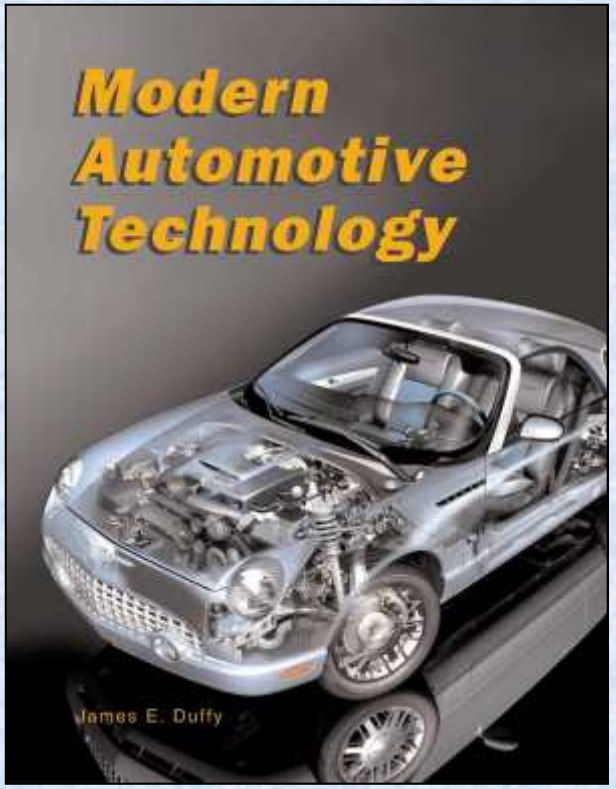
PowerPoint for

Modern Automotive Technology



by

Russell Krick

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Chapter 11

Emission Control Systems

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Contents (13 Topics)

- Air pollution
- Exhaust emissions
- Engine modifications
- Emission control systems
- Positive crankcase ventilation (PCV)
- Evaporative emissions control systems
- Exhaust gas recirculation (EGR)

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Contents

- Air injection system
- Pulse air system
- Thermostatic air cleaner system
- Catalytic converter
- Computerized emission control systems
- OBD II emission system monitoring

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Air Pollution

- Caused by an excess amount of harmful chemicals in the atmosphere
- Emission control systems are used on cars and trucks to reduce harmful chemicals in the atmosphere

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Air Pollution

There are many sources, both natural and man-made

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Natural Sources

- Volcanoes
- Forest fires
- Dust
- Decay of vegetation

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Man-Made Sources

- Factories
- Home furnaces
- Fireplaces
- Internal combustion engines

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Smog

- Visible cloud of airborne pollutants
- Derived from the words “smoke” and “fog”
- Harmful to humans, animals, and vegetation
- Formed when pollutants combine with oxygen and nitrogen in the presence of sunlight

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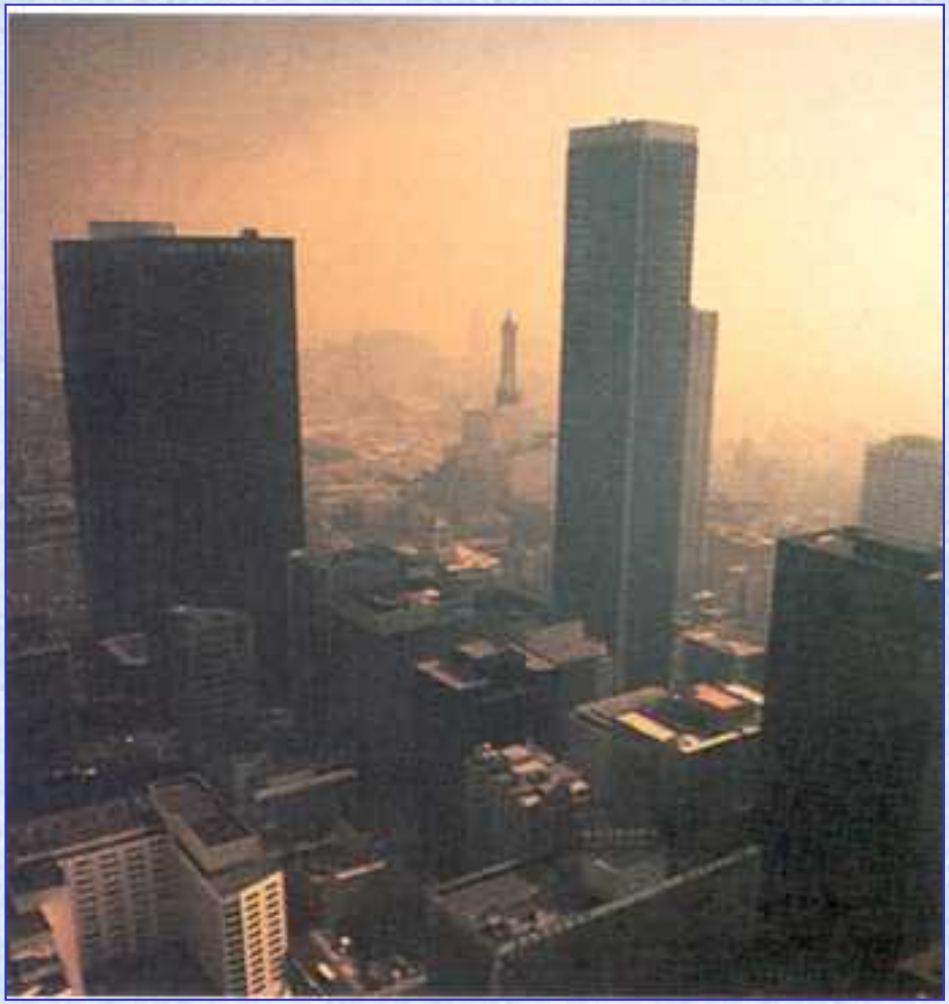
Smog

Common in large cities and industrial areas



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Exhaust Emissions

- Pollutants produced by internal combustion engines:
  - hydrocarbons (HC)
  - carbon monoxide (CO)
  - oxides of nitrogen (NO_x)
  - particulates

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Hydrocarbons (HC)

- Unburned fuel
- All petroleum products
- Produced by incomplete combustion or fuel evaporation

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Carbon Monoxide (CO)

- Extremely toxic
- Colorless and odorless
- Prevents blood cells from carrying oxygen to body tissues
- Caused by rich air-fuel mixtures

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Oxides of Nitrogen (NO_x)

- Air consists of 79% nitrogen and 21% oxygen
- Above approximately 2500 ºF (1370 ºC), nitrogen and oxygen combine
- Caused by high compression ratio, lean mixture, and high operating temperature

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Particulates

- Solid particles of carbon soot and fuel additives
- Serious problem with diesel engines
- Caused by rich air-fuel mixture or mechanical problems
- About 30% of particles settle out of the air quickly, 70% float for extended periods

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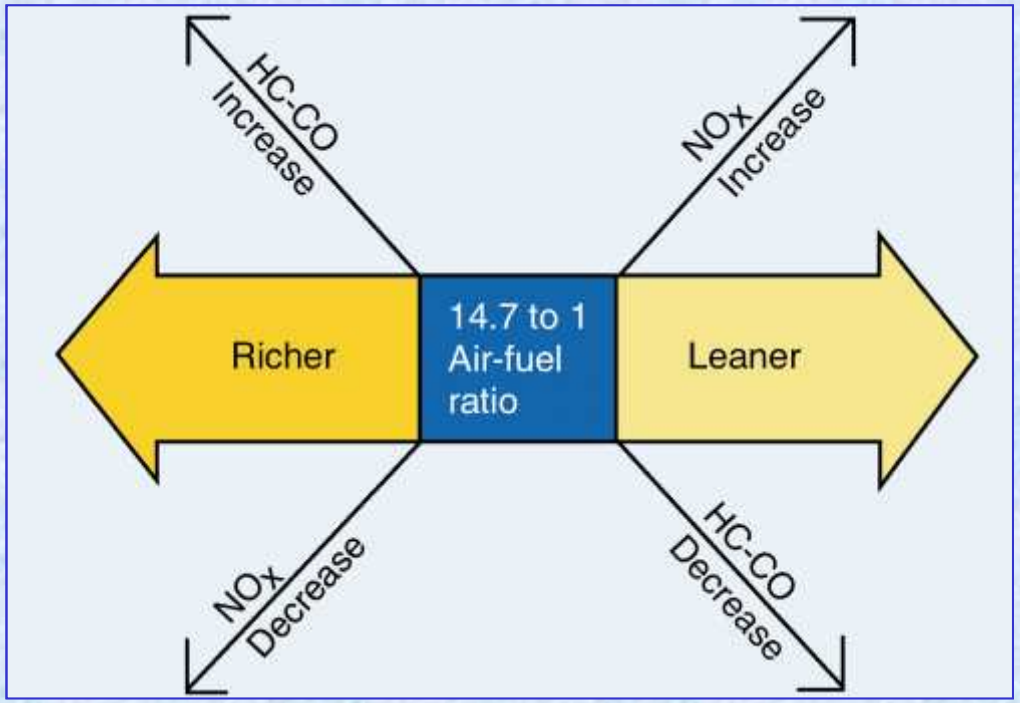
Air-Fuel Ratio and Emissions



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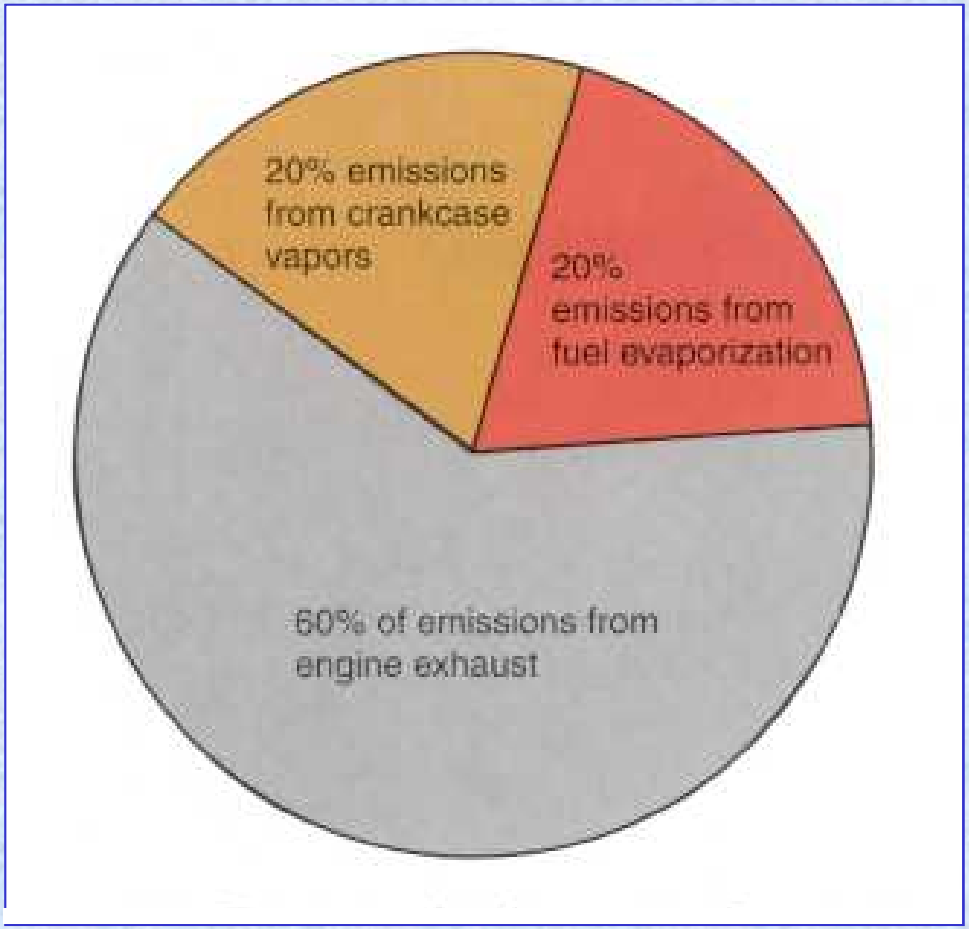
Vehicle Emission Sources



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Engine Modifications

- Engine designs that can minimize emissions:
  - lower compression
  - small combustion chamber surface
  - reduced quench areas
  - decreased valve overlap
  - hardened valves and seats

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Emission Control Systems

- Positive crankcase ventilation (PCV)
- Evaporative emissions control
- Exhaust gas recirculation (EGR)
- Air injection
- Thermostatic air cleaner
- Catalytic converter
- Computer control system

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Positive Crankcase Ventilation (PCV)

- Uses engine vacuum to draw blowby gases from the crankcase into the intake manifold for burning
- Blowby is caused by leakage past the piston rings
- Reduces HC, CO, and particulates

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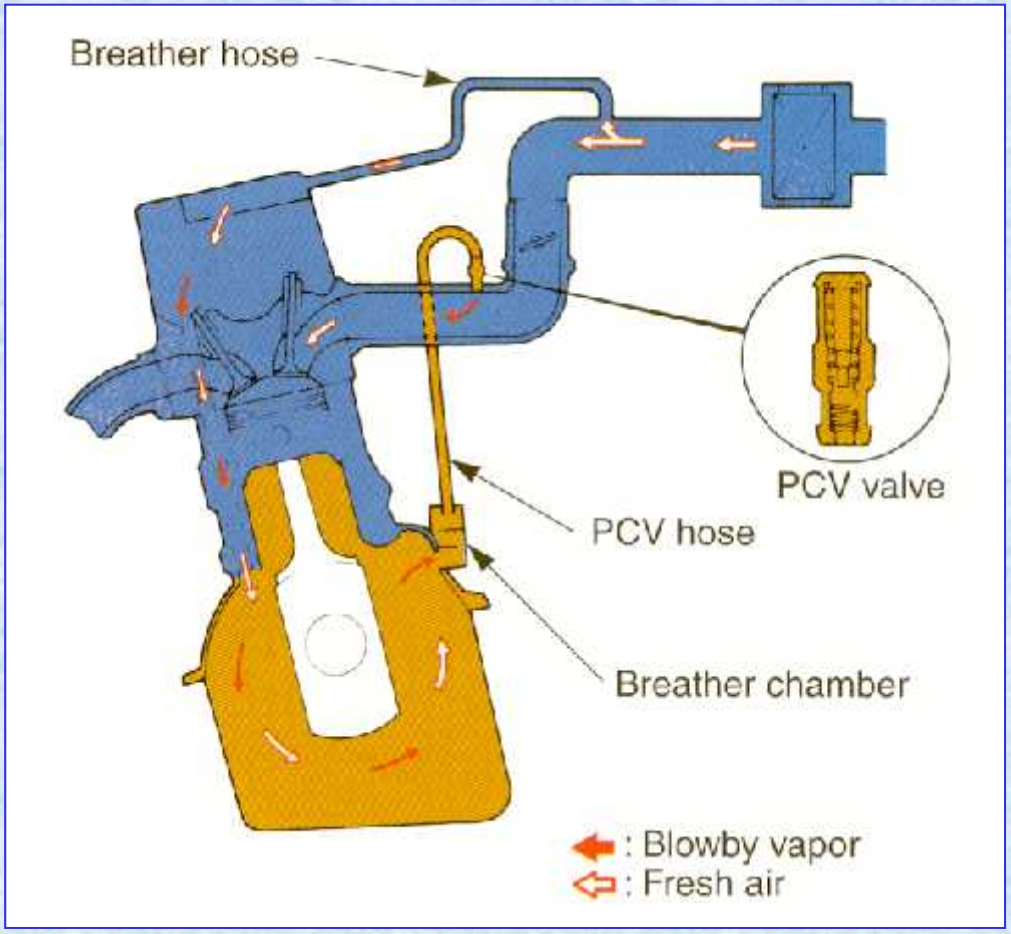
PCV System



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PCV Valve

- Controls flow through the system
- Located in the valve cover, intake manifold, or the side of the engine block
- Varies flow for idle, cruise, acceleration, wide open throttle, and engine-off conditions

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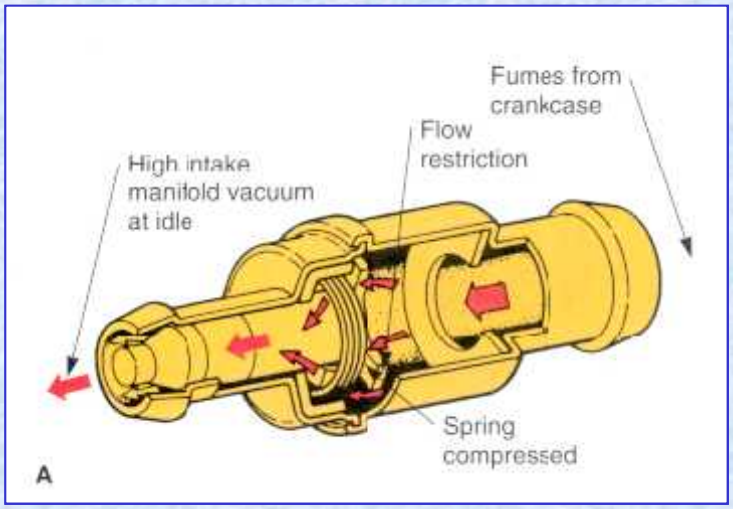
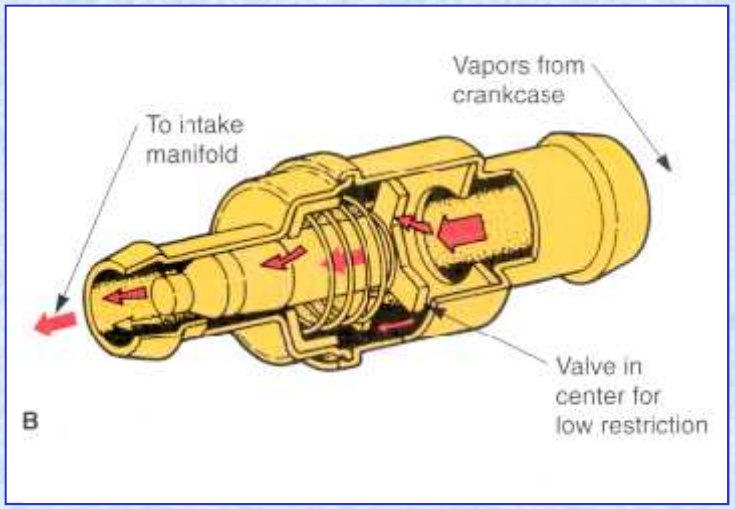
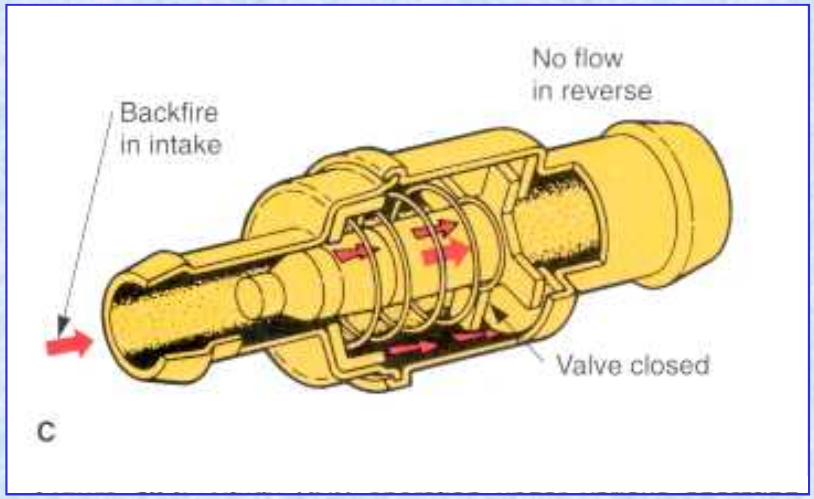
PCV Valve







A. Idle B. Acceleration C. Engine off

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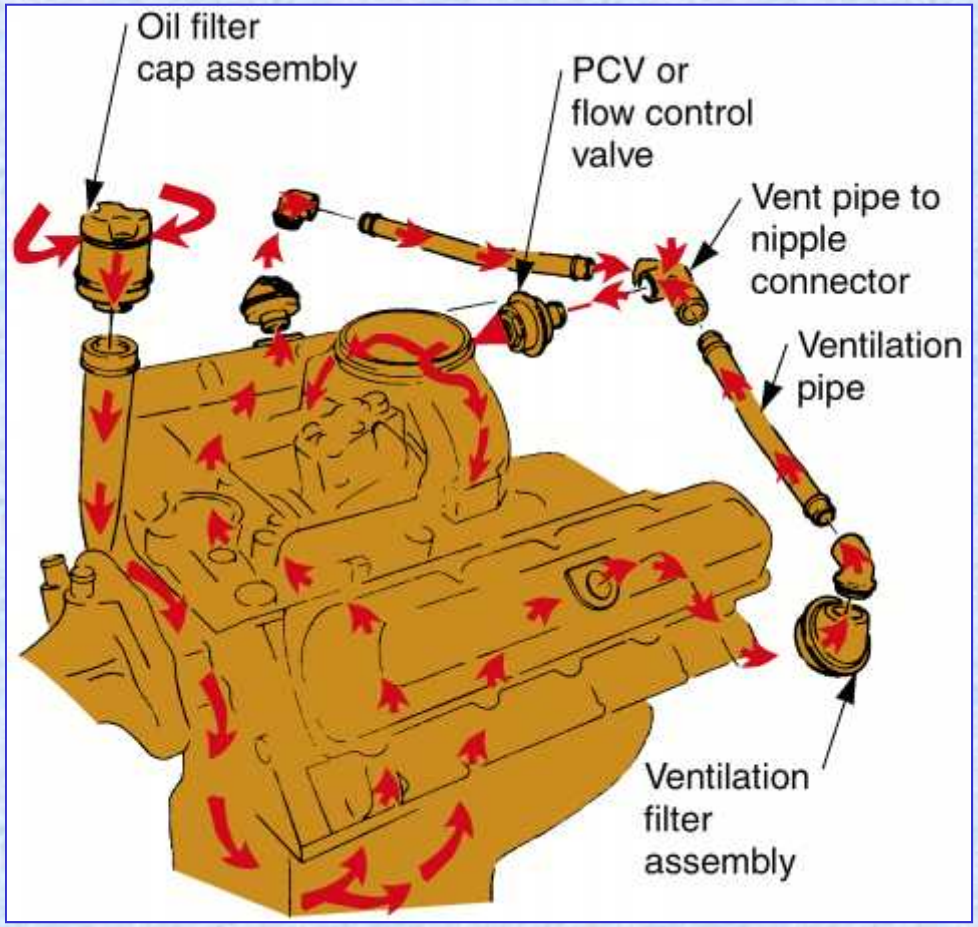
Diesel PCV System



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Air-Oil Separator

- May be used instead of a PCV valve
- Makes oil vapors condense and flow back into the oil pan

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Evaporative Emissions Control Systems

- Prevent fuel vapors from entering the atmosphere
- Before emission controls were used, vehicles vented vapors from their fuel tanks and carburetor bowls to the atmosphere

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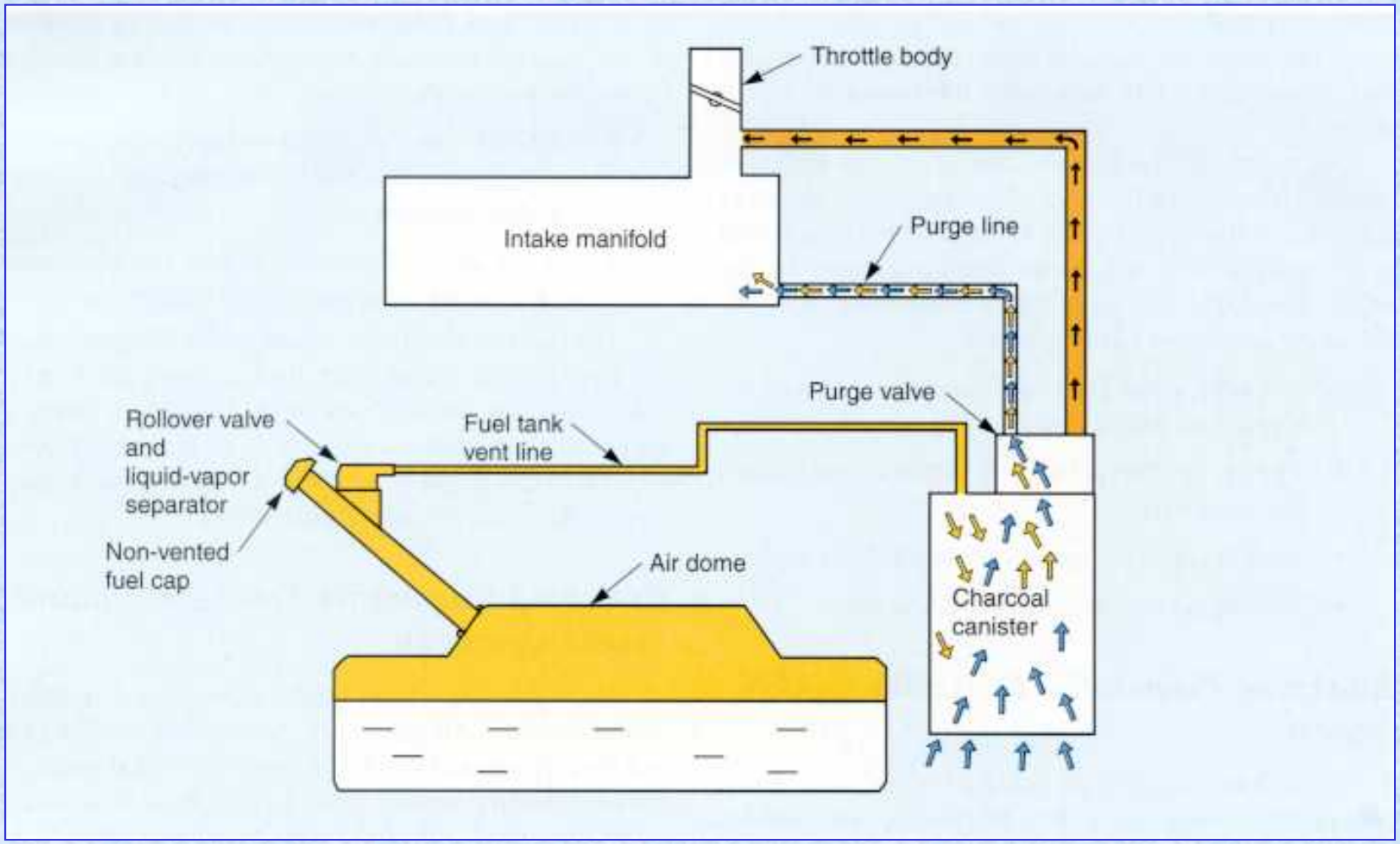
Evaporative System



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Components

- Non-vented fuel cap
- Air dome or liquid-vapor separator
- Rollover valve
- Charcoal canister
- Purge valve

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Non-Vented Fuel Cap

- Prevents fuel vapors from entering the atmosphere
- The pressure and vacuum relief valve will vent if tank pressure or vacuum levels get excessively high

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Air Dome

- A hump formed in the top of the fuel tank
- Allows for fuel expansion without spillage
- Provides about 10% air space to allow for fuel heating and expansion

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Rollover Valve

- Keeps liquid fuel from entering the vent line if the vehicle rolls over
- A metal ball or plunger valve blocks the vent line when the valve is turned over

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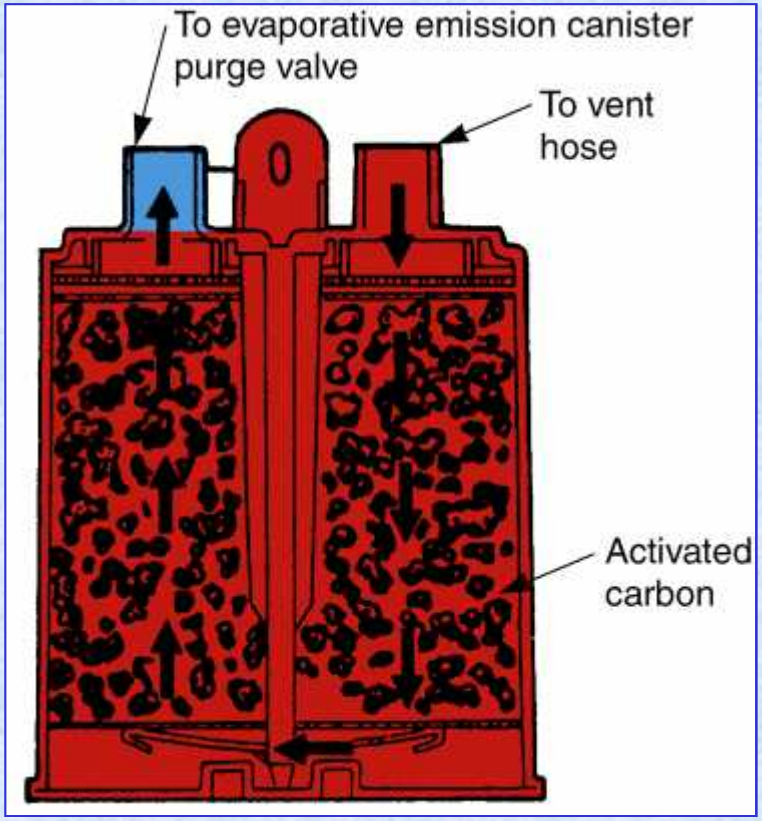
Charcoal Canister



Stores fuel vapors when the engine is not running

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Purge Valve

- Controls the flow of vapors
- Operated electrically or by vacuum
- Located on top of the canister or in the purge line
- Generally allows flow when the engine is operating above idle and at operating temperature

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Engine off Operation

- Fuel tank vapors are routed to the charcoal canister for storage
- Activated charcoal absorbs and holds the vapors

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Engine Running Operation

- Above idle, ported manifold vacuum causes the purge valve to open
- Gases flow through the purge line
- Fresh air is drawn into the canister
- Incoming air carries gases to the intake manifold for burning

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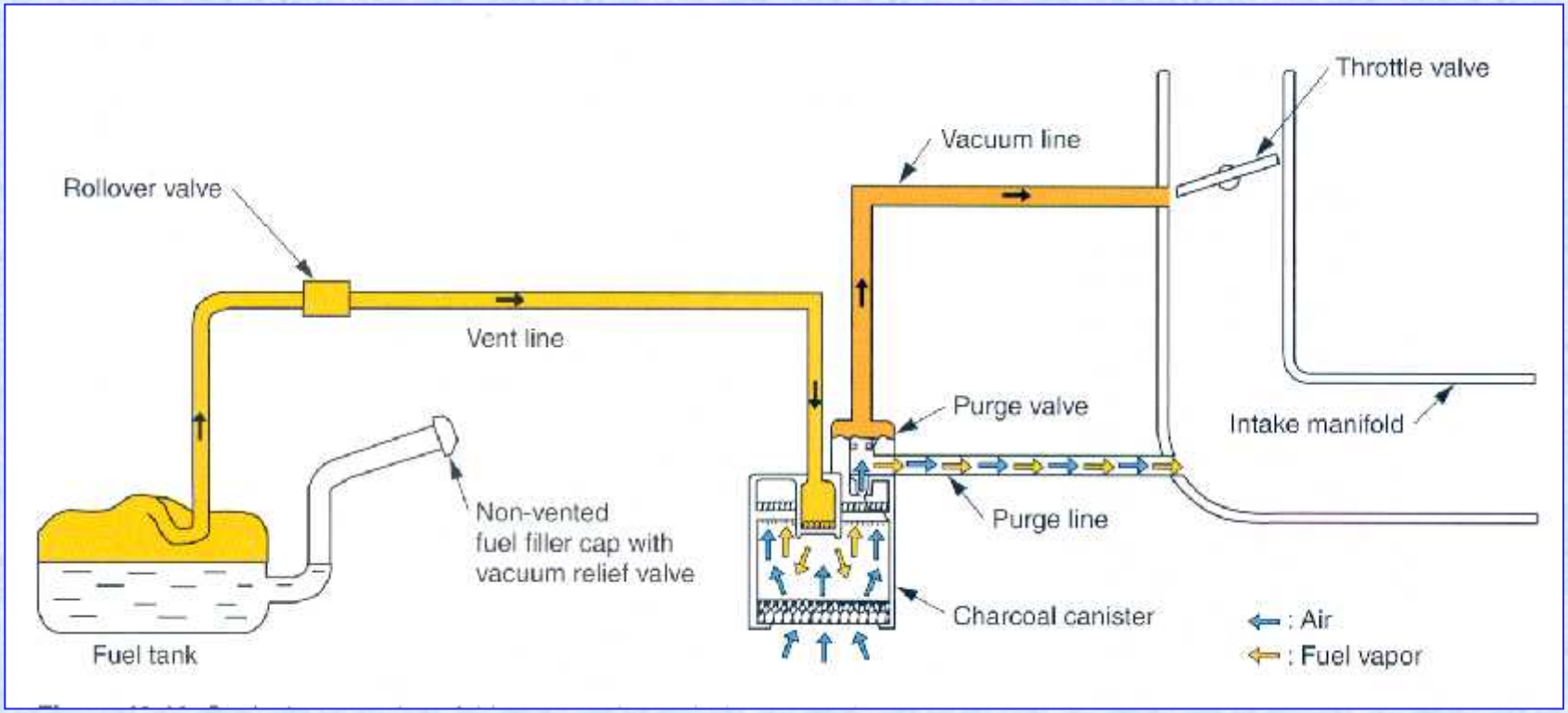
Evaporative System



This system uses a vacuum-controlled purge valve

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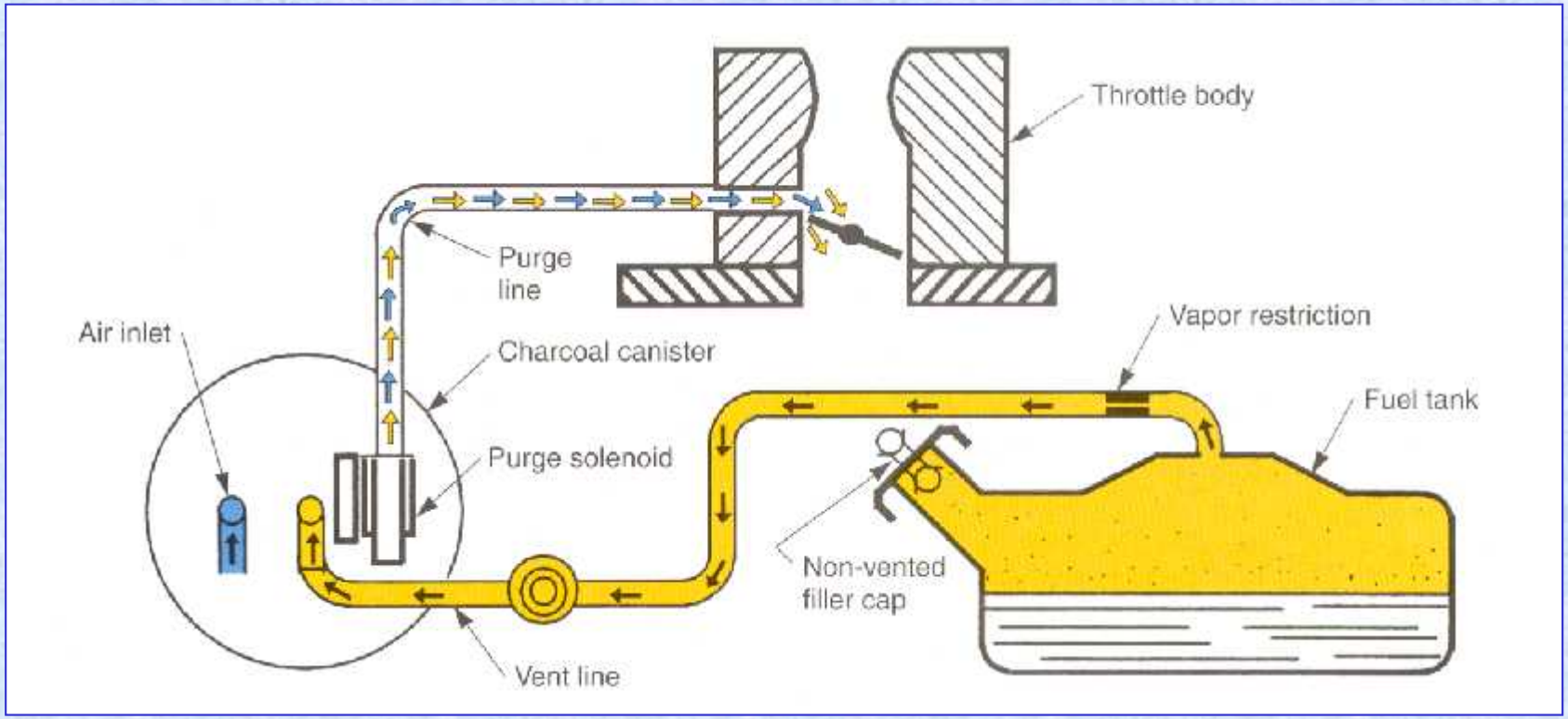
Evaporative System



This system uses an electronically-controlled purge solenoid

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Enhanced System

- Provides better control
- Monitors the condition of the fuel system

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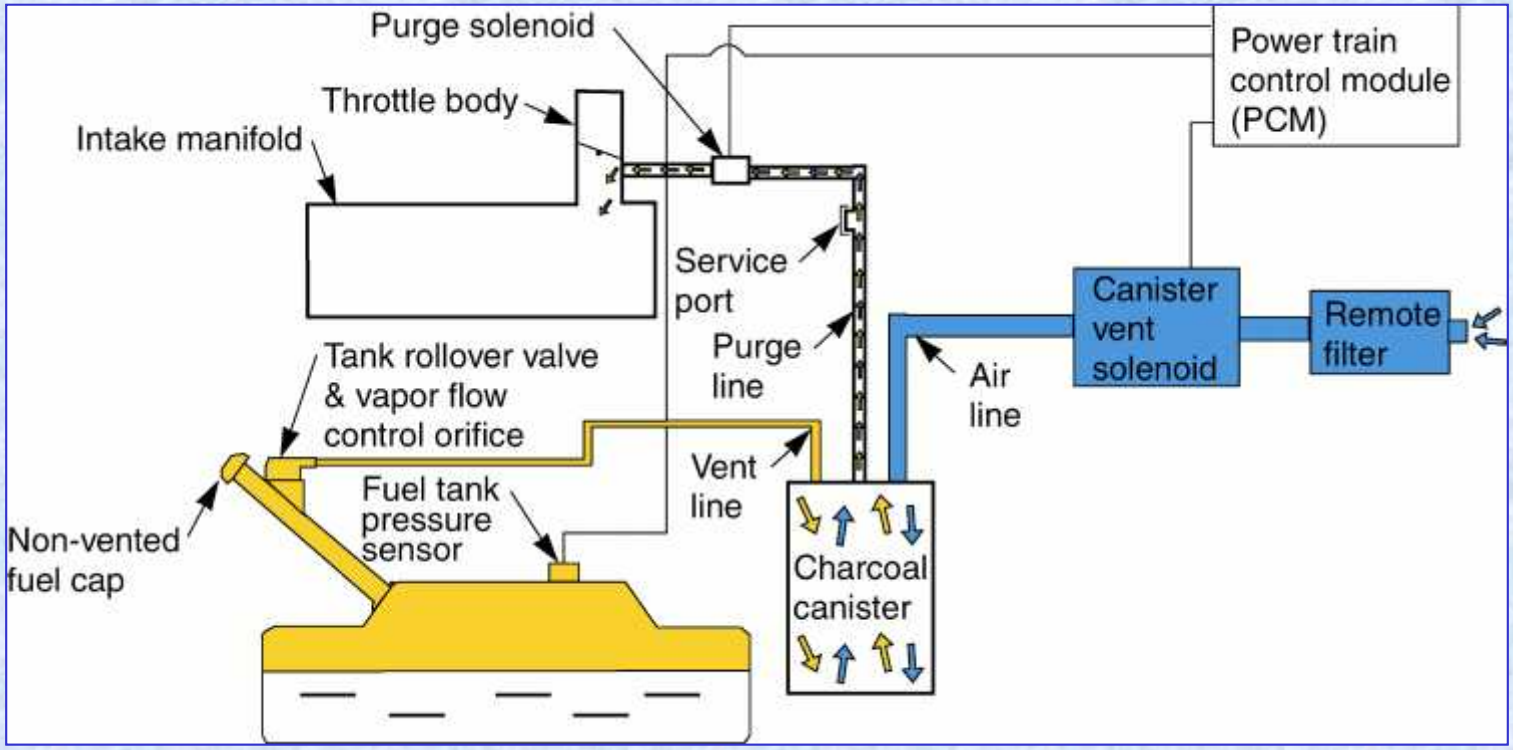
Enhanced System



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Components

- Fuel tank pressure sensor
- Canister vent solenoid
- Control module
- Service port

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Fuel Tank Pressure Sensor

- Monitors fuel tank pressure
- Sends a pressure signal to the control module

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Canister Vent Solenoid

- Electrically operated vacuum valve replaces the fresh air vent used on older canisters
- Closed by the control module to perform diagnostic tests on the evaporative system

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Service Port

- Used on many enhanced evaporative emission control systems
- Fitting allows the connection of service tools for testing and cleaning

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Enhanced System Operation

- Uses a normally closed, pulse-width modulated purge solenoid
- When energized, the purge solenoid allows vapors to flow to the intake manifold
- The canister vent solenoid is normally open, allowing fresh air into the canister, and may be closed by the control module during diagnostics

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Exhaust Gas Recirculation (EGR)

- Allows burned exhaust gases to enter the intake manifold
- Reduces combustion chamber temperature
- Reduces NO_x emissions

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Vacuum-Controlled EGR

- Uses vacuum to operate the valve
- Ported vacuum is not present at idle; the EGR valve stays closed
- Ported vacuum is present off idle; the EGR valve opens allowing flow

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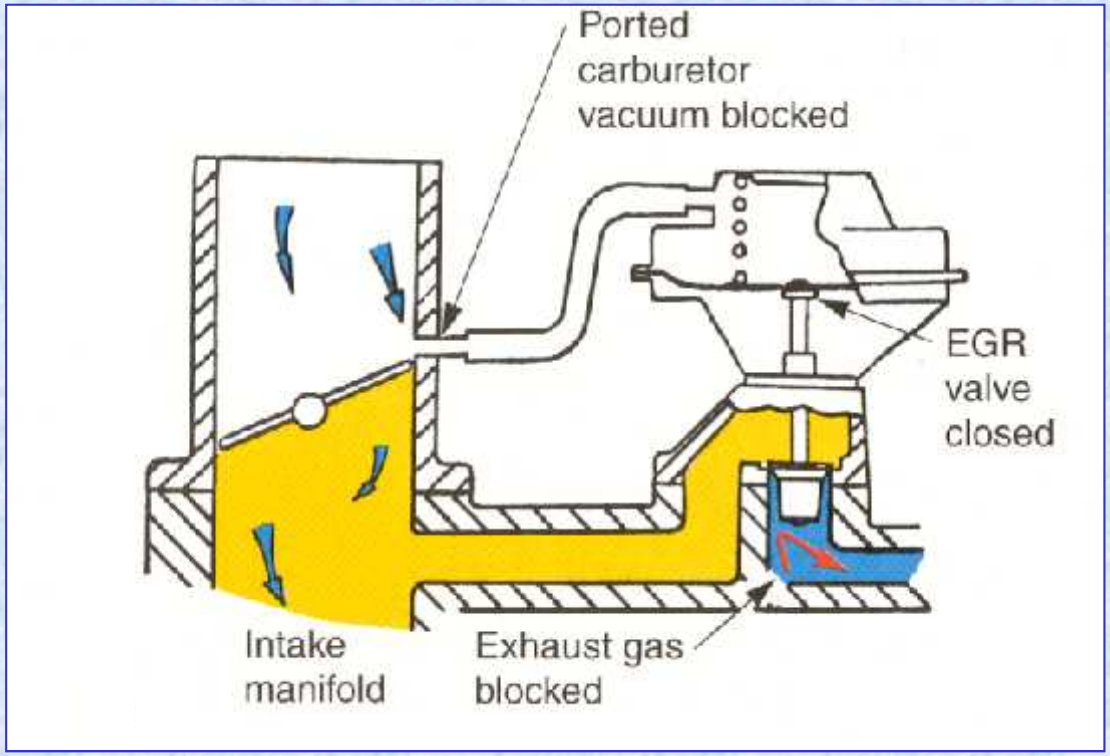
EGR System at Idle



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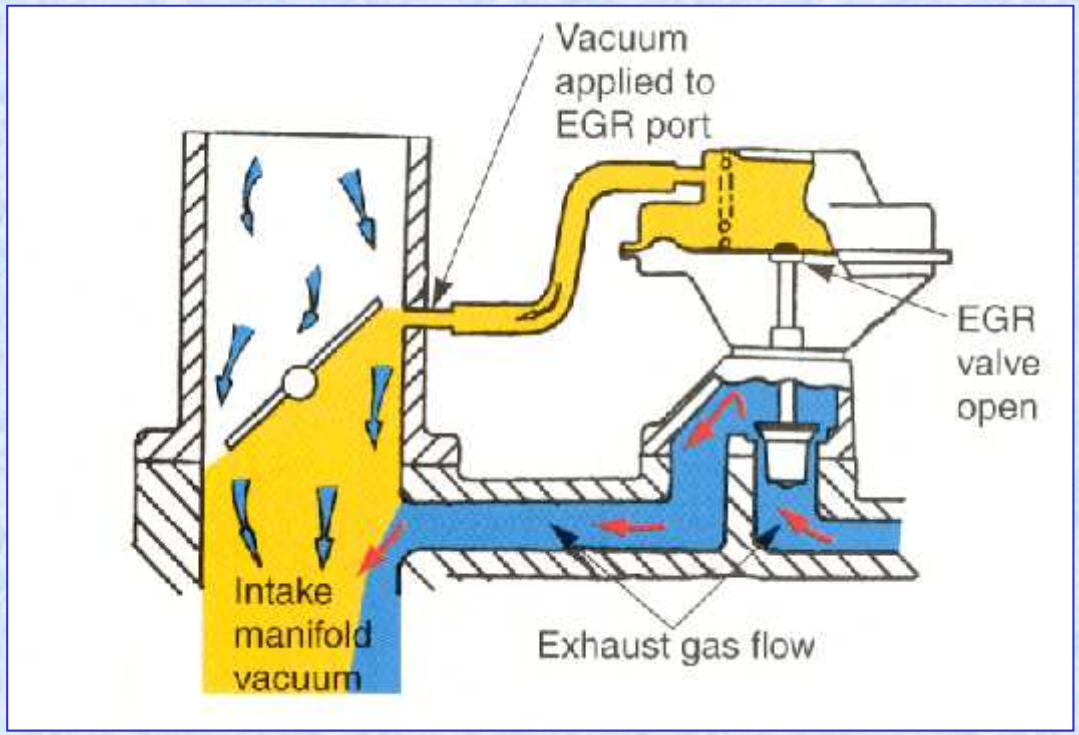
EGR System off Idle



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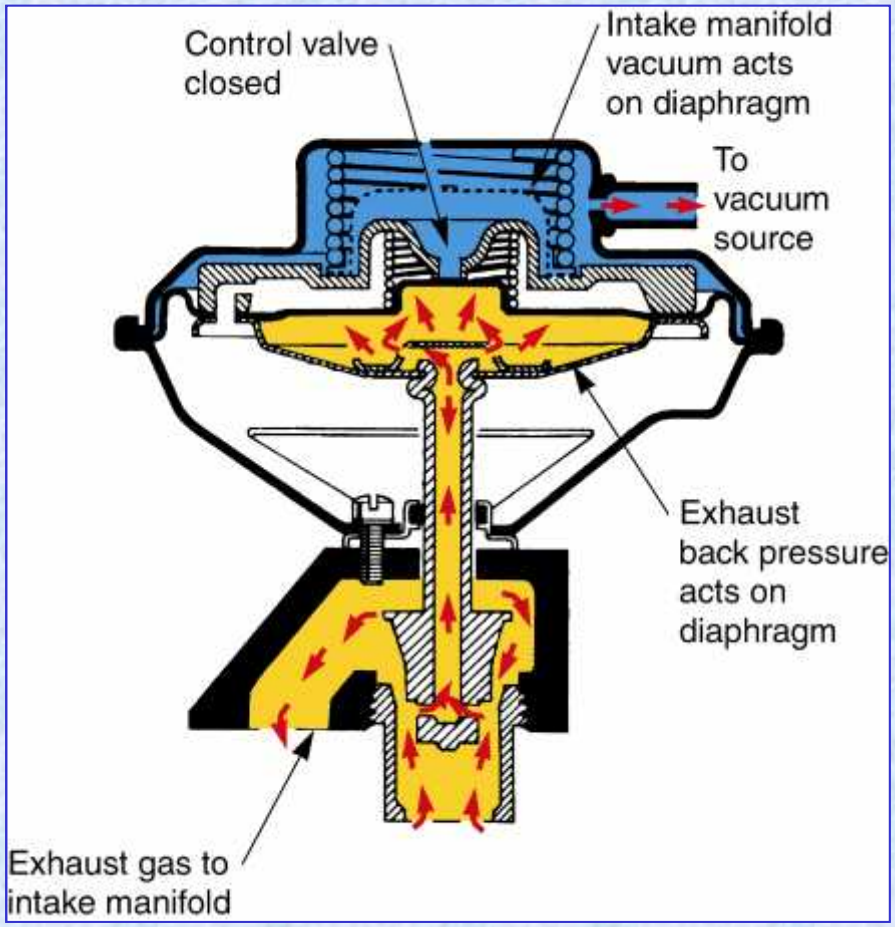
Backpressure EGR Valve



Exhaust backpressure modifies valve operation

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Electronic-Vacuum EGR

- Uses both engine vacuum and electronic control
- The EGR position sensor, located in the valve, sends data back to the control module
- The control module can modify the amount of vacuum sent to the valve to control the valve opening

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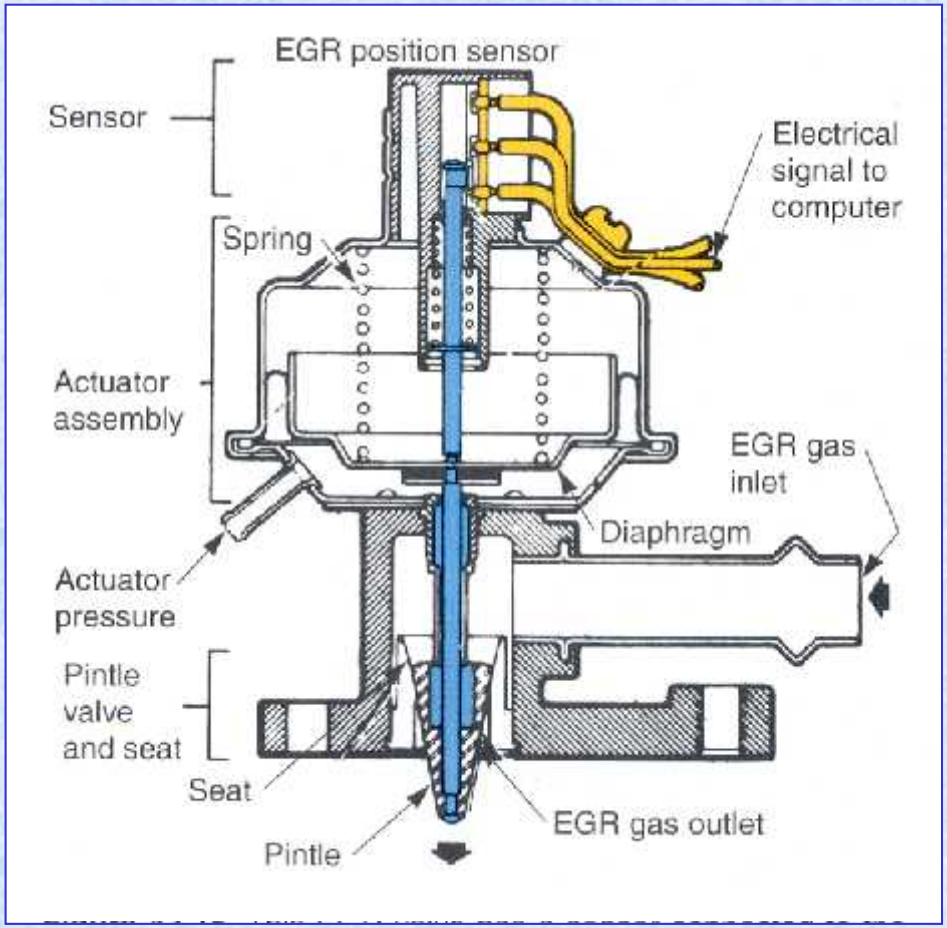
Electronic-Vacuum EGR



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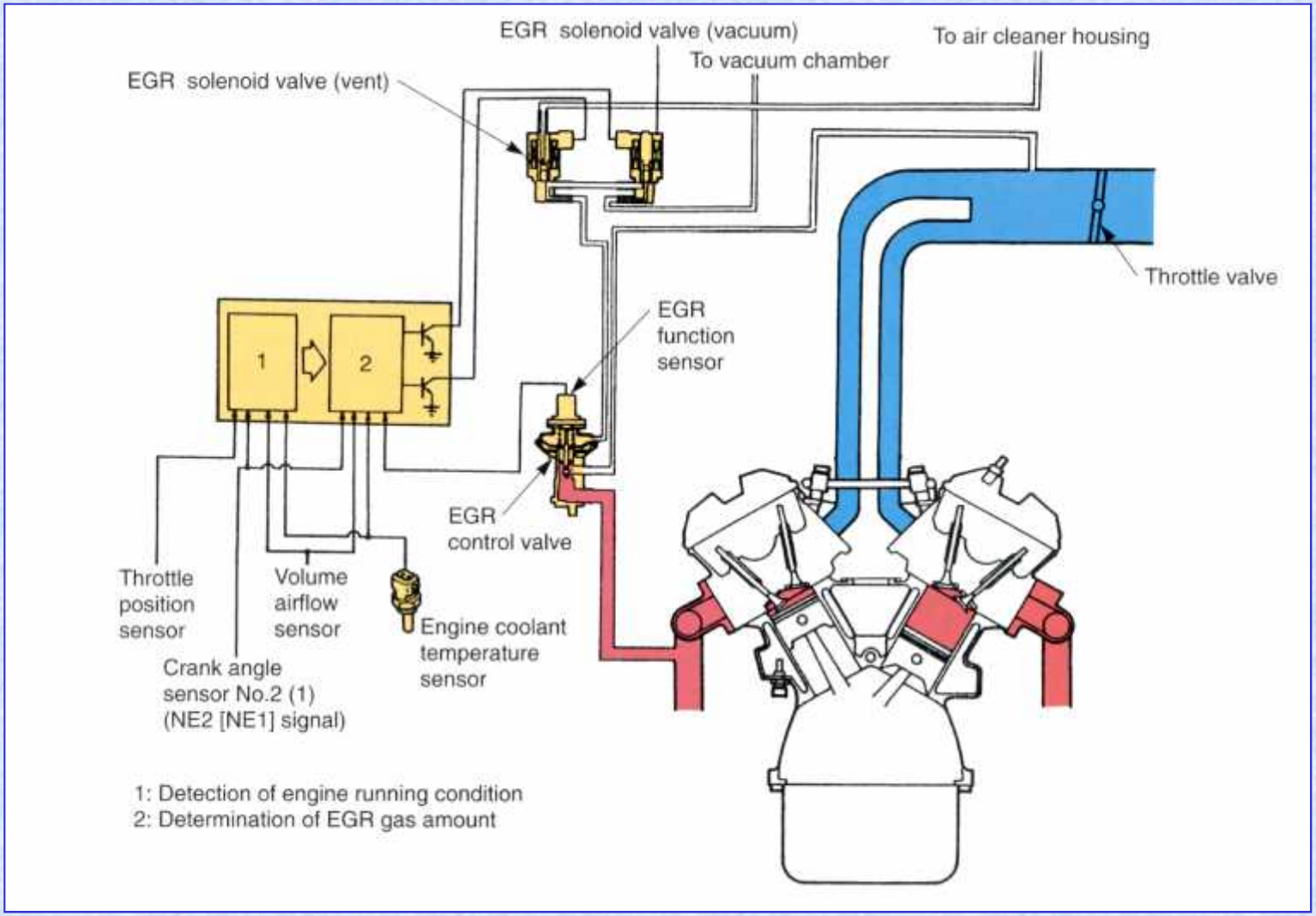
Electronic-Vacuum EGR



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Electronic EGR

- Uses a solenoid-operated EGR valve
- The control module uses engine sensors to calculate how much exhaust gas should be recirculated
  - controls the duty cycle to meter the correct amount of exhaust gases

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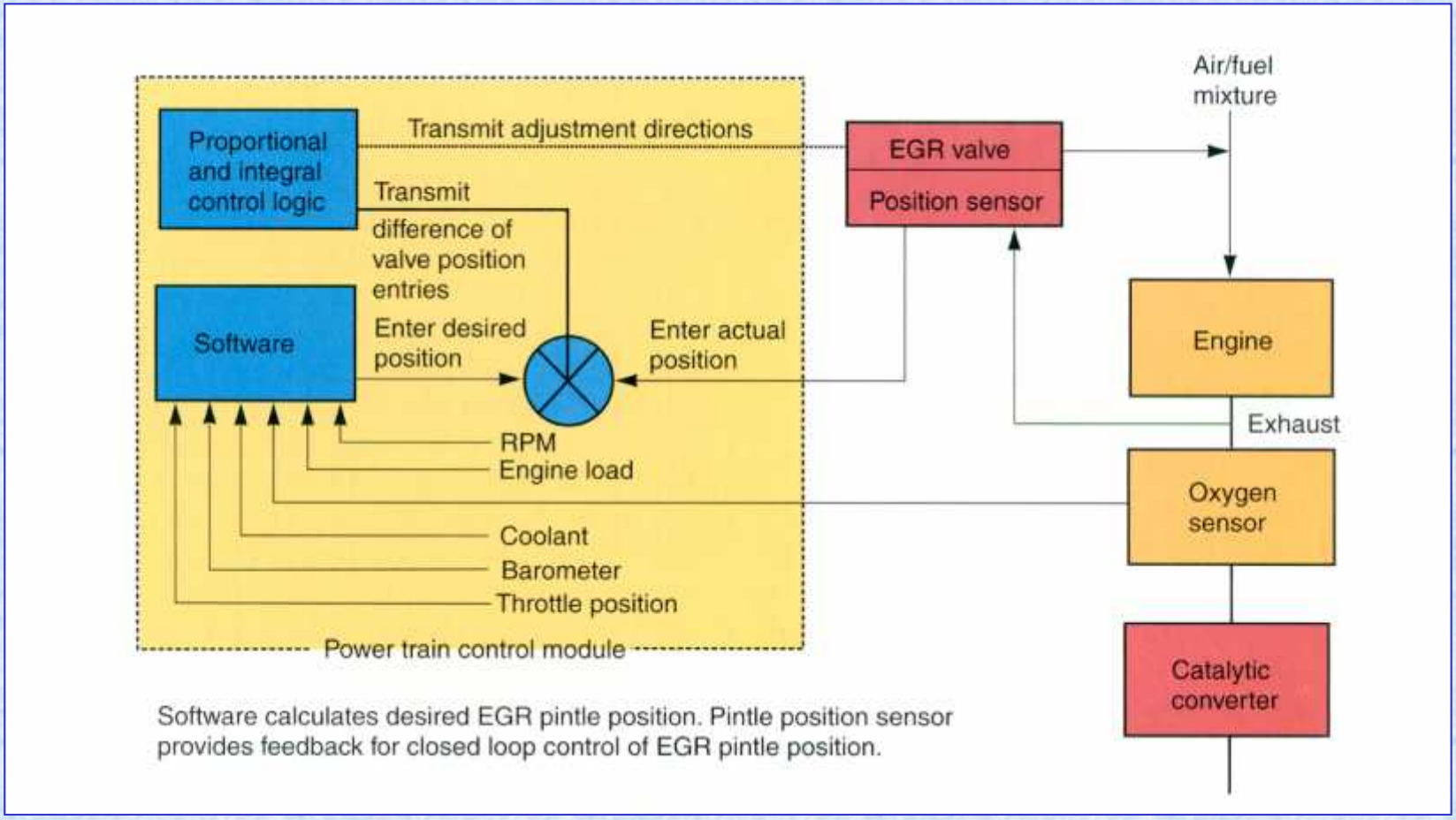
Electronic EGR



Software calculates desired EGR pintle position. Pintle position sensor provides feedback for closed loop control of EGR pintle position.

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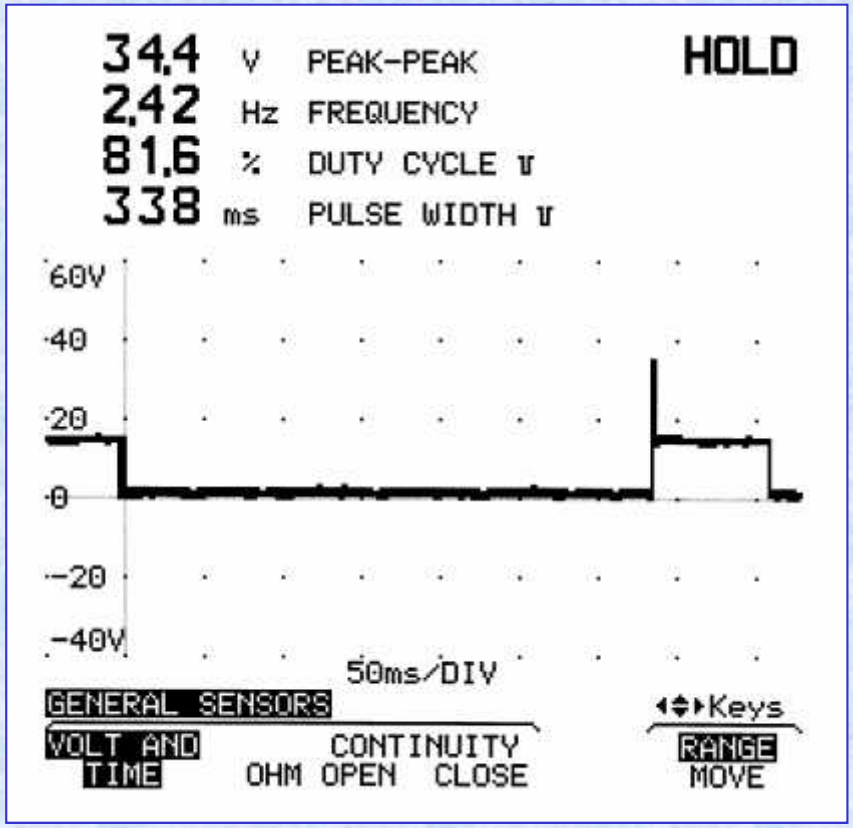
Electronic EGR Control



Waveform of electronic EGR control

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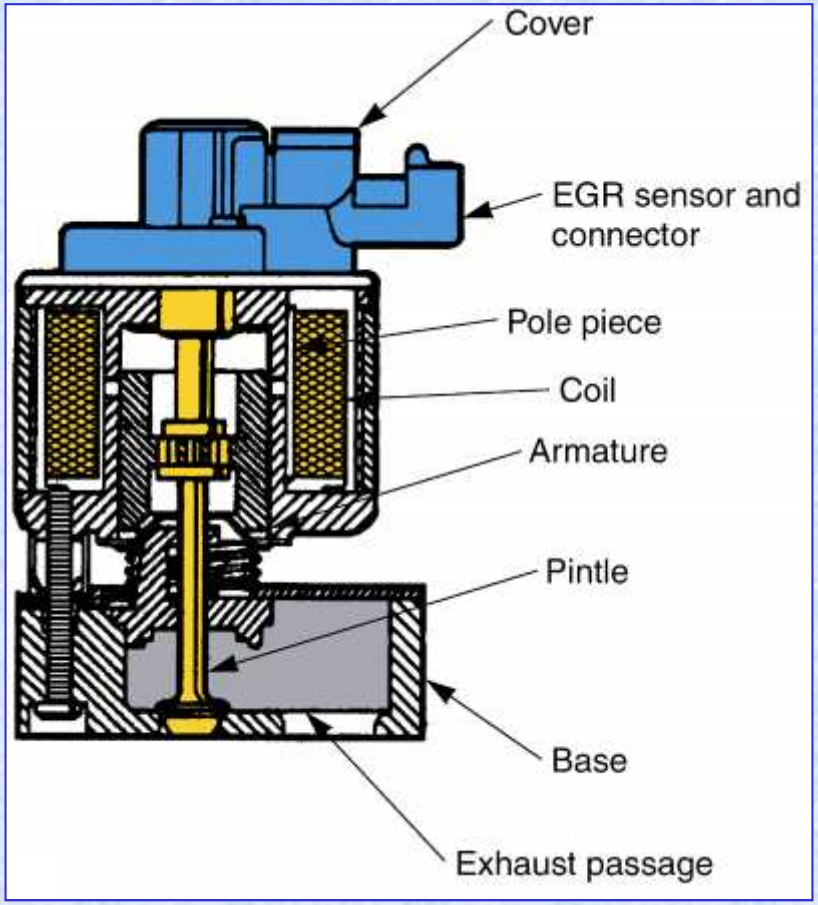
Electronic EGR Valve



Single stage (linear)

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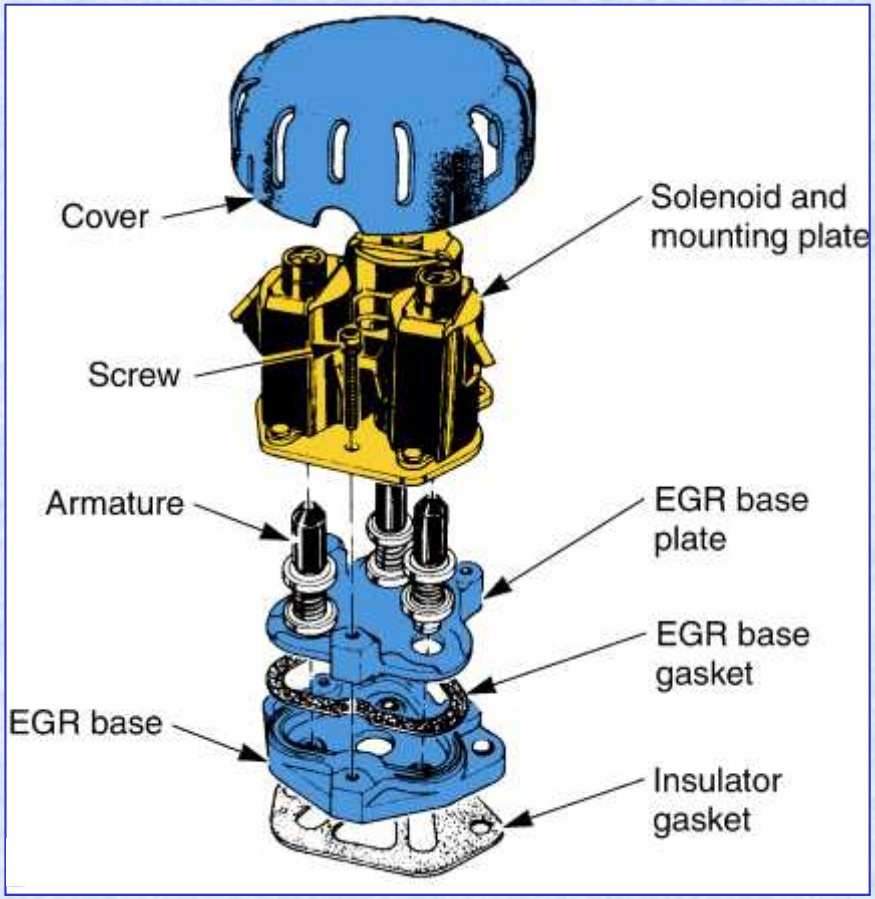
Electronic EGR Valve



Multistage (digital)

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Air Injection System

- Forces fresh air into the exhaust ports or catalytic converter to reduce HC and CO
- Causes exhaust gas to continue to burn in the exhaust manifold or catalytic converter

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Components

- Belt-driven or electric pump
  - forces air into the system
- Air distribution manifold
  - directs air toward each exhaust valve
- Air check valve
  - keeps exhaust gases from entering the air injection system

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Components

- Diverter valve
  - keeps air from entering the system during deceleration
  - high manifold vacuum during deceleration acts on the diaphragm in the valve
  - the valve switches the airflow to atmosphere
  - limits the maximum air pressure in system

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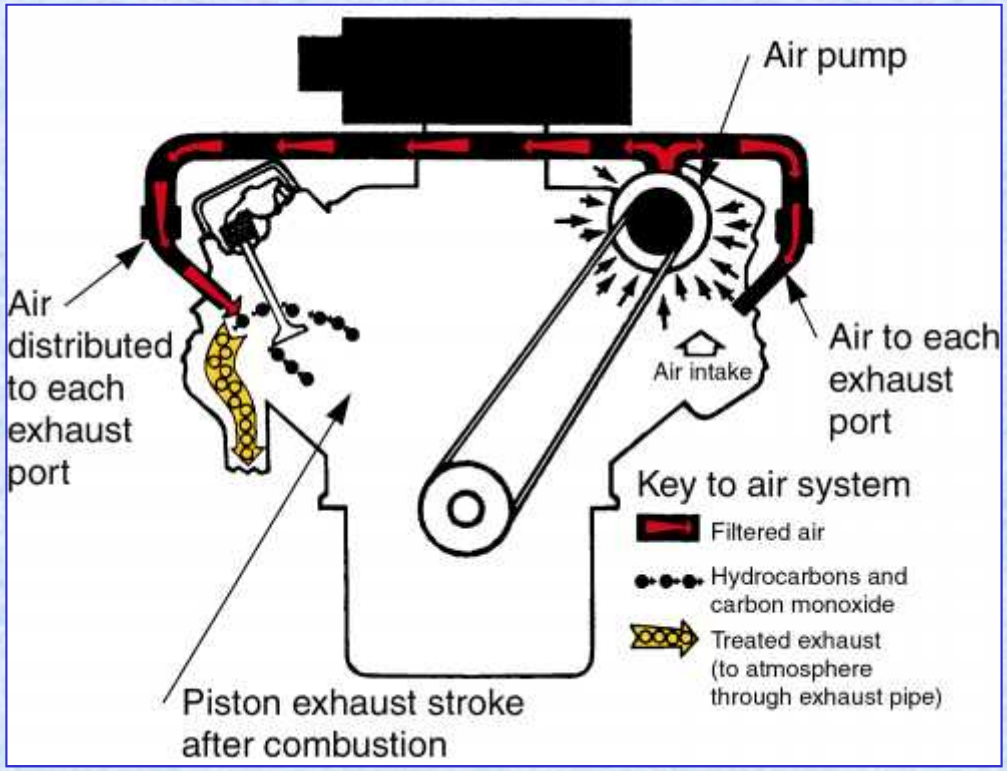
Air Injection System



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Operation

- The air pump forces air through the diverter valve, through the check valve, into the exhaust manifold
- Late-model vehicles may force air into the catalytic converter to help oxidize (burn) HC and CO

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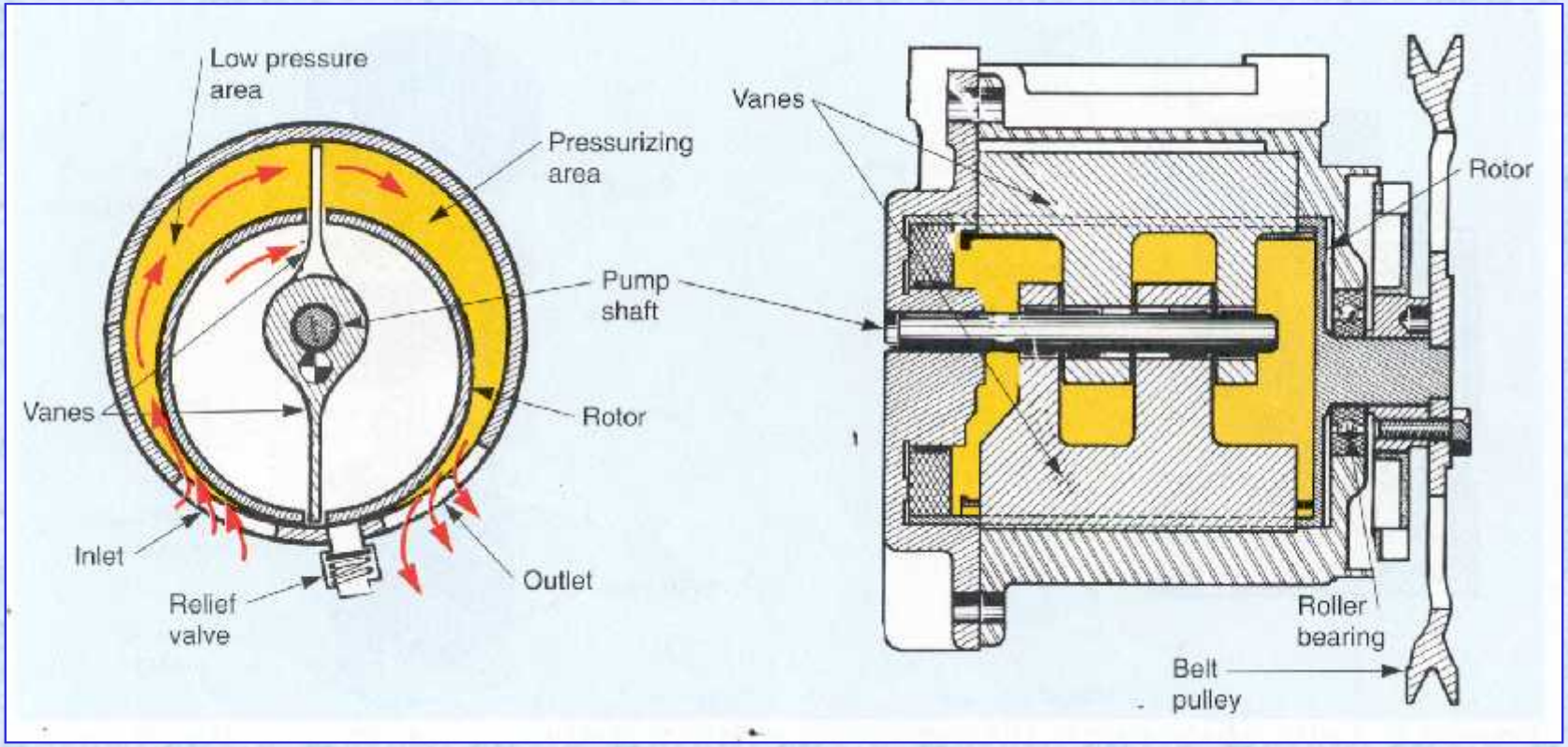
Air Injection Pump



Vanes trap and pressurize air

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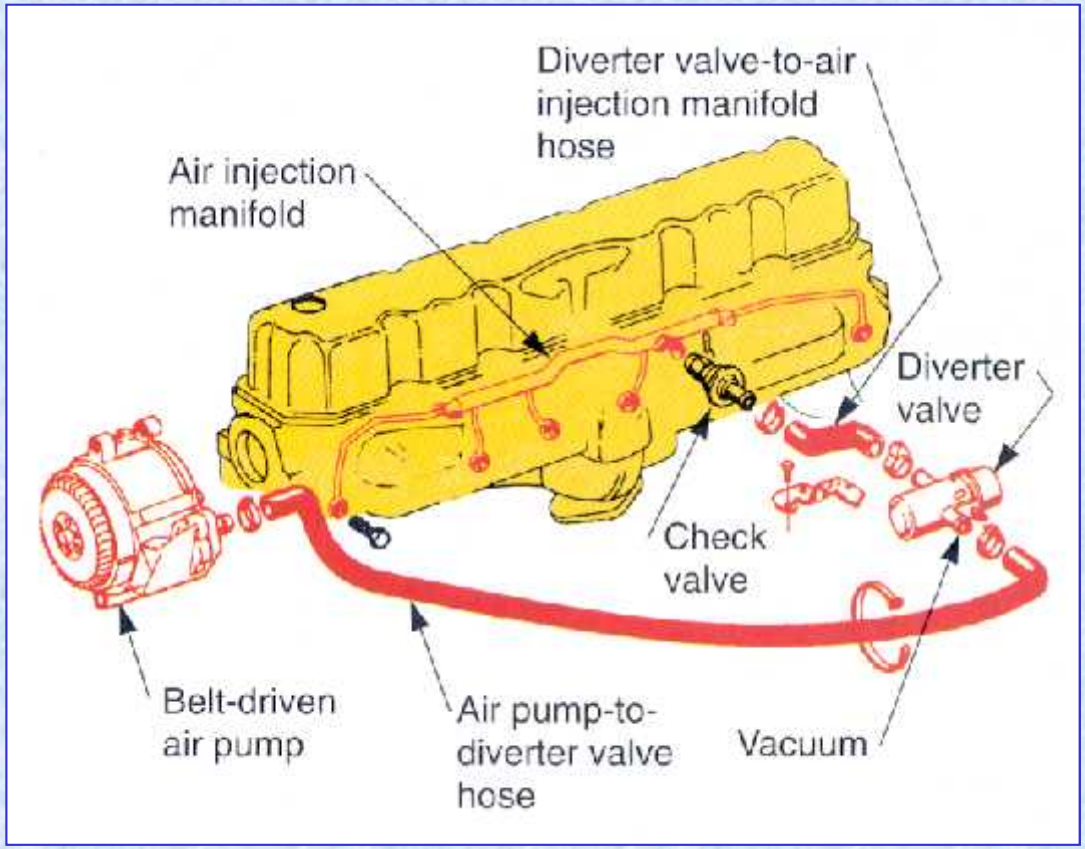
Air Injection System



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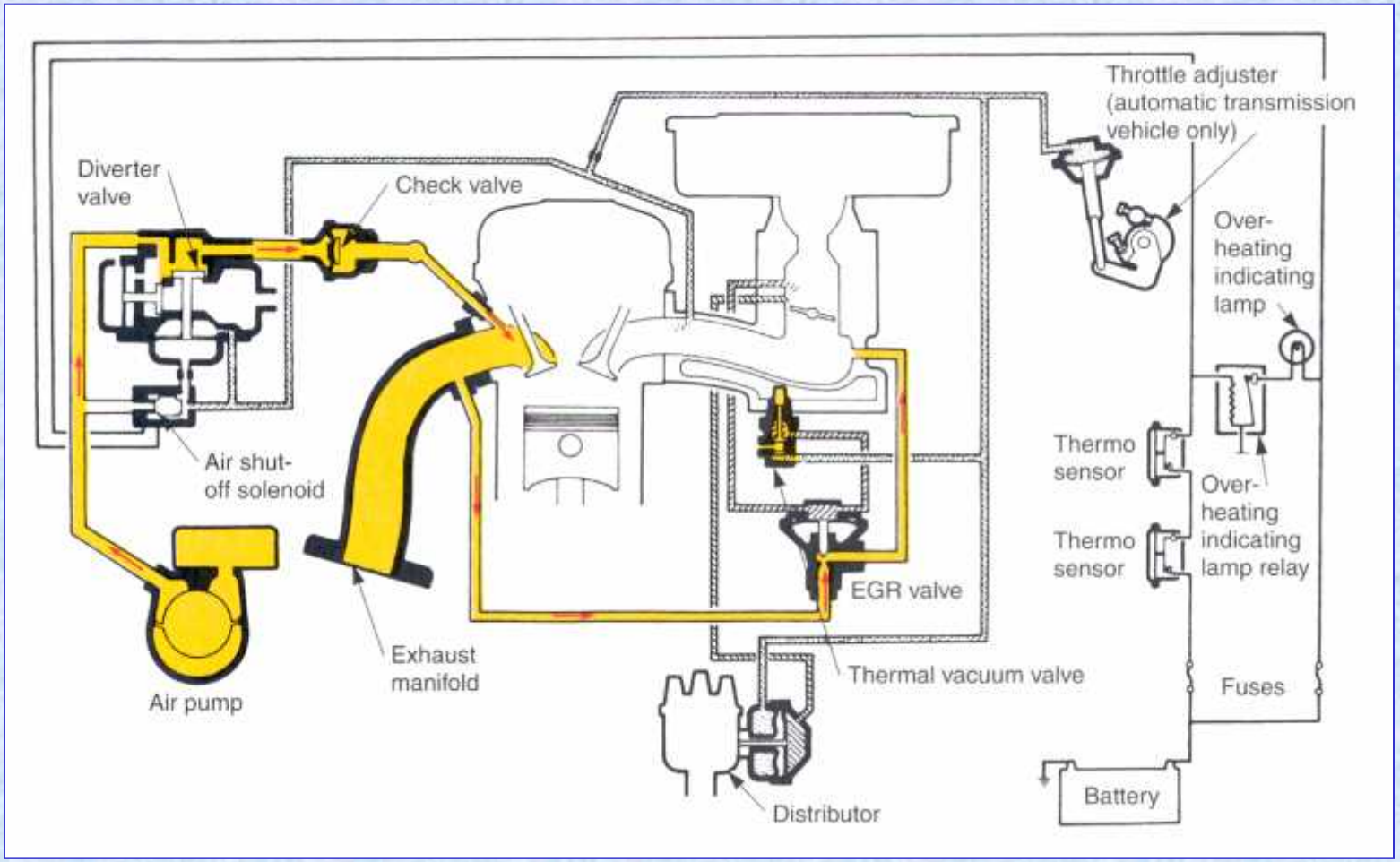
Air and EGR Systems



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Pulse Air System

- Functions much like an air injection system
- Instead of a pump, this system uses natural pressure pulses in the exhaust system to operate the aspirator valves

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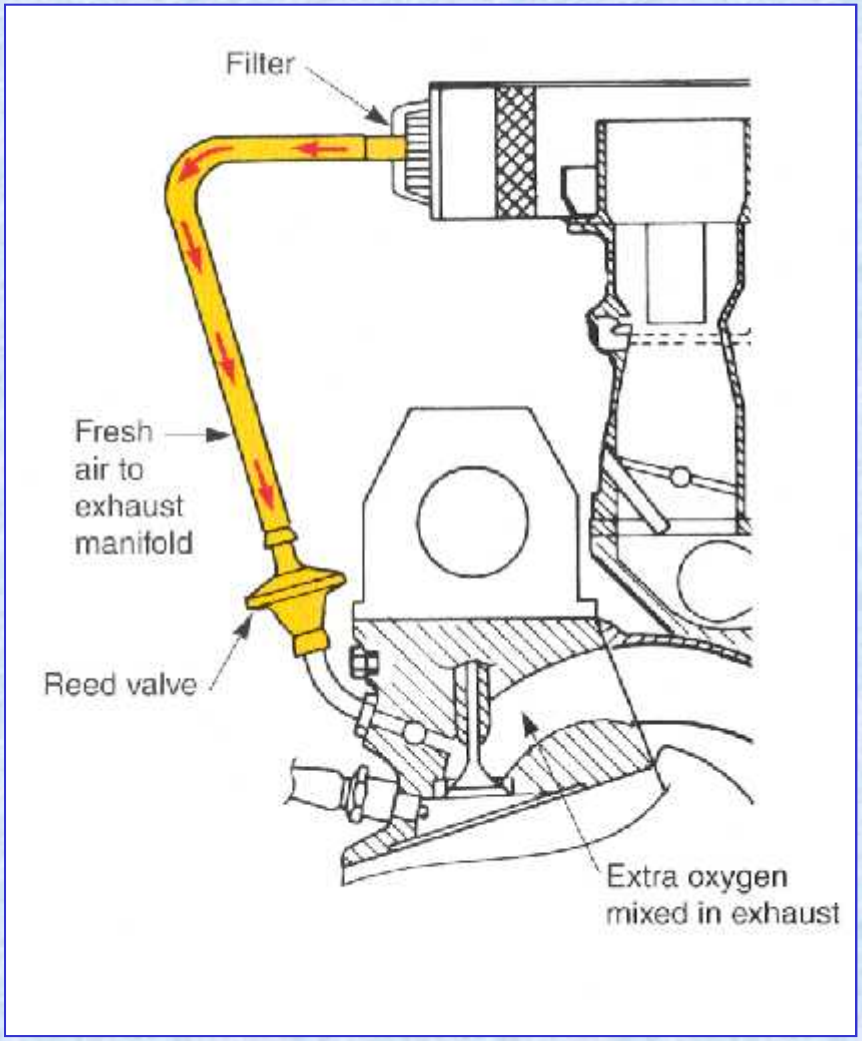
Pulse Air System

The aspirator (reed valve) allows fresh air into the exhaust manifold



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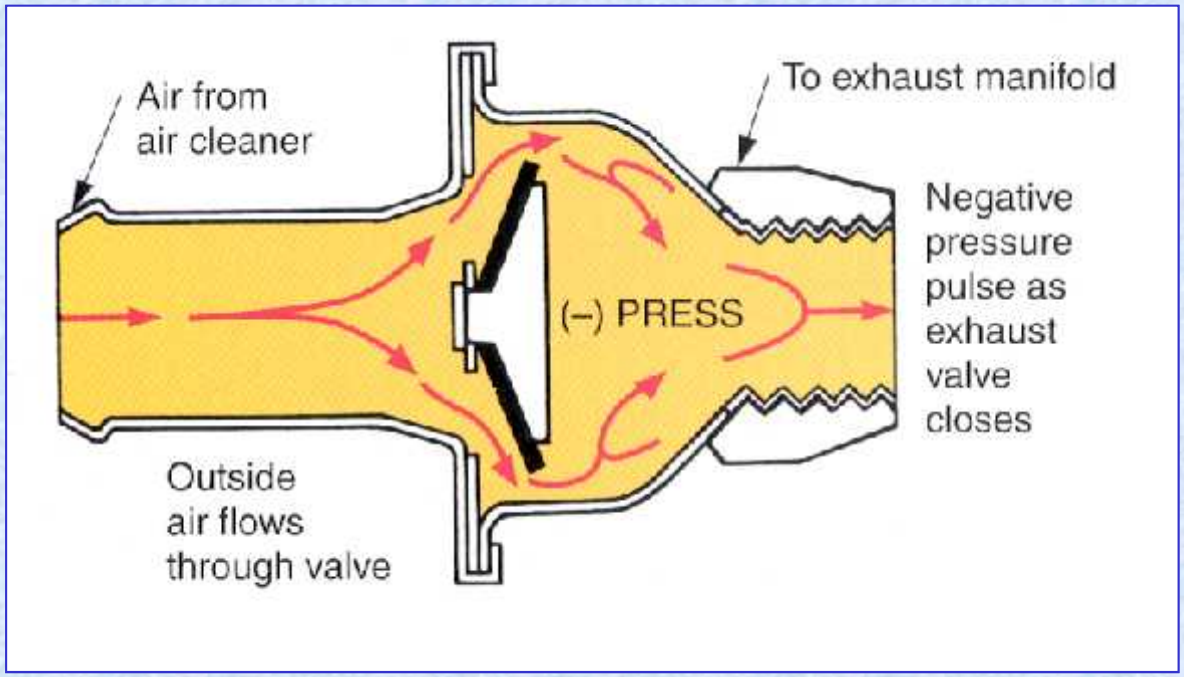
Aspirator Operation



When an exhaust valve closes, a vacuum pulse causes the aspirator to allow air through to the manifold

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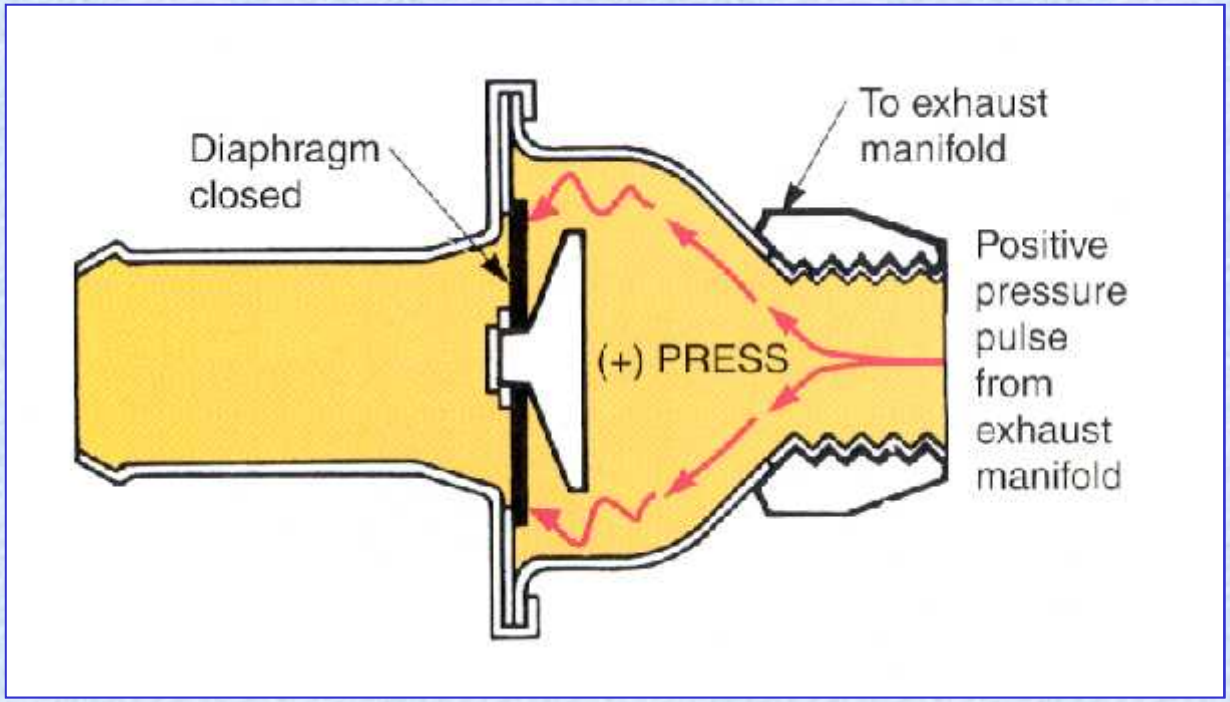
Aspirator Operation



When the exhaust valves open, producing a pressure pulse, the aspirator blocks airflow

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Thermostatic Air Cleaner System

- Speeds engine warm-up and warms the incoming airflow
- Most common on carbureted and throttle body injection engines

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Components

- Thermal vacuum valve
  - located in the air cleaner
  - controls the vacuum motor in relation to air temperature
- Vacuum motor
  - operates the heat control door
- Heat control door
  - routes cool or heated air into the air cleaner

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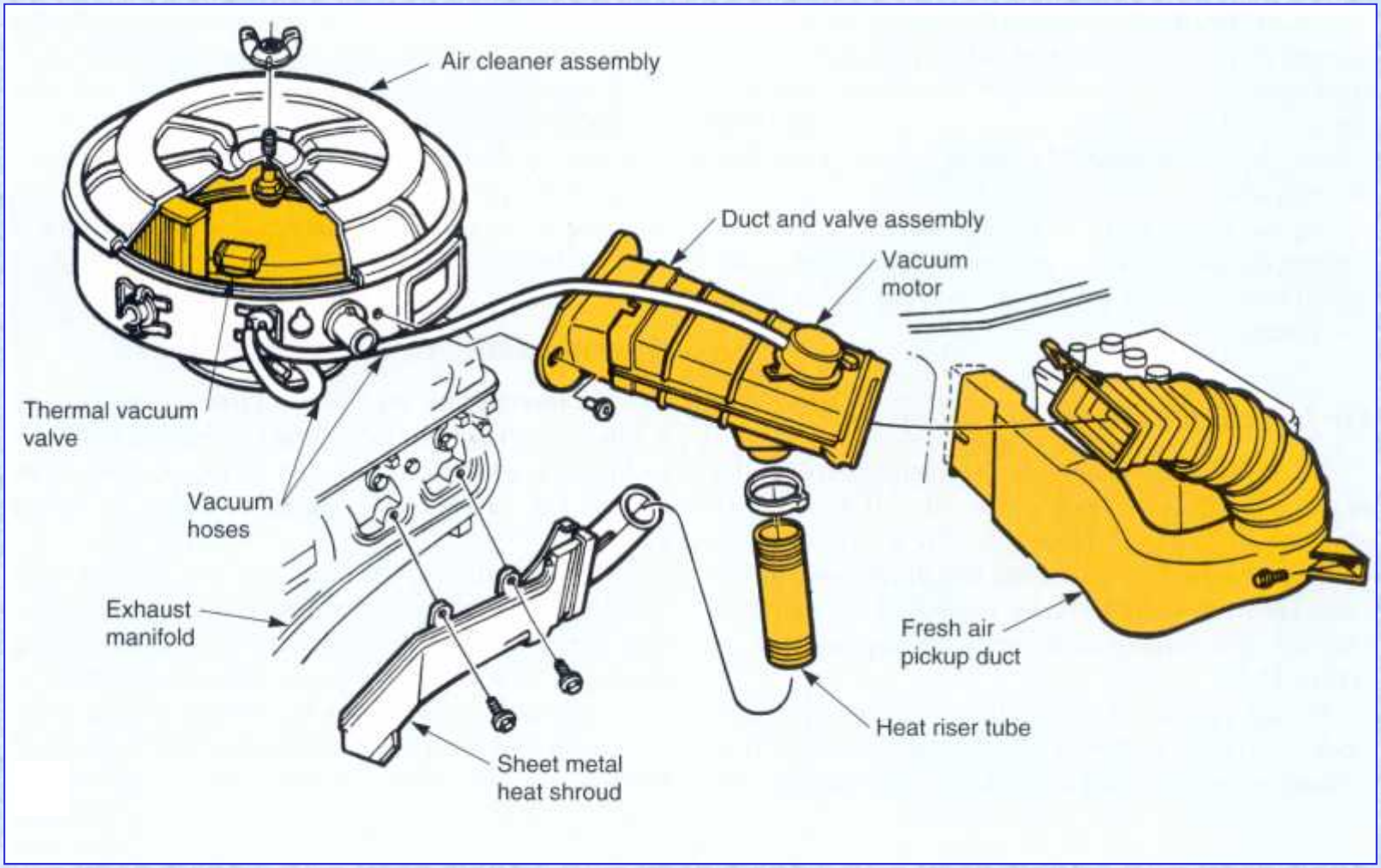
Components



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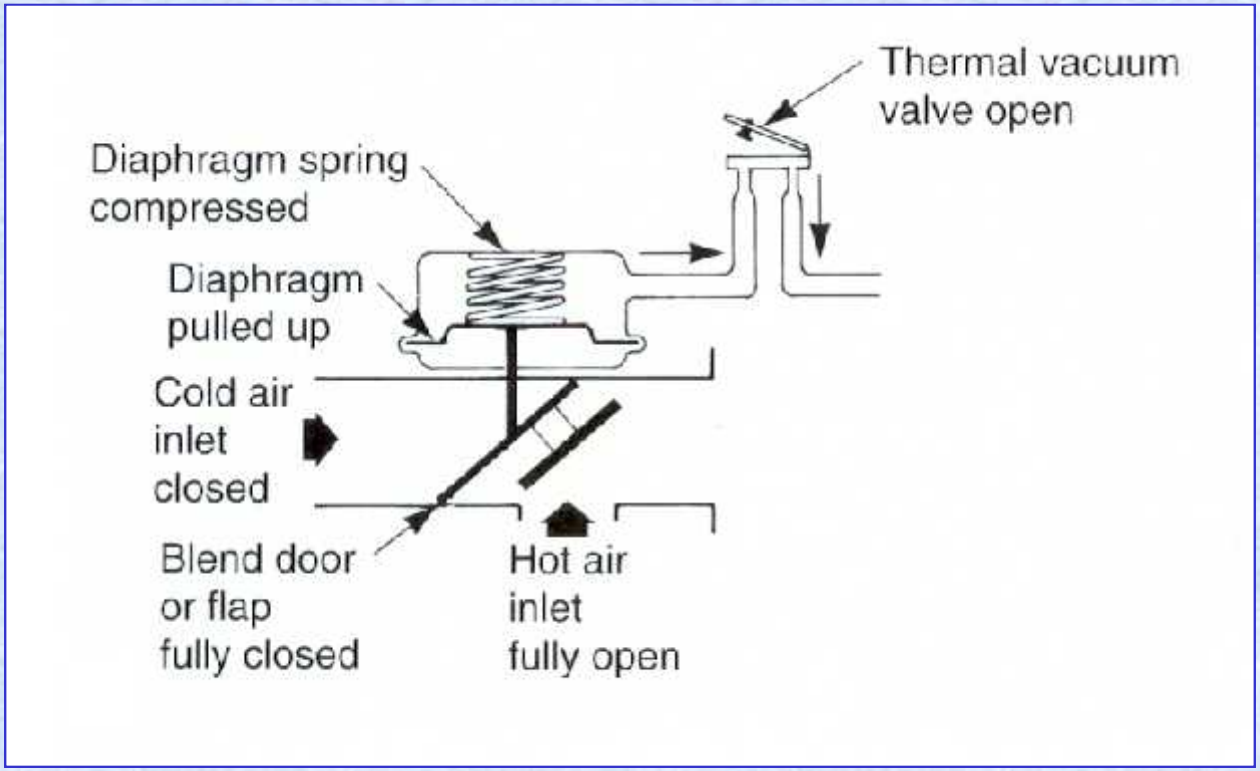
Cold Engine Operation



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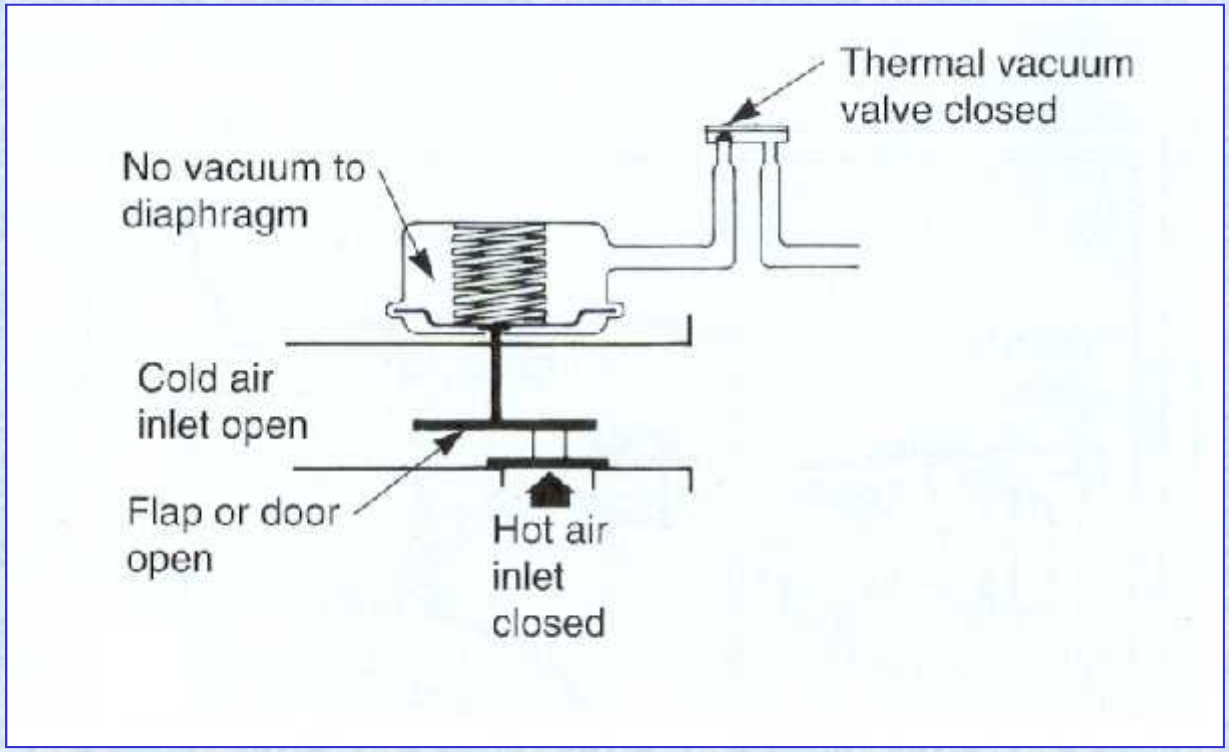
Warm Engine Operation



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Catalytic Converter

- Oxidizes (burns) HC and CO emissions
- Converts HC and CO into carbon dioxide (CO_2) and water (H_2O)
- A catalyst is a substance that speeds a chemical change without itself being changed
- NO_x may be converted to nitrogen (N_2) and oxygen (O_2)

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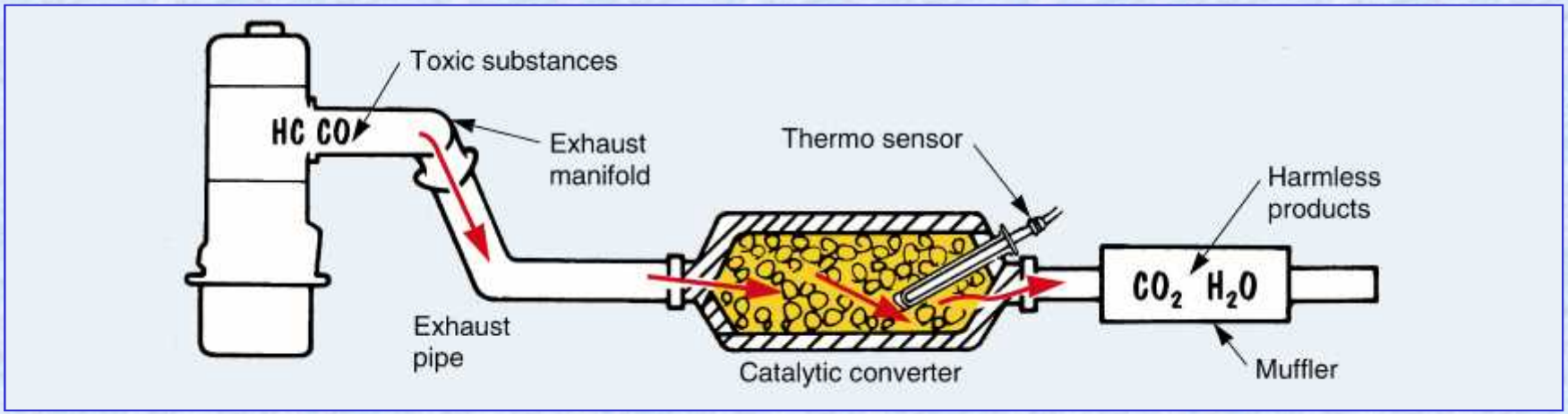
Catalytic Converter



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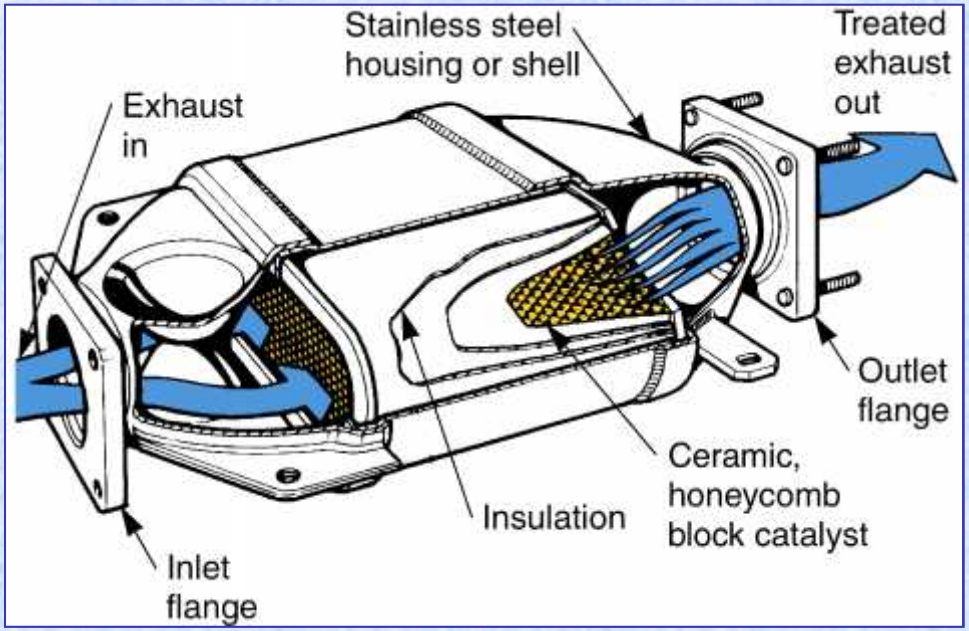
Monolithic Converter



Honeycomb-shaped ceramic material covered with active elements

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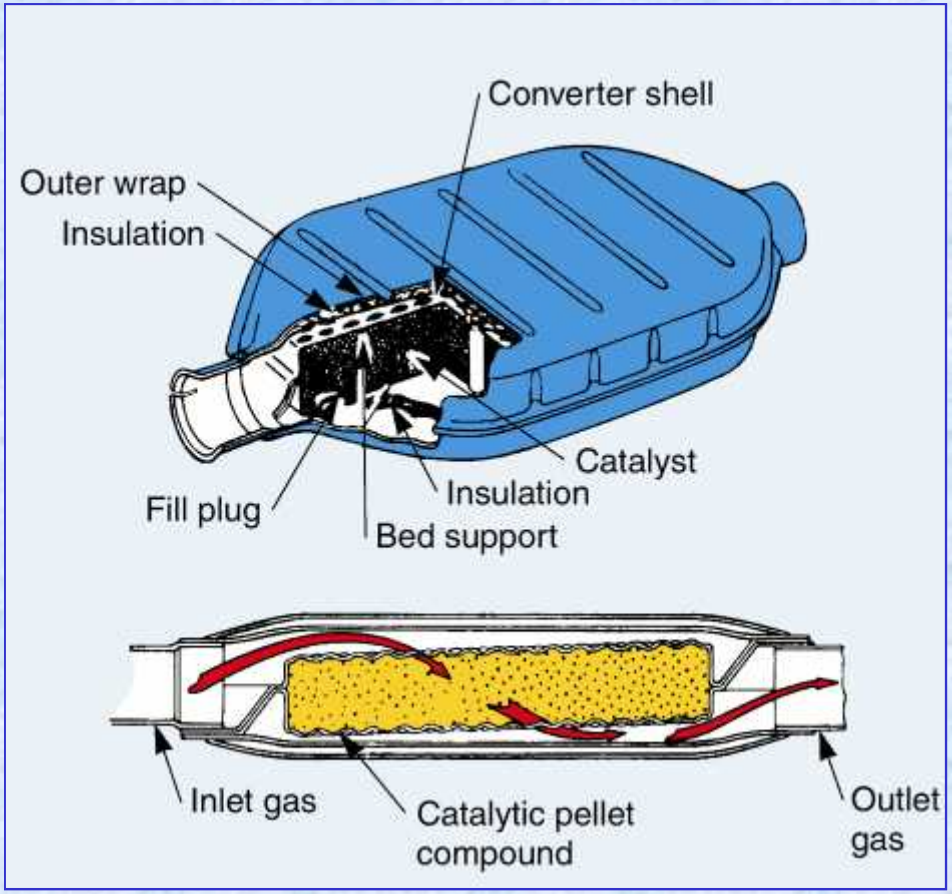
Pellet-Type Converter



Uses beads coated with active elements

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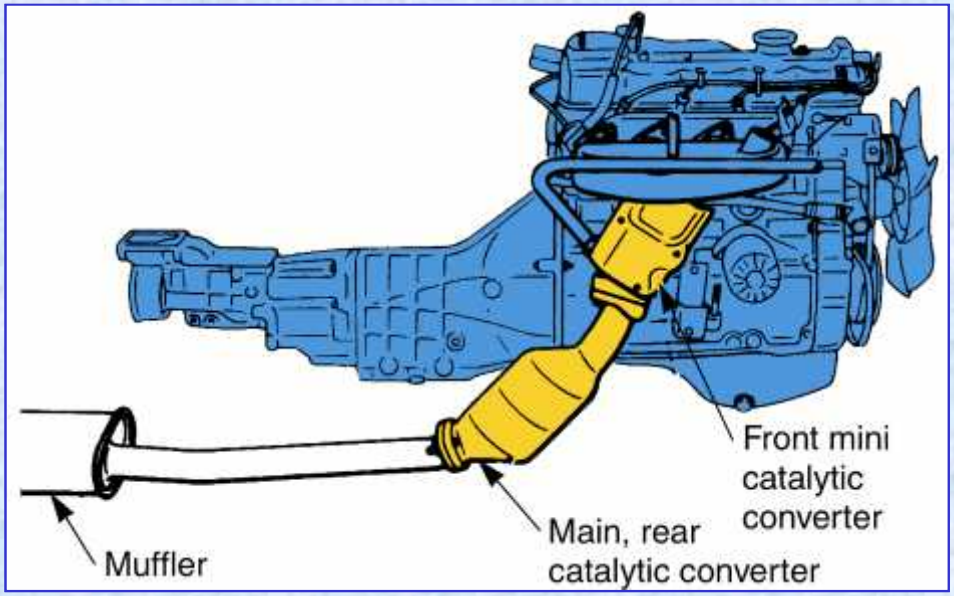
Mini Catalytic Converter



Mounted close to exhaust manifold to heat up quickly on startup

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Two-Way Converter

- Known as an oxidation converter
- Uses a single bed
- Reduces HC and CO
- Contains platinum

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Three-Way Converter

- Known as a reduction converter
- Single bed
- Reduces HC, CO, and NO_x
- Contains platinum and rhodium

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Dual Bed Converter

- Two separate catalyst units (beds) in a single converter
- Front bed is a three-way unit
- Rear bed is a two-way unit
- When the engine is hot, air is forced into a mixing chamber between the two beds, increasing oxidation efficiency

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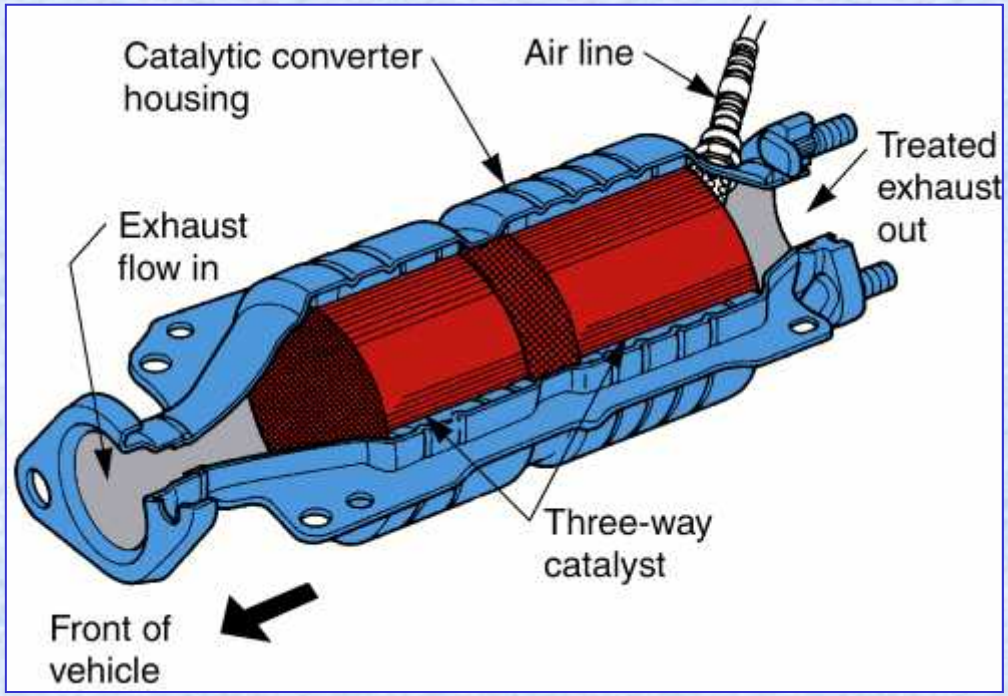
Dual Bed Converter



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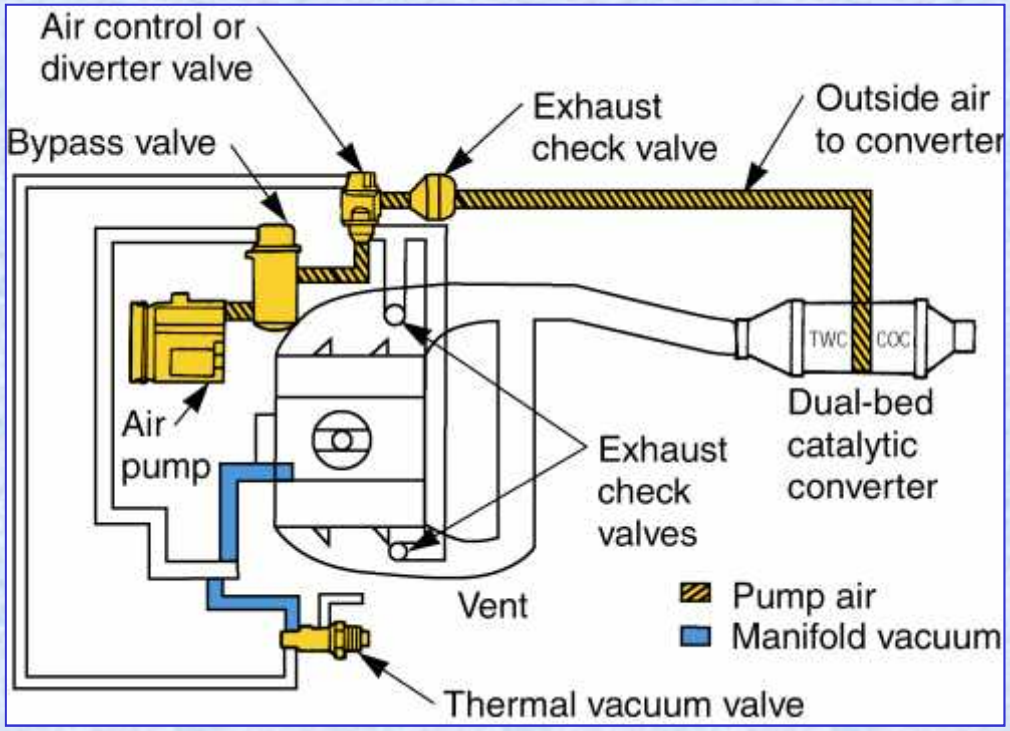
Dual Bed System



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Computerized Emission Control Systems

- Reduces emissions using:
  - various engine sensors
  - three-way converter
  - ECM
  - electronic fuel injection
  - computer-controlled emission devices

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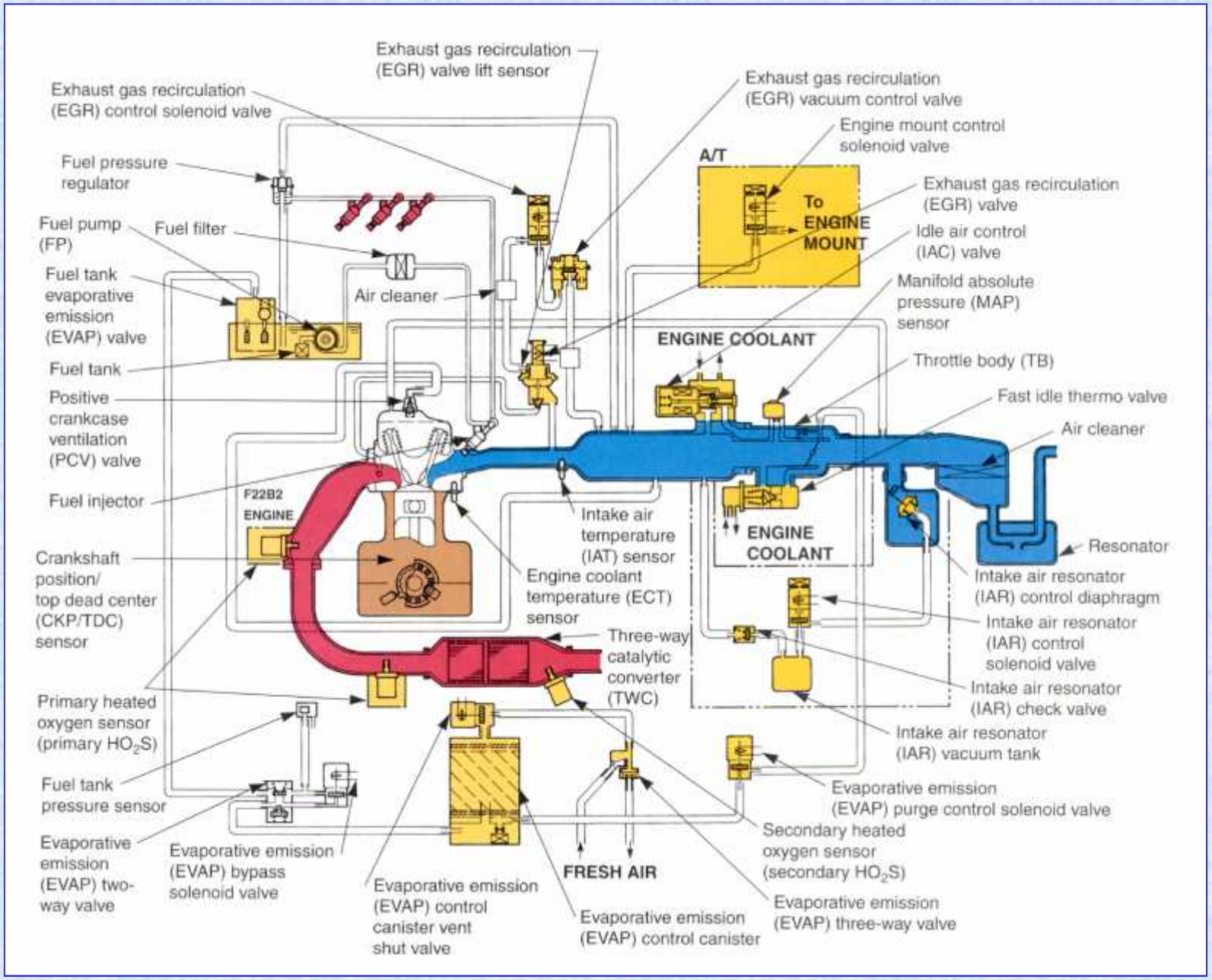

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Oxygen Sensors

- Primary or front
  - monitors oxygen in exhaust gases as they leave the engine
  - used for air-fuel mixture control
- Secondary or rear
  - downstream in exhaust
  - may monitor converter operation
  - may monitor the oxygen content of gases entering the converter

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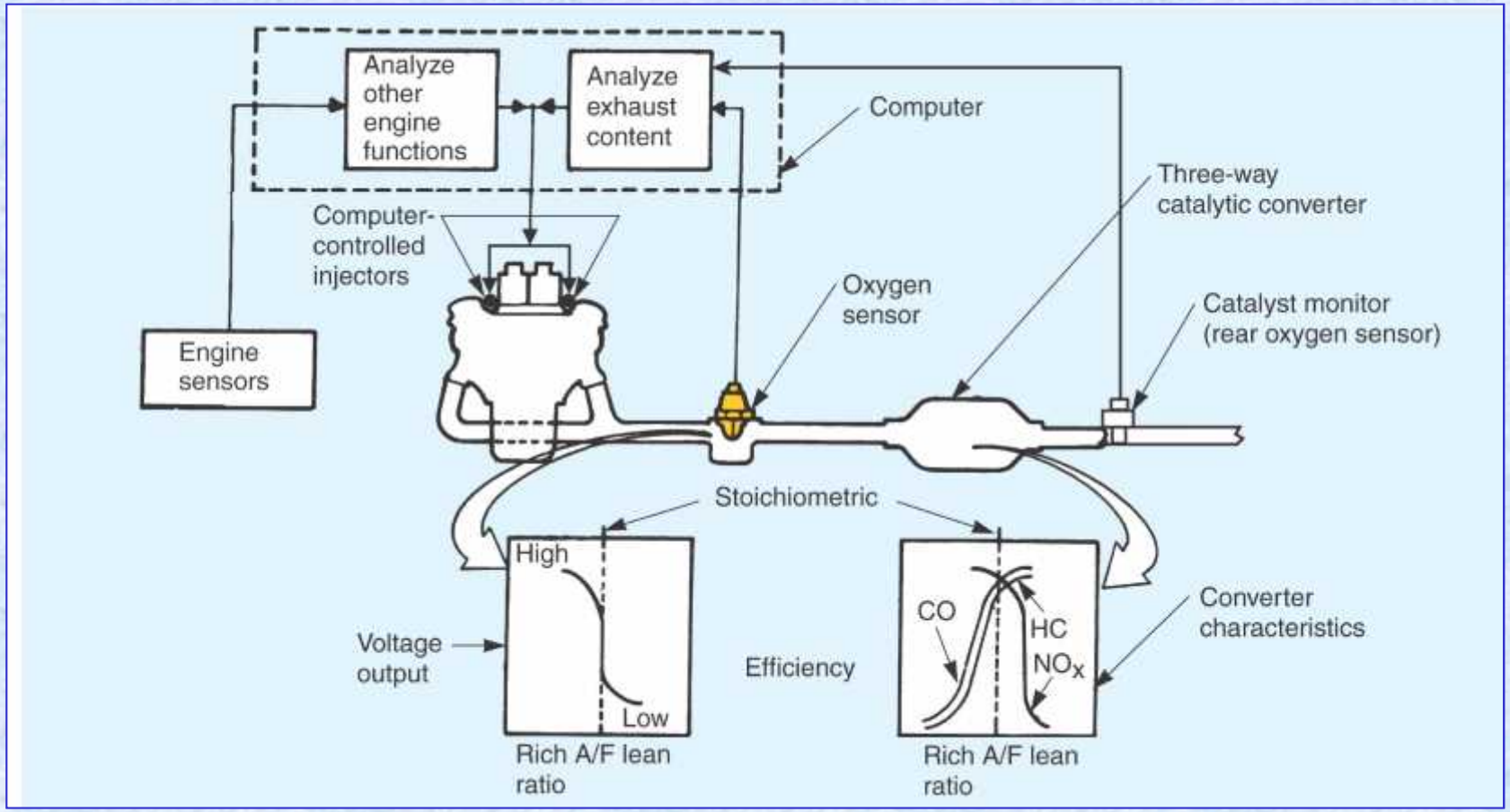
System Operation



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Oxygen Sensor Position

- Numbered by its location and order in relation to the engine's banks
- The sensor closest to the number one cylinder is **O_2 Sensor, Bank 1, Sensor 1**
- The sensor in the opposite bank is **O_2 Sensor, Bank 2, Sensor 1**
- Downstream sensors have higher numbers

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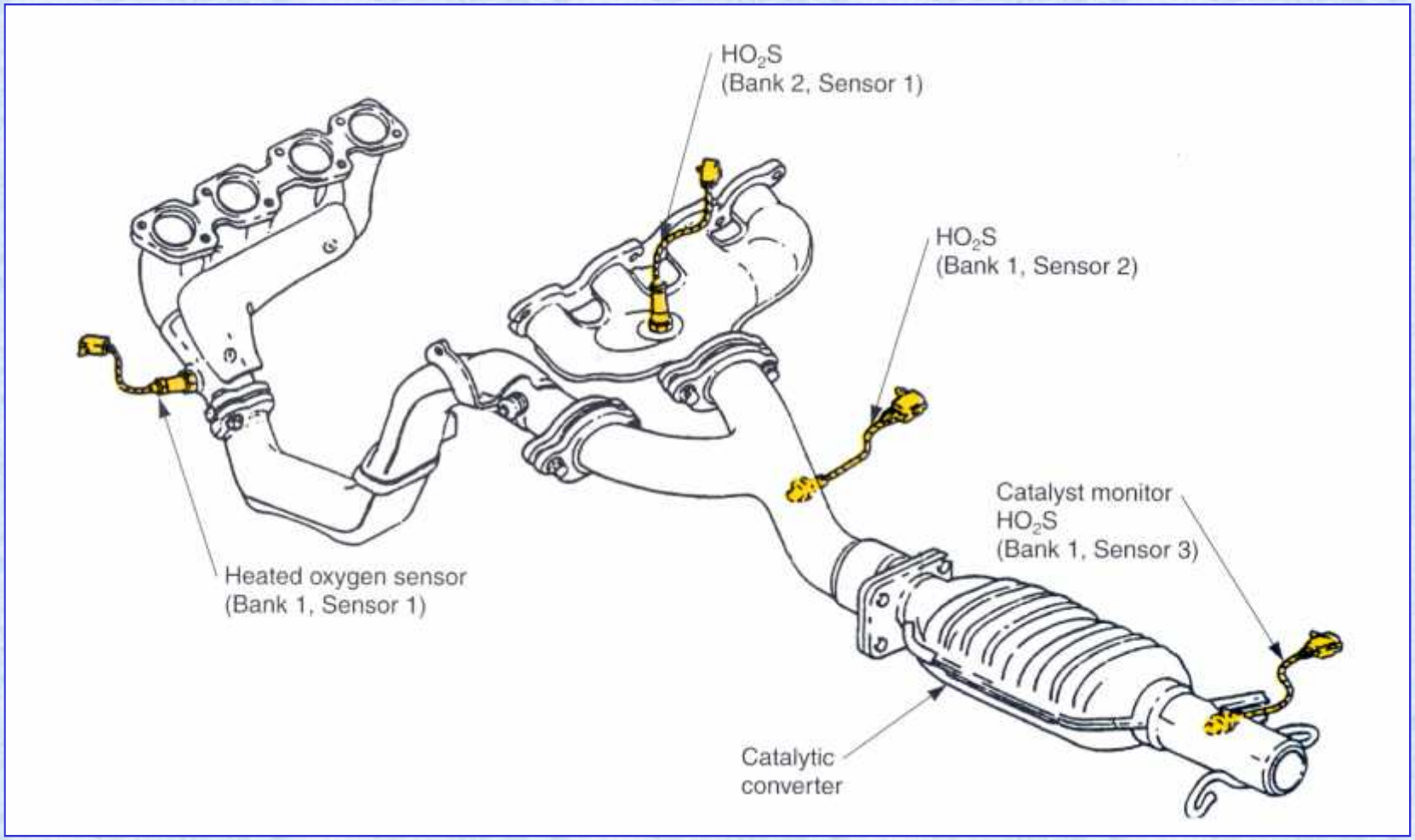
Oxygen Sensor Position



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Heated O_2 Sensors

- An internal electric heating element quickly warms the sensor to operating temperature
  - keeps the sensor warm during engine idle
  - provides useful O_2 signal sooner after startup

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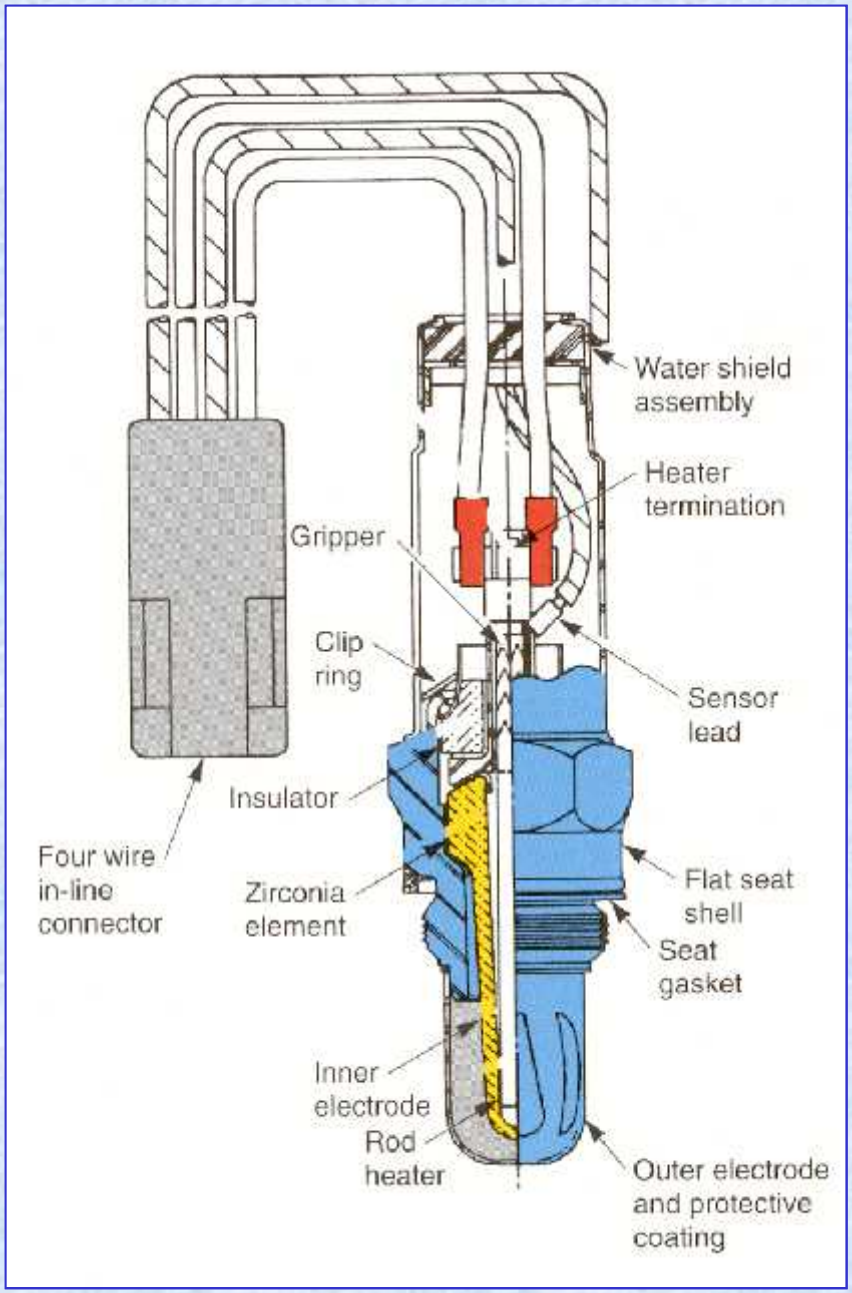
Zirconia Oxygen Sensor



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Zirconia Oxygen Sensor

- The inner and outer surfaces are coated with platinum, used to produce a voltage output
- Ambient air is supplied to the inside layer
- The outside layer is exposed to exhaust gas
- The minimum operating temperature is 600°F (315°C)

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Sensor Operation

- When hot, the sensor element becomes a semiconductor and generates a small voltage
- If oxygen in exhaust stream is low, as with a rich mixture, the sensor output is high
- If oxygen in exhaust stream is high, as with a lean mixture, the sensor output is low

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Reference Voltage

- A computer applies a reference voltage to the O_2 sensor circuit
  - 450 mV (0.45 volts)
- When the sensor pulls a voltage above this value, it signals a rich mixture, and the computer reduces fuel
- When sensor pulls voltage below this value, it signals a lean mixture, and the computer increases fuel

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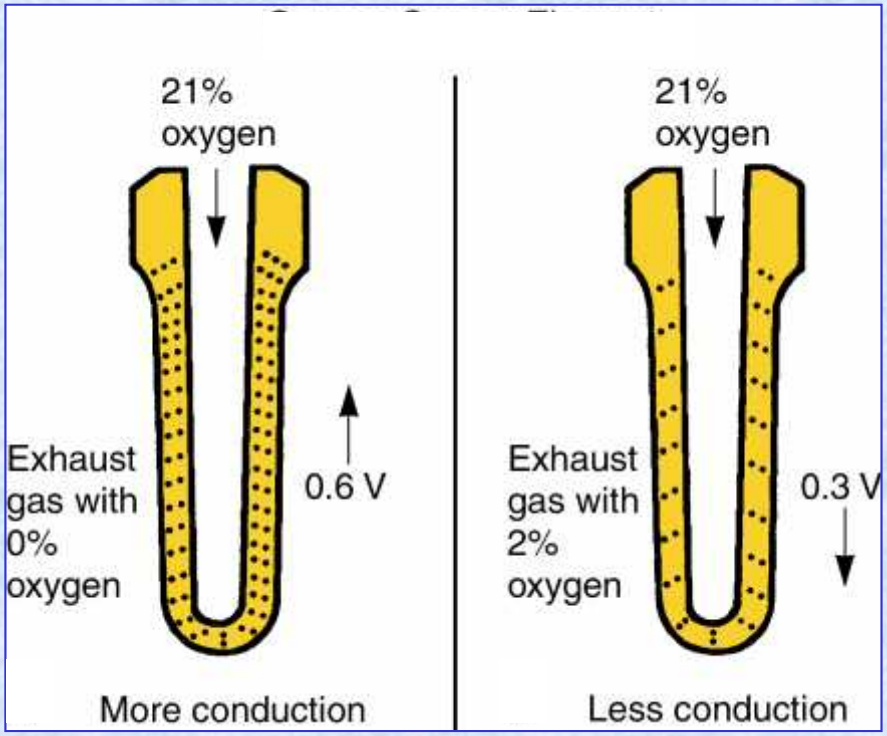
Oxygen Sensor Element



Rich mixture Lean mixture

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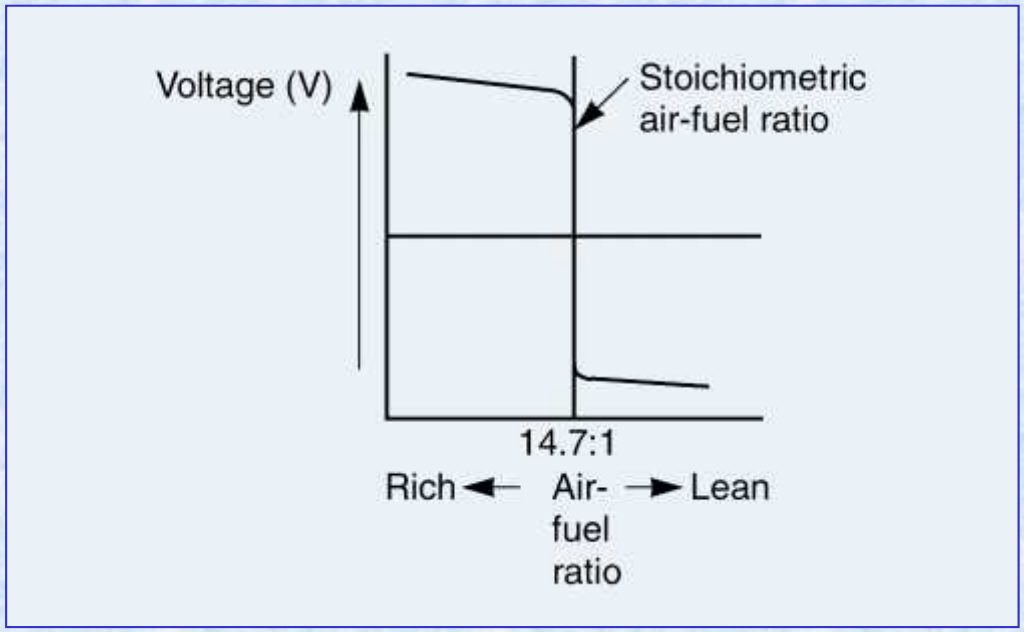
Oxygen Sensor Output



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Titania Oxygen Sensor

- Varies its internal resistance in relation to the exhaust oxygen level
- The internal resistance modifies a reference voltage
- Provides a signal almost immediately after startup
- Small, sealed unit

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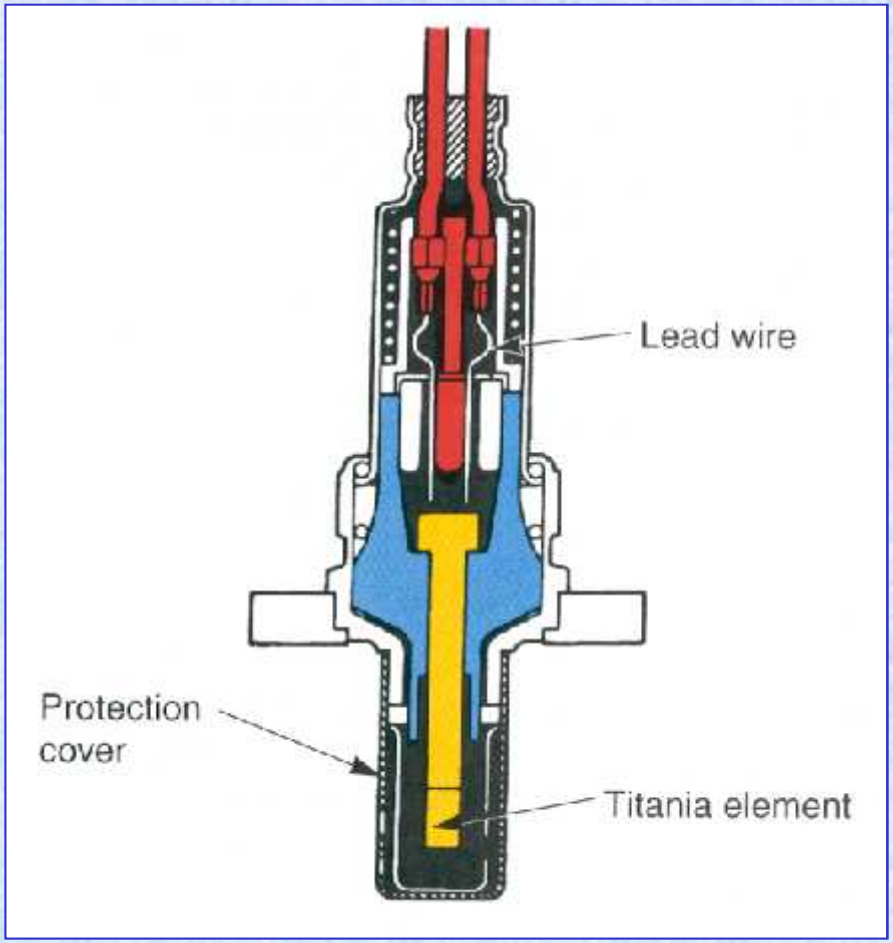
Titania Oxygen Sensor



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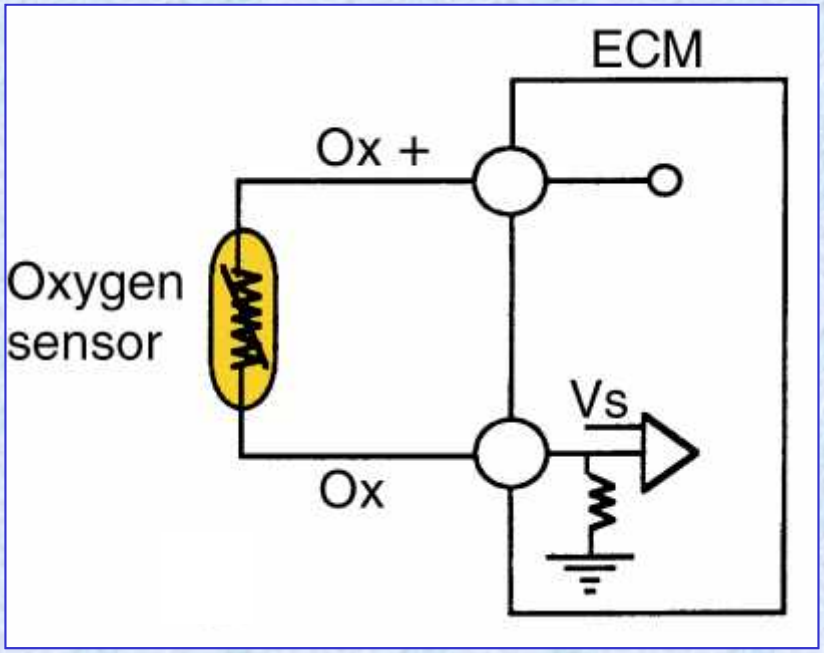
Titania Oxygen Sensor Circuit



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OBD II Emission System Monitoring

- Monitors for:
  - catalytic converter efficiency
  - engine misfire
  - O_2 sensor output
  - EGR valve action
  - fuel injection
  - air injection
  - evaporative emission system

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OBD II MONITORS	ECM INPUT	DATA FROM
Air-injection system	Oxygen content leaving the catalyst	Rear oxygen sensor
Fuel-injection system	Change in the air-fuel-ratio control limits	Front oxygen sensor
Catalyst efficiency	Catalytic converter's oxygen storage capacity	Front and rear oxygen sensors
Engine misfires	Crankshaft speed and road conditions	Crank-position sensors, vehicle accelerometers, ABS sensors
Oxygen sensors	Sensor switching frequency	Front and rear oxygen sensors
Exhaust-gas-recirculation system	Change in the air-fuel-ratio control limits	Front oxygen sensor
Fuel vapor leaks	Pressure capacity of the fuel tank and lines	Leak-detection pump

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Evaporative System Monitor

- Checks components for leakage and restrictions that could increase emissions
- If the system does not pressurize and depressurize normally, a DTC is set

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EGR Monitor

- The computer turns the EGR off while checking the O_2 sensor readings
- Changes in the EGR opening affect the air-fuel mixture
- If changes do not affect the O_2 sensor readings, a DTC is set

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Catalyst Monitor

- Uses at least two O_2 sensors
  - one before the converter and one behind it
- If the signal from the rear O_2 sensor becomes too similar to the engine-mounted sensor signal, the converter is not working properly
  - a DTC is set, and the MIL is illuminated

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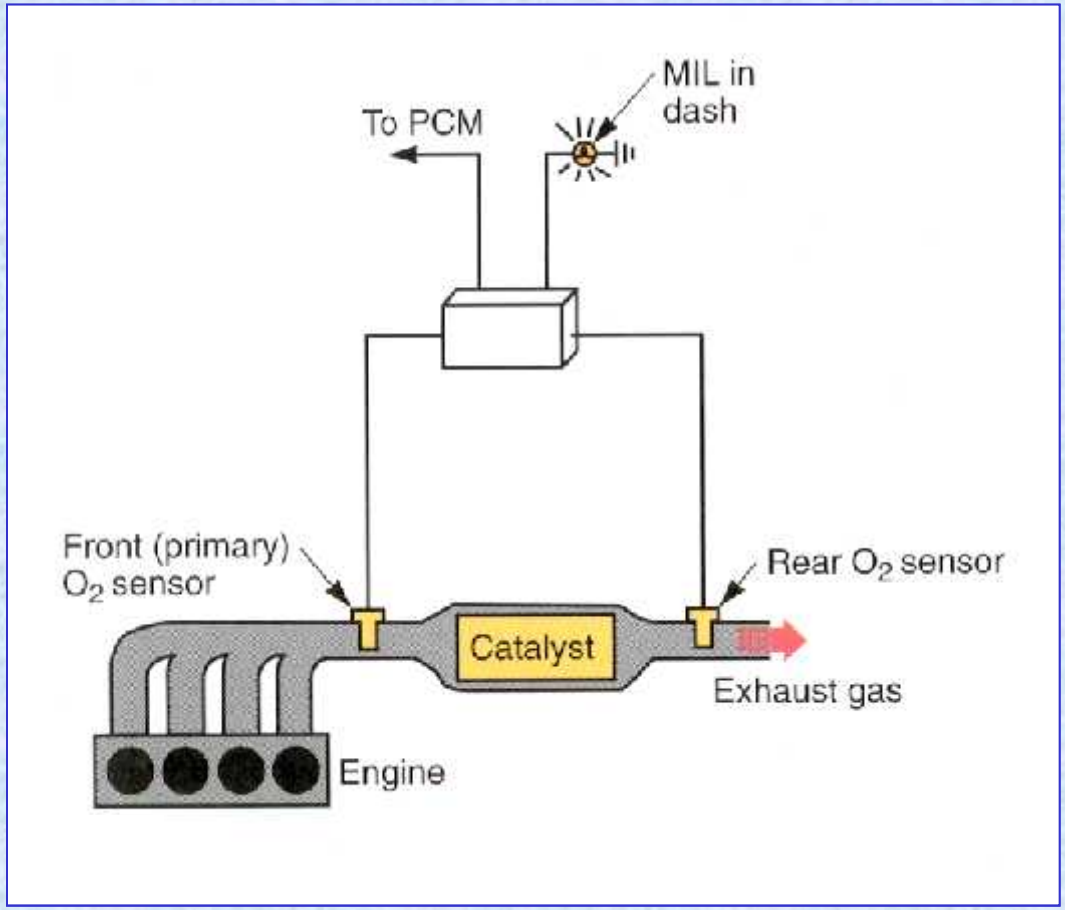
Catalyst Monitoring System



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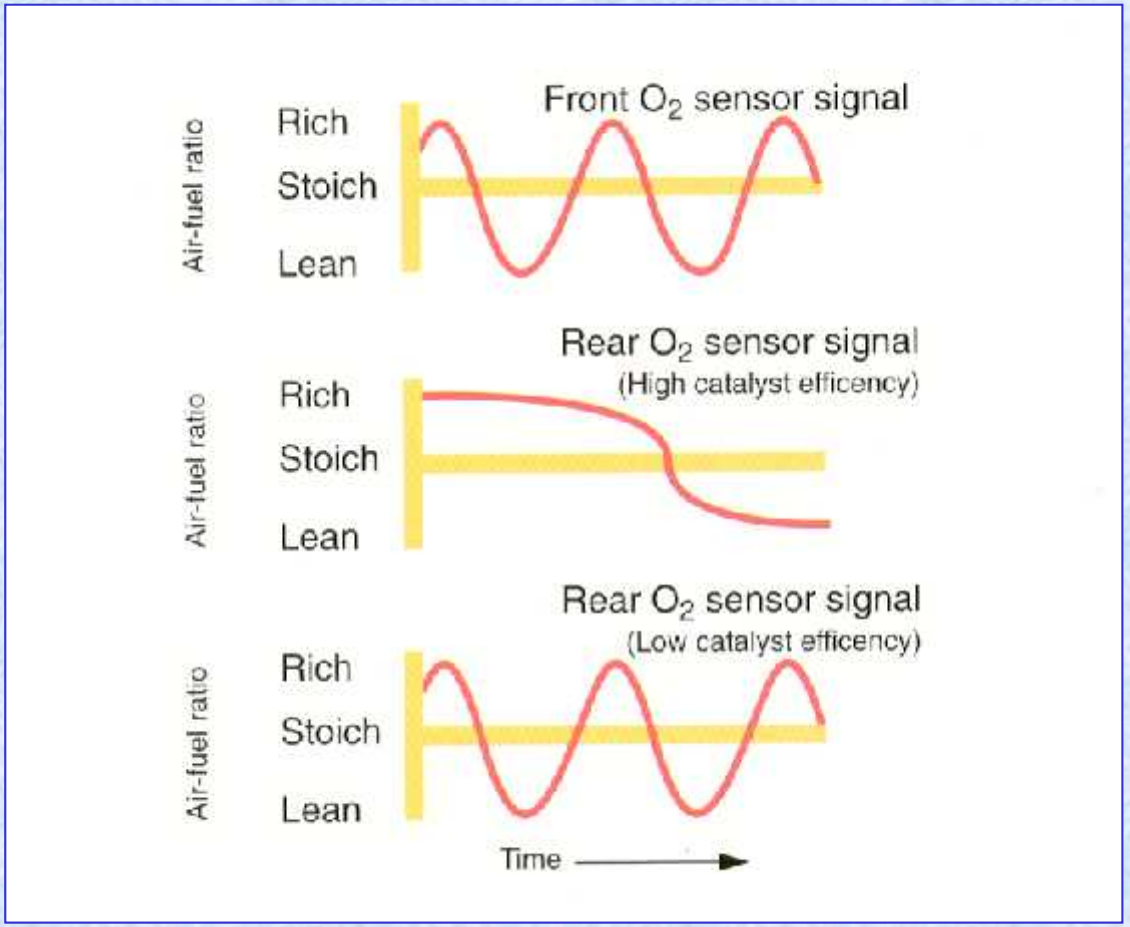
Catalyst Monitor



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Misfire Monitoring

- Uses crankshaft speed changes to signal an engine misfire
- If crankshaft speed fluctuations are detected, the ECM sets a diagnostic trouble code

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Sensor Monitoring

- The ECM compares normal sensor signal variations to the actual operating values
- If a sensor signal goes out of range, a diagnostic trouble code is set

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Actuator Monitoring

- The ECM determines if an actuator is drawing too little or too much current
- Detects actuators and circuits that have problems
  - injectors
  - EGR valves
  - evaporative solenoids

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