calculate airflow.

MAP = Manifold Absolute Pressure.

MAF = Mass Air Flow

115

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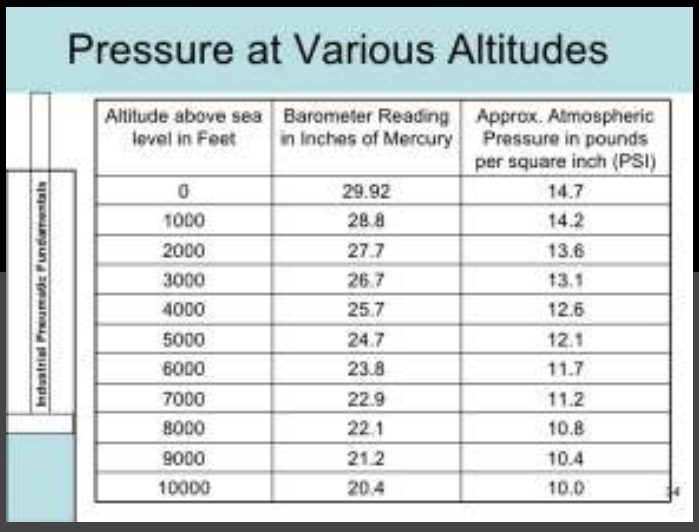
MAP/MAF Diagnosis

PCM needs MAP/MAF data to calculate the amount of fuel needed.

Less fuel is needed if there is less oxygen available (altitude).

32% drop at 10,000'

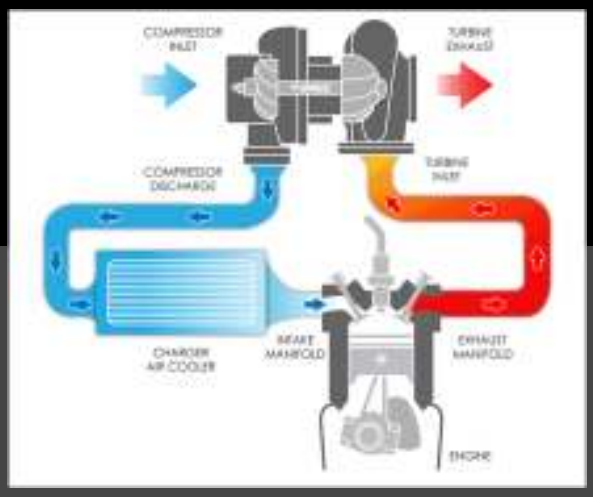


Altitude above sea level in Feet	Barometer Reading in Inches of Mercury	Approx. Atmospheric Pressure in pounds per square inch (PSI)
0	29.92	14.7
1000	28.8	14.2
2000	27.7	13.6
3000	26.7	13.1
4000	25.7	12.6
5000	24.7	12.1
6000	23.8	11.7
7000	22.9	11.2
8000	22.1	10.8
9000	21.2	10.4
10000	20.4	10.0

116

MAP/MAF Diagnosis

This is especially true if the engine has a pressurized induction system that can ADD to barometric pressure.



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MAP/MAF Diagnosis

These sensor typically send a variable voltage or Frequency output.

Frequency is measured in Hertz (Hz) and one pulse per second is 1 Hz. A thousand pulses per second is a KHz.
A DVOM or DSO (lab scope) is needed to test accurately.

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Do NOT jump into sensor testing if you have any reason to believe the engine needs work.

Low compression & vacuum leaks can cause sensors to be out of specification.

Fuel pressure can also cause issues.

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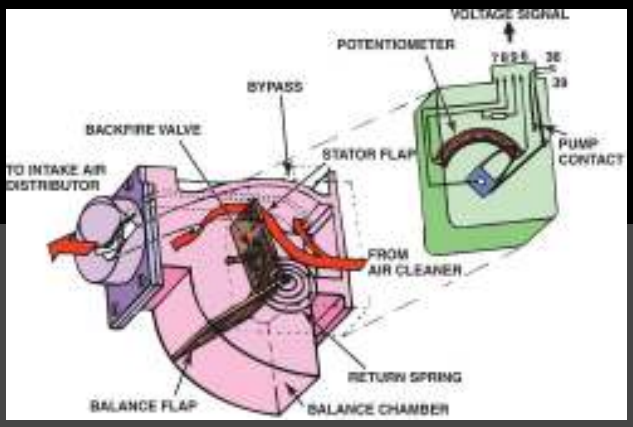
Airflow Sensor

Not a MAF

Analog sensor that measures air by how much the flap is moved by the incoming air. Has contacts to activate fuel pump.



120

MAP/MAF Diagnosis

"Speed-Density" systems all have a MAF sensor (most TBI). "Airflow" system have MAFs. Some f/inj systems have both and will use speed-density as a backup for MAF.

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MAP Diagnosis

The Manifold Absolute Pressure sensor has a vacuum line attached.
When the ignition is first turned on (KOEO), the ECM/PCM takes reading to determine what atmospheric pressure is outside the engine (BARO).

- Once the engine is running (KOER), the MAP sensor is placed under a vacuum from the attached line and the PCM uses the data for speed-density calculations.

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MAP Diagnosis

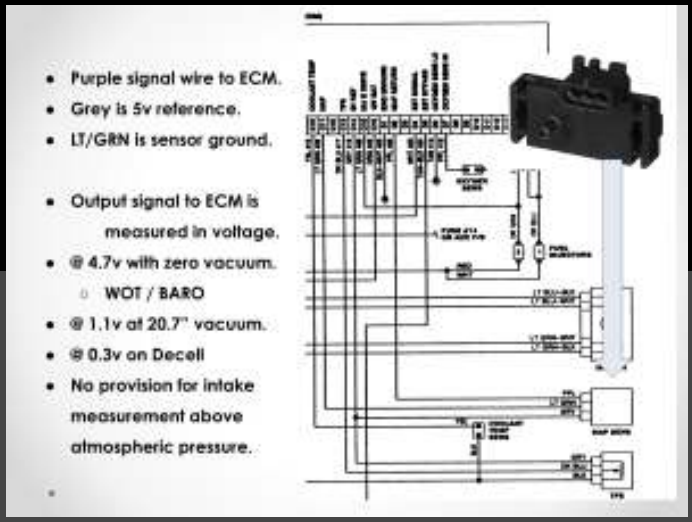
GM TBI Example shown:

Look up Service Info.

Read wiring diagram.

Locate MAP Sensor.

Locate connection point.



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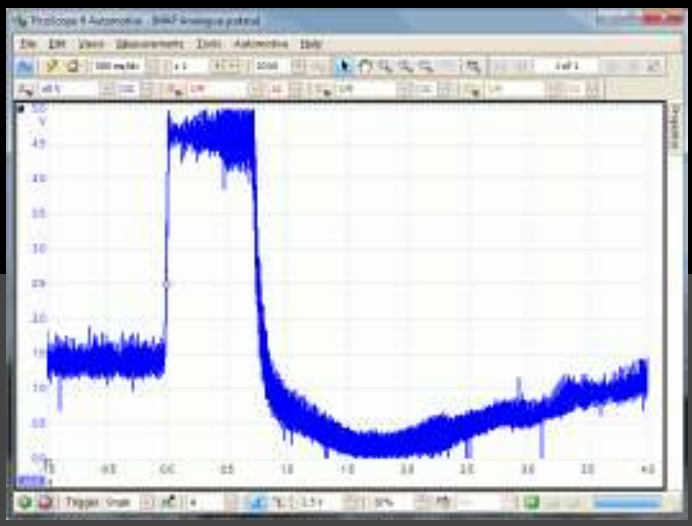
MAP Diagnosis

Analog example shown:

Notice how the vacuum dropped (voltage increased) when the throttle was snapped open.



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MAF Diagnosis

Use SI and wiring diagram to locate testing point and expected output.

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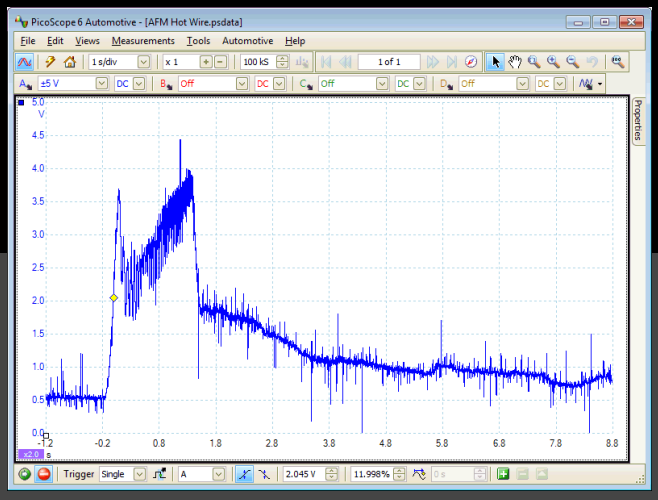
MAF Diagnosis

Measure the KOEO and idle speed output.

Snap throttle test.

Manufacturers specific tests.



126

Oxygen Sensors

The main sensor used for the PCM to make mixture adjustments during closed-loop operation.

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Oxygen Sensor = O_2

Monitors amount of oxygen in exhaust.

Lean air-fuel mixture contains excess oxygen after combustion (leftovers).

Rich air-fuel mixture contains little oxygen after combustion (O_2 poor).

Can produce its own voltage signal.

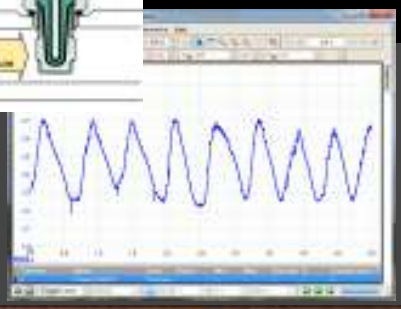
128

Oxygen Sensor = O_2

Is NOT an HC sensor... It senses oxygen.

Operates in a "0- 1.0" volt analog range.

450mv is the median or "middle" point.



Less voltage when high oxygen (lean).

More voltage when low oxygen (rich).

Note the "reverse" voltage reaction.

129

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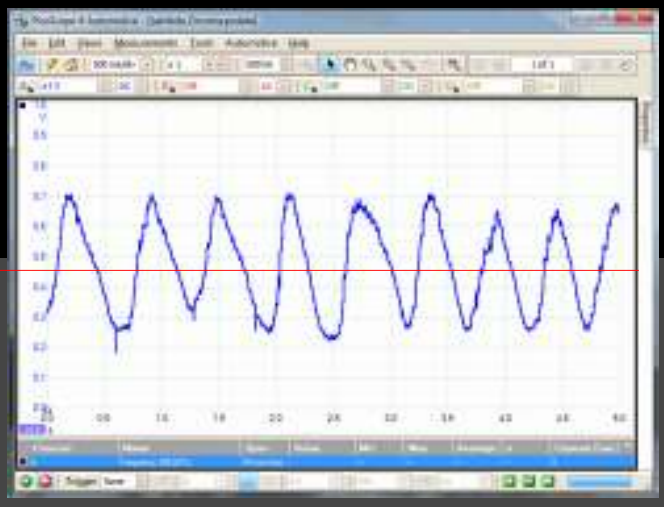
Oxygen Sensor = O_2

Operates in a "0- 1.0" volt analog range.



450mv is the median point.

Rich/Lean "Boarder Point"

Generic Spec:

Start at 450mv and cycles above 800mv, then to below 200mv and back to 450mv is a full cycle. 1 cycle per second is good.

130

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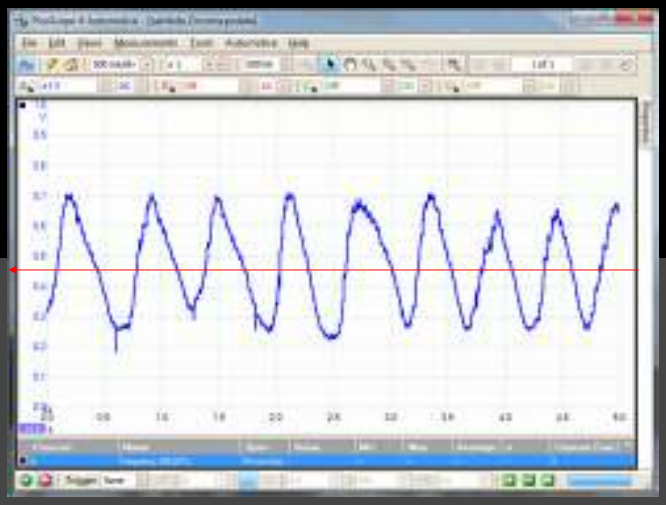
Oxygen Sensor Testing

What do you notice about this O2 Sensor pattern?



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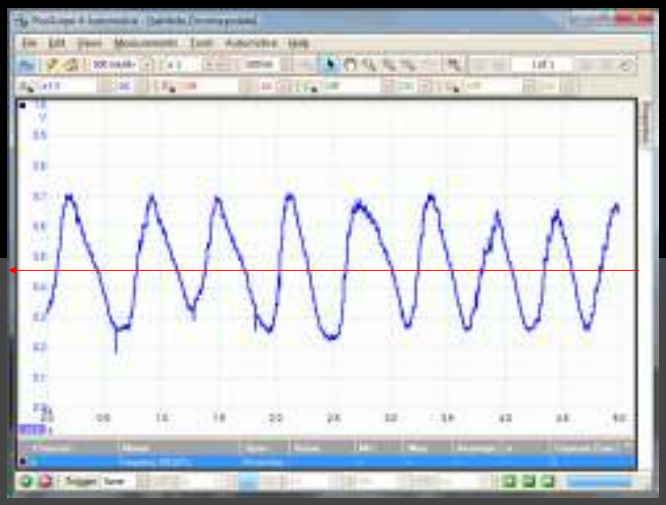
Oxygen Sensor Testing

What do you notice about this O2 Sensor pattern?

Not rising above 800mv or dropping below 200mv.



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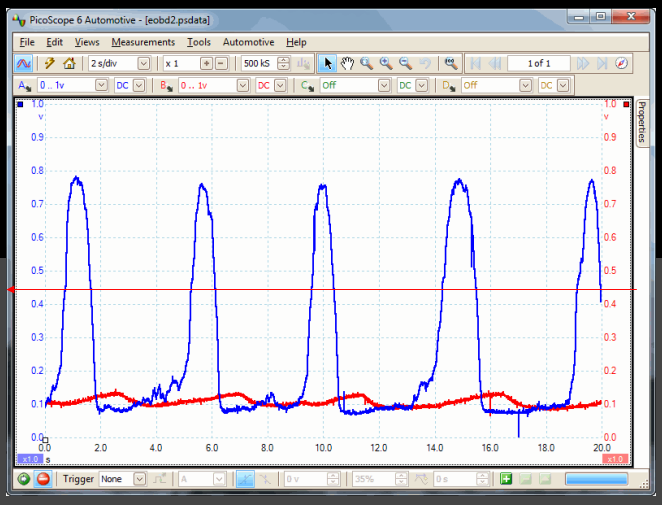
Oxygen Sensor Testing

Blue: Sensor-1 (pre-cat)

Red: Sensor-2 (post-cat)

Notice S1 is "Biased Lean" and roughly 4-second cycle time = Problem.



133

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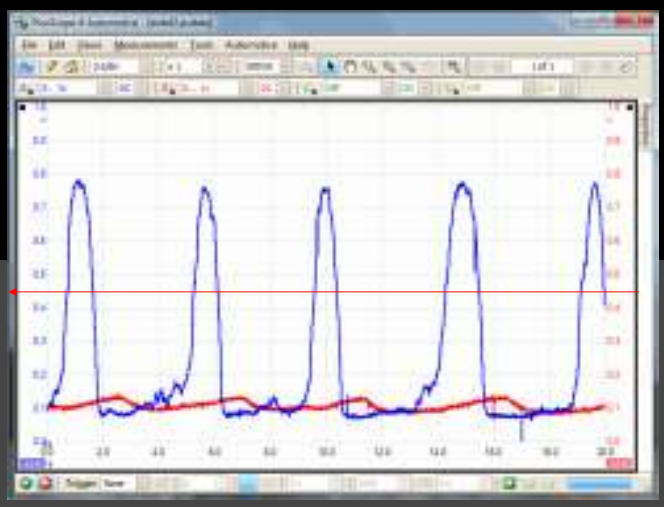
Oxygen Sensor Testing

Notice S1 is "Biased Lean" and roughly 4-second cycle time = Problem.

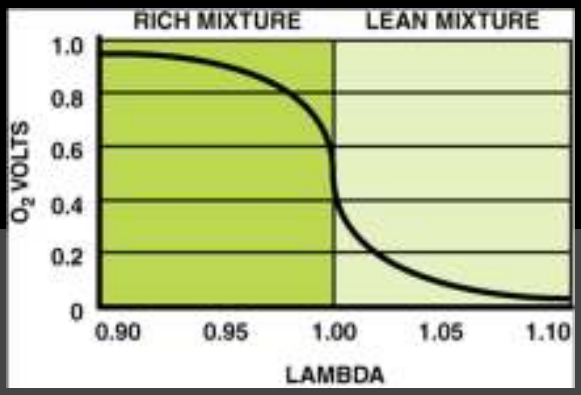
Maybe there is an exhaust valve leaking and pumping oxygen into the exhaust...?



134

Oxygen Sensor Testing

Traditional oxygen sensors can really only tell the PCM if the mixture is rich or lean, but not HOW rich or lean.



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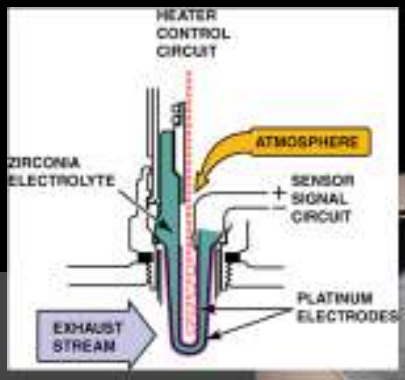
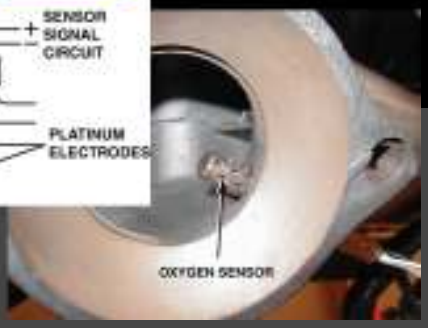
Oxygen Sensor Testing

The O2 content of the exhaust is compared to the air outside of the sensor.





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Oxygen Sensor Testing

The Wide-Band type sensor was designed to give modern f/inj systems more specific info about the A/F mixture.

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Wide-Band O2 Sensor

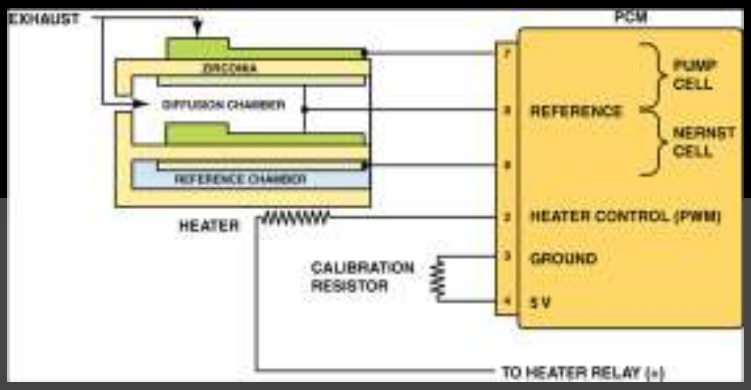
AKA: Air-Fuel Sensor

2 Chambers

Diffusion & Reference

2 Cells

Nernst & Pump

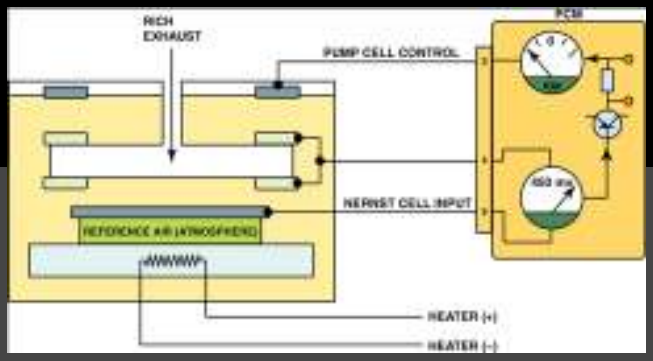


138

Wide-Band O2 Sensor:

Exhaust in Diffusion Chamber.

The Nernst cell acts just like a regular O2 sensor and compares the Diffusion Chamber to the Reference Chamber.



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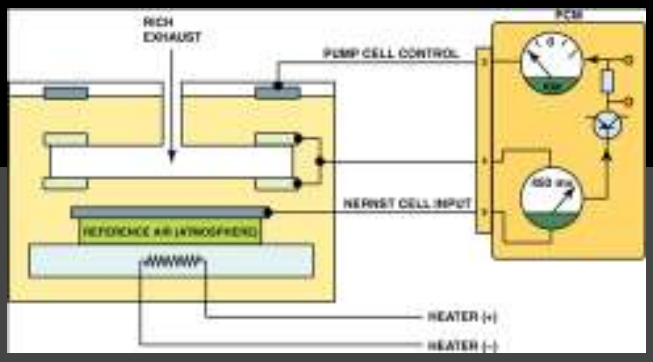
Wide-Band O2 Sensor

Exhaust is Diffusion Chamber.

The Nernst cell acts just like a regular O2 sensor and compares the Diffusion Chamber to the Reference Chamber.

The PCM reads Nernst and sends +/- current to the Pump Cell to alter the content of the Diffusion Chamber.



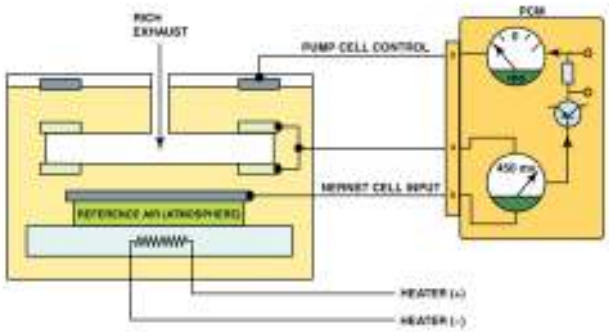
140

Wide-Band O2 Sensor

When Nernst is above 450mv, the PCM sends negative (-) current into the Pump Cell.

This is done until the Nernst Cell swings back to lean below 450mv.

When the exhaust is rich, the PCM applies a negative current into the pump cell.



141

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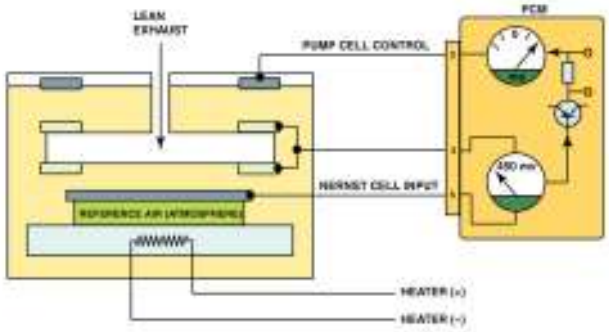
Wide-Band O2 Sensor

When Nernst is below 450mv, the PCM sends positive (+) current into the Pump Cell.

This is done until the Nernst Cell swings back to rich above 450mv.

When the exhaust is lean, the PCM applies a positive current into the pump cell.



142

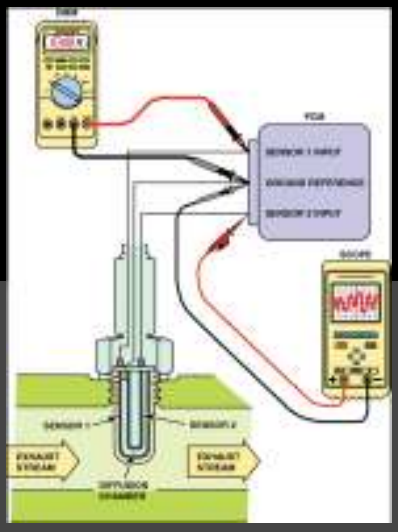
Wide-Band O2 Sensor

When Nernst is above 450mv, the PCM sends negative (-) current into the Pump Cell.

When Nernst is below 450mv, the PCM sends positive (+) current into the Pump Cell.

This is done until the Nernst Cell swings back to rich above 450mv.

The amount of -/+ current required to keep the Nernst Cell cycling at 450mv is an indicator of the Fuel Mixture – not just rich or lean.



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Review Question #1:

What are the two main methods used to calculate the amount of air entering an engine?

144

Review Question #1:

What are the two main methods used to calculate the amount of air entering an engine?

Airflow & Speed-Density

145

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Review Question #2:

What two types of signals do MAP/MAF Sensors generate to the PCM?

146

Review Question #2:

What two types of signals do MAP/MAF Sensors generate to the PCM?

Variable Voltage Signal (Analog)

Hertz Signal (Digital)

147

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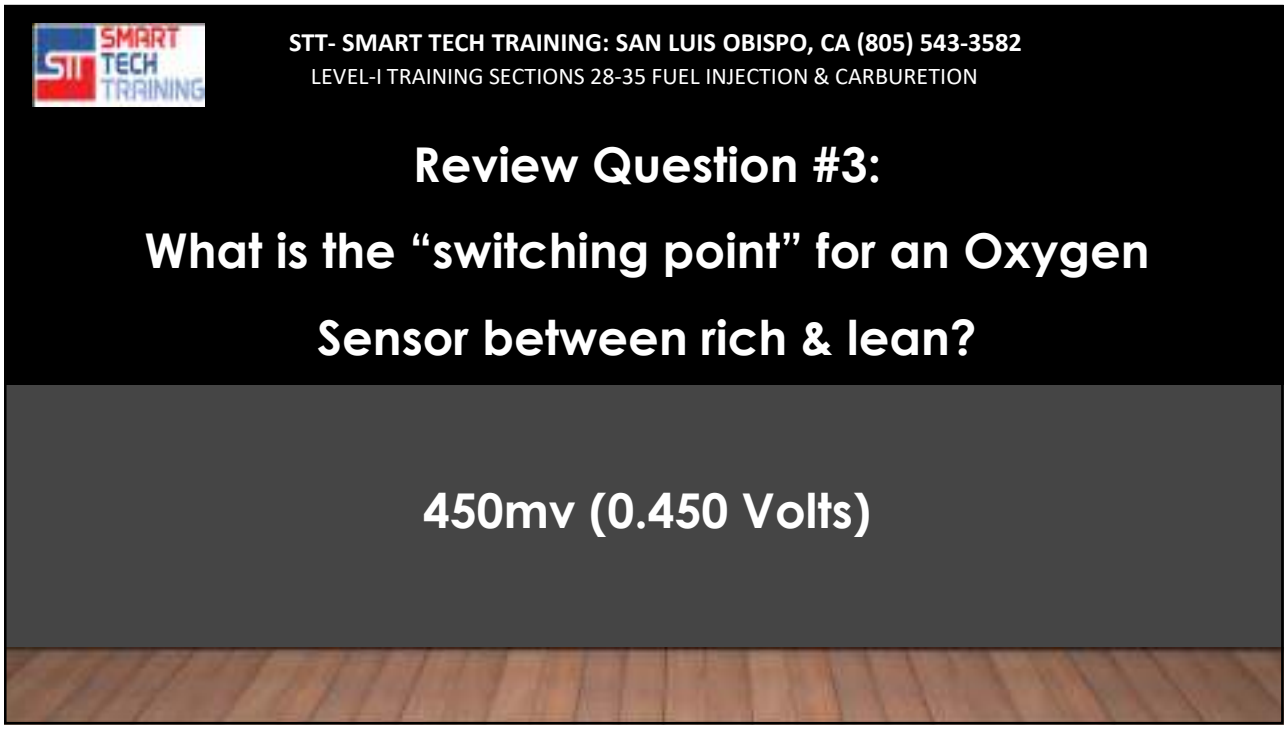
Review Question #3:

What is the "switching point" for an Oxygen Sensor between rich & lean?

148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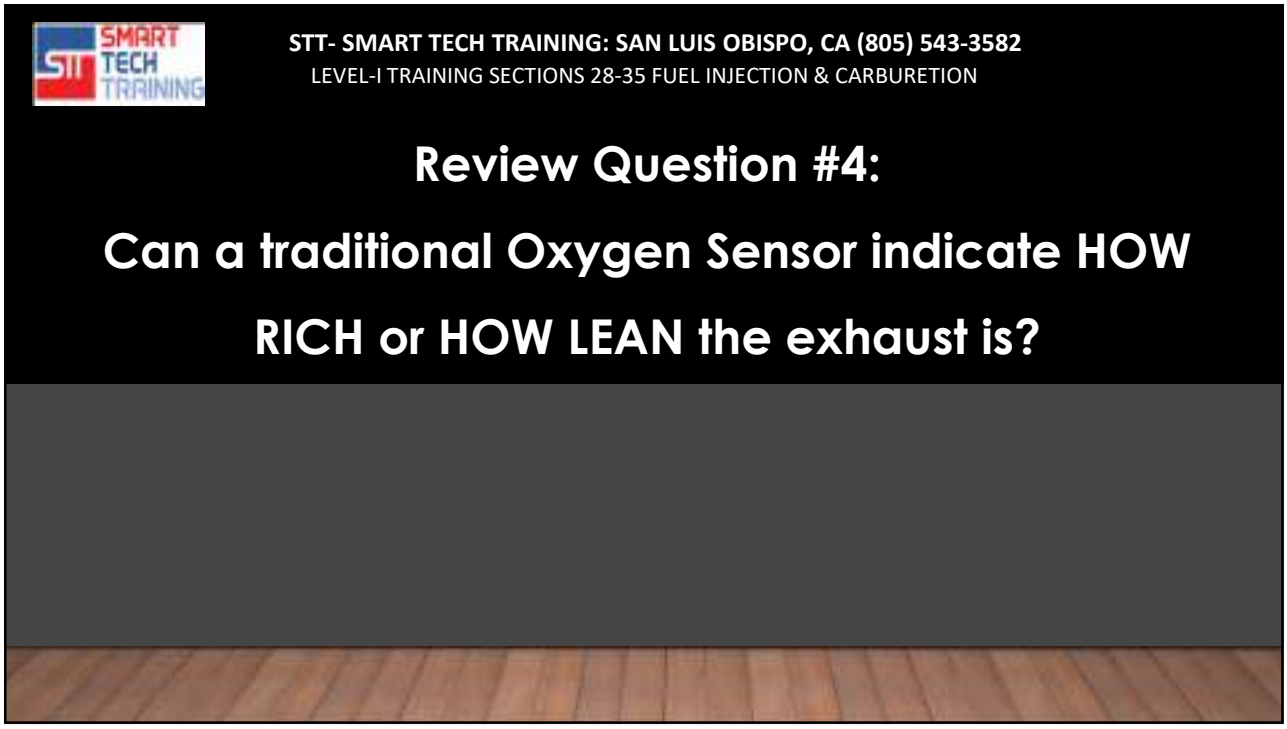
LEVEL-I TRAINING SECTIONS 28-35 FUEL INJECTION & CARBURETION
Review Question #3:
What is the "switching point" for an Oxygen Sensor between rich & lean?
450mv (0.450 Volts)

149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LEVEL-I TRAINING SECTIONS 28-35 FUEL INJECTION & CARBURETION
Review Question #4:
Can a traditional Oxygen Sensor indicate HOW RICH or HOW LEAN the exhaust is?

150

Review Question #4:

Can a traditional Oxygen Sensor indicate HOW RICH or HOW LEAN the exhaust is?

NO. A traditional O2 Sensor only can tell the PCM that the A/F mixture is +/- 14.7:1

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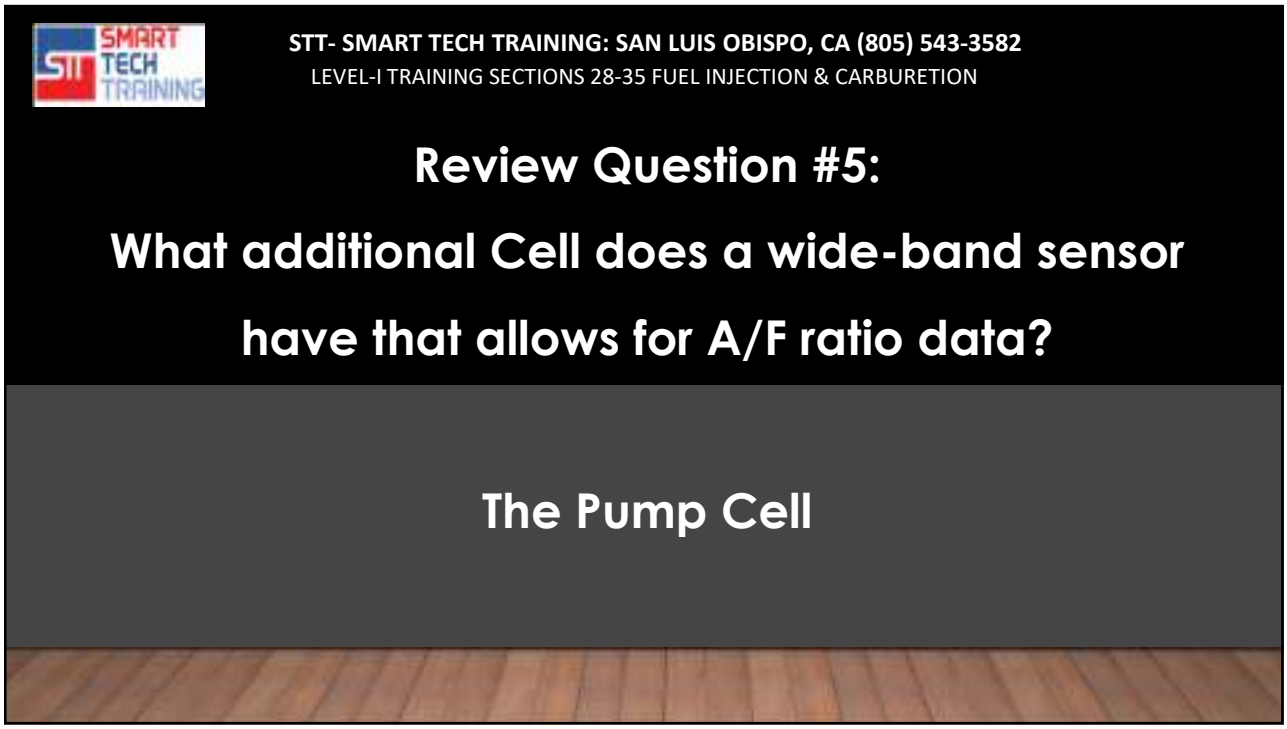
Review Question #5:

What additional Cell does a wide-band sensor have that allows for A/F ratio data?

152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Review Question #5:
What additional Cell does a wide-band sensor have that allows for A/F ratio data?
The Pump Cell

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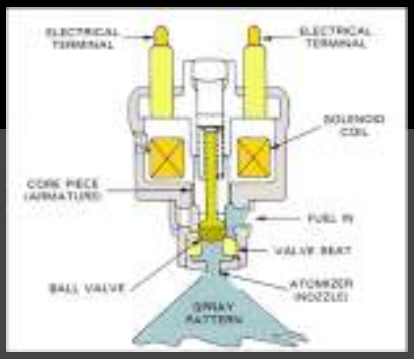
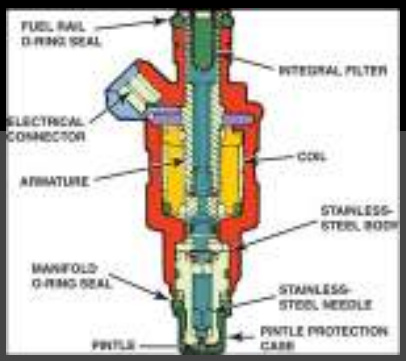
TBI

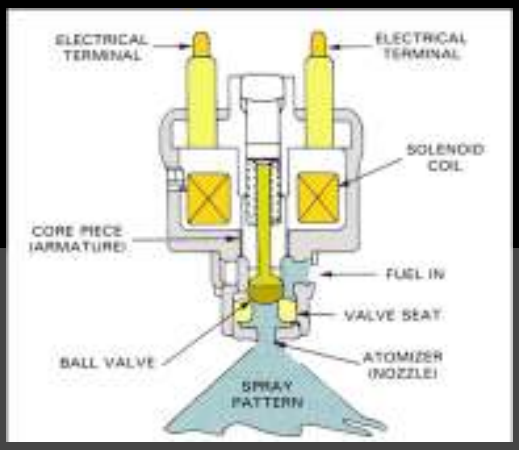


PFI



156

The injector in a **TBI** system is much larger than that of a port injector. These injectors are much less prone to plugging due to the "Ball Valve" design and large opening at the atomizer nozzle. With the air cleaner off they are easily viewed for inspection of the spray pattern.



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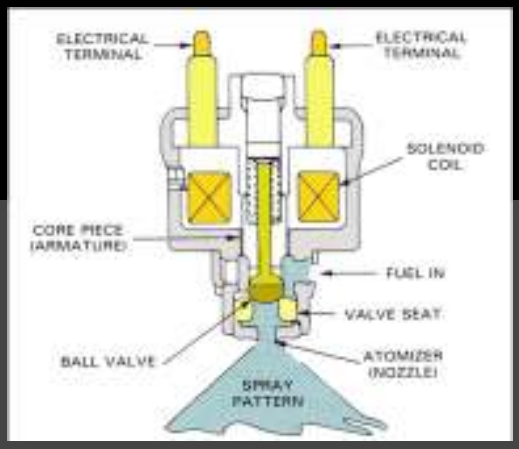
TBI Fuel Injector:

Much lower supply pressure (<30 PSI).
Speed-Density airflow calculation.
Battery/Alternator voltage is applied to the injector.
Ground side is controlled by PCM.
PCM provides high initial current (@4 amps) to open the injector.
PCM then reduces current to about 1 amp to hold injector open.
Lower current holds injector open and reduces heat build up.
Injector pulse width is commanded by PCM.
Resistance is typically 2 to 4 ohms (less than PFI).



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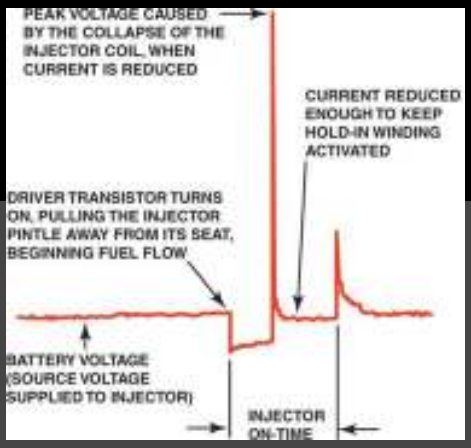
TBI Fuel Injector:

"Peak & Hold" means that the ECM/PCM ground the injector to get it open (requires more current).
To reduce heating, the current is reduced to a point that keeps the injector open.
After enough fuel has been dispensed, the ECM/PCM opens the ground circuit and the injector closes.
This causes two inductive voltage spikes.



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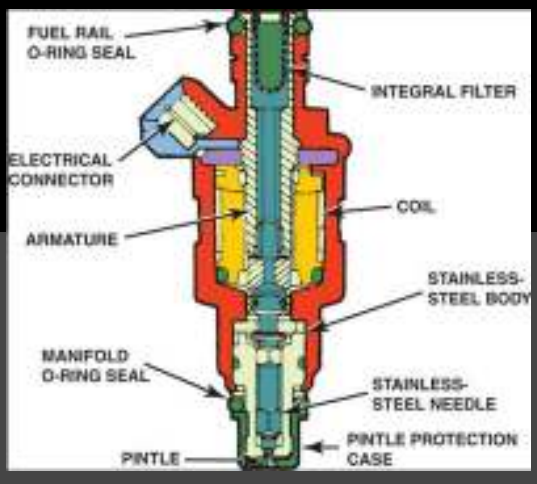
PFI – Electronic Port Fuel Injector

12 volts is applied to injector continually.
Ground for the injector is provided by the PCM.
The PCM completes the circuit ground to injector.
Coil reaches saturation in about 3ms.
Injector resistance is typically 12 to 16 ohms.
Inductive voltage spike occurs when the injector shuts off.



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PFI – Electronic Port Fuel Injector

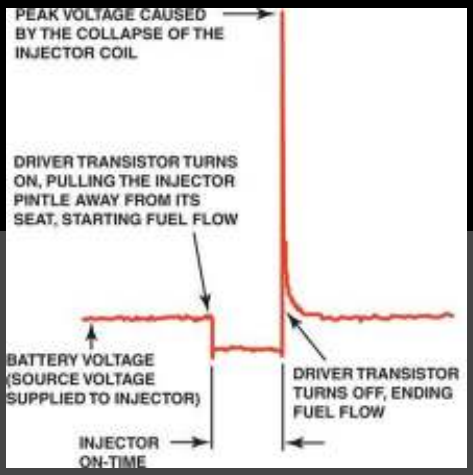
"Saturated-Switch" control circuit has only one inductive spike.

Shorter pulse-width "on" time than TBI.

Not all PFI systems are SFI.

Some are gang-fired or double-fired.

Fuel dispensed sits on back of intake valve until the next intake stroke of cylinder.



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Fuel Injectors:

It is important to note that an odd-looking fuel injector spray pattern does not mean it is faulty.

ALL of the fuel injectors in this image are GOOD!

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Math Time (sorry…)

An SFI engine turning at 3,000 RPM is injecting fuel how often?

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An SFI engine turning at 3,000 RPM is injecting fuel how often?

3,000 / 2 = 1,500 Squirts

1,500 RPM / 60 Seconds =

25 Squirts a Second

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An SFI engine turning at 3,000 RPM is injecting fuel how often?

3,000 / 2 = 1,500 Squirts = 1,500 Squirts / 60 Seconds = 25 Times a Second

What about at 6,000 RPM?

6,000 / 2 = 3,000 Squirts

3,000 / 60 Seconds = 50 Squirts a Second

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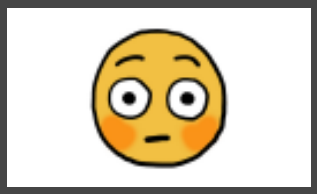
3,000 RPM / 2 = 1,500 Squirts = 1,500 RPM / 60 Seconds = 25 Times a Second

6,000 RPM / 2 = 3,000 Squirts = 3,000 / 60 Seconds = 50 Times a Second

There are 1,000ms in a Second of Time.

An "Intake Stroke" is HALF of a Crank Rotation...



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3,000 RPM / 2 = 1,500 Squirts = 1,500 RPM / 60 Seconds = 25 Times a Second

6,000 RPM / 2 = 3,000 Squirts = 3,000 / 60 Seconds = 50 Times a Second

There are 1,000ms in a Second of Time.

An "Intake Stroke" is HALF of a Crank Rotation.

6,000 RPM / 4 = 1,500 Intake Strokes

1,500 / 60 Seconds = 25 per Second

XXXXXXXXXXXXX

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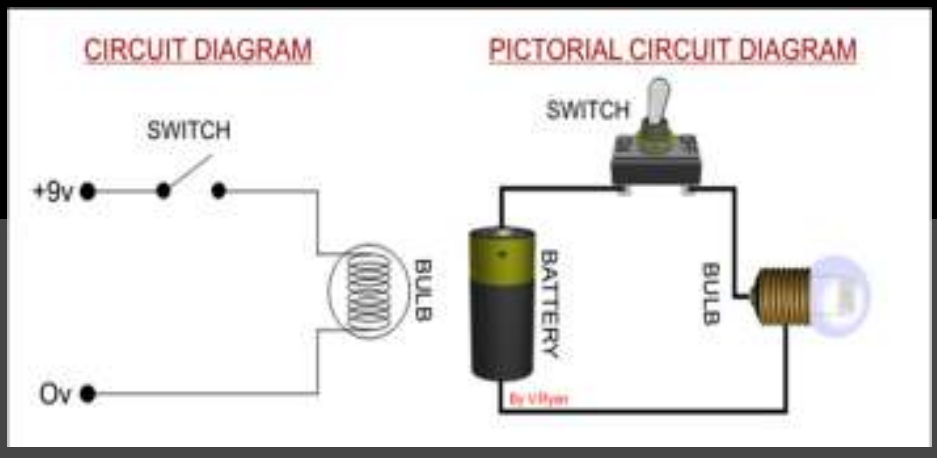

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