Common Sense Approach To Diesel Emissions

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Diesel Emissions

ONE

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Diesel Emissions

- ***Diesel Emission Advantages***
  - produces lower levels of Hydrocarbons and Carbon Monoxide than a comparable gasoline-fueled engine.

- ***Diesel Emission Disadvantages***
  - due to the nature of the combustion process and the lower refinement of fuel, diesel engines produce much higher levels of Oxides of Nitrogen and Particulate Matter.

Pollutants

Motor vehicles are a major source of pollutants that contribute to the formation of smog, and other environmental and health problems.

- These pollutants are:
  - **NO_x** Nitrogen Oxides
  - **VOCs** VOC's primarily HC's &partially oxidized HC's
  - **PM10** PM of 10 microns in diameter & smaller
  - **CO** - Carbon Monoxide
  - **SO_x** - Sulphur Oxides
  - **CO2** - Carbon Dioxide

Ozone Formation

In the presence of light and heat; NOx and VOC's react to form ozone

– a primary element of smog

- **Smog is a mixture of**
  – Gaseous
  – Solid
  – liquid pollutants
- **harmful to human health, plant life & building materials**

Ozone Formation

- Ozone occurs naturally in the upper atmosphere as a gas that shields the earth from ultraviolet radiation.

- At ground level, Ozone causes inflammation of the lungs and reduces their functional capability and resistance to infection.

- There is no “safe” or “acceptable” level of ozone in breathable air.

- Detrimental health effects linked to Ozone can occur at any concentration.

Particulate Matter Formation

- The term “Particulate Matter” (PM) refers to a mixture of solid particles and liquid droplets in the air.
- The origin of coarse PM10 includes
  – road dust
  – dust from agricultural activity

  comes from a wide variety of sources
    - including windblown dust
    - construction activity and grinding operations

Particulate Matter Formation

PM 2.5 can form from SO_x, NO_x & VOC's in the atmosphere after the initial combustion of fuel

PM is a form of carbon caused by incomplete combustion of diesel fuel.

- Sources for PM 2.5 include:
  - fuel combustion in motor vehicles (especially diesel trucks and buses)
  - power plants
  - factories
  - wood-burning stoves and fireplaces.

Health Effects

- Particulate matter varies widely in it origin, size and chemical/physical composition.

- Fine particles (2.5 microns and smaller), pose a threat to human health.

Health Effects

- PM that originates from diesel fuel combustion presents particular health risks
  - PM from diesel engines is typically smaller than 0.1 micron
- Particles this size are known as ultra-fine "nano" particles.
- penetrate deep within the air-carrying cells of the lungs.
- Ultra-fine particles from diesel engines consist of a number of substances

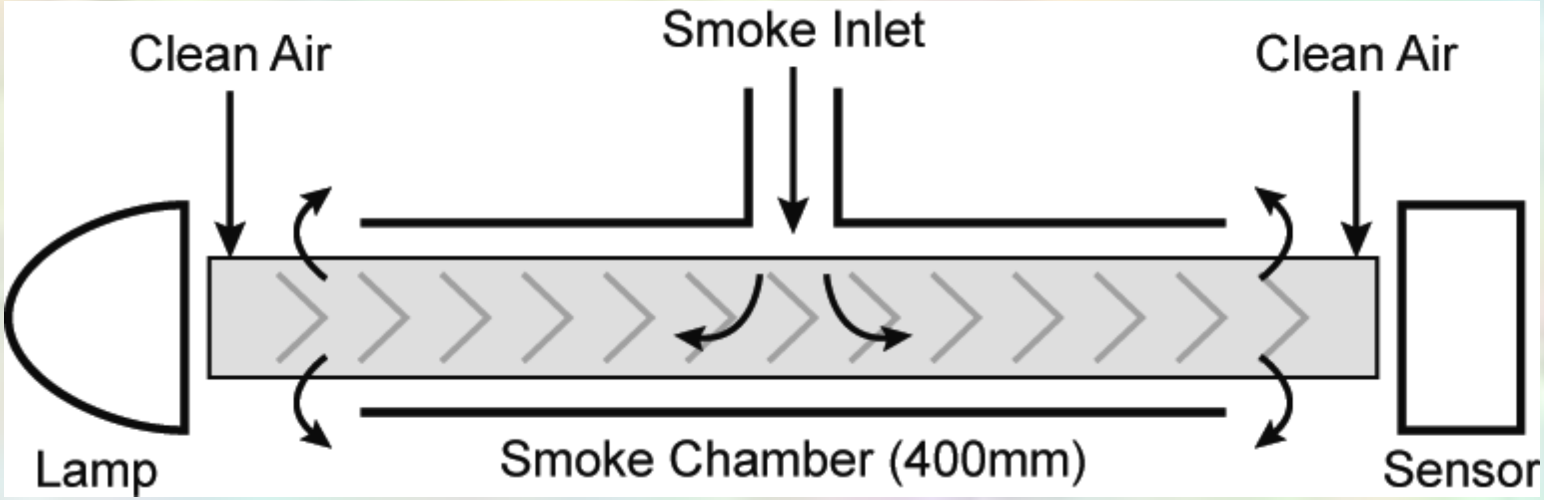
Health Effects

- particularly fine particles linked to such health effects as:

- Asthma attacks
- Coughing and difficulty in breathing
- Chronic bronchitis
- Decreased lung capacity
- Lowered resistance to infection
- Premature death

Diesel Emissions Testing
Opacity Meter

- An opacity meter is a smoke density, measuring device
- Light is directed through a chamber and an optical sensor measures the intensity of light received through the smoke sample



STUDY QUESTIONS

DIESEL EMISSIONS

1. PM from diesel engines is most often typically smaller than ________________.
   A. 10 microns
   B. 2.5 microns
   C. 0.1 micron
   D. None of the above

DIESEL EMISSIONS

2. When it pertains to emissions, one of the disadvantages of a diesel engine is

   A. diesel engines require changing engines several times during the life cycle of the vehicle

   B. HC and CO_2 emissions increase so less of these pollutants are admitted to the atmosphere.

   C. diesel engines produce much higher levels of NOx and particulate matter to the atmosphere.

   D. diesel engines produce much higher HC and CO levels than a gasoline engine.

DIESEL EMISSIONS

3. The health effect linked to Particulate Matter (PM), particularly fine particles are

   A. asthma attacks and chronic bronchitis

   B. coughing and difficulty breathing

   C. lowered resistance to infection and premature death

   D. All of the above

DIESEL EMISSIONS

4. One of the advantages of a diesel engine over a gasoline engine when it pertains to emissions is:

   A. a diesel engine does not create pollutants

   B. a diesel engine only creates NOx, and we do not test diesel engines for NOx

   C. a diesel engine produces lower levels of HC and CO than a gasoline engine

   D. a diesel engine produces lower levels of all pollutants than a gasoline engine

DIESEL EMISSIONS

5. At what size microns can Particulate Matter (PM) penetrate deeply into the lungs and pose a serious threat to human health?

   A. 10 microns

   B. 5 microns

   C. 2.5 microns

   D. 20 microns

Diesel Engine Operation

TWO

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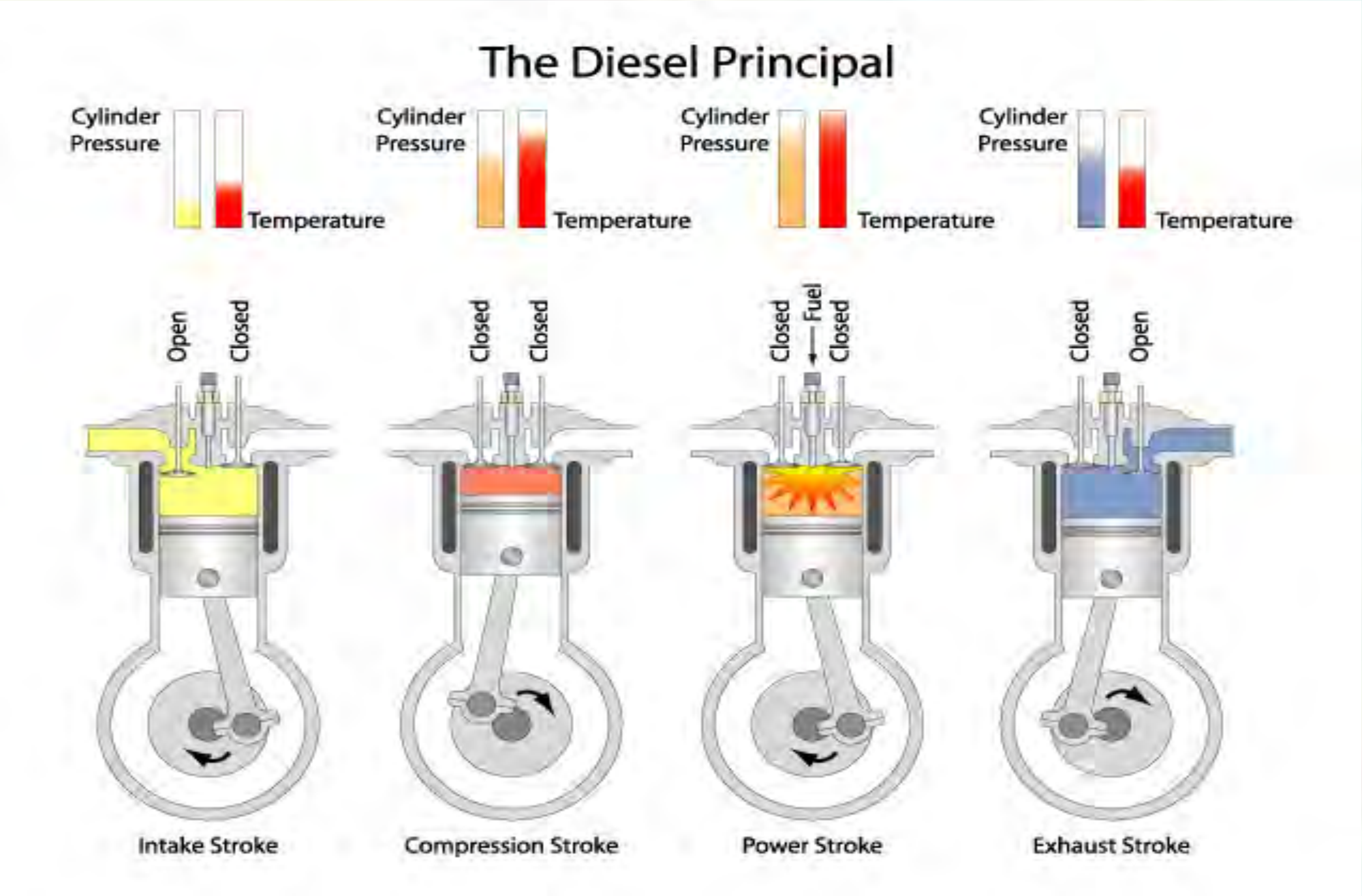
Four Stroke Diesel Engine Operations



Diesel Combustion Systems

Pre-Chambers (Indirect Injection-IDI Systems)

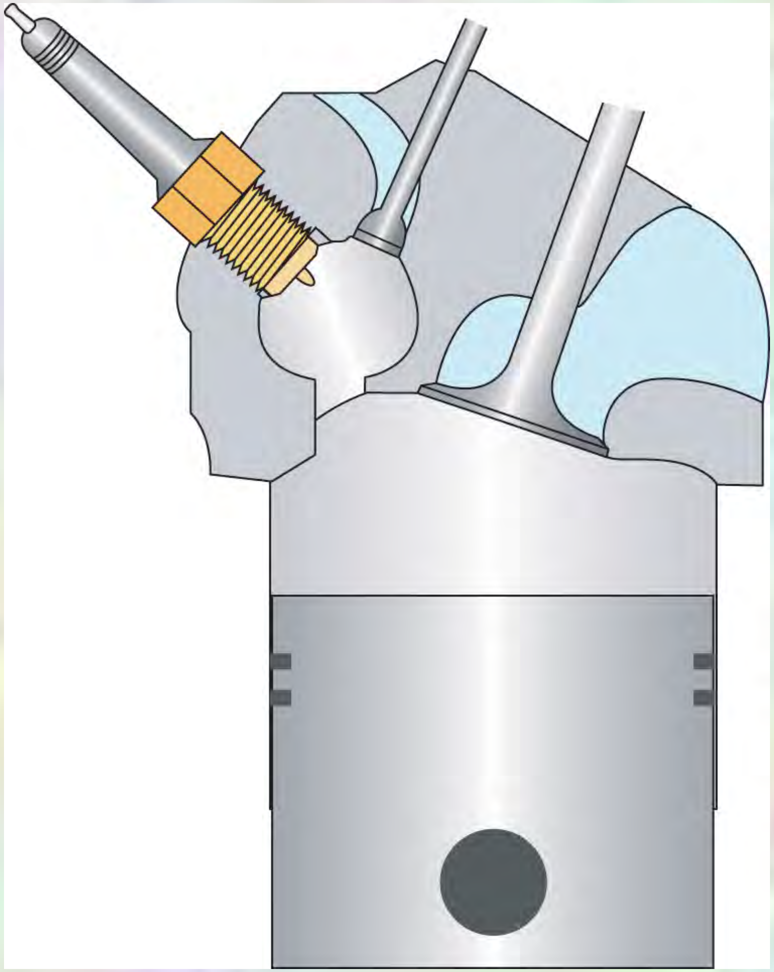
Small, auxiliary combustion chamber

Connected to main chamber by a narrow orifice

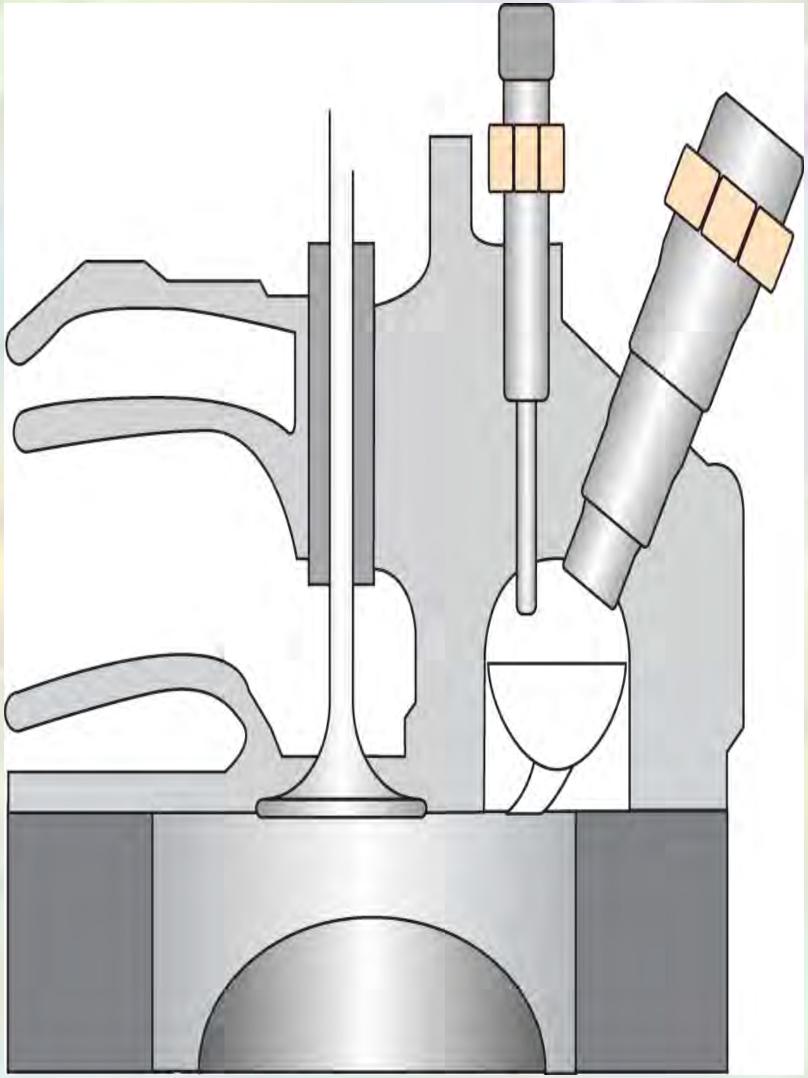
Fuel will ignite and cause the hot gases to expand into main chamber

Pre-chamber will generally equal approx. 20-30% of the cylinder's TDC volume

More emission-friendly, but not the most efficient for power creation



Swirl Chamber (Indirect Injection-IDI Systems)



- similar to the pre-combustion chamber
- use a separate chamber for both fuel mixture and the beginning of the combustion process
- Allow for lesser atomization of fuel, but still provide highly efficient combustion
- Will reduce particulate emissions while increasing power
- The swirl inside the combustion chamber reduces particulate emissions

DIRECT INJECTION

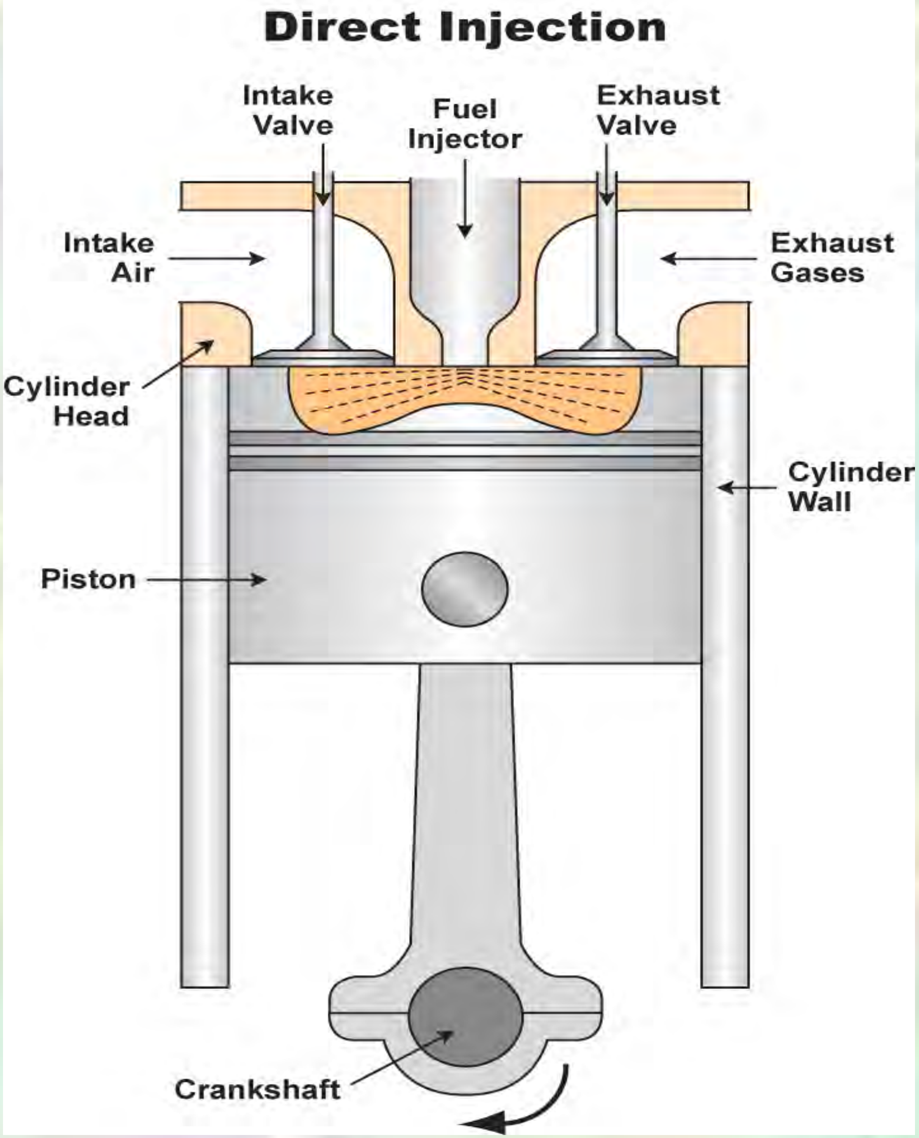
Most common in the world of heavy-duty trucks

Combustion chamber does not divide

Injects fuel directly into cylinder

Operates at higher fuel pressure for maximum fuel atomization

Achieves greater efficiency by enhancing fuel mixing through internal chamber turbulence which is created by the design of the piston crown



STUDY QUESTIONS

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DIESEL ENGINE OPERATION

1. **The most common type of combustion chamber for a heavy-duty truck is______________________**

A. Pre-Chamber

B. Direct Injection Chamber

C. Swirl Chamber

D. None of the above

DIESEL ENGINE OPERATION

2. **TRUE or FALSE** - Indirect injection systems use a separate chamber for both fueling and the beginning of the combustion process.
   TRUE

3. **TRUE or FALSE** - The combustion chamber does NOT divide in the direct injection chamber design.
   TRUE

Power

Fuel Economy

&

Low Emissions

THREE

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Improving Power Means Increasing Flow

To get more power out of an engine - increase
- the amount of air
- the amount of fuel that the engine can burn

- either by adding cylinders or making the cylinders bigger
  - or by
- increasing the volume of air and fuel moved through the engine by other means
  - Turbochargers
  - Superchargers
  - Intercoolers

Turbochargers

- a type of forced induction system

- Purpose is to compress the air flowing into the engine
- to squeeze more air into a cylinder

- More air means more fuel can be added
- More air and more fuel = more power from each explosion in each cylinder

- to accomplish this boost, the turbocharger uses the exhaust flow from the engine to spin a turbine, which in turn spins an air pump

Turbochargers

- This process forces approximately 50% more air into the engine
- a 30 - 40% power improvement is the norm
- Placing a turbine in the line of exhaust flow increases restriction in the exhaust
  - on the exhaust stroke, the engine must act against higher backpressure
  - taking away a certain amount of power from any cylinders that are firing at the same time

Turbochargers

- One of the main problems with turbochargers is
  - they do not provide an immediate power boost under acceleration
- The turbine takes a moment to reach speed before generating boost
  - results in a lag felt under acceleration
- to decrease this turbo lag
  - need to reduce the inertia of the rotating parts
    - by reducing their weight
    - allows the turbine and compressor to accelerate quickly and provide boost sooner
- A sure way to reduce the inertia is a smaller turbocharger that will provide boost more quickly and at lower engine speeds

Turbochargers

- Most Turbochargers have a Wastegate
  - allows the use of a smaller turbocharger to reduce lag, yet prevents the turbine from spinning too quickly at high engine speeds
- The wastegate is a valve that allows the exhaust to bypass the turbine blades
  - If pressure gets too high, it could indicate that the turbine is spinning too quickly
  - the wastegate allows the blades to slow down
- The wastegate senses boost pressure and bypasses some of the exhaust flow around the turbine blades, if necessary

Turbochargers

- Some engines use two turbochargers of different sizes
  - The smaller one spins up to speed very quickly, reducing lag
  - The larger unit takes over at higher engine speeds to provide more boost
  - Some engines use Variable Geometry Turbochargers that allow the effective aspect ratio to be altered as conditions change, for reduction of turbo lag at low speeds.

- As air is compressed, it heats up - when air heats up, it expands

- some of the pressure increase from a turbocharger comes as the result of heating the air before it goes into the engine

Turbochargers

- Intercooler or Air Charge Cooler
  - an additional component that looks similar to a radiator
- air passes through the inside as well as the outside of the intercooler
  - The intake air passes through sealed passageways inside the cooler
  - the engine cooling fan blows air from outside across the cooling fins

Turbochargers

- further increases the power of the engine by cooling the pressurized air coming out of the compressor before it goes into the engine
- This means that if the turbocharger is operating at a boost of 7 PSI
- the intercooler system will provide 7 PSI of cooler air

Turbochargers

Supercharger

A supercharger is another device that compresses the combustion air or the air/fuel mixture before it enters the engine cylinder

In a typical supercharger system, the engine itself will drive the unit through a system of

- gears
- a belt drive
- an electrical motor

Fuel Injection-Mechanical

Pump in-line injection systems

- similar to a carburetor
- remained in use for a long period
- being replaced by systems offering better performance

- a camshaft-driven pump determines fuel injection pressure & timing

- primary disadvantages
  - variation of injection pressure relative to engine speed
  - difficulty in generating high injection pressures at low speed

Fuel Injection

Rotary Pump Systems

- electronically or hydraulically controlled-offer a major improvement over pump in line systems
  - a single pumping element replaces the individual pumps
  - A rotary valve distributes fuel to the proper cylinder
  - There is a reduction in the number of components
  - insures that fuel delivery to each cylinder is identical
- This simplifies system calibration

Fuel Injection

Unit Injector Systems

Used in many large-bore diesel engines

- These combine the pump and injector into a single camshaft-driven unit

- The combination pump/injector design eliminates the pressure oscillations found on pump in line systems

  – the use of a lobe on the camshaft to drive the injector pump makes variation of timing with engine speed impossible

Fuel Injection-Electronic

Electronic Unit Injector (EUI) Systems

- use camshaft power to pressurize the fuel
- an electronically controlled solenoid determines injection timing & duration
- the high-pressure fuel is available only during a fixed cam period
- full control of injection parameters over a wide range of engine speeds and loads is still not possible with these units

Fuel Injection-Electronic

Electronic Direct Injection

- Electronic direct injection evenly distributes fuel from injector to injector throughout the system
  - creates more power with each injector pulse than indirect injection
  - pressure generation operates independently from engine speed
- The electronic direct injection system is programmable for optimal performance over the entire engine speed range to allow for new levels of
  - fuel efficiency
  - emissions
  - driving comfort under all conditions

Electronic Direct Injection

- The low-pressure pump draws fuel from the tank through the Electronic Driver Unit (EDU)
- The fuel then cools the electronics, which, in turn, actuate solenoid valves in each injector

Electronic Direct Injection

ELECTRONIC DRIVER UNIT (EDU)

- The EDU works with the Engine Control Module (ECM) to provide a strong, precise signal for each cylinder's combustion
- The ECM also controls pressure in the fuel rail to ensure correct, precise fuel delivery

From the EDU, fuel passes through an engine-mounted fuel filter

- The filter has
  - water sensor
  - water separator
  - fuel heater
    - If necessary, the heater warms the fuel to 57° F to prevent any waxing of the fuel

Electronic Direct Injection

- The fuel then goes to the high-pressure pump
- If the ECM and EDU function as the “brain” of the system, the high-pressure pump is the “heart”
- The high-pressure pump sends fuel to the rails at variably controlled pressures of up to 23,000 PSI
- From there, the system distributes fuel to the injectors at each cylinder
- With a constant pressure feed, the injector can now open, remain open or close as directed by the ECM and EDU

Electronic Direct Injection

- The systems interpret various sensor inputs in order to achieve effective combustion for the conditions present
- Typically located in the cylinder head-the injector features a custom-designed spray pattern matching the combustion chamber
- To enable
  - ❖ improved fuel efficiency
  - ❖ lower emissions
  - ❖ reduced thermal loss
  - ❖ most efficient combustion

Electronic Direct Injection

Common Rail Systems

- A common rail fuel system provides high injection pressures throughout the engine operating range by feeding a continuous flow of high-pressure fluid to each injector
- The configuration of a common rail system very closely matches a port-injected gasoline fuel injection system
- Individual injectors feed from a continuous supply of high-pressure fuel available at a fuel rail
- The ECU controls
  - common rail supply pressure
  - the start of injection
  - injection rate shape
  - quantity of fuel injected

Electronic Direct Injection

**Common Rail Injection System Contributes to The Advanced Clean Diesel
System**

- **All internal combustion engines need two key ingredients in order to operate:**
  - **air**
  - **Fuel**

- **Precision delivery of air and fuel makes clean and powerful combustion possible**

Common Rail Injection System

- high fuel pressure produces a fine mist of fuel that burns better and cleaner in the combustion chamber

- for each combustion cycle, the common rail allows up to five injections per cycle

- the benefits are
  - lower fuel consumption
  - better engine performance
  - less noise than offered by older diesel systems

Common Rail Injection System

- How an injector delivers fuel into the cylinders determines
  - the torque
  - fuel consumption
  - emissions
  - noise level of diesel engines
- Two factors are important:
  - the fuel pressure as it enters the cylinder
  - the shape and the number of the injections

Common Rail Injection System

- A common-rail injection system separates the functions of generating pressure and injecting fuel by
  - first storing the fuel under high pressure in a central accumulator rail
  - delivering it to the individual electronically-controlled injection valves (injectors) on demand
- This ensures that extremely high injection pressures (over 25,000 PSI in some systems) remain available at all times, even at low engine speeds

Hydraulic Electronic Injection (HEUI) System

- A solution to the shortcomings of the electronic unit injector system is the Hydraulic Electronic Unit Injector (HEUI) system developed by Caterpillar
  - In this system, a constant supply of high pressure engine oil feeds each injector and allows the injector to produce the required high injection pressure

Hydraulic Electronic Injection (HEUI) System

- A solenoid located in each injector controls the hydraulic system, allowing for a wide range of control over the injection event without the high-pressure distribution system used by common rail injection systems
- Using high-pressure lube oil from the engine to power down the piston of the injector barrel, the HEUI system lowers noise and allows for a much broader range of control over fuel delivery/timing

Exhaust Gas Recirculation (EGR) System

Pre-Combustion

Exhaust gas recirculation (EGR)-routing some of the exhaust gas to the intake manifold is widely used in internal combustion engines to control NOx emissions

Using an EGR in a diesel requires:

- electronic control of the EGR
- EGR cooling to limit the increase in Particulate Matter (PM)

Exhaust Gas Recirculation (EGR) System

Pre-Combustion

EGR displaces part of the intake air so it can increase the overall fuel-to-air equivalence ratio to a point that can lead to large increases in PM emissions

Hot EGR furthers this problem by increasing the temperature of the intake air

The increased temperature decreases air density and reduces the volume of intake air entering the engine

Exhaust Gas Recirculation (EGR) System

Exhaust Gas Recirculation (EGR) is an effective strategy to control NOx emissions from diesel engines

The EGR reduces NOx by lowering the oxygen concentration in the combustion chamber, as well as through heat absorption

Several proposed configurations of this system exist

- high-pressure loop EGR
- low-pressure loop EGR
- hybrid systems

Cooled EGR additions to the systems - in which an EGR cooler using jacket water cools recirculated exhaust gas have been put into operation to further reduce NOx emissions

Exhaust Gas Recirculation (EGR) System

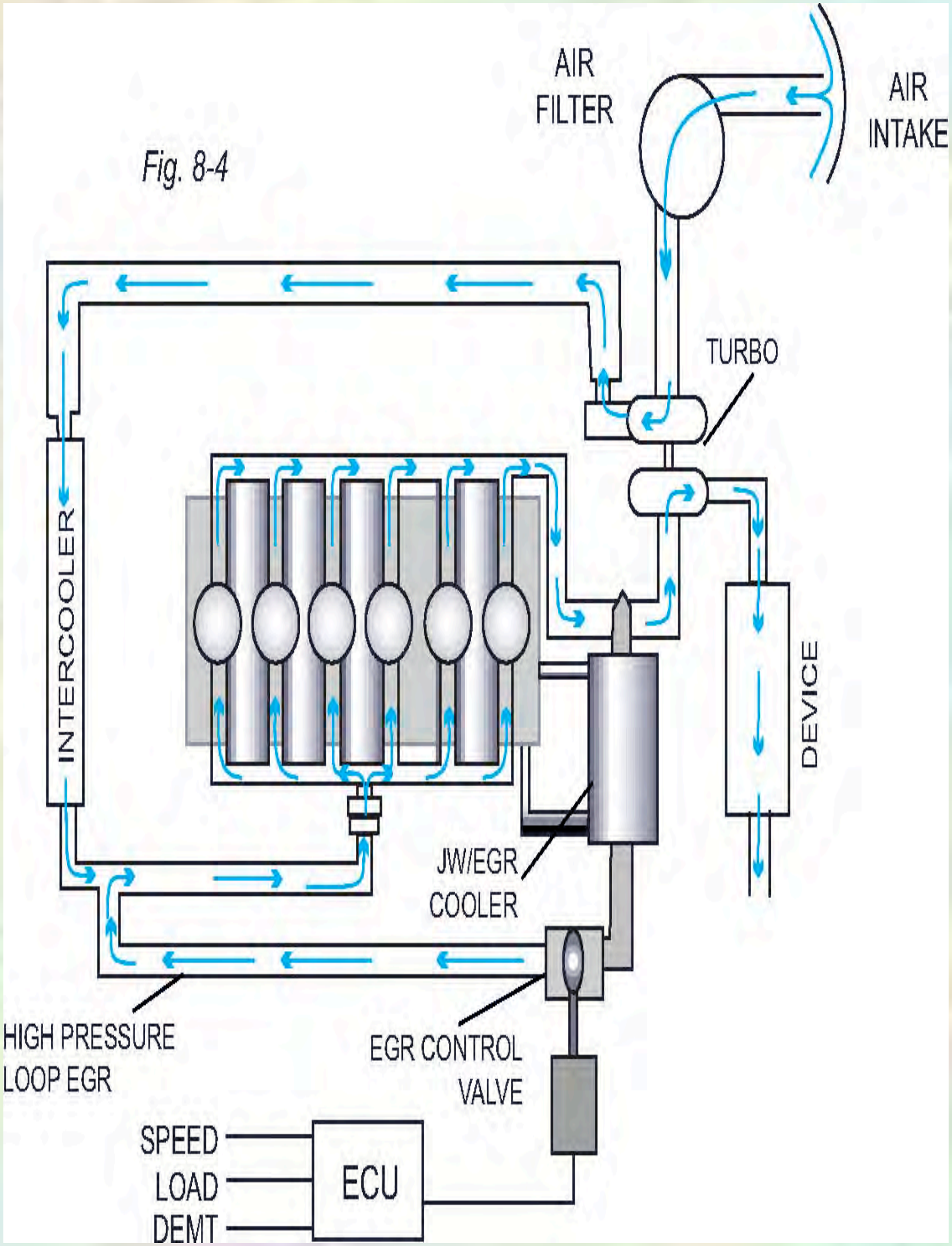
Cooled EGR systems typically use an engine coolant heat exchanger to cool the recirculated exhaust gases before mixing with the intake air.

EGR cooling can significantly reduce the increase in intake air temperature associated with EGR.

Though EGR cooling greatly extends the operational range over which EGR can be used electronic control of the EGR is necessary to prevent large PM increases under hard acceleration.

High-Pressure Loop (HPL) EGR

A portion of the exhaust flow returns to the engine cylinders through an electronically controlled EGR valve after cooling



High-Pressure Loop (HPL) EGR

In HPL EGR implementations, turbocharger matching usually compensates for a loss of turbocharger effectiveness

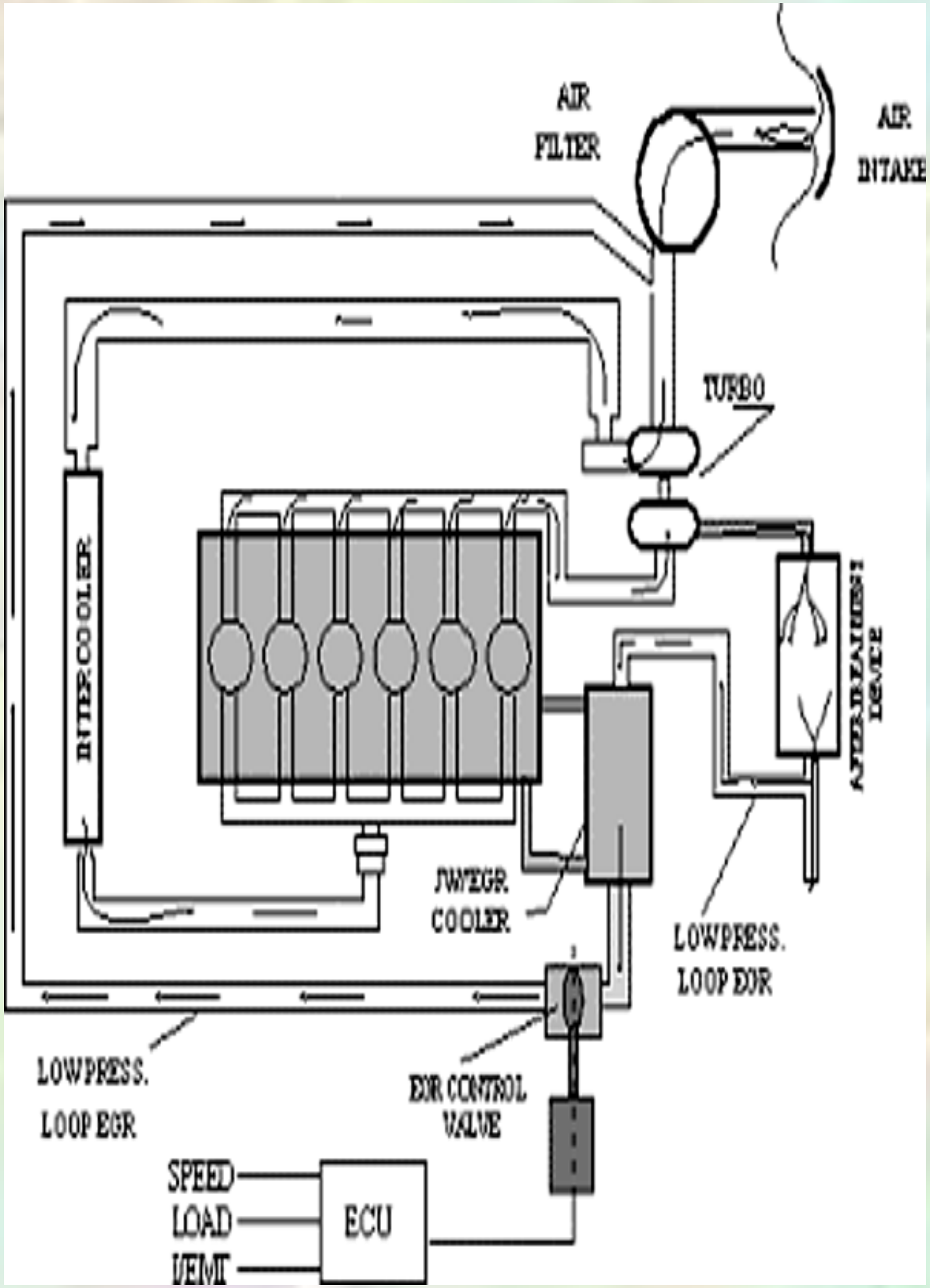
This occurs when a portion of the exhaust is intercepted and its energy re-routed away from the turbine wheel

To increase the pressure drop between the exhaust and intake manifolds, some applications have utilized a venturi to facilitate EGR flow into the engine inlet duct

These designs normally increase the kinetic energy of EGR, allowing more of it to flow with lower pumping losses

Low-Pressure Loop (LPL) EGR

Often used in conjunction with particulate filter-based after-treatment systems



Low-Pressure Loop (LPL) EGR

this system may add several benefits

To help the flow, EGR re-enters the engine just upstream of the turbocharger compressor.

The pressure difference between points downstream of the trap and upstream of the turbocharger is generally adequate for the EGR flow rates needed to reduce NOx to the mandated level required for heavy-duty diesel engines.

Low-Pressure Loop (LPL) EGR

- Advantages of the LPL EGR system include:
  - Lower fuel consumption and better turbocharger performance
  - Preserving engine durability by using a particulate filter to admit filtered exhaust through the turbocharger compressor to the inlet of the engine.
  - Higher heat absorbing capacity for flow rates similar to those of the HPL EGR, since exhaust gas downstream of the particulate filter is cooler than that from upstream of the turbocharger (as in the HPL case).

Low-Pressure Loop (LPL) EGR

- The opportunity to reduce EGR cooler size, and provide a more compact unit, because of the higher heat-absorbing capacity.

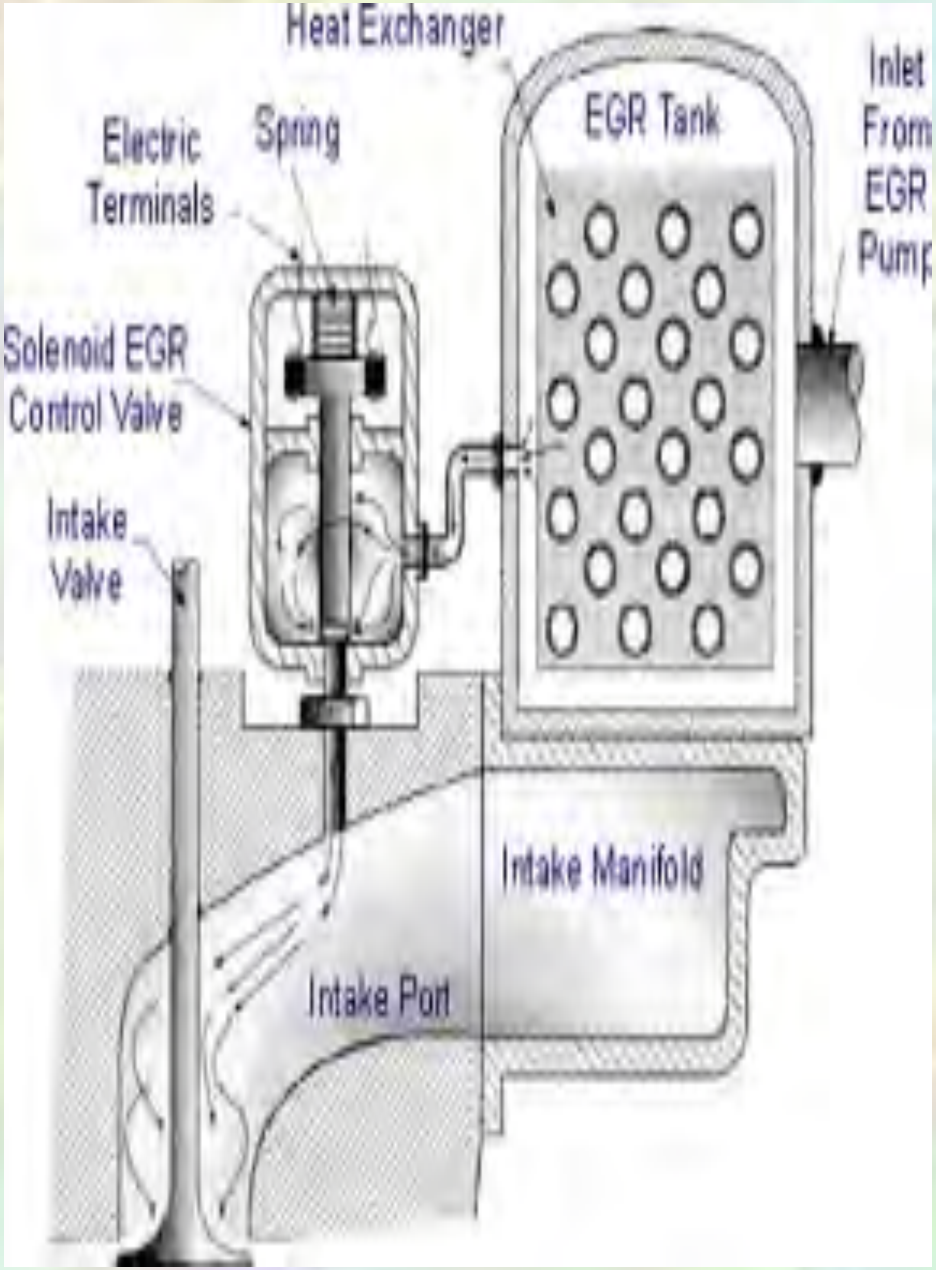
  In addition, the EGR cooler would have less heat rejected in the engine water jacket minimizing the cooling load the radiator has to handle.

Hybrid EGR

- combines features of both HPL and LPL
- EGR comes from a point upstream from the turbine (pre-turbine), as in a HPL configuration
- It then enters at a point pre-compressor, as in a LPL configuration
- While this system presents some of the same adverse features of the LPL EGR system, it provides an adequate pressure differential between the exhaust and intake manifolds allowing EGR rates for substantial NOx reduction without the need for a pump or excessive exhaust backpressure to drive EGR into the engine

Fast-Acting EGR Systems

The fast-acting EGR system will greatly minimize the EGR volume, making it easier for the engine to accelerate without interference from residual EGR by using a shell-and-tube EGR cooler to store cooled EGR.



Fast-Acting EGR systems

- The EGR valve sits very close to the intake port, reducing the volume of exhaust that an engine must consume, especially during acceleration.

- EGR enters the intake port at a position close to the intake valve

    - If EGR comes from a pre-turbine point, then it fits the description of HPL EGR

    - If it comes from downstream of the trap, it would be a LPL EGR system (which might require an EGR pump to elevate its pressure above that of the intake manifold)

Fast-Acting EGR systems

Many diesel EGR systems use a high pressure loop configuration.

This design taps exhaust gases from between the exhaust manifold and the turbocharger; sends them through the EGR cooler; then meters them into the intake air using an EGR valve.

The challenge with the system is how to make EGR gases flow when the intake pressure is being boosted by the turbocharger.

Fast-Acting EGR systems

This is typically addressed using an intake throttle valve and or a variable geometry turbocharger (VGT).

The throttle valve can be used to lower the pressure at the intake manifold, and the VGT can be used to increase exhaust pressure.

The PCM will actuate these controls to optimize EGR flow for all engine operating conditions.

Manifold Vacuum Regulator Valves

(Single Valve or Dual Switching Valves)

The Manifold Vacuum Regulator Valve for diesel engines regulates the intake manifold vacuum to achieve preferred rates of flow

Increasing the vacuum in the manifold will create suction on the EGR system when opened

This causes a higher flow rate that can help reduce emissions, particularly the formation of NOx

Manifold Vacuum Regulator Valves

(Single Valve or Dual Switching Valves)

Dual Switching Valve
switches intake sources between hot and cold to aid in the performance of Particulate Trap systems

Exhaust Air Control Valve

Post-Combustion

may be used to vary and/or restrict the flow of exhaust gases and air

Used to perform and enhance the EGR function for large displacement diesel engines

Helps improve catalyst heating

Catalysts & Traps

(Diesel Oxidation Catalysts-DOC's)

Diesel oxidation catalysts (DOC's) consist of a monolith honeycomb substrate coated with platinum group metal catalysts packaged in a stainless steel container.

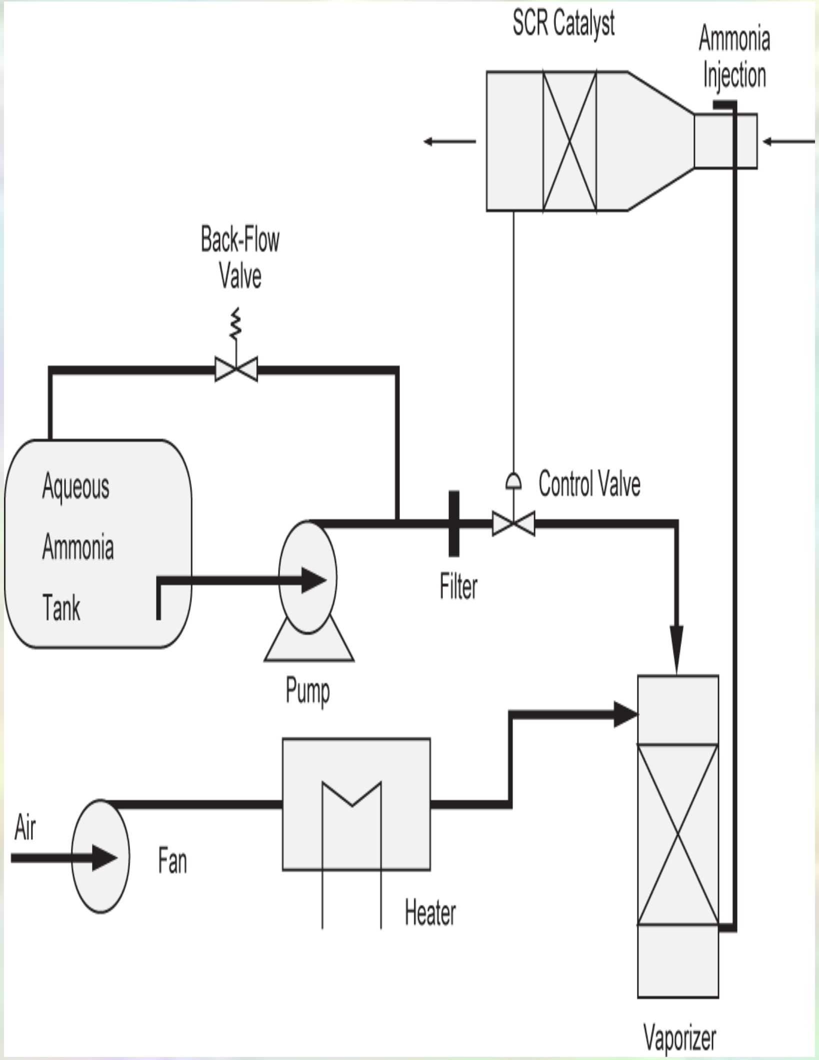
DOC's oxidize CO, HC, and the SOF (unburned fuel) fraction of particulate matter.

Conversion of diesel particulate matter is an important role of the modern DOC.

These catalysts also oxidize sulfur dioxide present in diesel exhaust following the combustion of fuels containing sulfur.

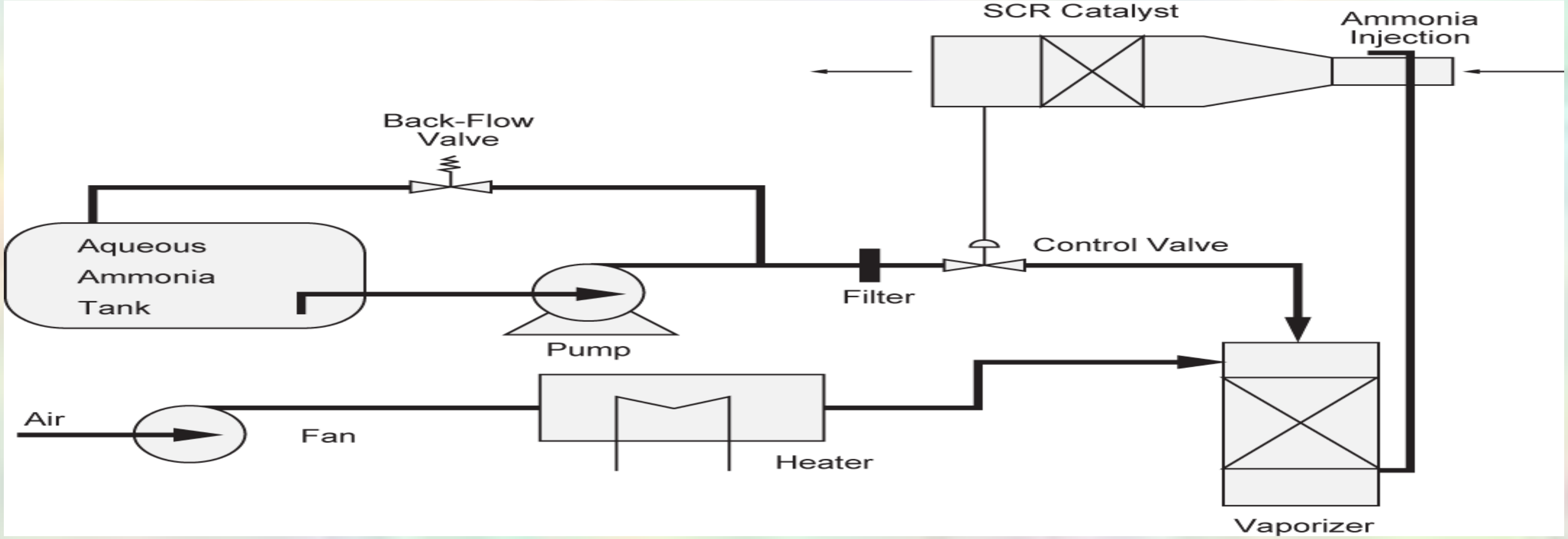
Selective Catalytic Reduction

Industrial processes and stationary diesel engine applications have used Selective Catalytic Reduction (SCR) of NOx using ammonia or urea for many years.



Selective Catalytic Reduction

In the SCR process, NOx reacts with the ammonia injected into the flue gas stream before the catalyst.



Selective Catalytic Reduction

Different SCR catalyst systems (based on platinum, vanadium oxide or zeolites) have different operating-temperature windows.

Each particular SCR process requires the careful selection of a specific type of SCR catalyst.

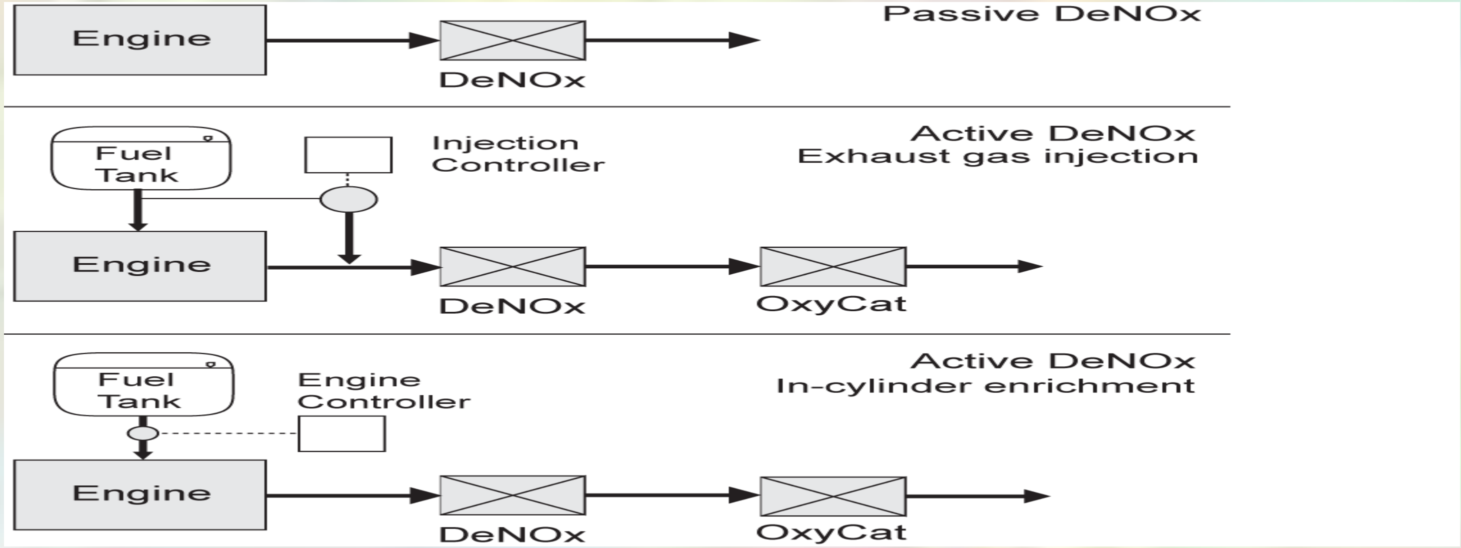
SCR is still the only catalyst technology capable of reducing diesel NOx emissions to the levels required by future emission standards.

Lean NOx Catalysts

Two groups of catalyst systems reduce of NOx with hydrocarbons:

a copper substituted zeolite ZSM-5 catalyst (active at high temperatures)

a platinum/alumina catalyst (exhibiting low temperature activity).



Lean NOx Catalysts

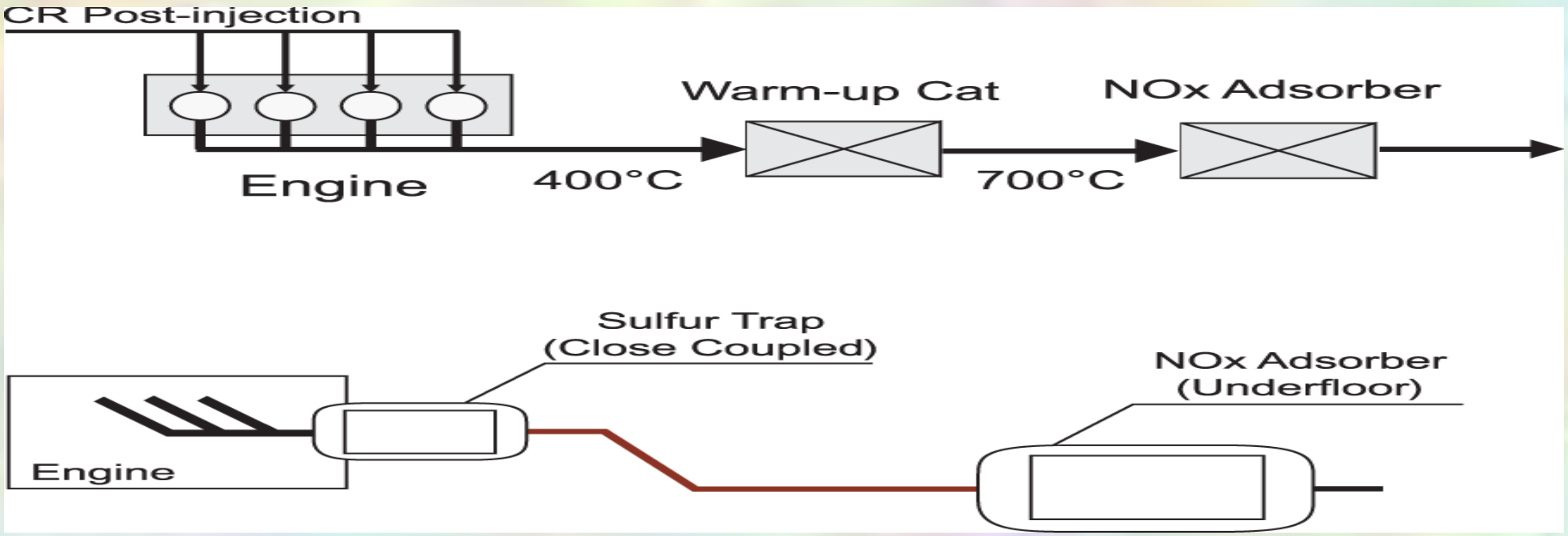
Both catalysts have narrow operating temperature windows.

This results in only a limited NOx reduction efficiency and contributes to other problems.

In an attempt to provide small de-NOx functionality in diesel oxidation catalysts, some commercial applications have adopted lean NOx catalysts.

NOx Adsorbers

NOx adsorbers (traps) for diesel and partial lean burn gasoline engines.



NOx Adsorbers

The adsorbers incorporated into the catalyst washcoat chemically bind oxides of nitrogen during lean engine operation.

After the adsorber becomes saturated, the system regenerates and catalytically reduces released NOx during a period of rich engine operation.

Deactivation of Diesel Catalysts

Poisoning and thermal degradation caused by either lubrication-oil additives or sulfur may cause a deactivation of the diesel catalysts.

Phosphorus is the most common oil-derived catalyst poison.

Sulfur is uniformly distributed over the catalyst length and washcoat depth, while phosphorus is selectively adsorbed at the catalyst inlet and in a thin, outer washcoat layer.

Diesel Particulate Filters

Diesel particulate filters are used to physically capture particulate matter and soot from diesel exhaust.

Diesel Filter Regeneration

A dynamic equilibrium between the soot captured and oxidized in the filter characterizes the regeneration of diesel filters

Soot oxidation rates depend on the filter temperature, soot load in the filter and a number of other factors

Diesel Filter Regeneration

Continuously regenerating filters operate at a balance temperature

can be determined through a laboratory measurement

To facilitate filter regeneration on diesel engines in real operation

one must either increase exhaust gas temp or lower the soot ignition temp using a catalyst

Wall-Flow Monoliths

Wall-flow monoliths became the most popular diesel filter design

They stem from flow-through catalyst supports where alternatively plugged channel ends force the gas flow through porous walls that act as filters

Wall-flow monoliths are made from such specialized ceramic materials as cordierite and silicon carbide

A number of mechanical and thermal properties characterize and differentiate different monoliths.

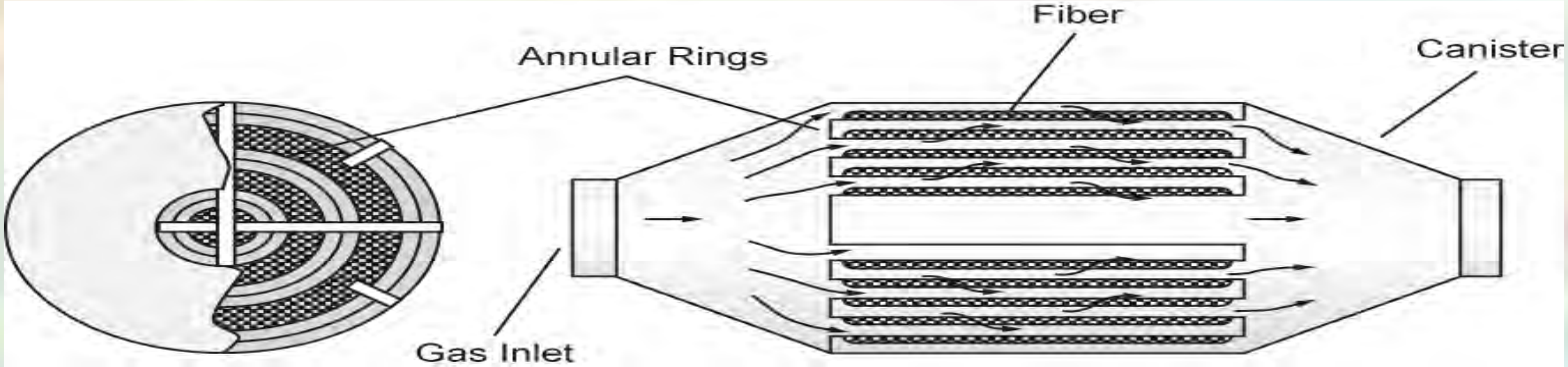
Ceramic Fibers & Cartridges

Cartridges for filtering diesel particulates can be made from high-temperature ceramic fibers.

Fiber filters capture particulates through depth filtration mechanisms.

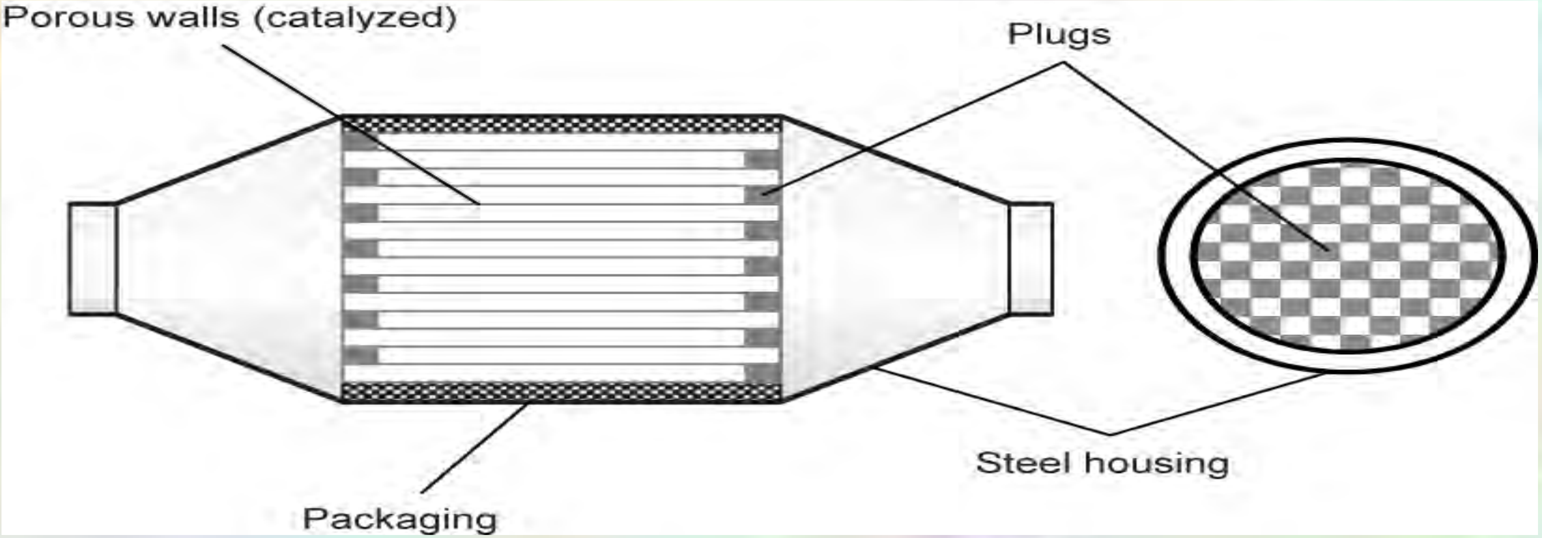
A number of cartridge designs have been developed.

Some of them incorporate electric heaters for regeneration.



Catalyzed Diesel Filters

Most catalyzed diesel filters utilize monolithic wall-flow substrates coated with a catalyst

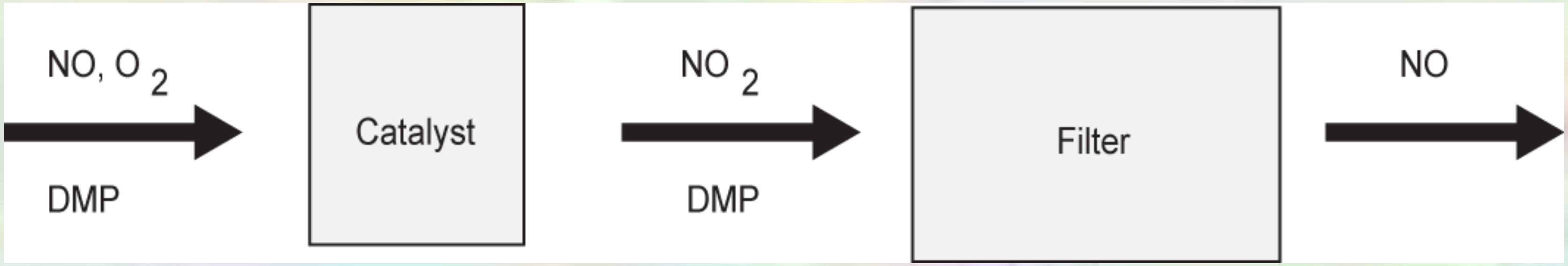


Catalyzed Diesel Filters

The catalyst lowers the soot combustion temperature, allowing the filter to self-regenerate during periods of high exhaust gas temperature

CRT Filter

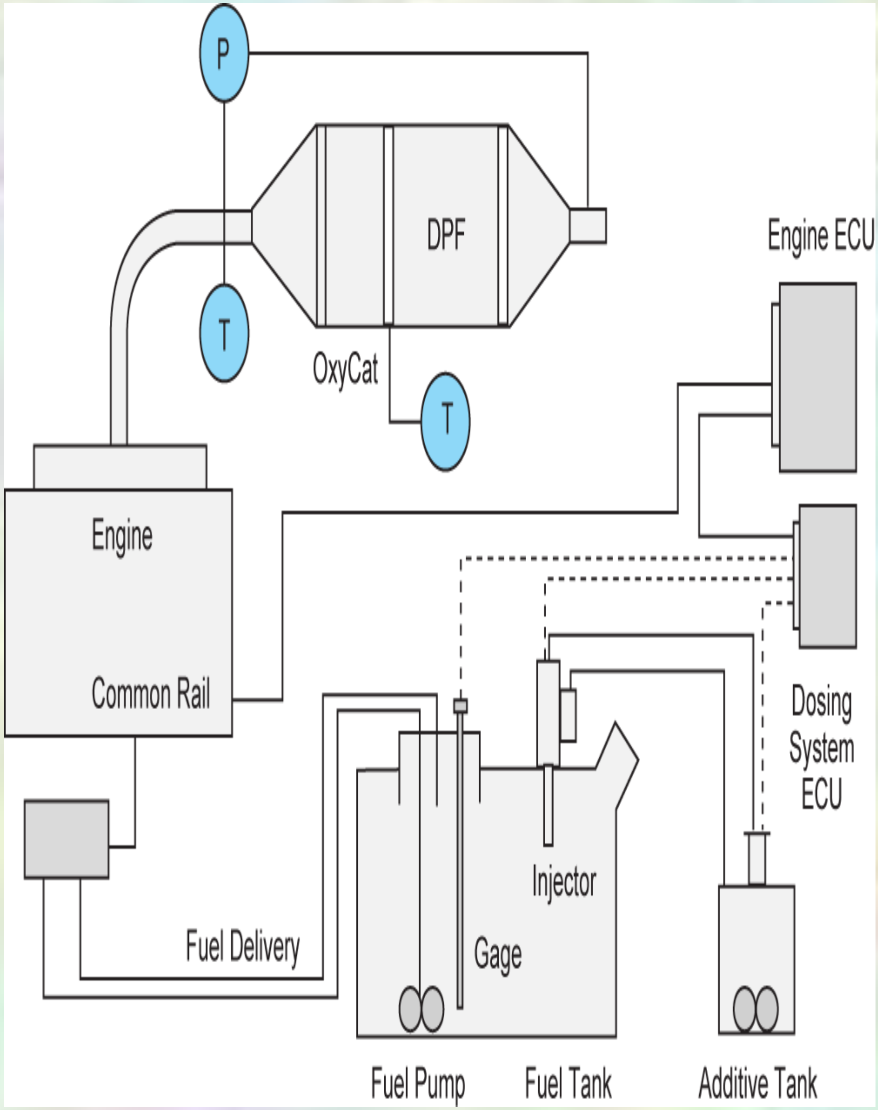
The CRT is a trade name for a two-stage, catalytic, passive filter configuration.
The CRT system utilizes a ceramic wall-flow filter to trap particulates.
Nitrogen dioxide generated in an oxidation catalyst placed upstream of the filter continuously oxidizes the trapped particulate matter
The CRT requires ultra-low-sulfur fuel and a certain minimum NOx/PM ratio for proper operation



Filters & Fuel Additives

Fuel additives (also called fuel soluble catalysts) can lower the soot combustion temperature and facilitate filter regeneration in passive diesel filter systems

The most common additives include iron, cerium and platinum



Electrically Regenerated Filters

The electric regeneration of diesel filters can follow on-board and various off-board configurations

Partial-flow layouts or regeneration with hot air are more energy efficient

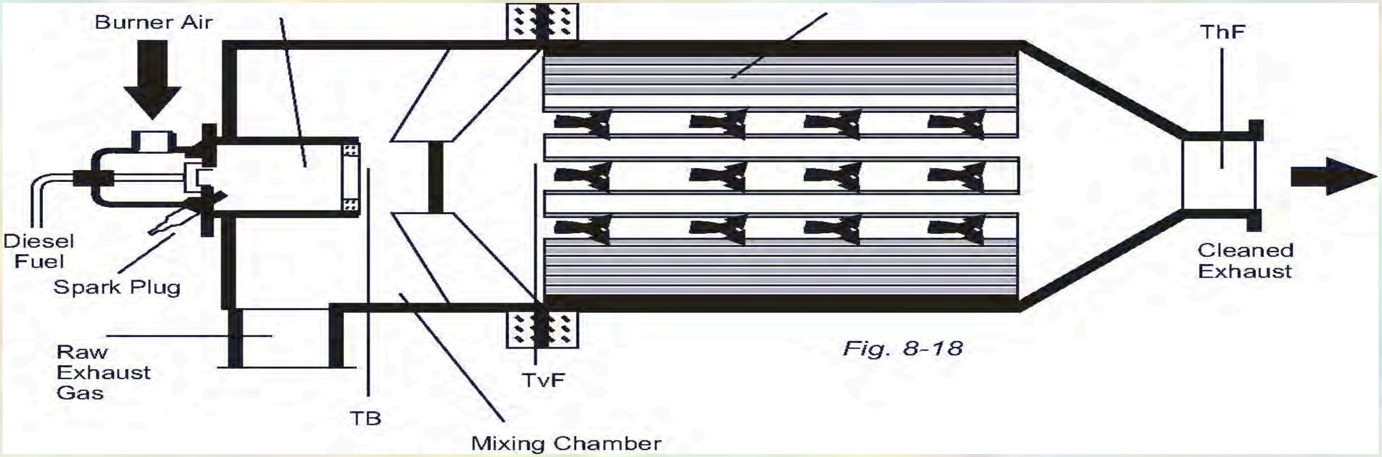
Some filter systems require an external power source or are removed from the vehicle for off-board regeneration

Filters with Fuel Burners

Diesel fuel burners can increase the exhaust gas temperature upstream of a particulate filter in order to facilitate its regeneration

Fuel burner filters fall into two categories:

single-point systems & Full-flow systems



The full-flow systems can regenerate during regular vehicle operation but require complex control strategies to ensure a thermally balanced regeneration

Filters with Fuel Burners

Regeneration is the removal or cleaning of PM that has been collected by the particulate filter.

The key is maintaining sufficient exhaust temperatures so that the system can continually clean the PM from the filter.

This is known as Passive regeneration.

Filters with Fuel Burners

Under conditions where there is not enough heat in the exhaust Active regeneration is used.

This is done by raising the exhaust temperatures with the injection of small amounts of fuel upstream of the DOC.

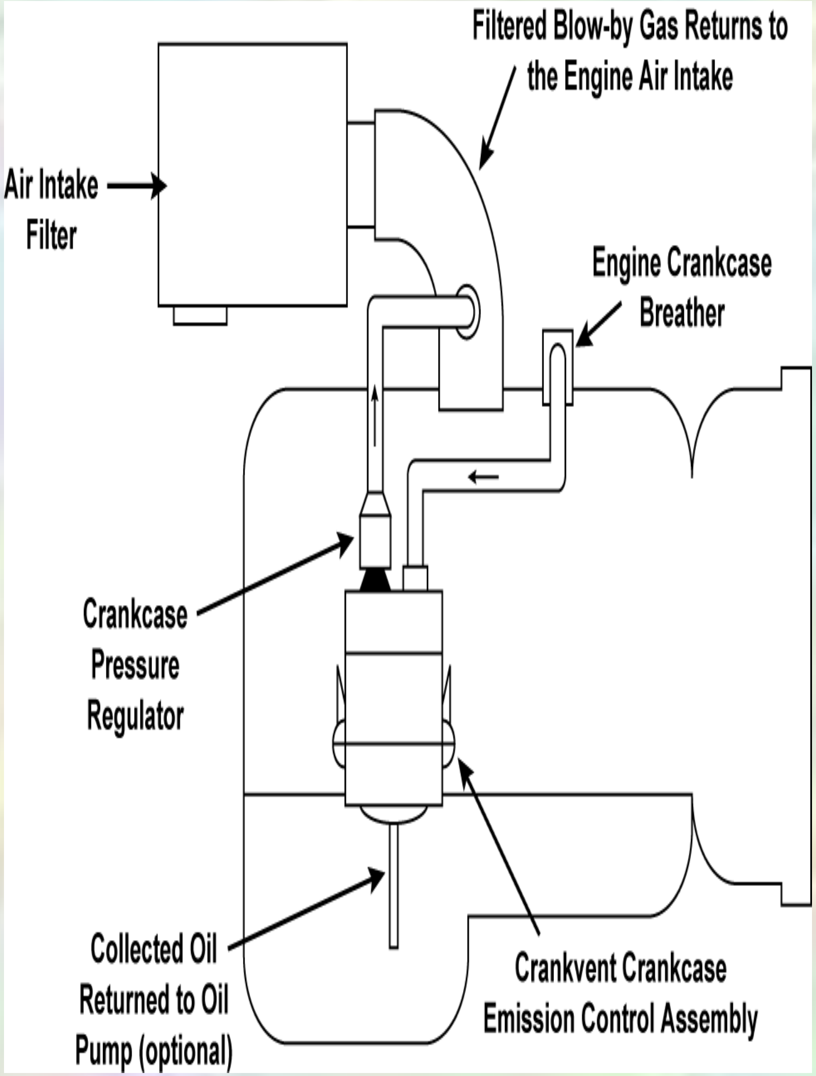
Both passive and active regeneration can happen while the vehicle is operating.

Crankcase Ventilation Systems

Crankcase blow-by is produced when combustion gases, under high-pressure, become contaminated with oil mist when blown past the piston rings into the crankcase

crankcase blow-by vented to the atmosphere has become a larger contributor to total emissions

To further reduce the total emissions of engines, it is becoming necessary to route these gases into the air intake system



Crankcase Ventilation Systems

In a closed system, this contaminated blow-by is ingested by the engine intake system

While the closed crankcase breather system offers the highest reduction in measurable emissions, the impact of unfiltered crankcase blow-by on engine components and performance must be considered

Crankcase Ventilation Systems

Many manufacturers use a Crank Case Ventilation (CCV) filtering system to prevent damage that can be caused by heavy blow-by or excessive oil mist coating the intake system

Other systems more closely resemble the Positive Crank Case Vent (PCV) of a spark ignited engine.

The positive flow type systems use a blower or air compressor system to force air thru the crankcase and into the air induction system

Crankcase Ventilation Systems

Routine maintenance required for the Crankcase Ventilation Filter System is filter replacement

Typical service intervals are recommended in the manufacturer's service information

Some variations in service life occur depending on

- load profile
- engine wear condition
- flow
- aerosol mass concentration of crankcase emissions
- soot concentration

STUDY QUESTIONS

Arizona Department of Environmental Quality

POWER, FUEL ECONOMY & LOW EMISSIONS

1. How much of a power improvement is the norm on a diesel engine with a turbo?

   A. 40 to 50%

   B. 90 to 100%

   C. 30 to 40 %

   D. No power improvement-it quiets the engine

ELECTRONIC CONTROL

of

DIESEL EMISSIONS

FOUR

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Today’s Diesel Systems

All use one or more on-board computers

- ECM
- ABS
- PCM

These computers work with assorted sensors

- Speed Sensors
- Engine Speed Sensors
- Engine Coolant Temp Sensors and more…

The sensors generate electronic or digital signals that provide input to the ECM.

Today’s Diesel Systems

To properly repair the vehicle, the technician should have access to all the information shared between the vehicle’s ECM and the sensors.

- knowledge of
  - input and output values
  - component location
  - wiring schematics
- essential to performing successful repairs

Today's Diesel Systems

- Electronically connected components that enable an information processing cycle are comprised in three distinct stages:
  - Data Input (sense)
  - Data Processing (decide)
  - Outputs (act)

Electronic Control Module System Functions

- Regulate Reference Voltage (V-REF)
- Input Conditioning, Amplification, and ADC (Analog to Digital Converter)
- Processing
- Manage Output Drivers

The Basics First

Over the years on-board computers have increased in their ability to control and monitor vehicle systems.

This includes adaptive strategies

- The substitution of values for failed sensors
- the ability to relearn information.

Even with the advancement of on-board computers, some areas remain unchanged

The Basics First

- The computer still needs
  - a good power supply and ground
  - the mechanical parts of the engine must be in good operating condition
  - the fuel and its delivery system must both be sound
  - the proper amount of air must enter the induction system
- Before rushing to the computer or a computer component
  - check the basic systems first

The Basics First

Here are a few areas that could cause you to extend Your diagnostic time or misdiagnosis the problem:

- Engine oil (check level, correct grade/viscosity, check for contaminants)
- Battery and Charging systems
- Grounds Vehicle & Computer
- Wiring harness/connectors
- Engine operating temperature
- Exhaust restrictions
- Fuel pressure and volume
- Leaking Fuel Pressure Regulator
- Engine compression
- Crankcase pressure
- Sticking/dirty injectors

The Basics First

- Glow Plugs/Relay (if equipped)
- Boost pressure
- Waste Gate operation
- Restricted intake
- Carbon deposits

Values seen on scan tool data stream may be different from voltages that originate at a sensor or actual state of an output device, always verify with DVOM

Data Input

- Data comes from these monitoring sensors:
  - Command Sensors
  - Thermistor
  - Switches
  - Signal Generator
  - Potentiometer
  - Variable Capacitors
- Sensors include anything that signals input data to the ECM
- The signals used can be either analog or digital
  - Supplied 5-Volt reference (usually)
  - ECM compares the return signals

Types of Sensor
Thermistors

- NTC (Negative Temperature Co-efficient)
  - resistance decreases as temperature increases
- PTC (Positive Temperature Co-efficient)
  - resistance increases as temperature increases

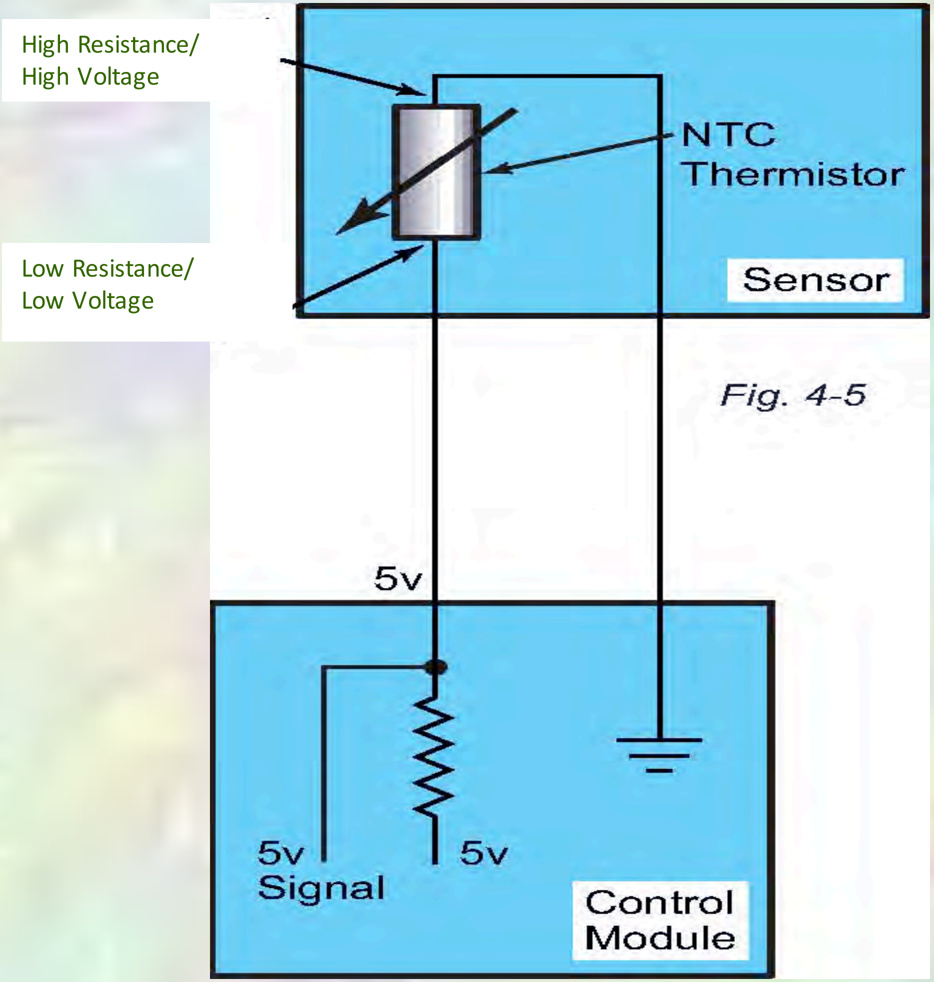
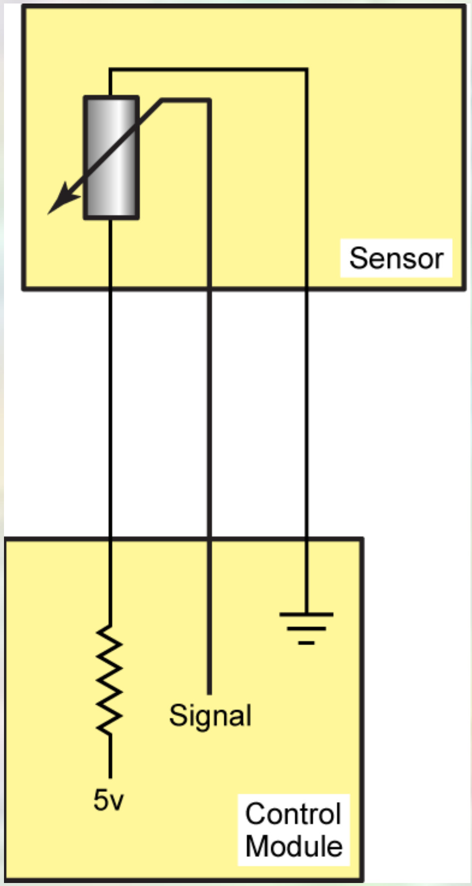


Fig. 4-5

Types of Sensor

Variable Capacitors

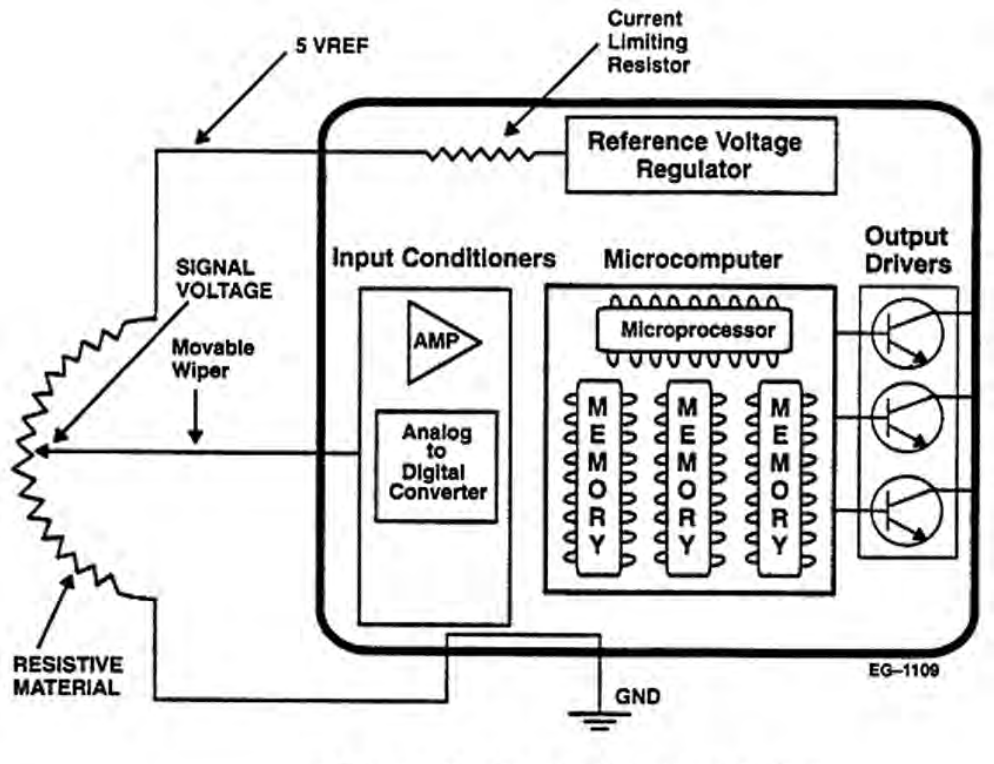
Three-Wire Sensor
Supplied with Reference Voltage
Designed to Measure Pressure
Signal from Sensor Analog



Variable Capacitance Sensors:
- Oil Pressure
- MAP
- BARO

Types of Sensor
Potentiometers

- Three-wire sensor
  - Signal analog
  - is proportional to the position of a mechanical device



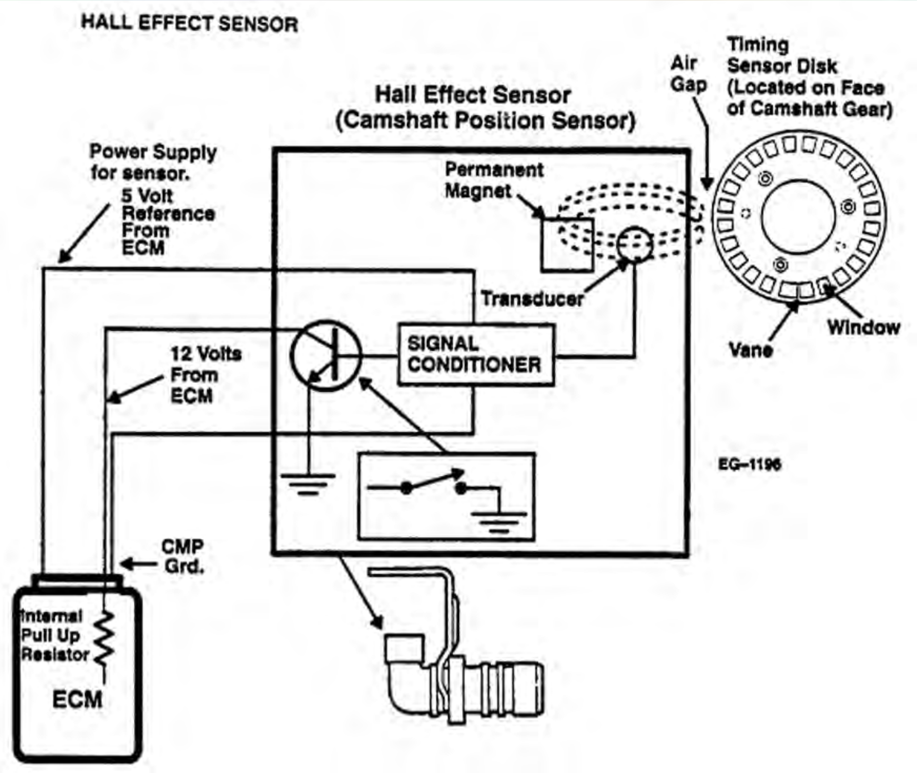
Potentiometer (Variable Resistance Voltage Divider)

Types of Sensor
Signal Generating Sensors

- Three-wire sensor
- Digital signal
- Supplied reference voltage

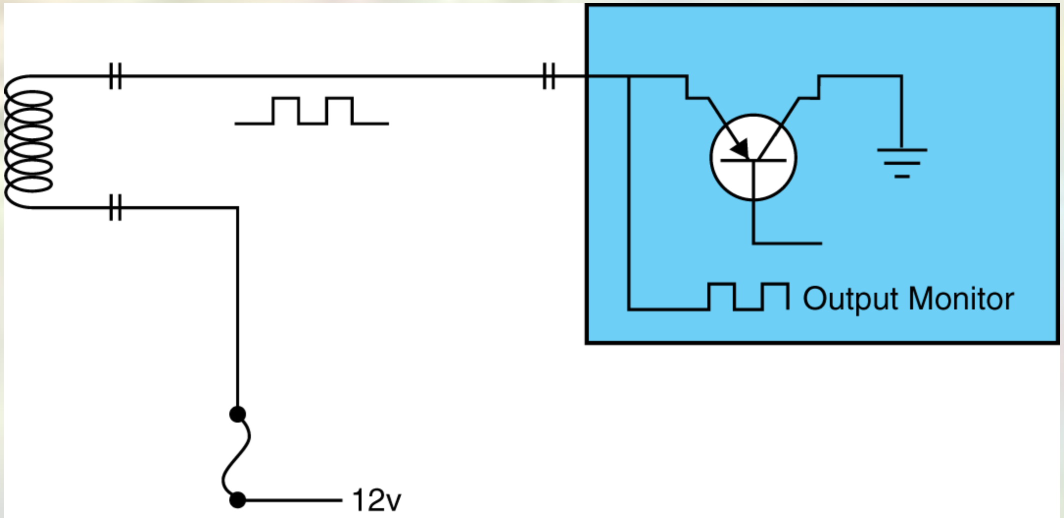
Signal generating sensors:

CPS camshaft sensor
TRS timing reference sensor
EPS engine position sensors



Outputs/Actuators

Fan Controls
Fuel Injectors
Retarder Solenoids
Idle Speed



Data Processing

Central Processing Unit (CPU) – Electronic Control Module (ECM) in the Heavy-Duty Industry:

Executes program instructions

Random-Access Memory (RAM):

Electronically retained data, can be manipulated by (CPU/ECM) primary or main storage (note pad)

At start-up, RAM is electronically loaded with vehicle-management operating instructions and all necessary running data retained in other data categories

Data Processing

Random-Access Memory (RAM):

Data storage is temporary called (volatile) memory

Most HD ECMs use only volatile memory when an EEPROM is used

Data Processing

Read-Only Memory (ROM):

Input and magnetically retained data, transferred to (RAM) for processing

Permanent information, designed not to be overwritten

Master program for system management is loaded into ROM

ROM contains all the protocols (rules and regulations) to master engine management

Data Processing

Programmable Read-Only Memory (PROM):

Contains tire size, fuel delivery tables, gear ratios for differential and transmission pertinent to a specific chassis application

Reprogramming is done by replacing the chip

Electronically Erasable PROM (EEPROM):

Contains customer data, programmable options and proprietary data that can be altered and modified using a variety of tools

Two Types of Reprogramming

<u>Customer Data</u>

- Tire rolling radius
- Governor type
- Cruise control limits/transmission ratio
- Road speed limit/torque rise profile
- Shutdown sensors/peak brake power
- Idle speed/idle shutdown duration

<u>Proprietary</u>

- Fuel mapping
- System monitoring
- Command inputs

STUDY QUESTIONS

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ELECTRONIC CONTROL OF DIESEL ENGINES

1. To properly repair a modern diesel vehicle, the technician should have knowledge of

   A. input and output values

   B. component location and wiring schematics

   C. a way of accessing information shared between the vehicle's ECM and sensors

   D. All of the above

ELECTRONIC CONTROL OF DIESEL ENGINES

2. Variable Capacitance sensors are used to measure:

   A. Oil Pressure
   B. Manifold Absolute Pressure
   C. Barometric Pressure
   D. All of the above

3. Signal generating sensors provide information such as timing, camshaft position?

   A. Yes
   B. No

ELECTRONIC CONTROL OF DIESEL ENGINES

4. The output of a potentiometer is __________

   A. A digital signal that is proportional to the motion of a mechanical device

   B. A frequency that is proportional to the motion of a mechanical device

   C. A signal responding to the pressure created by a sensor

   D. An analog voltage signal that is proportional to the position of a mechanical device

ELECTRONIC CONTROL OF DIESEL ENGINES

5. True or False - One of the four basic functions for an ECM on a diesel is managing output drivers?
   A. True
   B. False

6. The master program for system management which contains permanent information that is designed not to be overwritten is called __________.
   A. Random Access Memory (RAM)
   B. Programmable Read-Only Memory (PROM)
   C. Read-Only Memory (ROM)
   D. Electronically Erasable PROM

UNDERSTANDING

&

USING SCAN DATA

FIVE

Arizona Department of Environmental Quality

Diagnostic Connectors

The most-common diagnostic connectors for HD vehicles are the Deutsch 6- and 9-pin connectors

These two connectors allow you to access the on-board systems

Using the Heavy Duty Standard application software, you can access the following:

- Data Stream
- Codes (Active and Inactive)
- Clear Codes
- Trip Information

Diagnostic Connectors

The diagnostic connector is usually located under the dash on the left side of vehicle – not all connectors share this location

They can also be found in locations such as:

- In the center of the dash
- Hidden behind panels
- Behind or under drivers seat
- On the right side of the vehicle
- Engine compartment

- You should always refer to the shop manual for the vehicle on which you are working for proper location and proper diagnostic connector to use

Heavy Duty Vehicle Data List

- Each manufacturer has a set data list based on the electronic system being used. The early systems were very limited in data. However, the industry has advanced to 32-bit processors and an almost endless data stream.

- Observing certain sensors information and grouping them together will help to accurately diagnose.

Related Data Parameter Categories

- Data parameters group into fields relating to engine and vehicle operating systems
- Some vehicles will have more fields than others, as well as more data for each field
- During troubleshooting, we often must evaluate several parameters from two or more categories together in order to make an accurate diagnosis

Heavy Duty Vehicle Data List

the different categories are:

- General/Shared Parameters
  - Several different vehicle systems need this information in order to operate
  - Most vehicles include engine/vehicle speed, indications of general PCM output commands, overall system condition and engine load
- Fuel Delivery Parameters
  - The information covers fuel delivery and the output commands from the PCM to fuel control devices

Heavy Duty Vehicle Data List

- Accelerator Pedal Position (Throttle Position) and Idle Control Parameters
  - The information covers the position of the accelerator (throttle) and the operating condition of various idle speed control devices
  - The information could indicate PCM command to idle and throttle control devices

- Engine Coolant, Oil, Transmission Oil, Fuel Temperature Parameters
  - The information covers the engine and fuel temperature, as well as the temperature or condition of the coolant, engine oil and transmission fluid

Heavy Duty Vehicle Data List

- Air Pressure, Manifold Pressure, and Turbocharger Parameters
  - The information covers ambient air pressure and high or low pressure inside the intake manifold
  - The ECM uses these input parameters for the engine protection system, injection timing, fueling control, and to monitor conditions that could derate the engine.
- Airflow and Air Temperature Parameters
  - The information covers the primary input parameters that the ECM uses for the engine protection system, the timing and fueling control, and air flow rate.

Heavy Duty Vehicle Data List

- Electrical Parameters
  - The information covers the condition of the vehicle electrical system
- Heating, Ventilating and Air Conditioning Parameters
  - The information covers PCM commands to and signals from various actuators and sensors in the HVAC system
  - On some vehicles, PCM signals to and from the engine-cooling fan control its operation

Data Categories

Understanding Diagnostic Codes

- The Society of the Automotive Engineers (SAE) and The Maintenance Council (TMC) of the American Trucking Association developed a standard data interchange format/set-up referred to as J1587.

- This standard data interchange format/set-up identifies the messages that are sent from one electrical device to another on a vehicle serial data link. It defines a standard data list, controller names and numbers, parameter names and numbers, and diagnostic fault code formats and numbers.

Data Categories

MESSAGE IDENTIFIERS (MIDS)

- MIDS identify the controller that is sending the message (engine, transmission, brakes)
- MIDS are the microprocessors used in heavy-duty vehicle applications. These microprocessors transmit messages on the Serial Data Link (SDL) and control the engine, transmission and brakes.
  - J1922 MIDs (69-86) are used on a dedicated communication link for interactive control between electronic engine, transmission, ABS/Traction Control and retarder systems.
  - J1587 MIDs (128-186) are used by the microprocessors to communicate messages and data on a common link.

Data Categories

SUBSYSTEM IDENTIFIERS (SIDS)

- SIDS identify the part of the controller that has a fault (engine timing actuator, brake relay).
  - The SID is identified by a number and a description in a standardized list.

PARAMETER IDENTIFIERS (PIDS)

- PIDS identify the data in the message (coolant temperature, engine RPM).
  - The PID is identified by a number and a description in a standardized list.

Heavy Duty Vehicle Data List

FAILURE MODE IDENTIFIER (FMI)

- FMIS identify how the system or part failed (shorted low, shorted high).
  - The FMI is identified by a number and a description in a standardized list.

STUDY QUESTIONS

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UNDERSTANDING & USING SCAN DATA

1. Message Identifiers (MIDs) identify

   A. Diagnostic trouble codes for engine control

   B. Memory chips for fuel control

   C. the controller sending the message

   D. Analog to Digital converters

UNDERSTANDING & USING SCAN DATA

2. The standard data interchange format that describes the messages that are sent from one electrical device to another on a vehicle serial data link is defined as

   A. Message Identifiers (MIDs), & Subsystem Identifiers (SIDs)

   B. Parameter Identifiers (PIDs), & Failure Mode Identifiers (FMIs)

   C. Neither A or B

   D. Both A and B

UNDERSTANDING & USING SCAN DATA

3. In the General/Shared parameter categories most vehicle manufacturers provide information about __.

   A. engine/vehicle speed

   B. engine load

   C. overall system condition

   D. All of the above

DIESEL EMISSIONS

&

SMOKE DIAGNOSTICS

SIX

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Preventive Maintenance & Emissions

- Inspections and maintenance are vital
  - to maintaining engines (diesel and gasoline) in proper operating condition
  - to reducing the occurrence of major repairs caused by mechanical failure
- A relatively minor engine malfunction, might well develop into a major mechanical repair
- Recognizing the symptoms of developing malfunctions can be done by using all your senses.

Basic Maintenance Checks

- Intake system
  - inspection of intake system components
  - Inspection and/or replacement of filters
    - testing and maintaining
      - piping
      - filter housing
      - gaskets
      - connection and seals
      - installation of appropriate gauges
      - appropriate servicing intervals
      - detection and correction of problems

Basic Maintenance Checks

- Exhaust system
  - Monitoring exhaust backpressure and emissions
  - evaluating installation and damage of exhaust system components
  - monitoring the condition and performance of after-treatment devices

- Fuel Injection System
  - Diagnosing problems
  - scheduling checks of primary fuel pressure
  - examining filters
  - verifying air/fuel ratio
  - Checking for fuel leaks
  - checking fuel temperature and air in fuel
    - using filtered vents on fuel tanks
  - adjustment and replacement of components

Basic Maintenance Checks

- Cooling System
  - Scheduling maintenance and cleaning of cooling systems
  - important service practices
  - verifying operating condition of gauges and alarm sensors
  - diagnosing and correcting problems
- Fuel Quality and Handling
  - Proper storage, transfer of fuels, filtration and cleanliness

Diesel Smoke Diagnostics

- Black smoke is often an indicator that a diesel engine is in need of repair
- Excessive smoke indicates conditions that can result in shorter engine life & reduced fuel economy

- Heavy-Duty Diesel Vehicle (HDDV) programs test only to determine whether they are emitting excessive amounts of visible smoke

Diesel Smoke Diagnostics

- Excessive smoke can result from:
  - Restricted or clogged air filters
  - Improper or malfunctioning injection timing
  - Clogged, worn, or mismatched injectors
  - A faulty fuel injection pump
  - A defective or malfunctioning puff limiter
  - Low air box pressure
  - Air manifold leaks
  - A malfunctioning turbocharger
  - A malfunctioning intercooler
  - A defective air/fuel controller
  - Poor fuel quality or a malfunctioning governor

Blue Smoke

- Root Cause and Condition:
  - Excessive blue smoke indicates problems from
    - low engine compression &/or worn piston rings
    - scored cylinder walls
    - leaking valve stem seals
- Blue smoke results from crankcase oil entering the combustion chamber, where it partially combusts before exiting through the exhaust stream

White Smoke

- White smoke occurs mainly during cold starts
  - the fuel tends to condense into liquid and does not burn due to cold engine parts

- The most-common reasons for white smoke
  - inoperative glow plugs or a cold engine
  - low engine compression
  - a bad injector spray pattern
  - injection pump problems
  - late injection timing

Black Smoke (high opacity issues)

- Root Cause & Condition:
  - Excessive black smoke results from a rich air-fuel mixture
- This may stem from problems with
  - injection pump
  - injection timing
  - a clogged air cleaner/filter
  - worn fuel injectors
  - contaminated diesel fuel
  - a problem with the engine itself

Gray Smoke (low opacity issues)

- Root Cause & Condition:
  - may occur at engine start-up whether or not the engine is at normal operating temperature.
  - can occur at all ambient temperatures and should dissipate after 1-2 minutes of driving the vehicle
- Blue-white smoke can return when ambient temperature is below 10°C (50°F) and the engine has warmed up
  - due to the cooling of the combustion chambers that occurs during extended periods at idle
- Heavy gray smoke may also occur at full throttle with the transmission in neutral or park

STUDY QUESTIONS

DIESEL EMISSIONS & SMOKE DIAGNOSTICS

1. True or False - Black smoke is usually an indicator that the engine is operating normally?

   False

2. Black smoke can commonly be an indication of____.

   A. a plugged fuel filter
   B. low cylinder heat
   C. a plugged air filter

DIESEL EMISSIONS & SMOKE DIAGNOSTICS

3. Blue smoke indicates problems with ________.

   A. injectors

   B. the turbocharger

   C. scored cylinder walls

   D. a bad computer

DIESEL EMISSIONS & SMOKE DIAGNOSTICS

4. The most common reasons for white smoke are

A. late injection timing

B. inoperative glow plugs

C. a cold engine

D. All of the above

DIESEL EMISSIONS & SMOKE DIAGNOSTICS

5. Basic system checks of the cooling system should include______.

   A. verifying airflow and fuel pressure

   B. monitoring exhaust pressure and emissions

   C. testing and maintaining intake system piping

   D. scheduled maintenance and cleaning of cooling system

DIESEL EMISSIONS & SMOKE DIAGNOSTICS

6. Basic system checks of the intake system should include

   A. verifying airflow and fuel pressure

   B. monitoring exhaust pressure and emissions

   C. testing and maintaining intake system piping

   D. scheduled maintenance and cleaning of cooling system

DIESEL EMISSIONS & SMOKE DIAGNOSTICS

7. Basic system checks of the fuel injection system should include

A. monitoring exhaust temperatures

B. monitoring coolant temperatures

C. checking primary fuel pressure and leaks

D. none of the above

DIESEL EMISSIONS & SMOKE DIAGNOSTICS

8. Hard starting problems can be caused by_____.
   A. Bad glow plugs
   B. Slow cranking speed
   C. Neither A and B
   D. Both A and B

9. Low Power can be caused by _______________.
   A. plugged air filter
   B. plugged fuel filter
   C. tank cap vent plugged
   D. all of the above

STUDY QUESTIONS

POWER, FUEL ECONOMY & LOW EMISSIONS

2. The Electronic Direct Injection System is ______.

A. the least fuel efficient of all systems

B. a belt-driven unit

C. programmable for optimal performance over the entire engine's speed range

D. not programmable and has difficulties providing fuel at low speed

STUDY QUESTIONS
POWER, FUEL ECONOMY & LOW EMISSIONS

3. One way to get more power out of a diesel engine is to increase the volume of air and fuel by:________.

   A. removing the air cleaner
   B. adding a larger diameter exhaust system
   C. adding a forced induction device such as a turbocharger
   D. adding a particulate trap system

STUDY QUESTIONS
POWER, FUEL ECONOMY & LOW EMISSIONS

4. A wastegate on a turbo________________________.

   - A. causes a turbo to overboost
   - B. causes the engine to be sluggish
   - C. allows a smaller turbo to be used to reduce lag
   - D. allows fuel to be wasted to lighten the load

5. Yes/No - An Exhaust Gas Recirculation (EGR) on a diesel engine requires both electronic control of the EGR and EGR cooling to limit the increase in Particulate Matter (PM)?

   Yes

STUDY QUESTIONS
POWER, FUEL ECONOMY & LOW EMISSIONS

6. The Engine/Electronic Control Module (ECM) controls ________________, as well as working with the Electronic Driver Unit (EDU) to provide a strong precise signal for each cylinder's combustion

   A. fuel rail pressure for precise fuel delivery
   B. cylinder pressure
   C. fuel tank pressure for the evap system
   D. transmission pressure

STUDY QUESTIONS
POWER, FUEL ECONOMY & LOW EMISSIONS

7. A common-rail injection system separates the functions of generating pressure and injecting fuel by _______.

   A. storing the fuel under extremely high pressure in central accumulator rail
   B. using a constant supply of high pressure engine lube oil
   C. delivering the fuel to the individual electronically-controlled injectors on demand
   D. Both A and C

STUDY QUESTIONS

POWER, FUEL ECONOMY & LOW EMISSIONS

8. The exhaust air control valve is effectively used in air control systems of large displacement or heavy duty diesel engines to:

   A. to restrict air flow re-entering the engine
   B. to perform & enhance the EGR function & help improve catalyst heating
   C. replace the EGR
   D. None of the above

STUDY QUESTIONS

POWER, FUEL ECONOMY & LOW EMISSIONS

9. The most popular diesel filter design is?

A. $N0_x$ Adsorbers

B. Diesel Filter Regeneration

C. Lean $N0_x$ Catalyst

D. Wall-Flow Monoliths

STUDY QUESTIONS

POWER, FUEL ECONOMY & LOW EMISSIONS

10. Closed crankcase breather systems offer the highest reduction in blow-by emissions by___________________.

    A. allowing the engine to vent to atmosphere
    B. routing the blow-by gases to the particulate trap system
    C. routing these gases into the air intake system

STUDY QUESTIONS

POWER, FUEL ECONOMY & LOW EMISSIONS

11. Yes/No - The Fast-Acting EGR system greatly minimizes the EGR volume, making it easier for the engine to accelerate without interference from residual EGR by storing the cooled EGR.

    Yes

STUDY QUESTIONS
POWER, FUEL ECONOMY & LOW EMISSIONS

12. True/False – Crankcase Ventilation Systems are designed to re-route blow-by gasses into the air intake system.

    True

13. True/False - Selective Catalyst Reduction is the only catalyst technology capable of reducing NOx to the levels required by the future EPA emissions standards?

    True

STUDY QUESTIONS
POWER, FUEL ECONOMY & LOW EMISSIONS

14. The advantages of using a Low Pressure Loop (LPL) EGR, rather than HLP EGR are __________.

A. the designs will normally increase the kinetic energy of EGR; allowing more of it to flow with lower pumping losses.
B. better turbocharger performance and lower fuel consumption
C. the introduction of additional recirculated heated air into the engine
D. All of the above

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