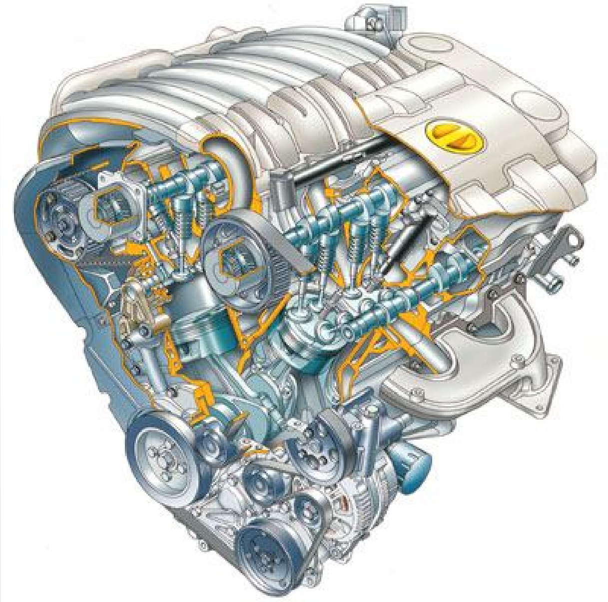
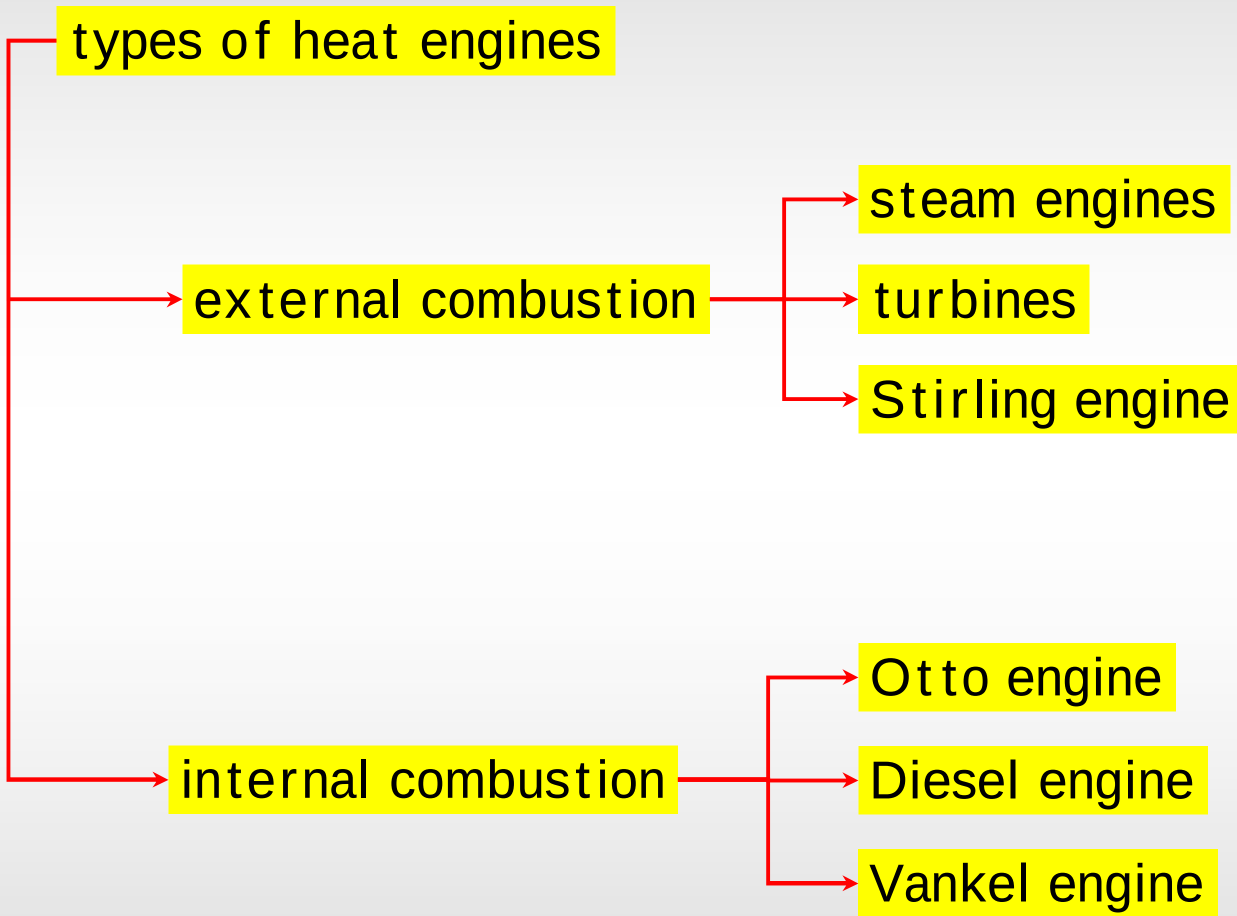
# Internal Combustion Engines

Dr. Ch Tirumala Rao
Mechanical Engg. Dept.
Acharya Nagarjuna University



# Internal Combustion Engines

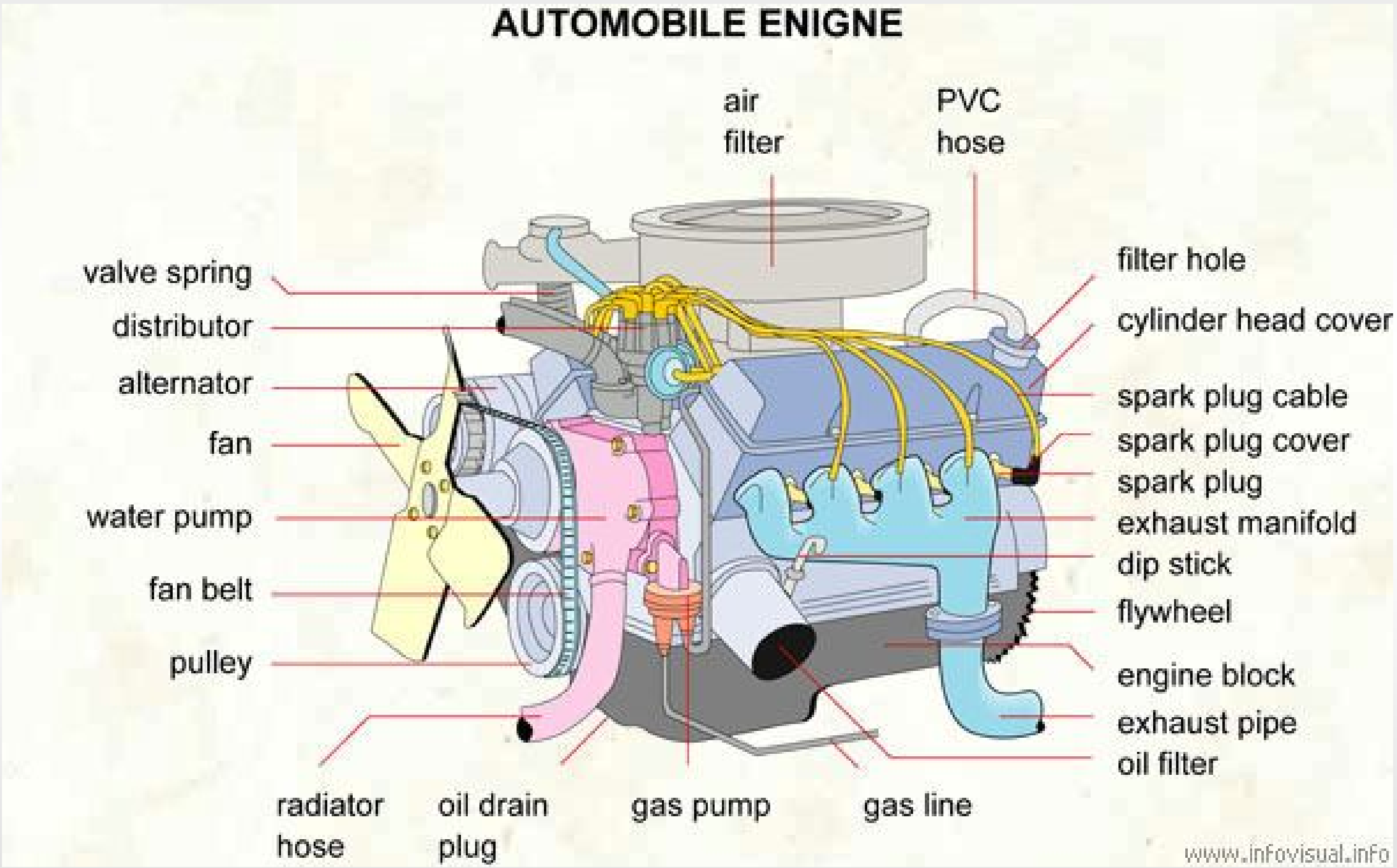


# Internal Combustion Engines

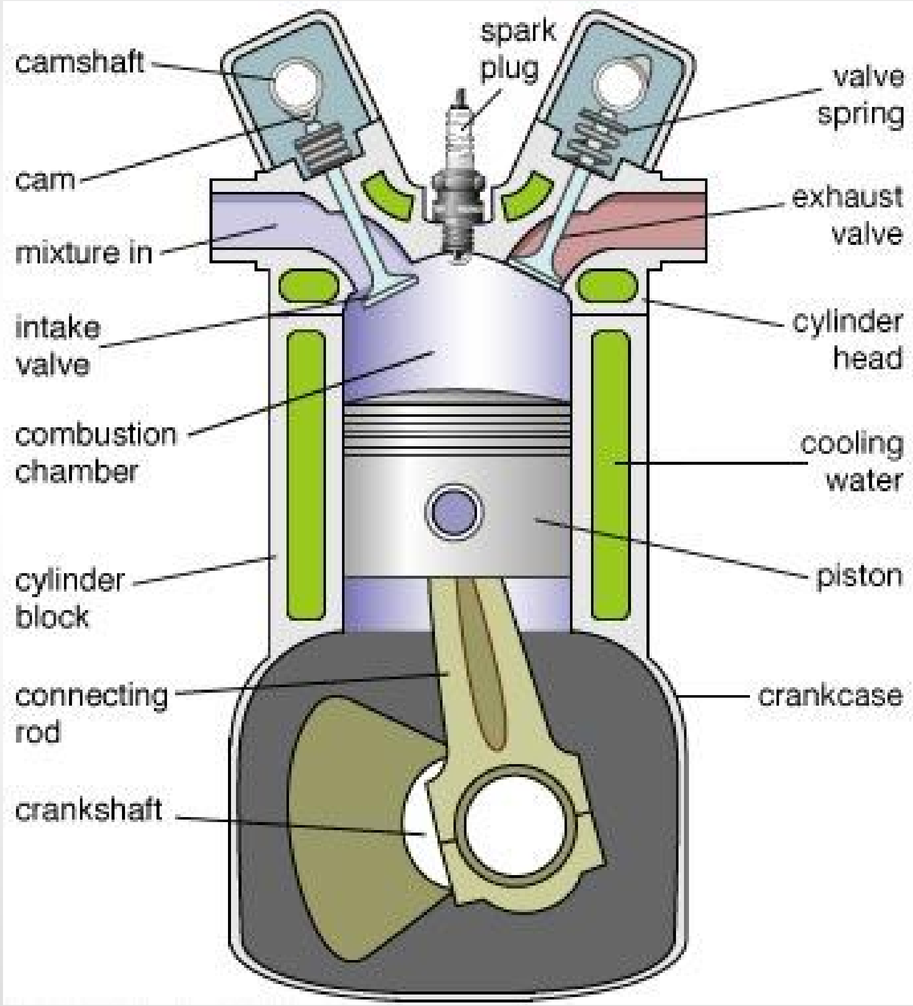
***The internal combustion engine is an engine in which the combustion of fuel-oxidizer mixture occurs in a confined space***

applied in:
automotive
rail transportation
power generation
ships
aviation
garden appliances

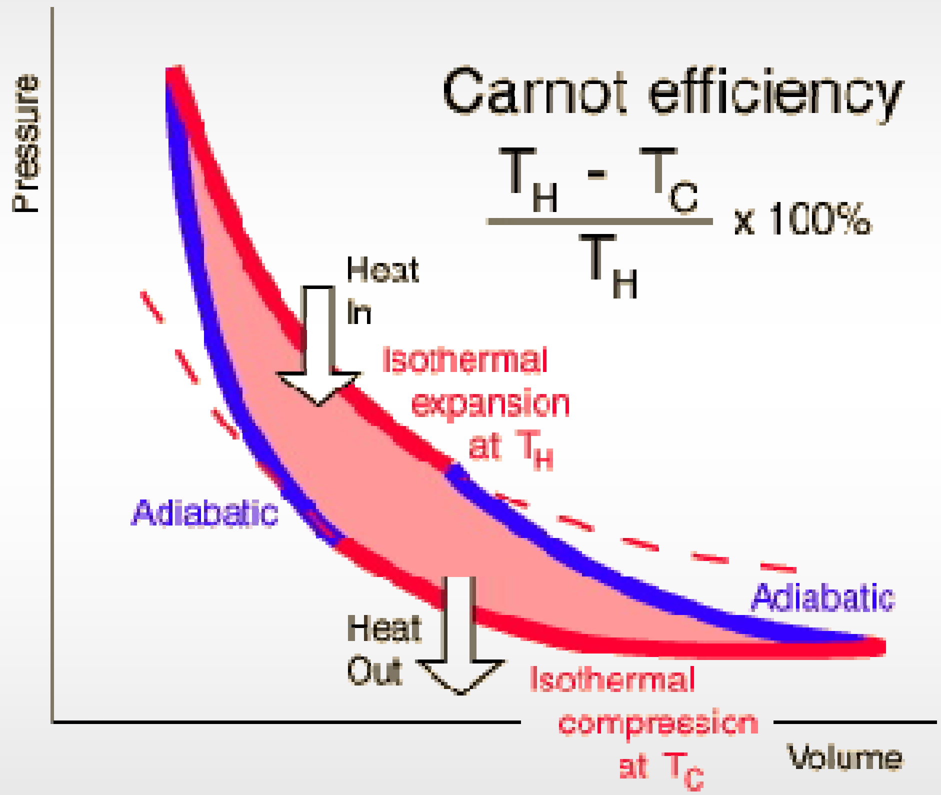
# Internal Combustion Engines



# Internal Combustion Engines



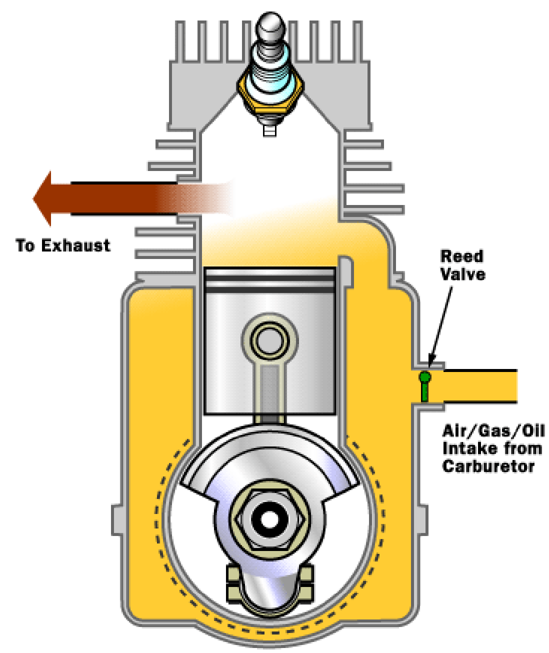
# Internal Combustion Engines
# – Carnot cycle -



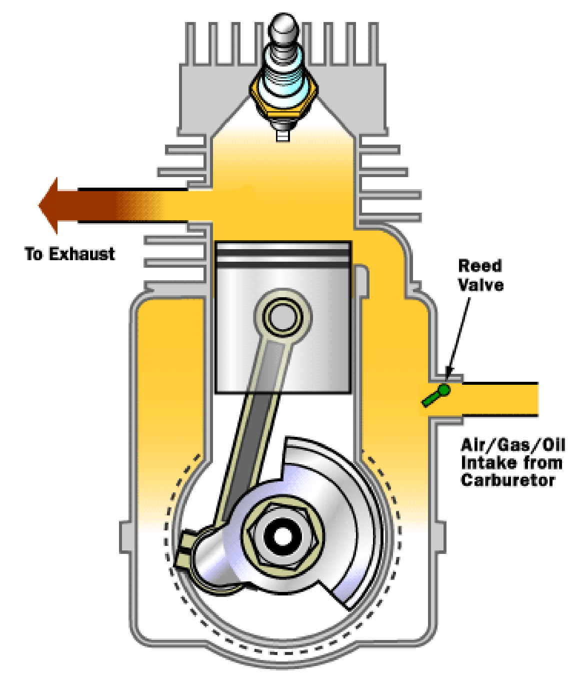
# Internal Combustion Engines
# – two stroke -

1. Power / Exhaust
   a. ignition
   b. piston moves downward compressing fuel-air mixture in the crankcase
   c. exhaust port opens

2. Intake / Compression
   a. inlet port opens
   b. compressed fuel-air mixture rushes into the cylinder
   c. piston upward movement provides further compression



Fuel-intake position of a two-stroke engine



Compression action of a two-stroke engine

# Internal Combustion Engines
# – two stroke -

**Advantages**:

•lack of valves, which simplifies construction and lowers weight

•fire once every revolution, which gives a significant power boost

•can work in any orientation

•good power to weight ratio

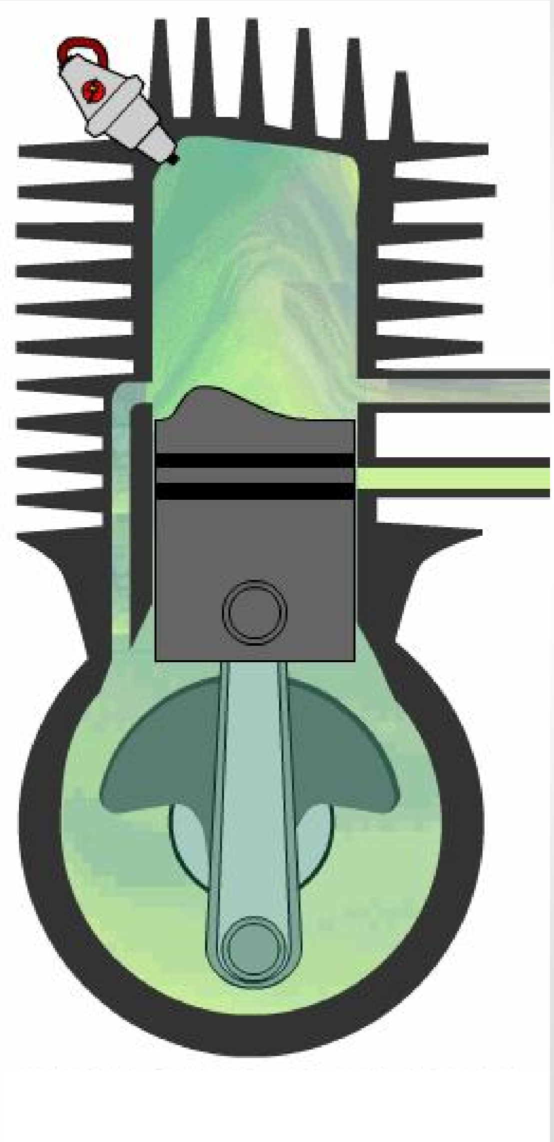
**Drawbacks:**

•lack of a dedicated lubrication system makes the engine to wear faster.

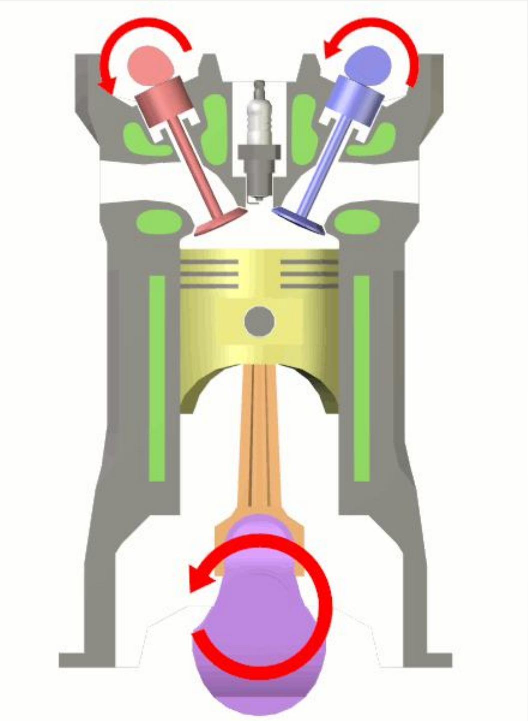
•necessity of oil addition into the fuel

•low efficiency

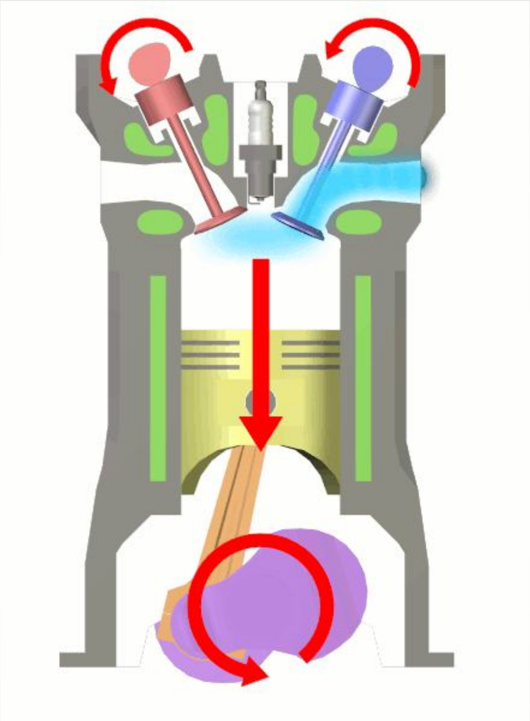
•produce a lot of pollution



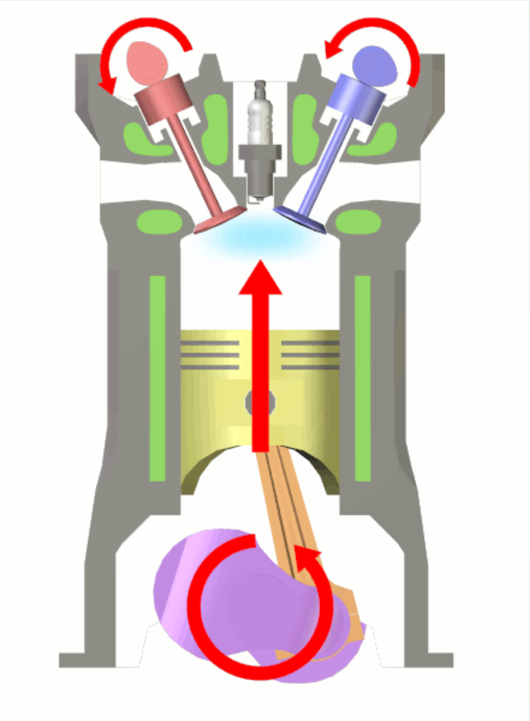
# Internal Combustion Engines
# – four stroke -



starting position



1. intake

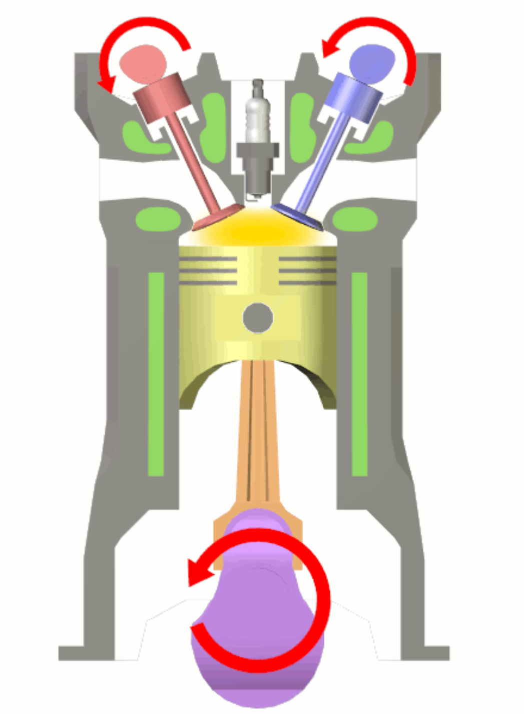


2. compression

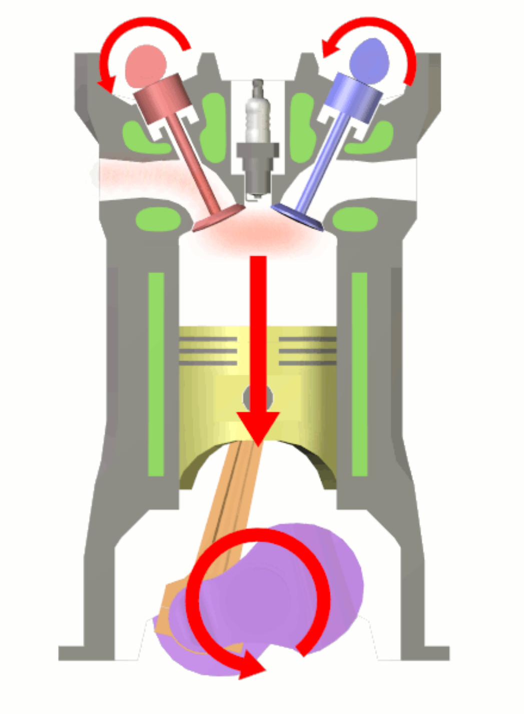
a. piston starts moving down
b. intake valve opens
c. air-fuel mixture gets in

a. piston moves up
b. both valves closed
c. air-fuel mixture gets compressed

# Internal Combustion Engines
# – four stroke -

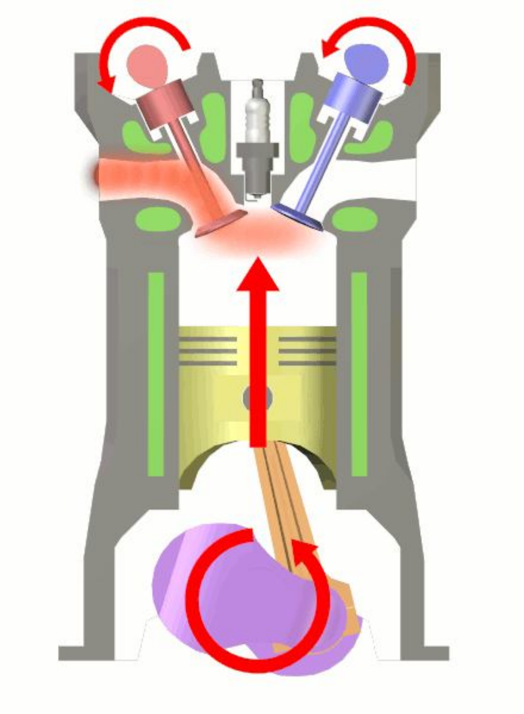


ignition



3. power

a. air-fuel mixture explodes driving the piston down



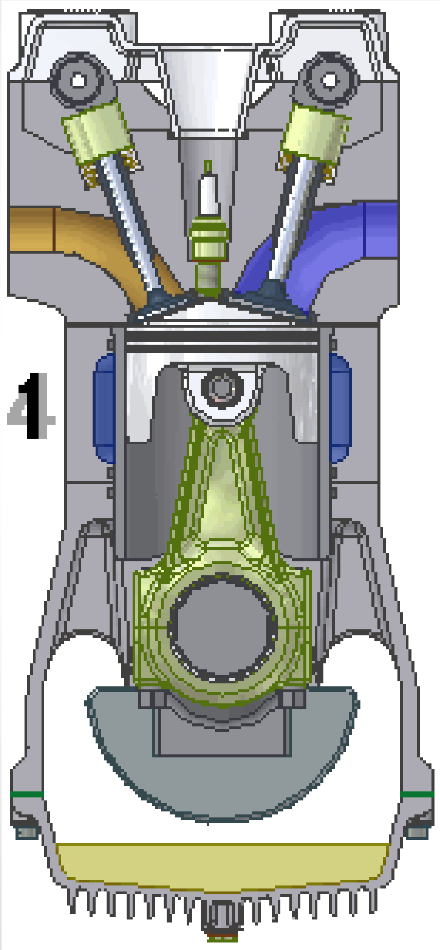
4. exhaust

a. piston moves up
b. exhaust valve opens
c. exhaust leaves the cylinder

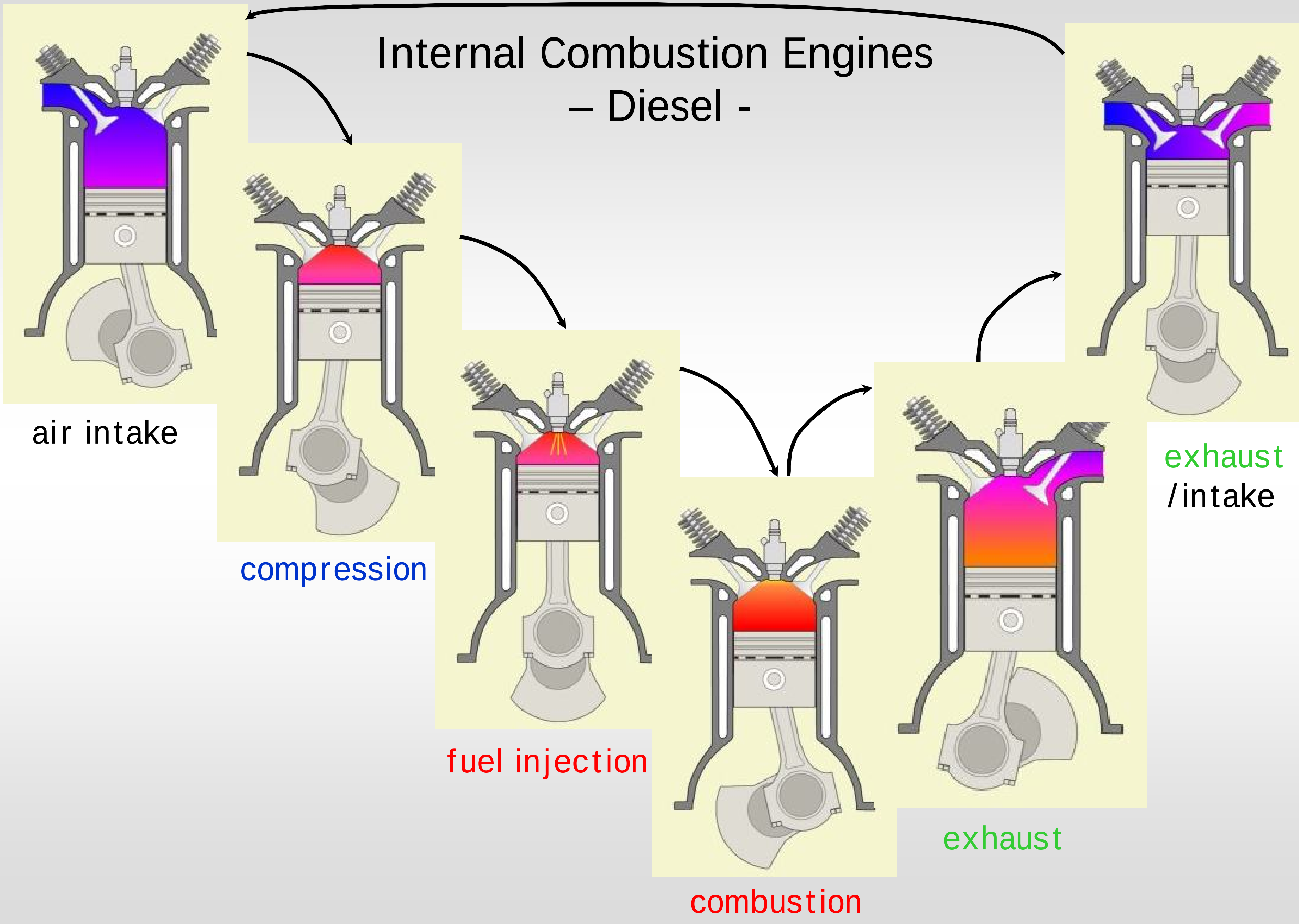
# Internal Combustion Engines
# – four stroke -

**Advantages**:
•dedicated lubrication system makes to engine more wear resistant
•better efficiency that 2-stroke engine
•no oil in the fuel – less pollution

**Drawbacks:**
•complicated constriction
•should work in horizontal position due to lubrication



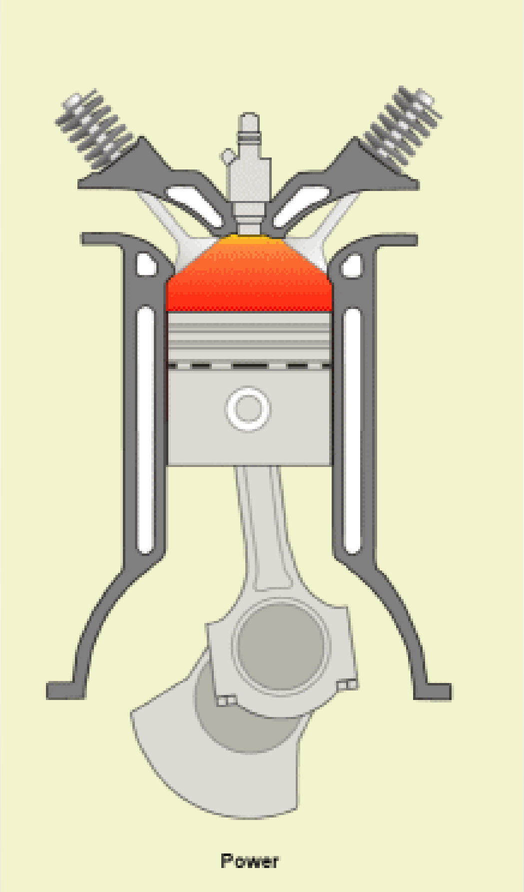
# Internal Combustion Engines – Diesel -



# Internal Combustion Engines
# – Diesel -

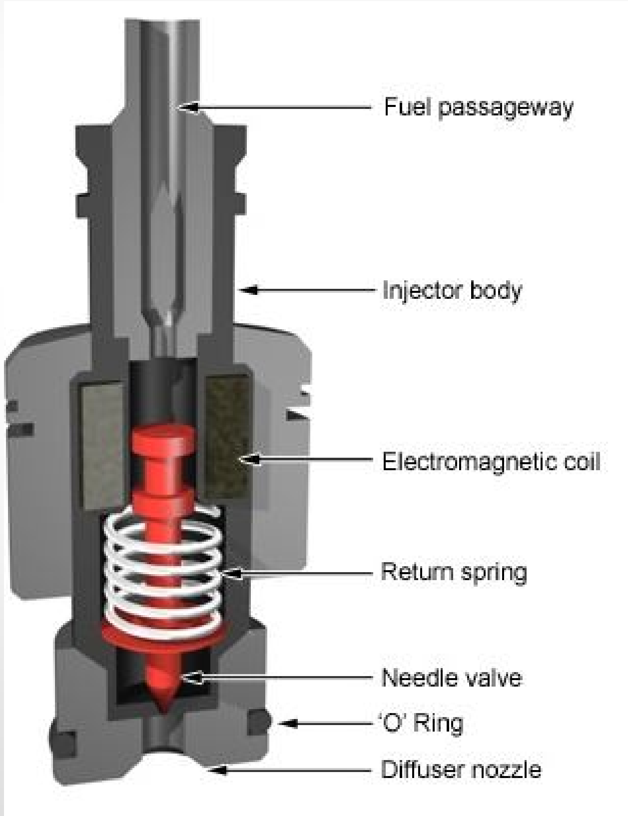
**Advantages**:
•self ignition (without electrical spark plug)
•better efficiency
•reliability
•higher durability
•supplied with worse fuels

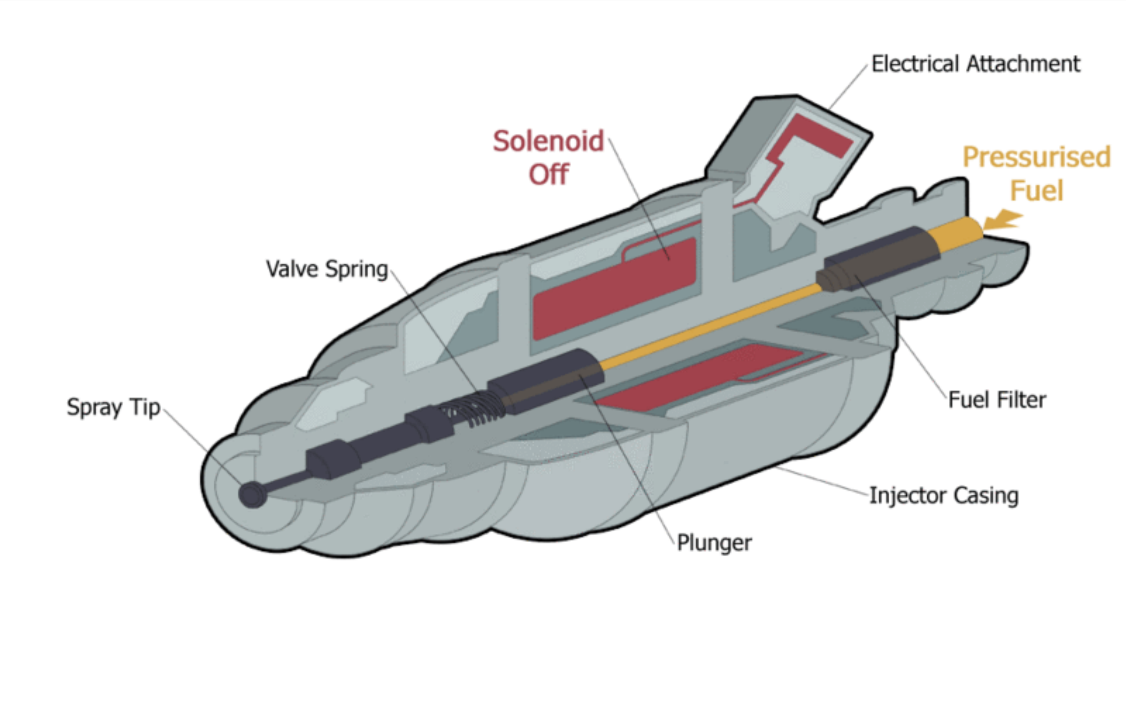
**Drawbacks:**
•more $NO_x$ production
•more expensive production
•more weight
•louder
•lower revolutions



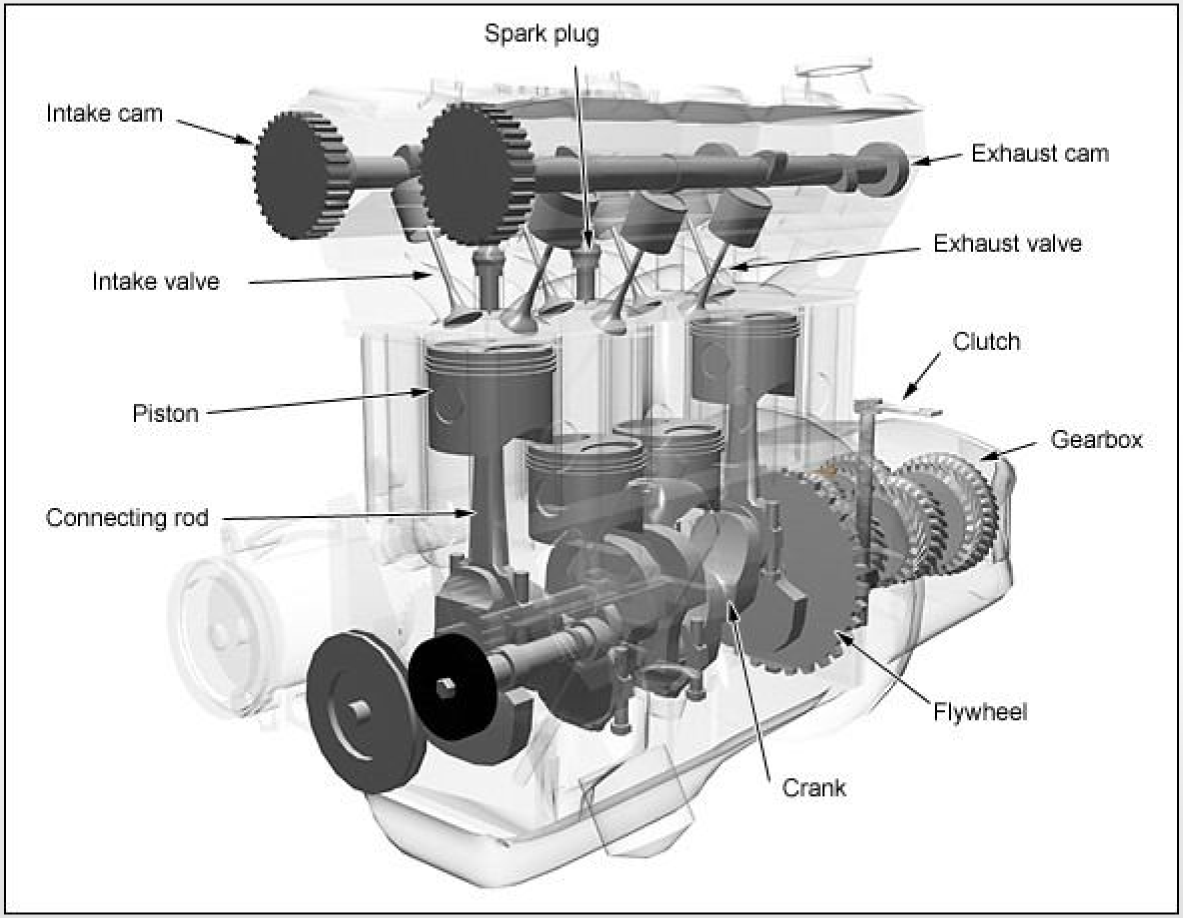
# Internal Combustion Engines
# – Diesel -

## fuel injector



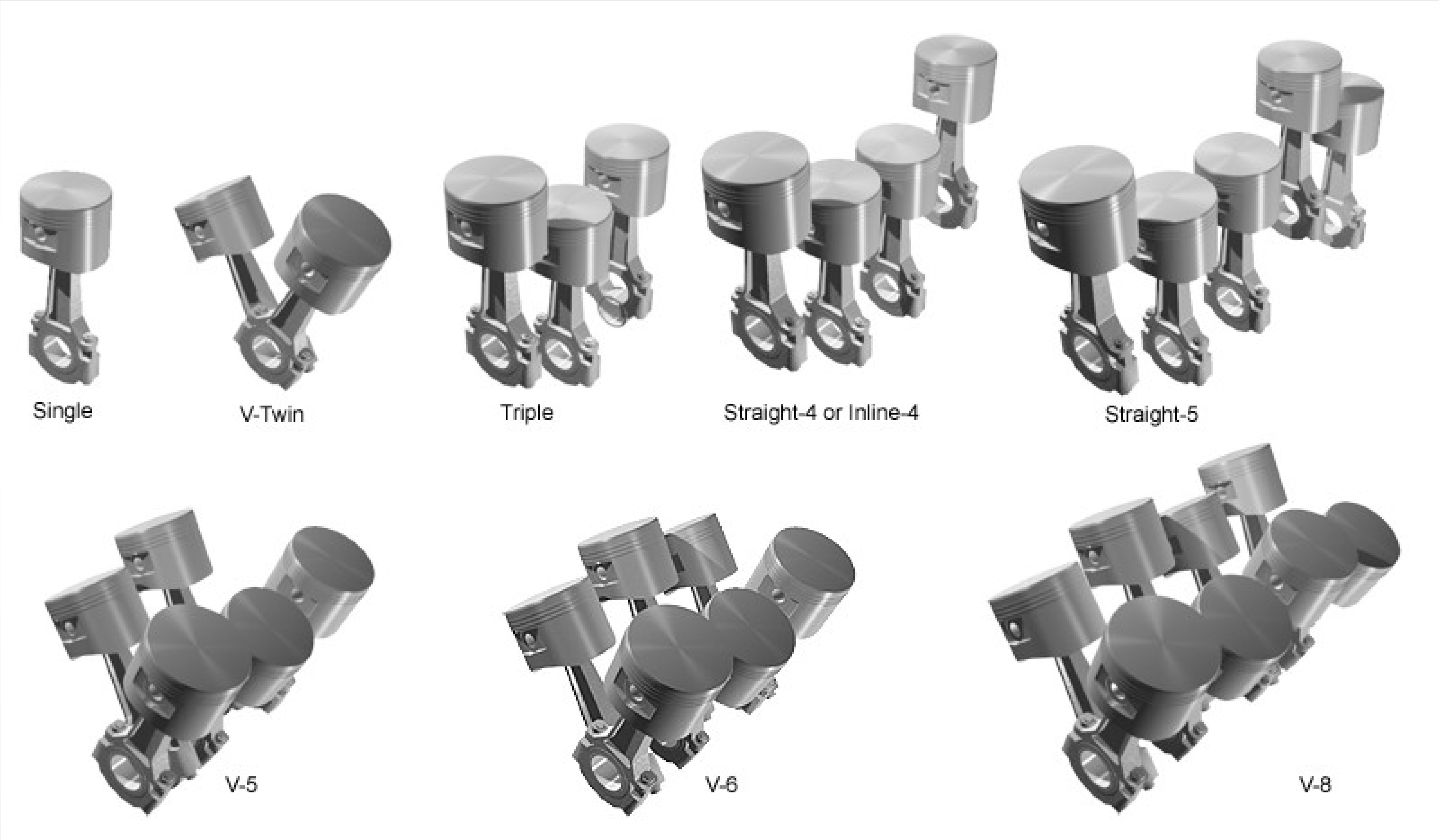



# Internal Combustion Engines – multi-cylinder -



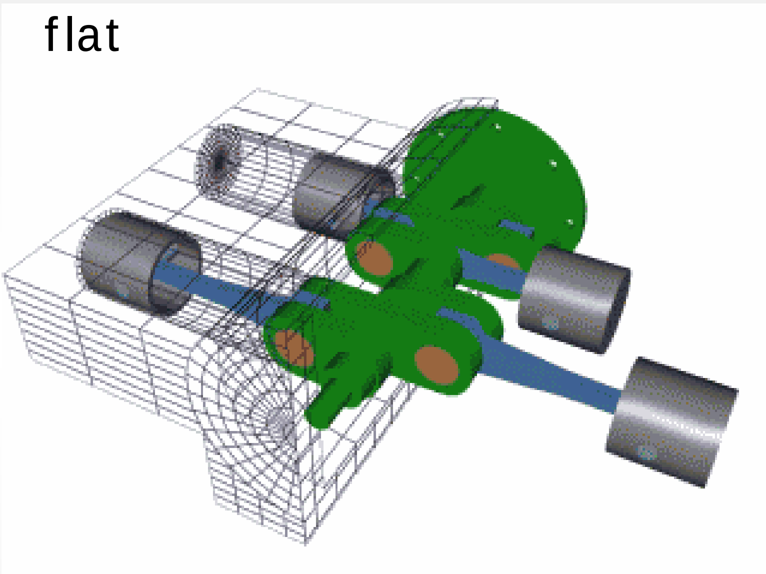
# Internal Combustion Engines
# – multi-cylinder -

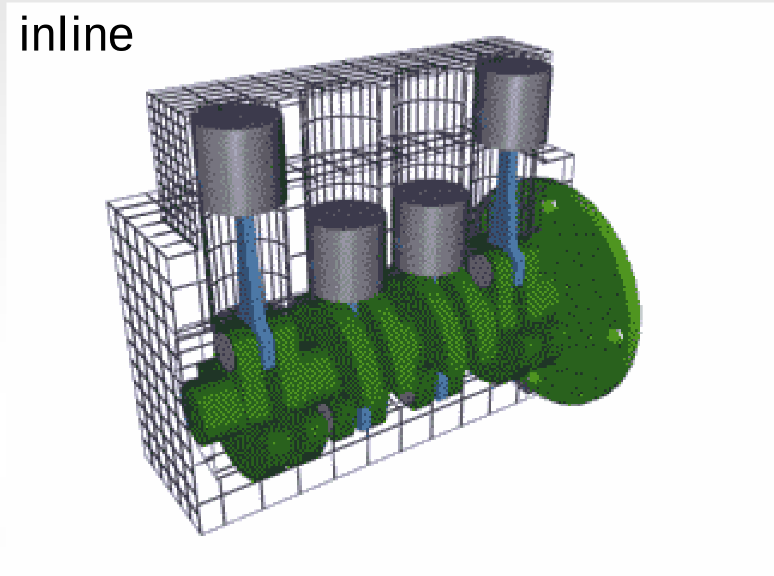
**Cylinder layouts**

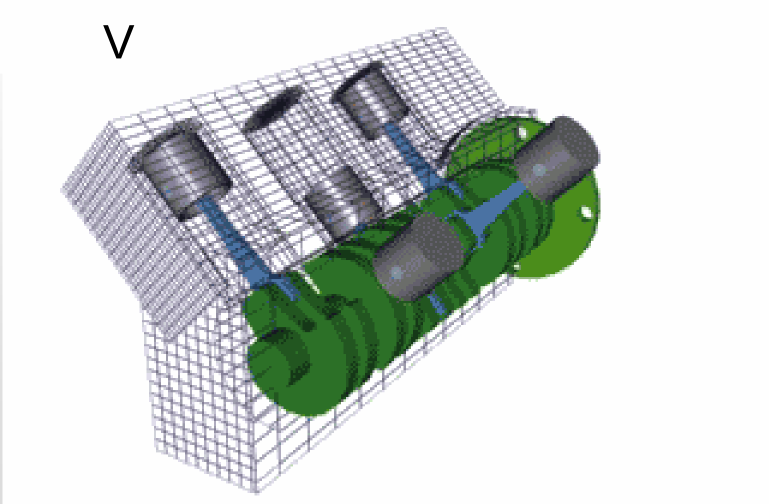


# Internal Combustion Engines
# – multi-cylinder -

**Cylinder layouts**



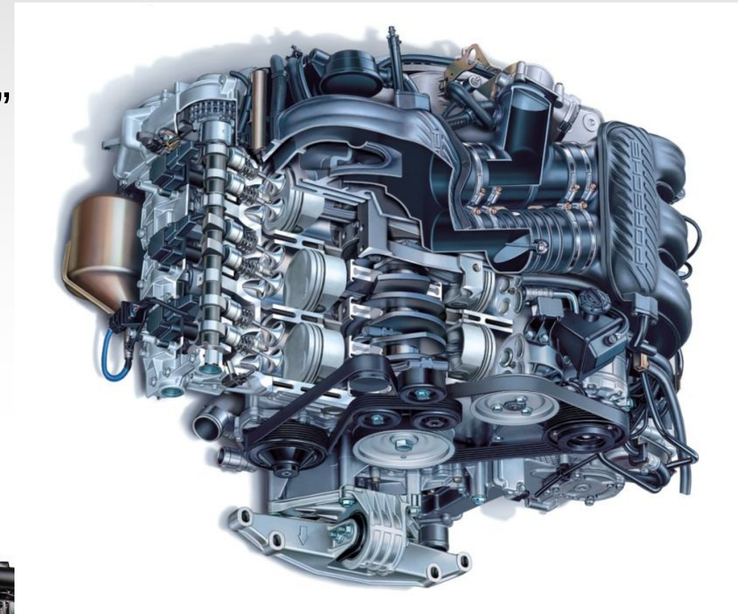



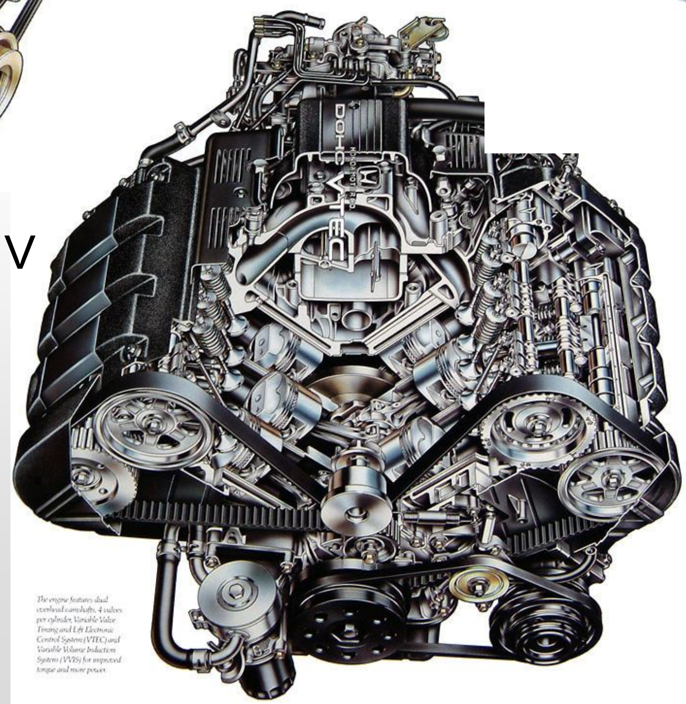
# Internal Combustion Engines
# – multi-cylinder -

inline

flat
„boxer”

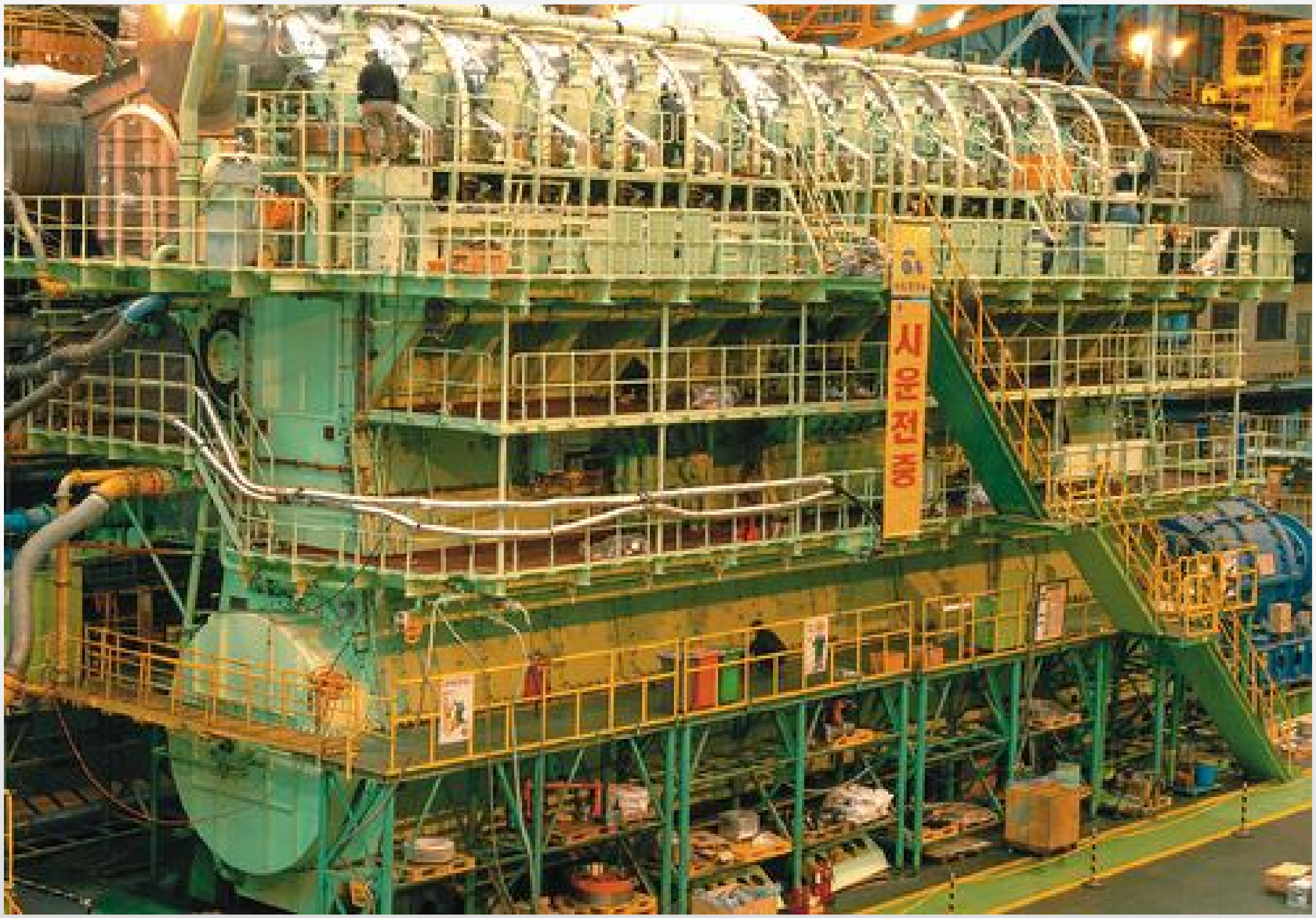


V



# Internal Combustion Engines
# – multi-cylinder -

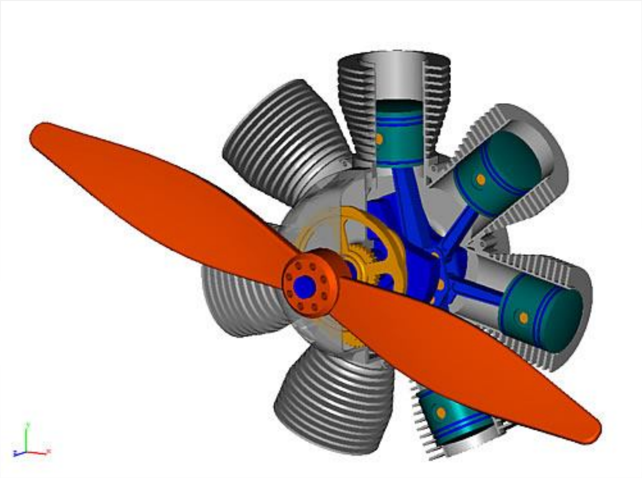
14 cylinder Diesel engine (80 MW)

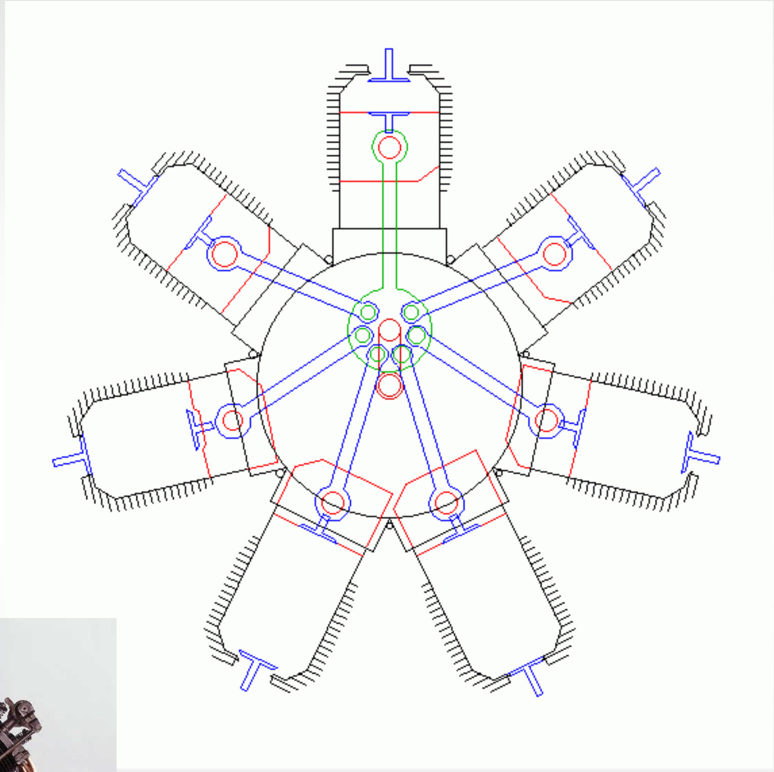


# Internal Combustion Engines
# – multi-cylinder -

**Cylinder layouts**

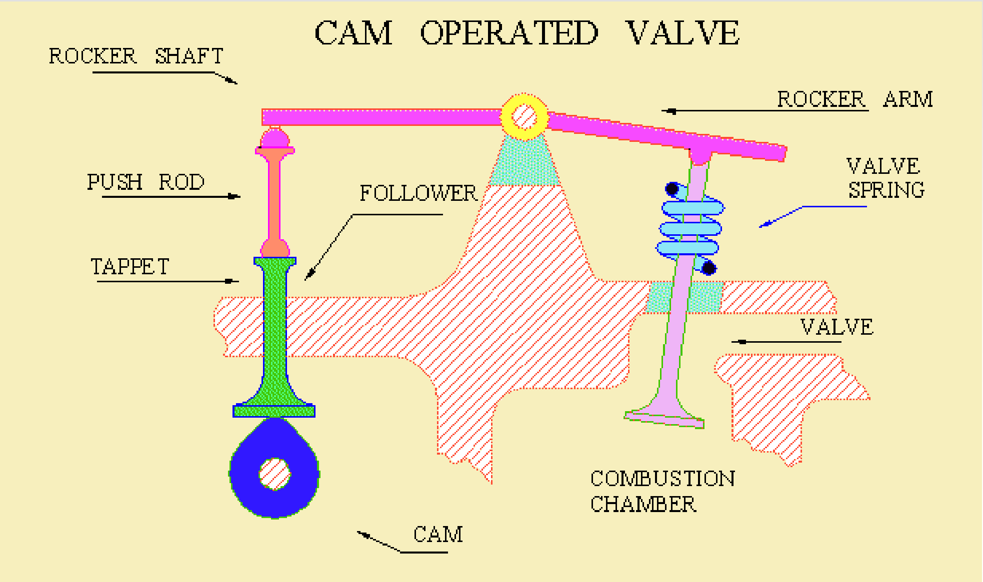
radial

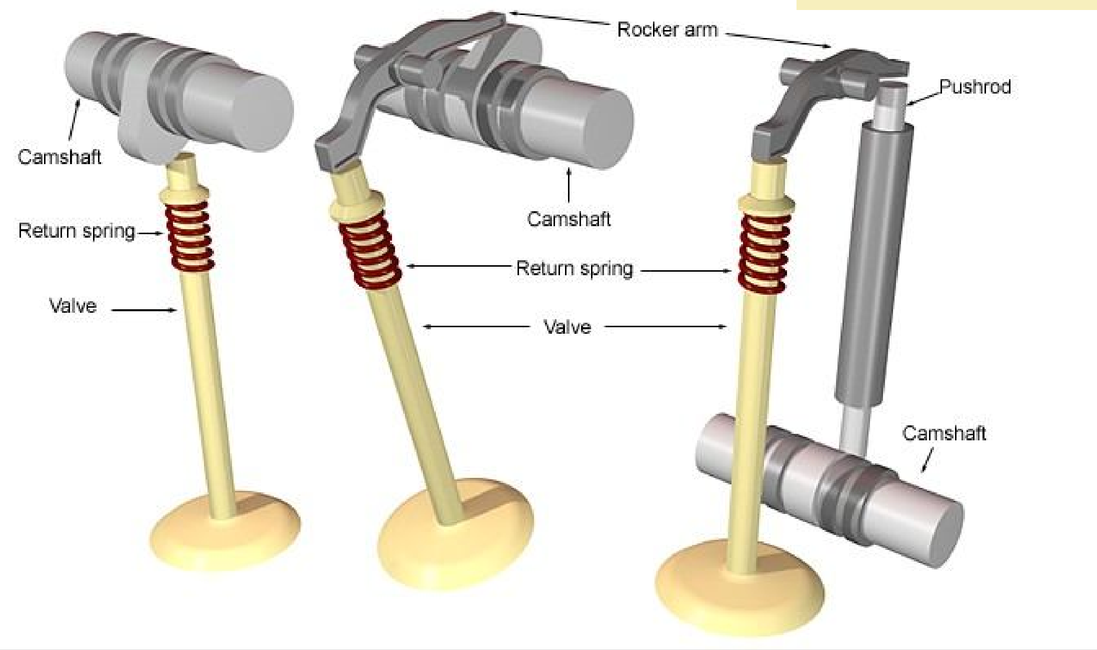




# Internal Combustion Engines

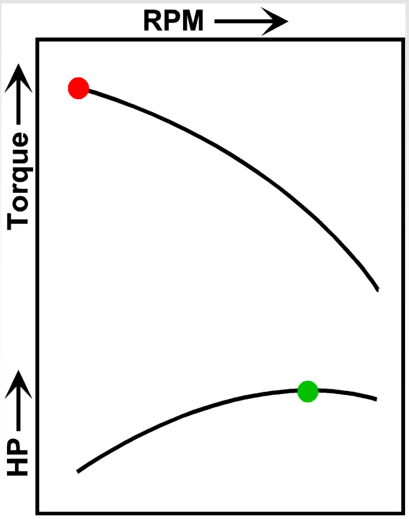
Valve operation



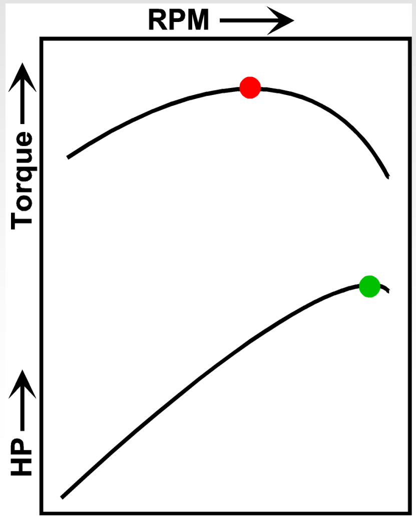



# Internal Combustion Engines

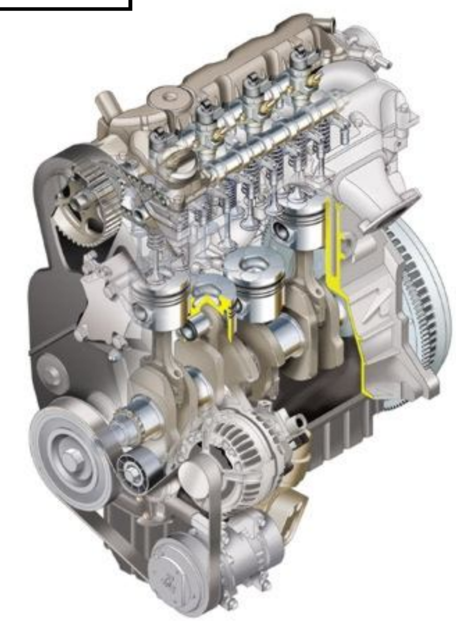
Engine characteristic

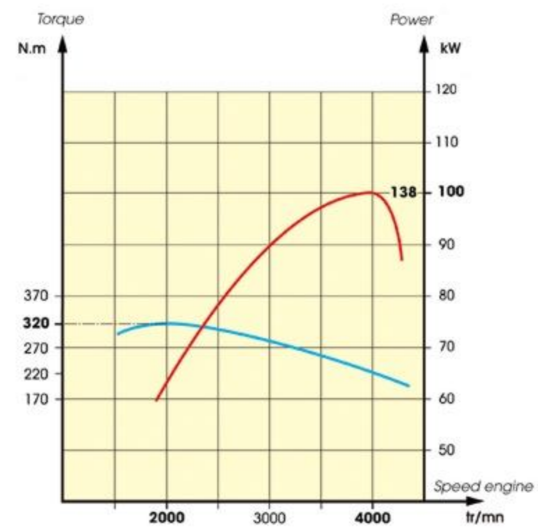



Diesel



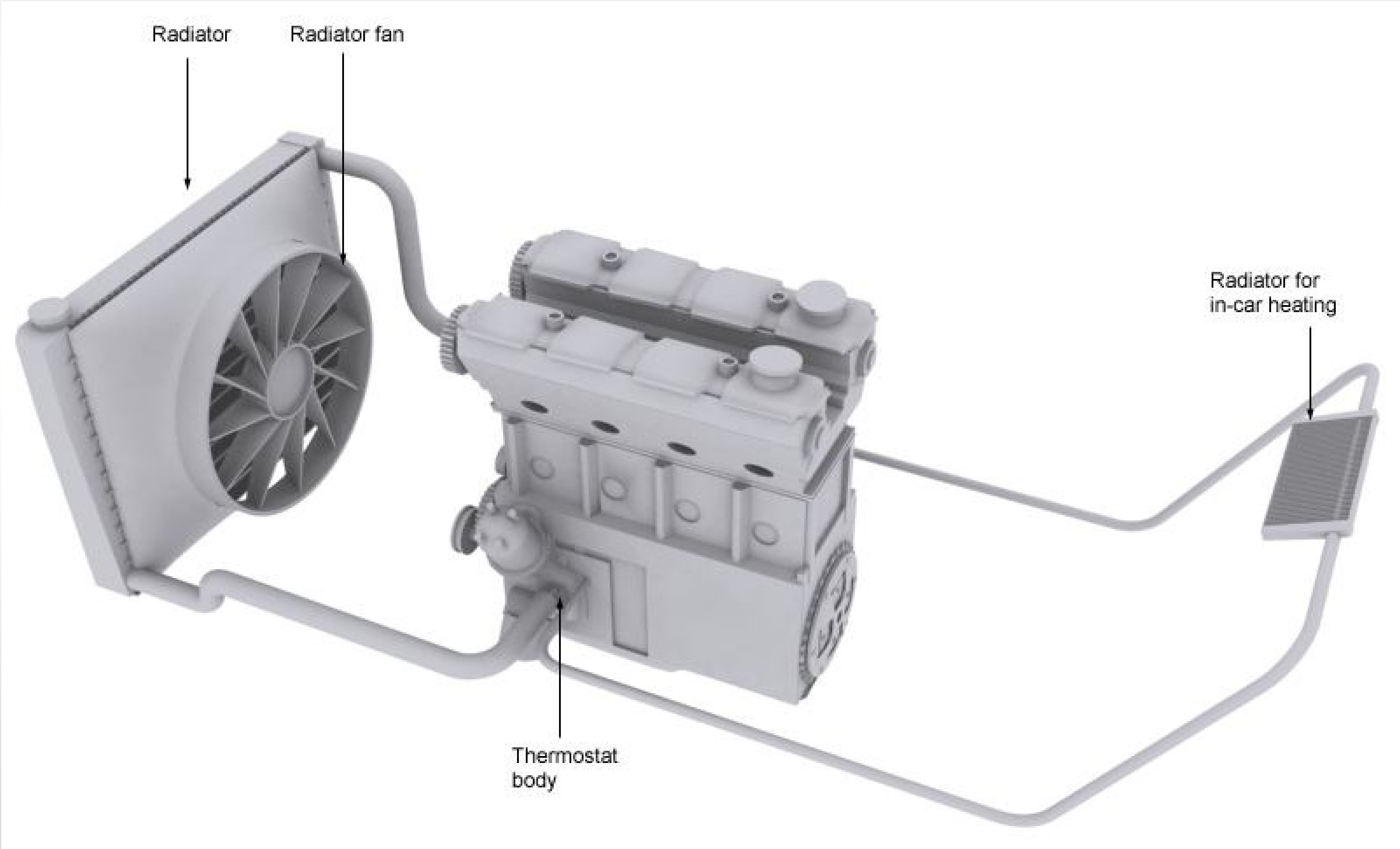

Petrol





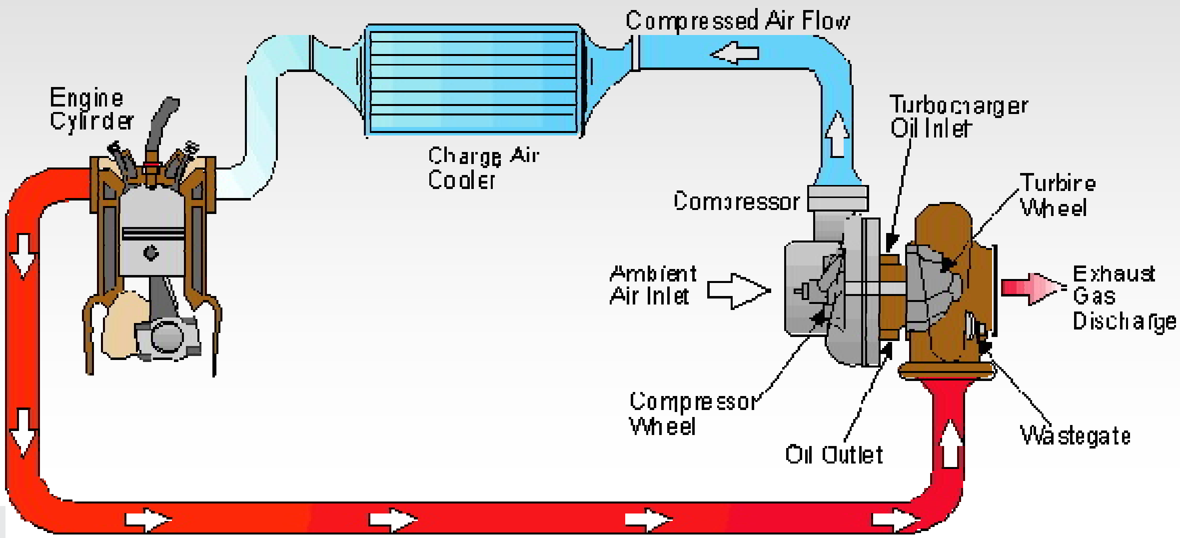
# Internal Combustion Engines

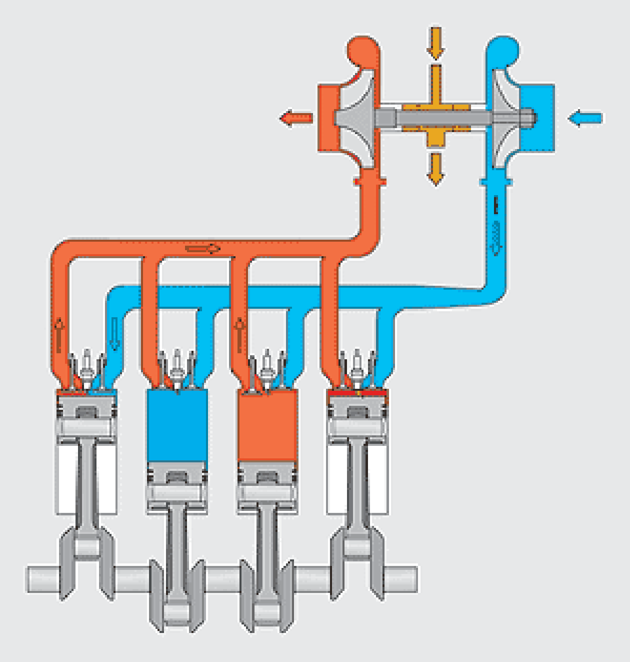
## Engine cooling



# Internal Combustion Engines

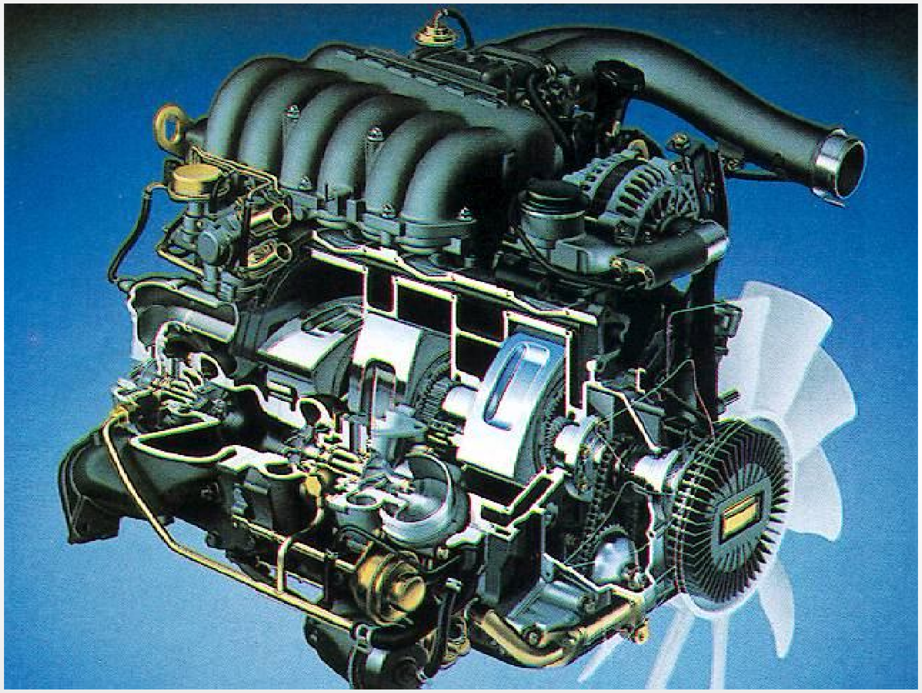
Turbocharged engine

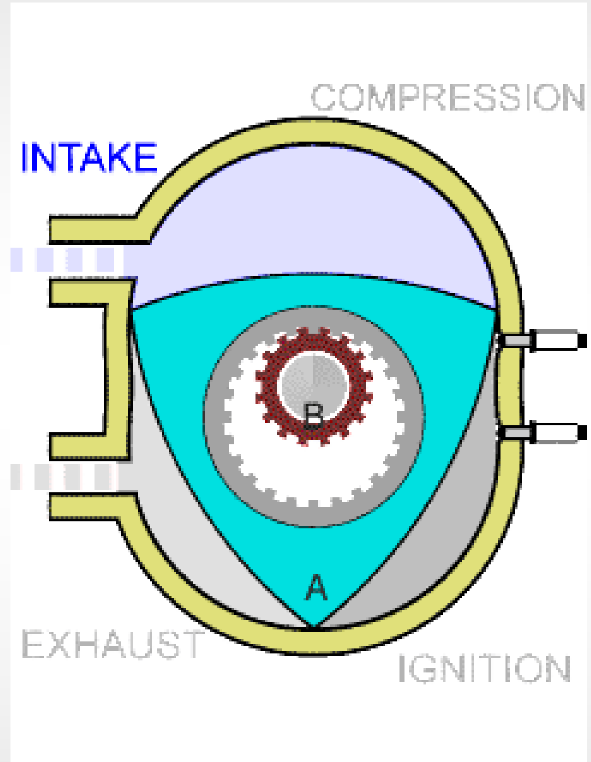


# Internal Combustion Engines

Wankel rotary engine






**Advantages**:
- higher power output
- no reciprocating mass
- simpler and lighter construction

**Drawbacks:**
- increased wear of rubbing parts
- higher fuel consumption
- requirement for better materials

# Introduction

- system used in automotive petrol engines, having almost completely replaced carburetors in the late 1980s.

- A fuel injection system is designed and calibrated specifically for the type(s) of fuel it will handle. Most fuel injection systems are for gasoline or diesel applications.
- The basic function of a fuel injection system is to inject fuel to the engine cylinders in ***proper quantity***, at ***correct time*** and at a ***pre-determined rate***.

# FUEL INJECTION SYSTEMS

# History and Development

- ***Herbert Akroyd Stuart*** developed the first system laid out on modern lines with a highly accurate 'jerk pump' to meter out fuel oil at high pressure to an injector. This system was adapted and improved by ***Robert Bosch*** and ***Clessie Cummins*** for use on diesel engines — Rudolf Diesel's original system employed an 'air-blast' system using highly compressed air.
- Fuel injection was in widespread commercial use in diesel engines by the mid-1920s. Because of its greater immunity to wildly changing g-forces on the engine, the concept was adapted for use in gasoline-powered aircraft during World War II, and direct injection was employed in some notable designs like the ’Junkers Jumo 210’, the ’Daimler-Benz DB 601’, the ‘BMW 801’, and later versions of the ’B-29 Super-fortress’.

# Objectives Of Fuel Injection System

The injection system of the compression ignition engine should fulfill the following objectives consistently and precisely:

1. Meter the appropriate quantity of fuel, as demanded by the speed of, and the load on, the engine at the given time.
2. Distribute the metered fuel equally among cylinders in a multi-cylinder engine.
3. Inject the fuel at the correct time (with respect to crank angle) in the cycle.
4. Inject the fuel at the correct rate (per unit time or crank angle degree).
5. Inject the fuel with the correct spray pattern and sufficient atomization as demanded by the design of the combustion chamber.
6. Begin and end injection sharply without dribbling.

- There are two major divisions of Fuel Injection systems:
  - **Solid Injection systems**, which inject only the liquid fuel through the injectors.
  - **Air Injection systems**, which inject air along with the liquid fuel.

  However, the air injection systems have proved to be less efficient and costlier than other systems and hence, is now obsolete.
- The commonly used types of Solid Injection system are:
  - <u>Individual pump system</u>: This consists of a separate metering and compression pump for each cylinder.
  - <u>Common rail system</u>: A single pump for compressing the fuel, plus a metering element for each cylinder.

# Individual Pump Fuel Injection System

- As shown in the adjoining figure, the fuel is drawn from fuel tank by means of a fuel feed pump which is operated from the injection pump camshaft.
- The fuel is then passed through a filter and there-by to the fuel injection pump.
- The filter prevents any abrasive matter in the fuel flow towards the injection pump, which would otherwise result in poor starting, irregular idling and deterioration in performance due to decreased fuel delivery from the injection pump.

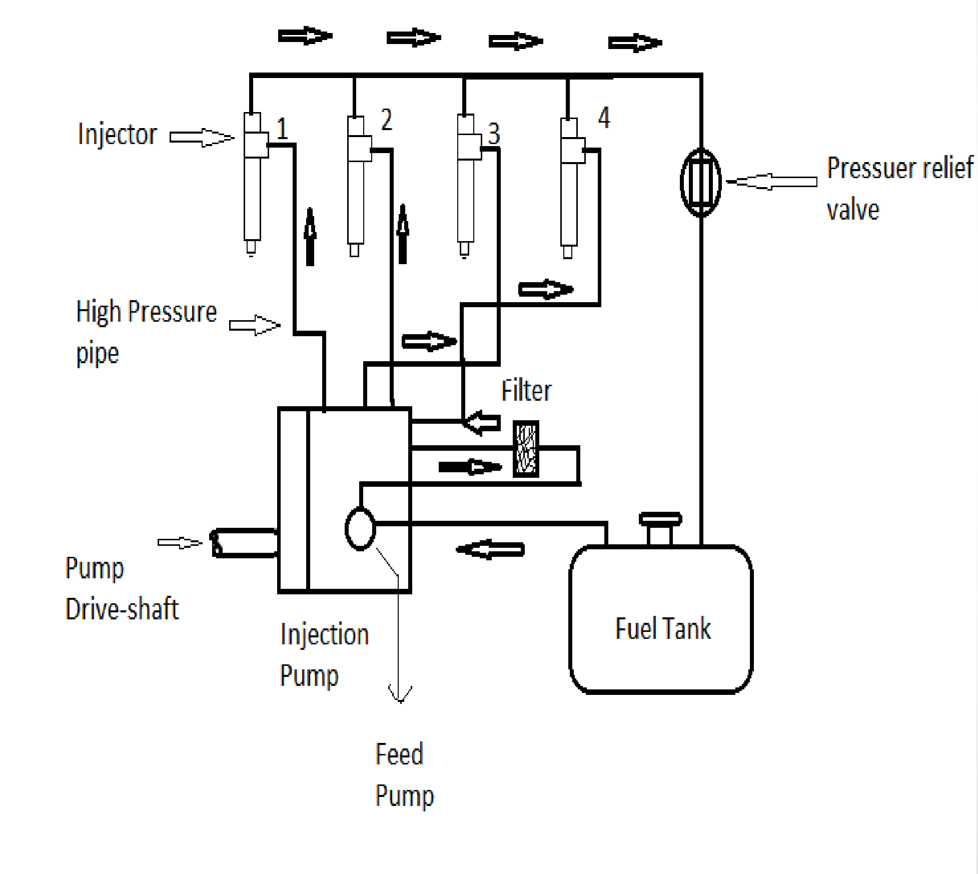



**Fig**.: Individual Pump Injection System using in-line injection pump

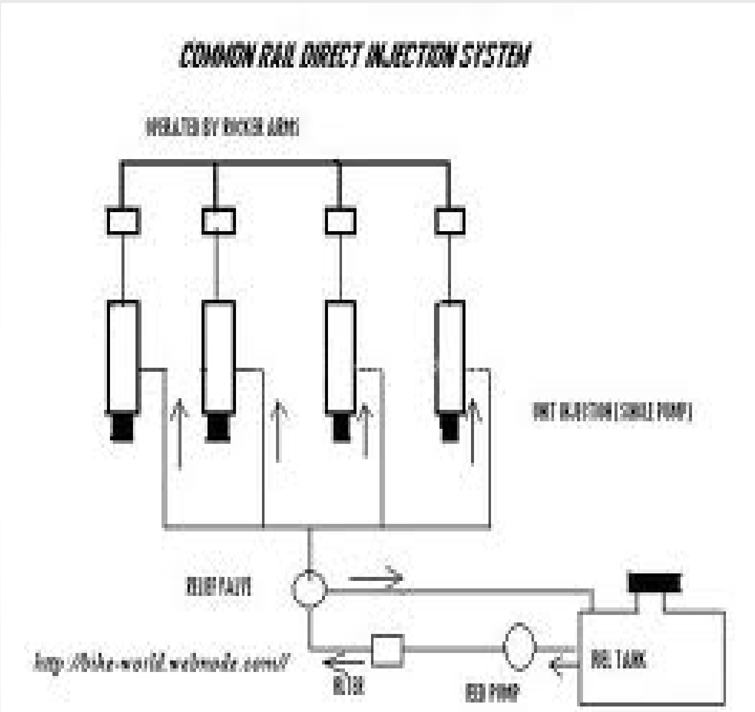
- The fuel injection pump then injects definite quantity of fuel into each cylinder in turn, according to the firing order, through the injectors fitted on them.
- The injection pump is gear driven from the engine camshaft so that it is driven at half the engine speed.
- Also a governing device is placed at the side of the injection pump to provide automatic speed control.
- Any excess fuel after lubrication of injector nozzle is returned to the fuel tank.
- The most successful working of this system is found in Swaraj Mazda SL engine.

# COMMON RAIL DIRECT INJECTION SYSTEM

# HISTORY

- The common rail system was developed in the late 1960s by Robert Huber of Switzerland and the technology further developed by Dr. Marco Ganser
- The common rail fuel system is developed for heavy duty vehicles and turned it into practical use of this system mounted on the Hino Rising Ranger truck and sold for general use in 1995.

# COMMON RAIL DIRECT INJECTION SYSTEM




•In this system the unit injectors is employed on each  cylinders.

•The unit injectors are operated by rocker arms.

•The fuel taken from the fuel tank by feed pump then passed through filter and common rail and same quantity of fuel is injected in each cylinder

# MODERN COMMON RAIL SYSTEM

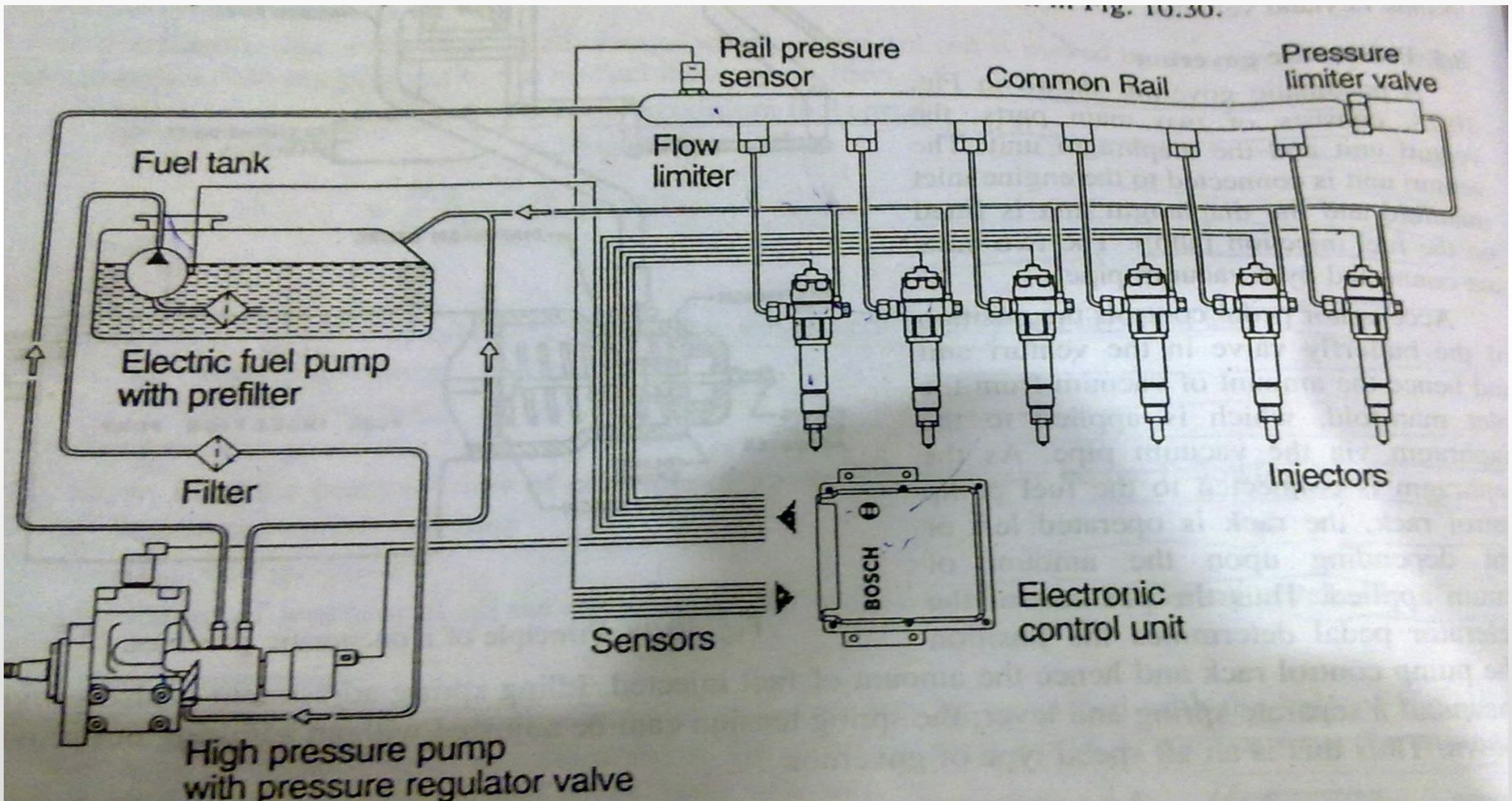



Fig. 10.29. Layout of Bosch K5-common rail system for passenger car engine.
(Courtesy—MICO, India)

- This system is the similar to the common rail injection system.
- In modern CRS the injector are operated by ECU(electronic control unit)
- The fuel from the fuel tank is pumped by a low pressure electric fuel pump through a filter, to the high pressure pump, which builds up the high pressure in the common rail with the help of a pressure regulator valve which is controlled by an ECU through pressure sensor.
- Thus the fuel pressure in the rail is independent of engine speed.
- The injector receives its operation signal from the ECU.
- The main component of the system are the low pressure pump, the high pressure pump the common rail ECU, the injector.

# Advantages of CRS(common rail system)

- It increases fuel economy.
- It lowers emission.
- It delivers less noisy operation.
- The system can be easily integrated in wide variety of engines.
- It is relatively simple in construction & needs less maintenance.

# MULTI POINT FUEL INJECTION SYSTEM

# *INTRODUCTION*

- MPFI- a technology used in petrol engines
- Uses a small computer to control the car’s engine
- In MPFI engine one fuel –injector is installed near each cylinder ,that is why it is called multi point fuel injection.
- Before MPFI system, there was a technology called “**Carburetor**”

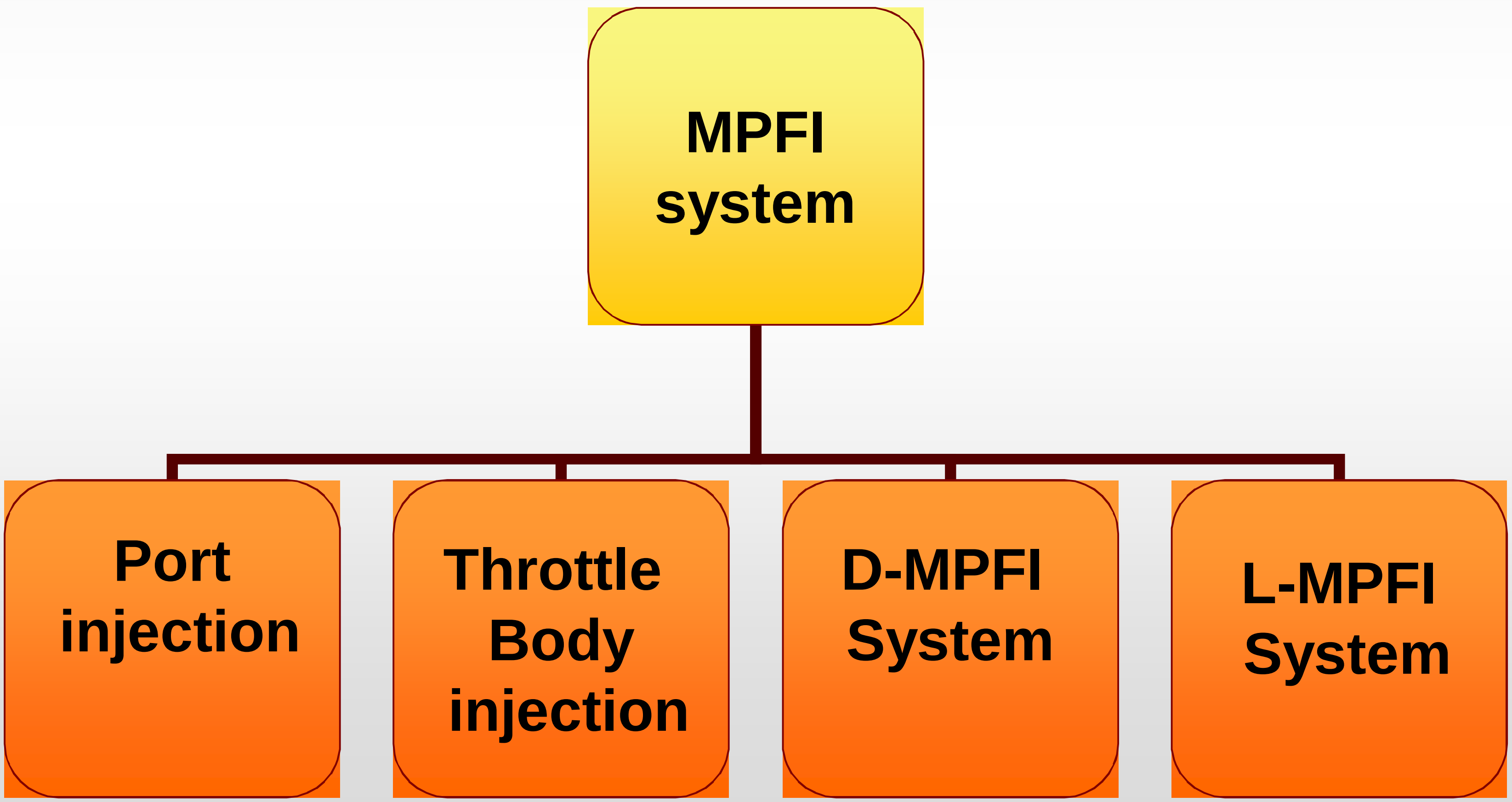
- The computer in the MPFI system decides what amount of fuel to inject
- System also learns from the drivers driving habits
- MPFI system makes engine fuel efficient

# FUNDAMENTALS OF FUEL INJECTION

- MPFI Systems can either be:
  - Sequential
  - Simultaneous
  - Group
- These techniques result in better ‘power balance’ amongst the cylinders, higher output from each one of them, along with faster throttle response

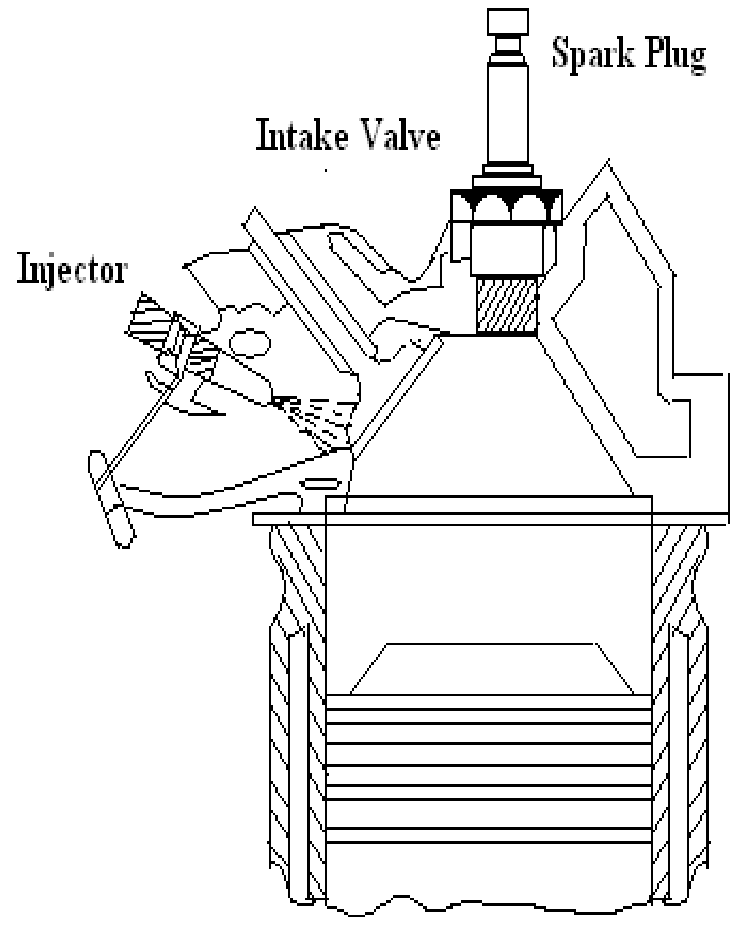
- 'Sequential' is the best from the above considerations of power balance/output
- “Sefi’’-Sequential Electronic Fuel Injection - technically is the best of the above variants of MPFI
- The ‘on-board’ ECU primarily controls the Ignition Timing and quantity of fuel to be injected

# *VARIOUS INJECTION SYSTEM*



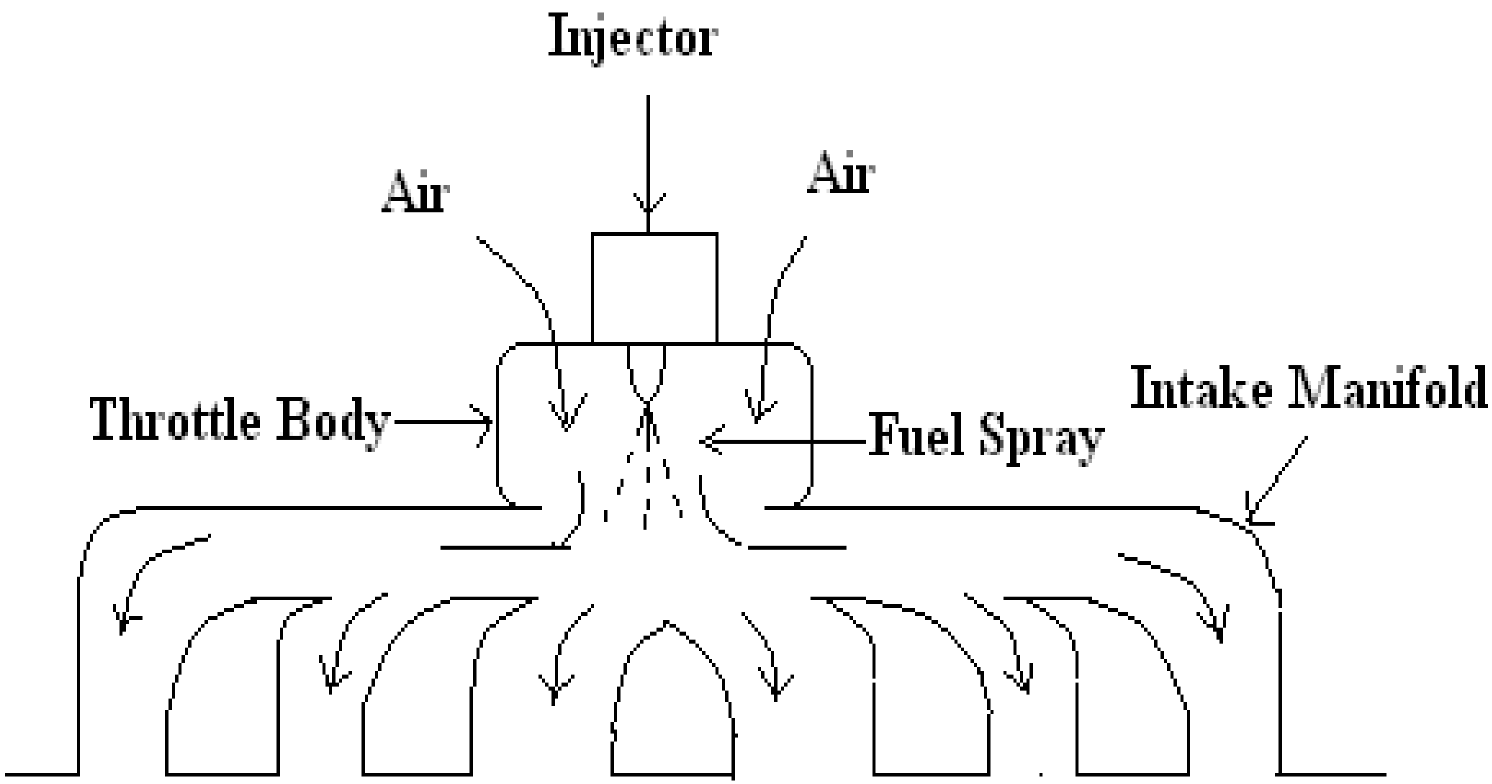
- The injector is placed on the side of the intake manifold near the intake port

- Every cylinder is provided with an injector in its intake manifold



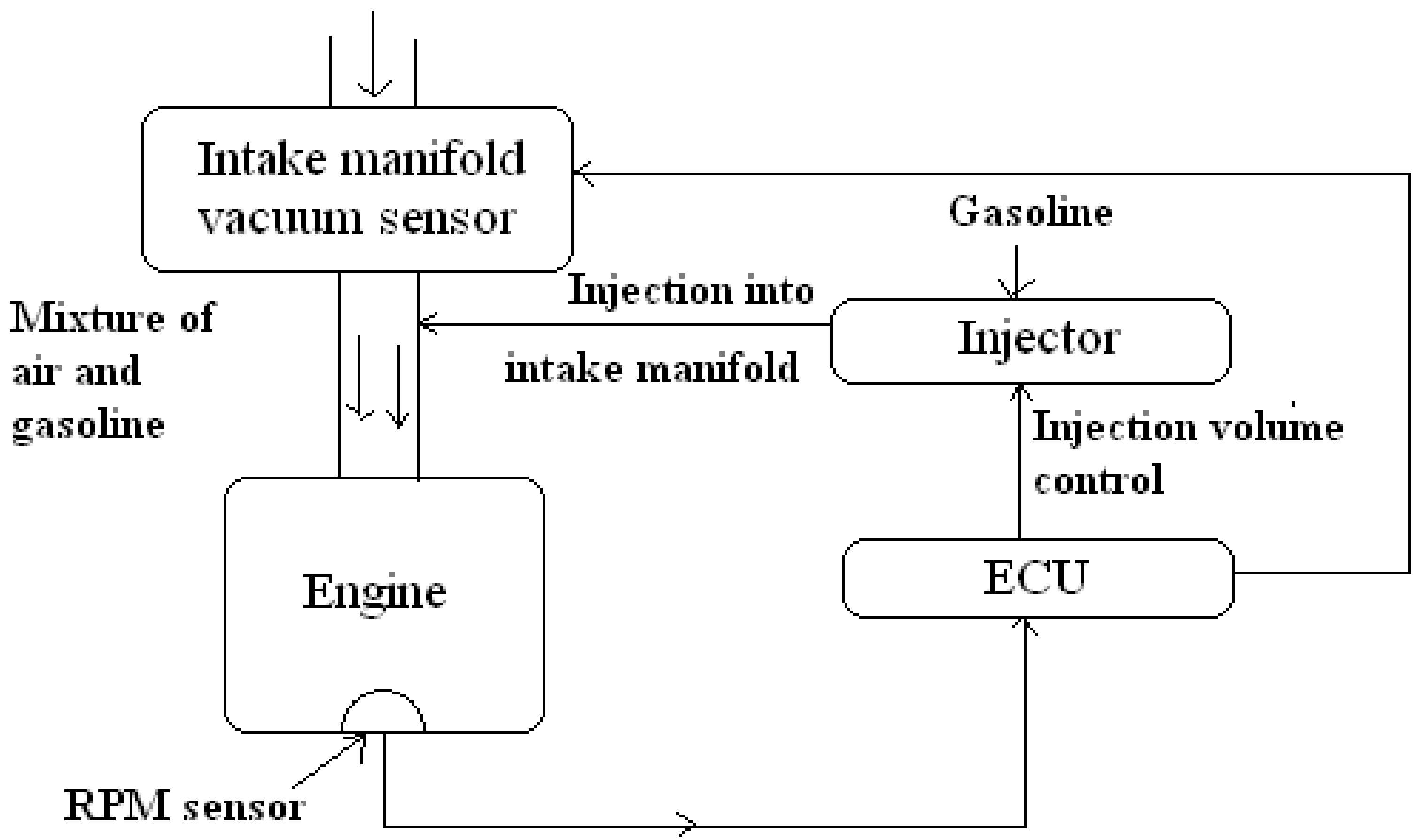

Port Injection System

# Throttle Body Injection System



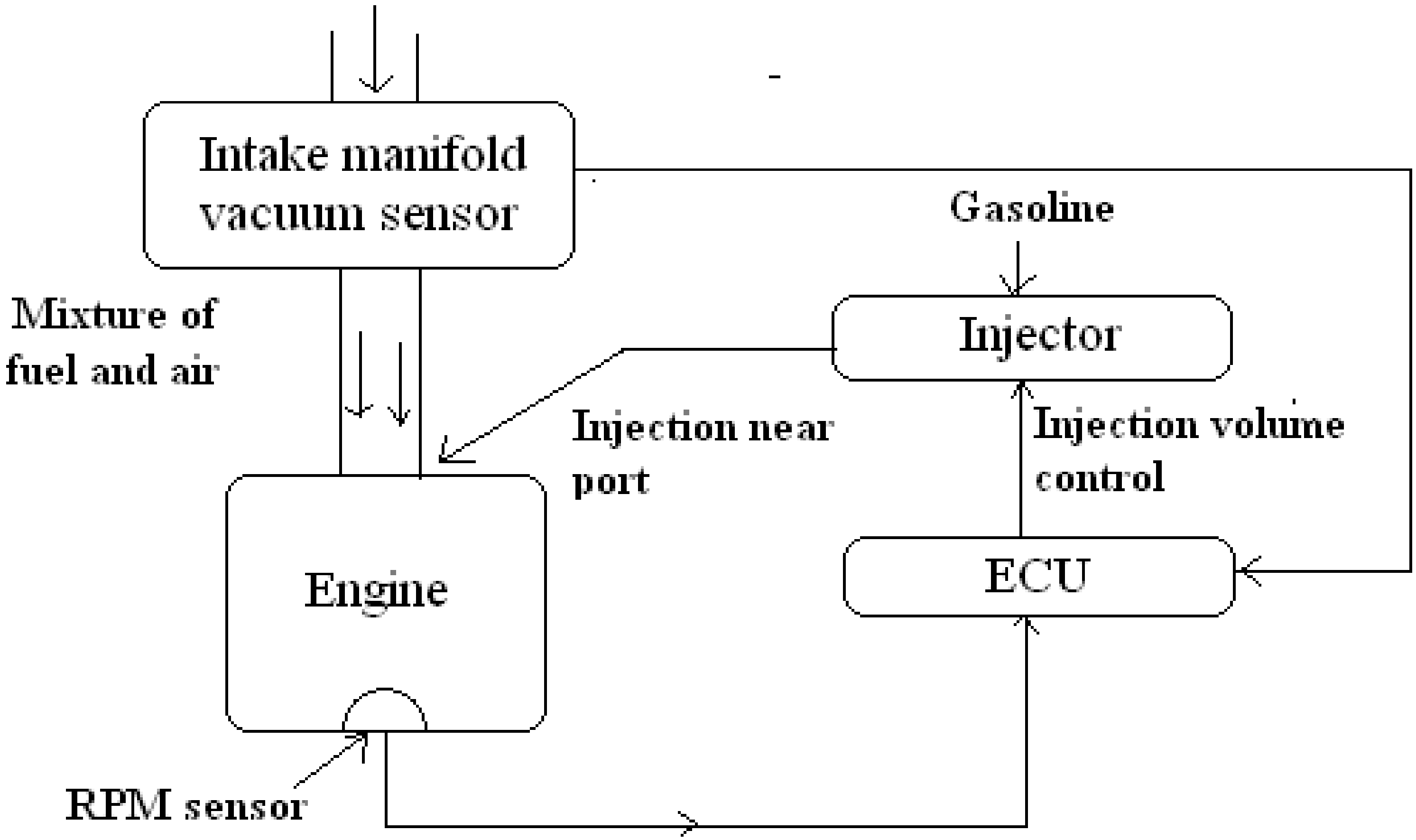

Throttle Body Injection (Single Point)

# D-MPFI System




*D-MPFI Gasoline Injection System*

# L-MPFI System




*L-MPFI Gasoline Injection System*

# ADVANTAGES

- Improved fuel consumption
- Better for the environment
- Better performance

# Engine Fuel System (SI Petrol)

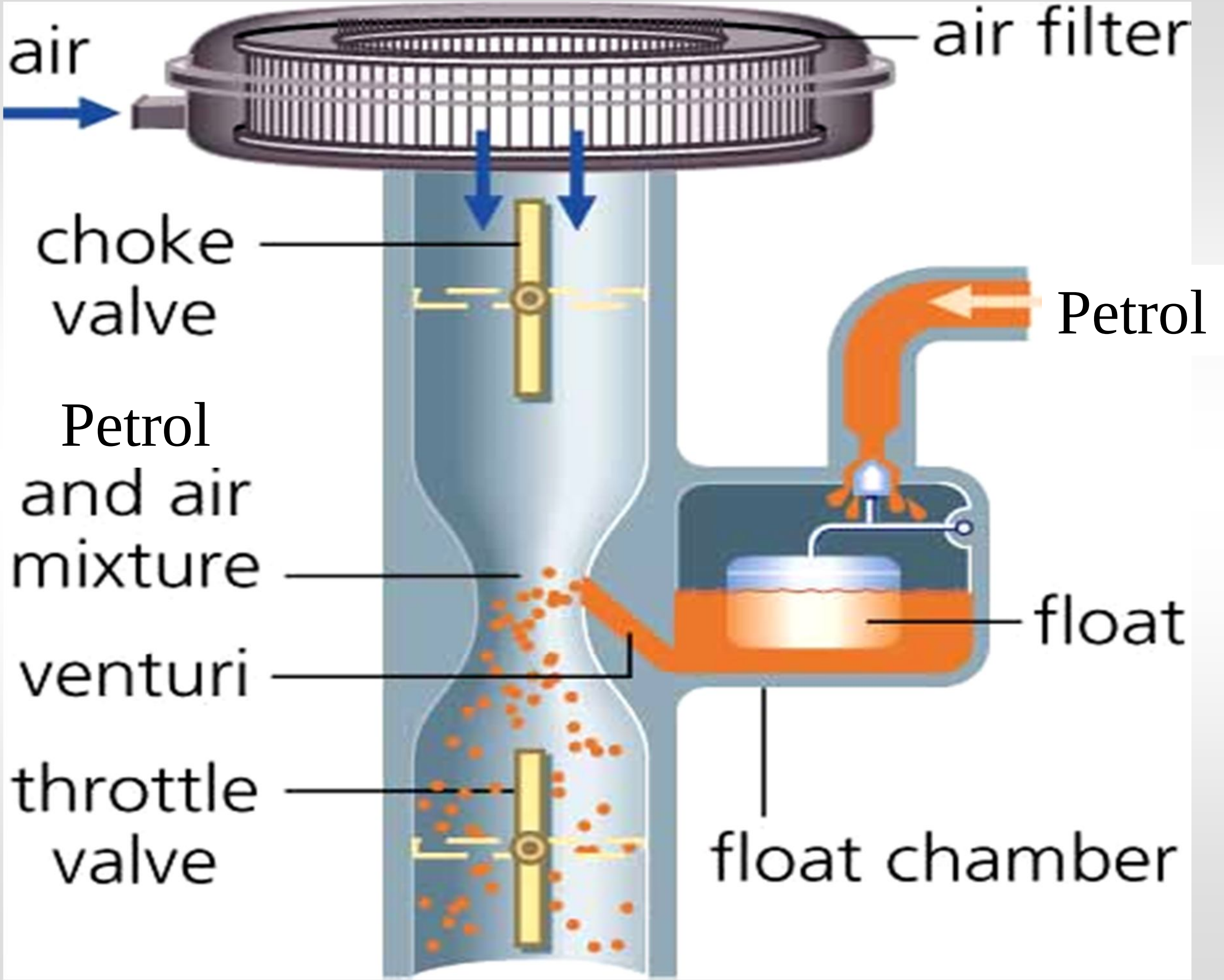
- Fuel Filters – to prevent dirt and fluff entering the fuel pump a filter is fitted on the suction side of the pump. On the pressure side of the pump a secondary filter is used, this is a much finer filter in that it prevents very small particles of dirt reaching the carburettor or fuel injection equipment. It should be renewed at the correct service interval as recommended by the manufacturer. When the filter is replaced, it must be fitted in the direction of fuel flow.
- Air Filters – air cleaners and silencers are fitted to all modern vehicles. Its most important function is to prevent dust and abrasive particles from entering the engine and causing rapid wear. Air filters are designed to give sufficient filtered air, to obtain maximum engine power. The air filter must be changed at the manufactures recommended service interval. The air filter/cleaner also acts as a flame trap and silencer for the air intake system.
- Fuel Pump – this supplies fuel under high pressure to the fuel injection system, or under low pressure to a carburettor.
- Carburettor – this is a device which atomizes the fuel and mixes it which the correct amount of air, this device has now been superseded by modern electronic fuel injection.

# Engine Fuel System (SI Petrol)

- Fuel Tank – normally positioned in the rear boot area, either under the floor pan for estate cars or over the rear axle for saloons, the latter being a safer position. Should the engine be mounted in the rear, the fuel tank is normally positioned in the front boot area, either over the bulkhead or flat across the boot floor pan , the latter providing more boot space, but is more exposed to danger in a head on crash. The fuel tank made be made from pressed steel and coated inside to prevent corrosion, or a synthetic rubber compound or flame resistant plastic. Inside the fuel tank is normally located the fuel gauge sender unit and electrically driven fuel pump with a primary filter in a combined module. Internal fuel tank baffles are used to prevent fuel surge. The fuel tank is pressurised to about 2 psi to prevent fuel vaporization and pollution. The fuel tank is vented through its own venting system and the engine managements emission control systems again to control pollution.
- Fuel pipes – These can be made from steel or plastic and are secured by clips at several points along the underside of the vehicle. To allow for engine movement and vibration, rubber hoses connect the pipes to the engine. Later fuel pipes use special connectors which require special tools to disconnect the pipes.

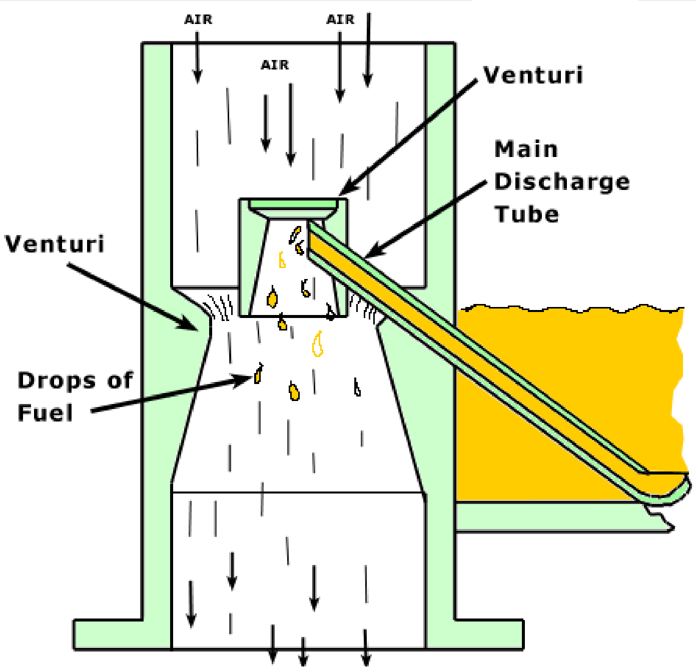
# Engine Fuel System (SI Petrol)

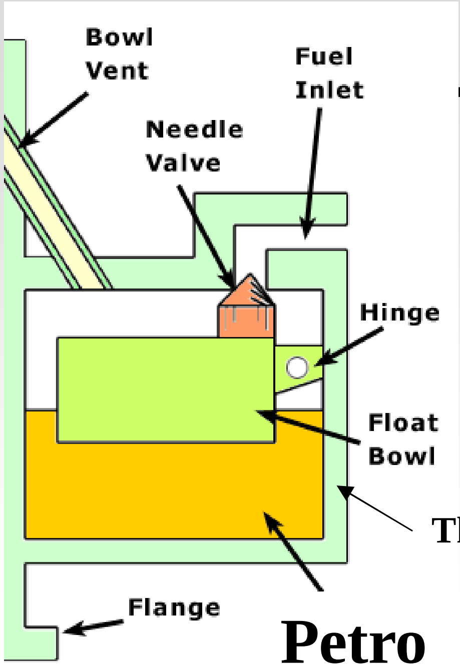
- Fuel Filters – to prevent dirt and fluff entering the fuel pump a filter is fitted on the suction side of the pump. On the pressure side of the pump a secondary filter is used, this is a much finer filter in that it prevents very small particles of dirt reaching the carburettor or fuel injection equipment. It should be renewed at the correct service interval as recommended by the manufacturer. When the filter is replaced, it must be fitted in the direction of fuel flow.
- Air Filters – air cleaners and silencers are fitted to all modern vehicles. Its most important function is to prevent dust and abrasive particles from entering the engine and causing rapid wear. Air filters are designed to give sufficient filtered air, to obtain maximum engine power. The air filter must be changed at the manufactures recommended service interval. The air filter/cleaner also acts as a flame trap and silencer for the air intake system.
- Fuel Pump – this supplies fuel under high pressure to the fuel injection system, or under low pressure to a carburettor.
- Carburettor – this is a device which atomizes the fuel and mixes it which the correct amount of air, this device has now been superseded by modern electronic fuel injection.


air
air filter
choke
valve
Petrol
Petrol
and air
mixture
venturi
float
throttle
valve
float chamber

- Float chamber (function) – to set and maintain the fuel level within the carburettor, and to control the supply fuel to the carburettor venturi.
- Operation – when air passes through the venturi due to the engines induction strokes, it creates a depression (suction), around the fuel spray outlet. Atmospheric pressure is acting on the fuel in the float chamber, the difference in theses pressures causes the fuel to flow from the float chamber, through the jet and into the stream. This causes the petrol to mix with the air rushing in to form a combustible mixture. The required air fuel ratio can be obtained by using a jet size which allows the correct amount of fuel to flow for the amount of air passing through the
- **Defects of the simple carburettor.**
- **As engine speed increases, air pressure and density decreases i.e. the air gets thinner, however the quantity of fuel increases i.e. greater pressure exerted on the fuel, this causes the air/fuel mixture to get progressively richer (to much fuel).**
- **As the engine speed decreases, the air/fuel mixture becomes progressively weaker. Some form of compensation is therefore required so that the correct amount of air and fuel is supplied to the engine under all operating conditions.**

# The Simple Carburettor

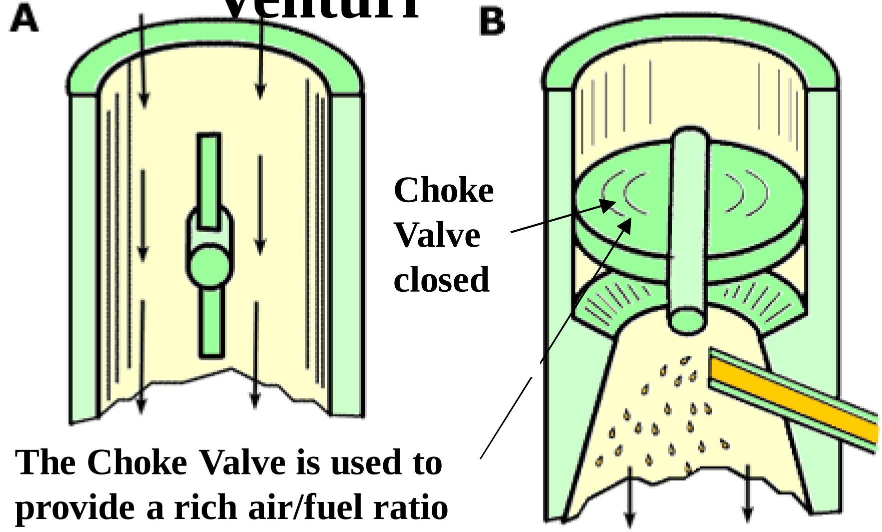



The Float Chamber

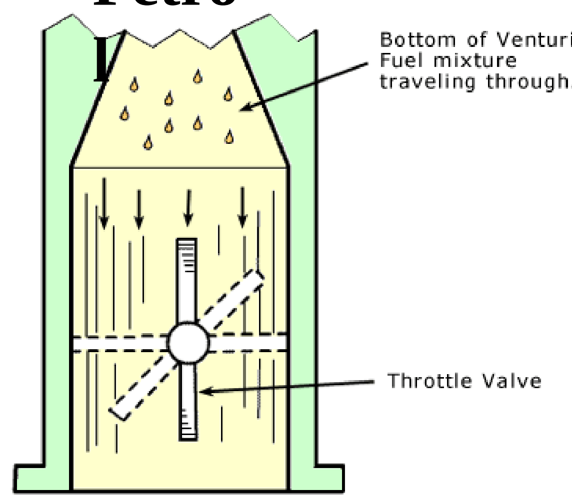
Petrol

## Operation of the Venturi

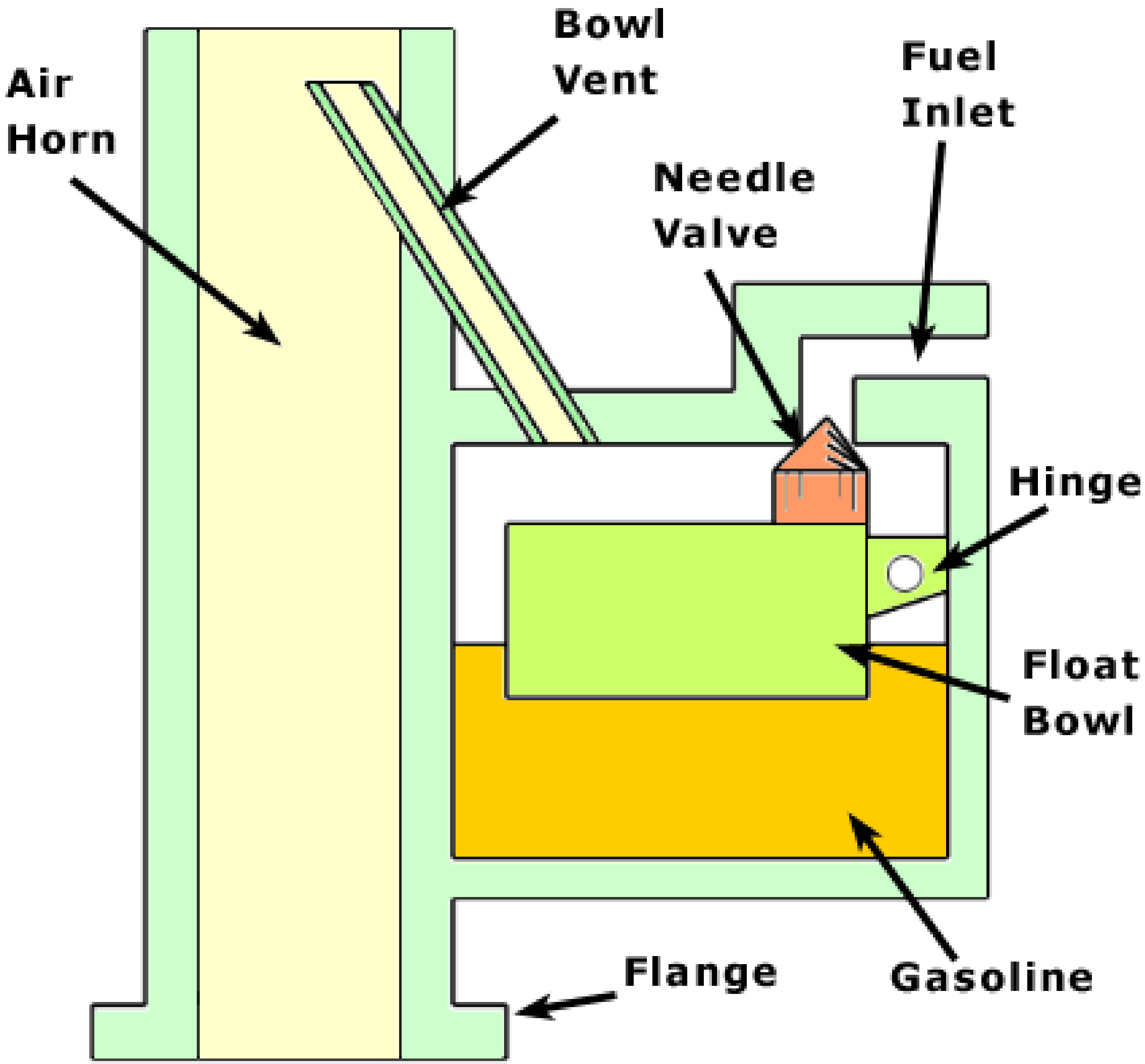



Choke Valve closed

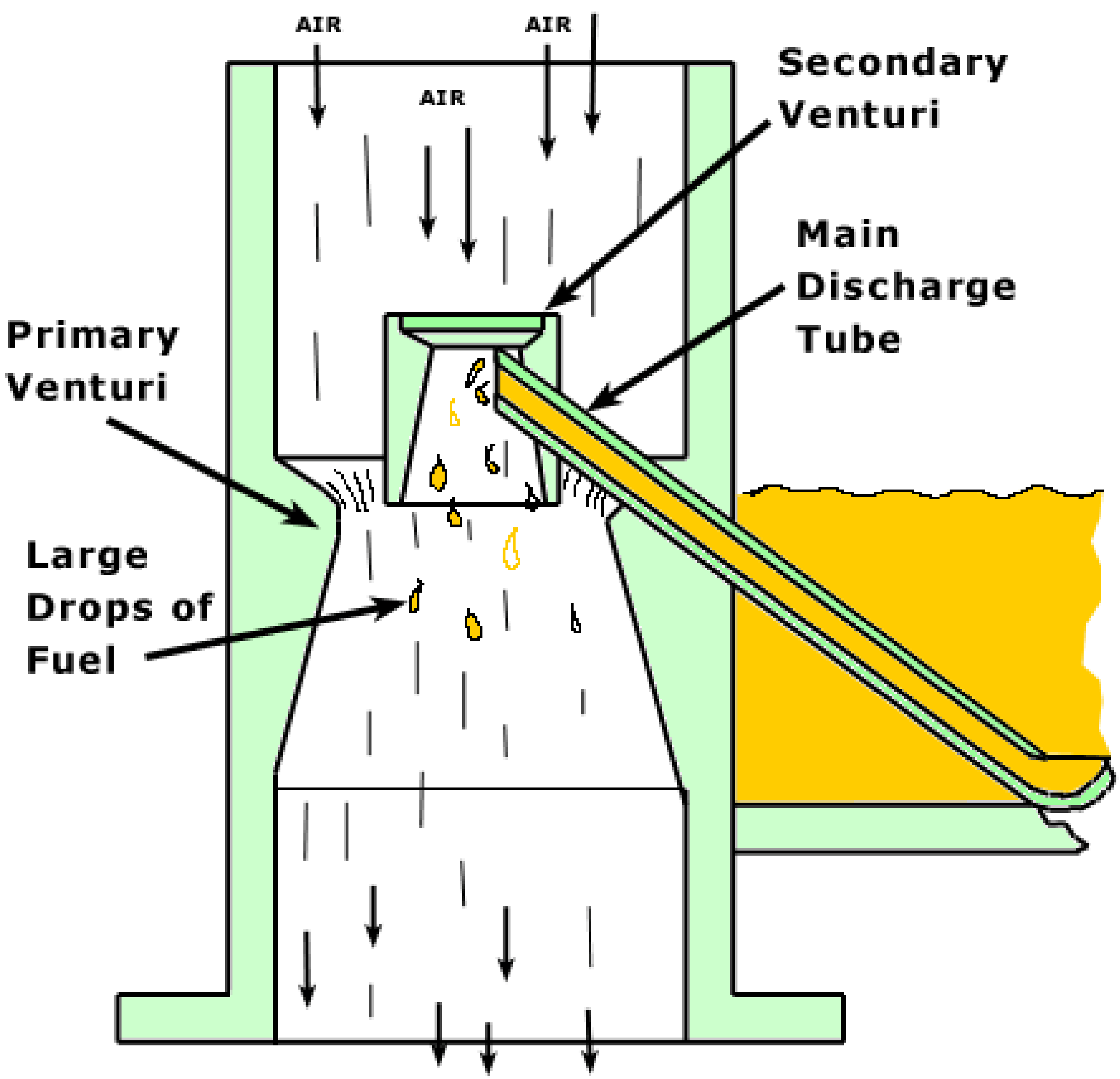
The Choke Valve is used to provide a rich air/fuel ratio for cold starting



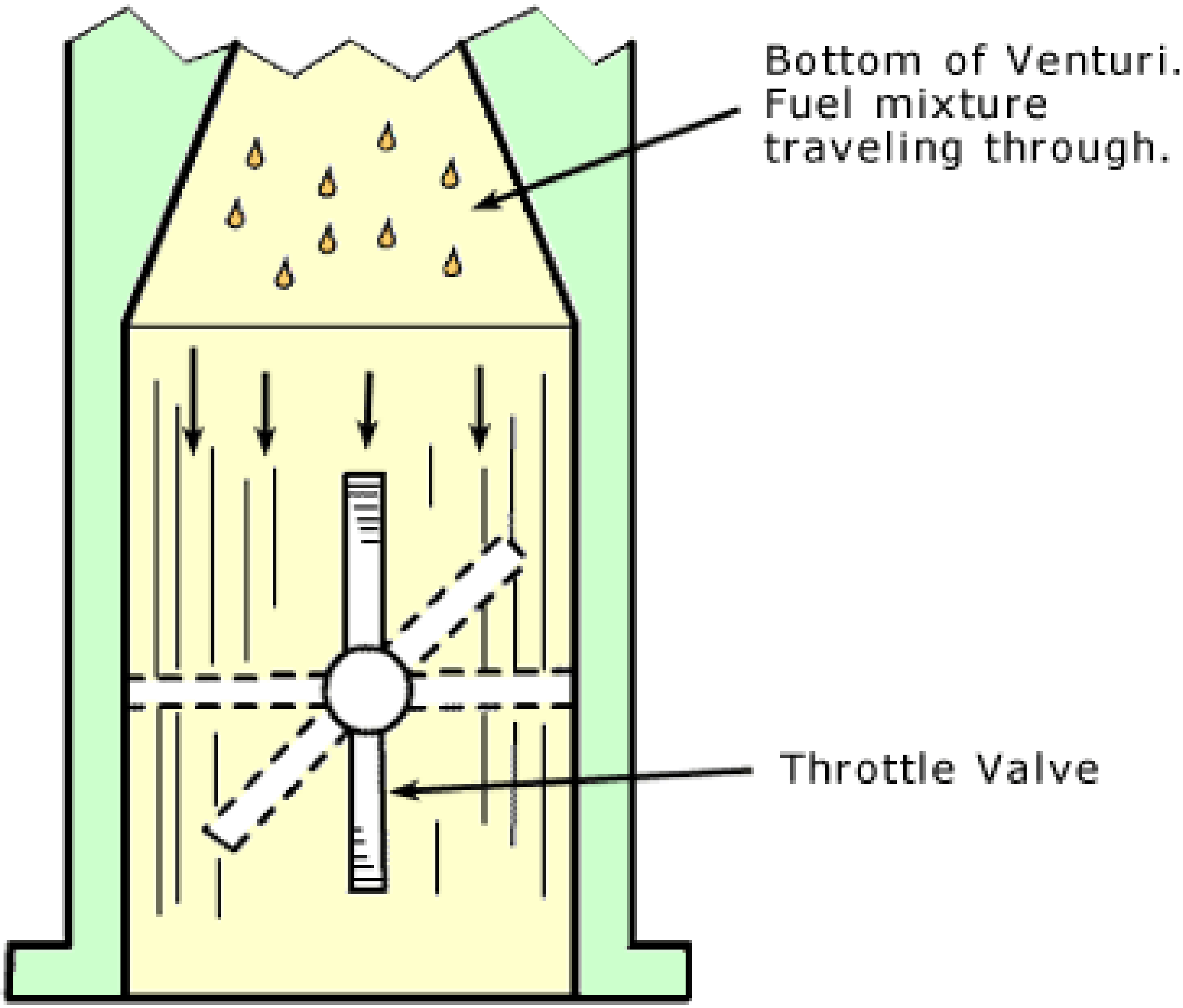

The Throttle Valve controls the amount of air fuel mixture entering the engine and therefore engine power



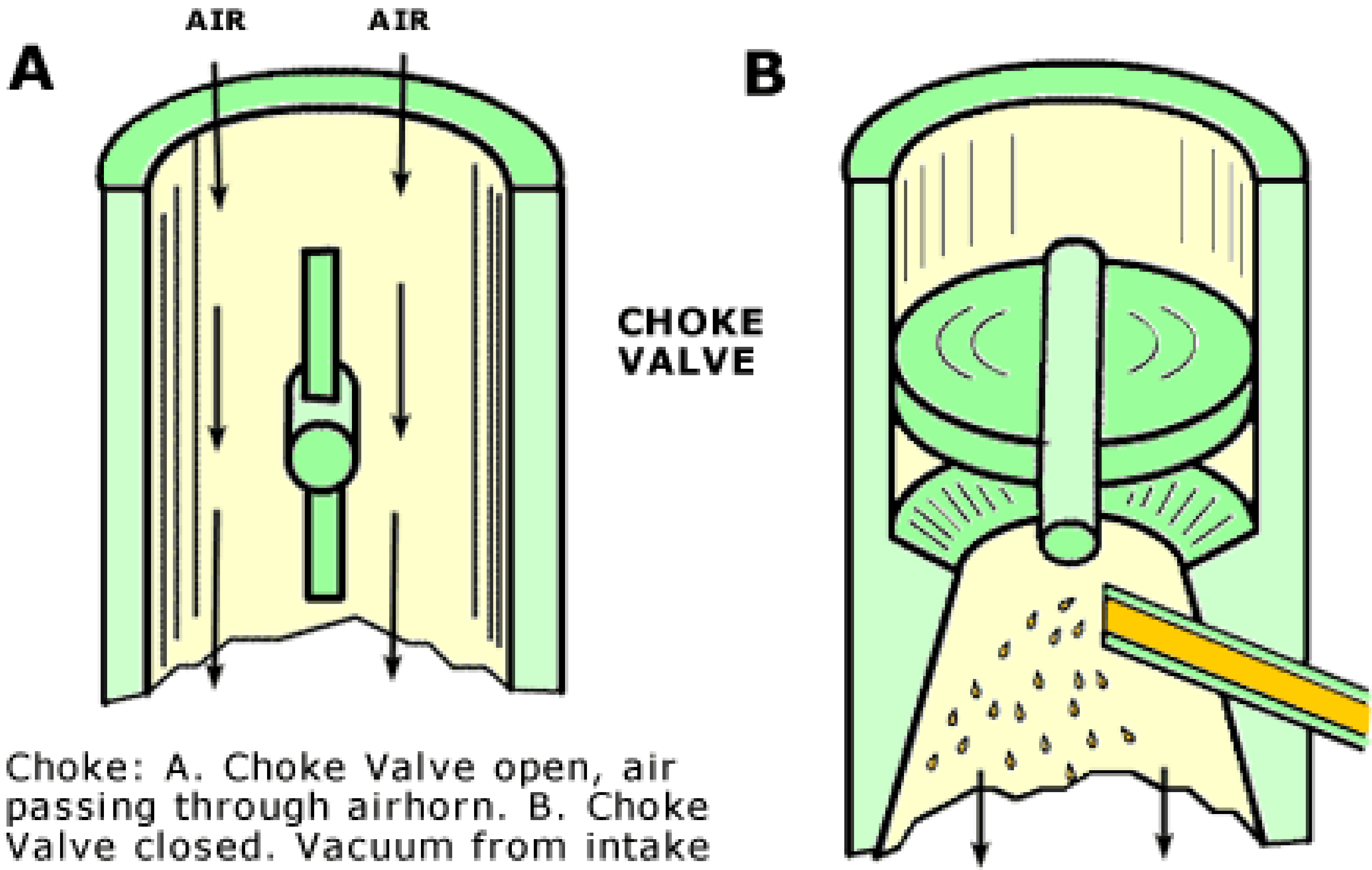

Air Horn, Float Bowl & Vent




Our Tube now has a venturi, along with a discharge tube.




Throttle Valve regulates flow of fuel mixture. Shown in wide open, half open and closed positions.




Choke: A. Choke Valve open, air passing through airhorn. B. Choke Valve closed. Vacuum from intake drawing on discharge nozzle.

# Air Fuel Ratio

- Fuel mixture strengths – petrol will not burn unless it is mixed with air, to obtain the best possible combustion of the fuel, which should result in good engine power and fuel consumption and low emissions (pollution), the air fuel ratio must be chemically correct i.e. the right amount of air and fuel must be mixed together  to give an air fuel ratio of 14.7 to 1 by mass. This is referred to as the shoitcmetreic air fuel ratio, this ratio can also be describe by the term Lambda. Lamba is the Greek word meaning ‘air’. When their is more air present than fuel in the air fuel mixture, it is said to be ‘weak’ or ‘lean’ i.e. not enough fuel e.g. a ratio of 25 to 1, this results in a Lambda reading of more than 1.When their is not enough air present, the mixture is referred to as ‘rich’ e.g. a air fuel ratio of 8 to 1, in this case Lambda equals less than 1.
- Weak/lean air/fuel mixtures – can result in low fuel consumption, low emissions (pollution), however, weak air fuel mixtures can also result in poor engine performance (lack of power) and high engine temperatures ( because the fuel burns more slowly)
- Rich air/ fuel mixtures – can result in greater engine power, however this also results in poorer fuel consumption and greatly increased emissions (pollution)

# Engine S I Fuel System

- ECU – Electronic control unit. This contains a computer which takes information from sensors and controls the amount of fuel injected by operating the injectors for just the right amount of time.
- Air flow/mass meter – A sensor used to tell the ECU how much air is being drawn into the engine.
- MAP sensor – Manifold absolute pressure sensor. This senses the pressure in the engines inlet manifold, this gives an indication of the load the engine is working under.
- Speed/crankshaft sensor – This tells the ECU has fast the engine is rotating and sometimes the position of the crankshaft.
- Temperature sensor – Coolant temperature is used determine if more fuel is needed when the engine is cold or warming up.
- Lambda sensor – A sensor located in the exhaust system which tells the ECU the amount of oxygen in the exhaust gases, form this the ECU can determine if the air/fuel ratio is correct.
- Fuel pump – A pump, normally located in the fuel tank, which supplies fuel under pressure to the fuel injectors.

# Engine S I Fuel System

- Fuel filter – keeps the fuel very clean to prevent the injectors becoming damaged or blocked.
- Fuel rail – A common connection to multi point injectors, acts a reservoir of fuel (small tank of fuel).
- Injector – A electrical device which contains a winding or solenoid. When turned on by the ECU, the injector opens and fuel is sprayed into the inlet manifold, or into the combustion chamber itself.
- Idle actuator – A valve controlled by the ECU which controls the idle speed of the engine.
- ECU – Electronic Unit. This contains a computer which takes information from sensors and controls the amount of fuel injected by operating the injectors for just the right amount of time. The ECU also controls the operation of the ignition and the other engine rated systems.

# Typical Fuel System

**1. Fuel Supply System**

Components that supply clean fuel to the fuel metering system (fuel pump, fuel pipes, fuel filters).

**2. Air Supply System**

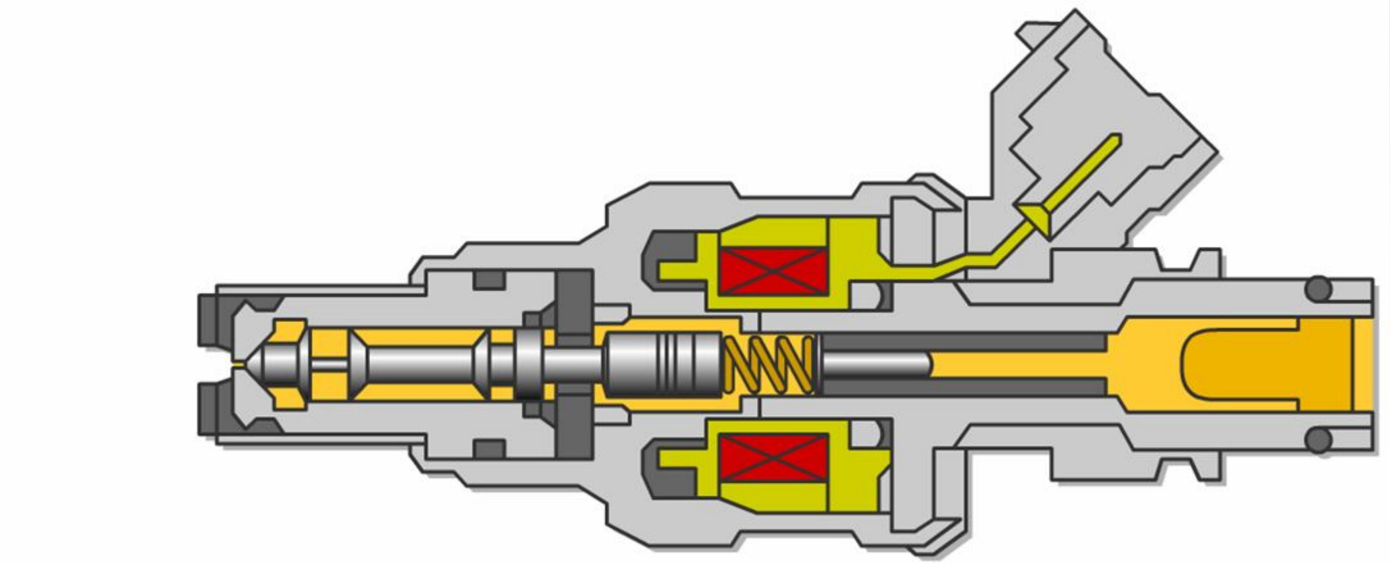
Components that supply controlled clean air to the engine (air filter, ducting, valves).

**3. Fuel Metering System**

Components that meter the correct amount of fuel (and air) entering the engine (injectors, pressure regulator, throttle valve).

The exact components used will vary with fuel system type and design.

# Introduction to Electronic Petrol Throttle/Single Point Fuel Injection Systems



The Carburettor has now been replaced with petrol injection systems. These systems supply the engine with a highly atomized mixture of air and fuel in the correct air/fuel ratio. This has the following advantages over the carburettor systems

**Lower exhaust emissions (pollution)**

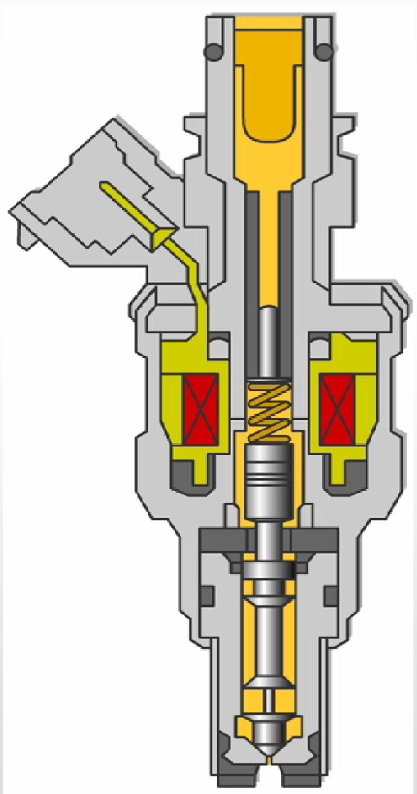
**Better fuel consumption**

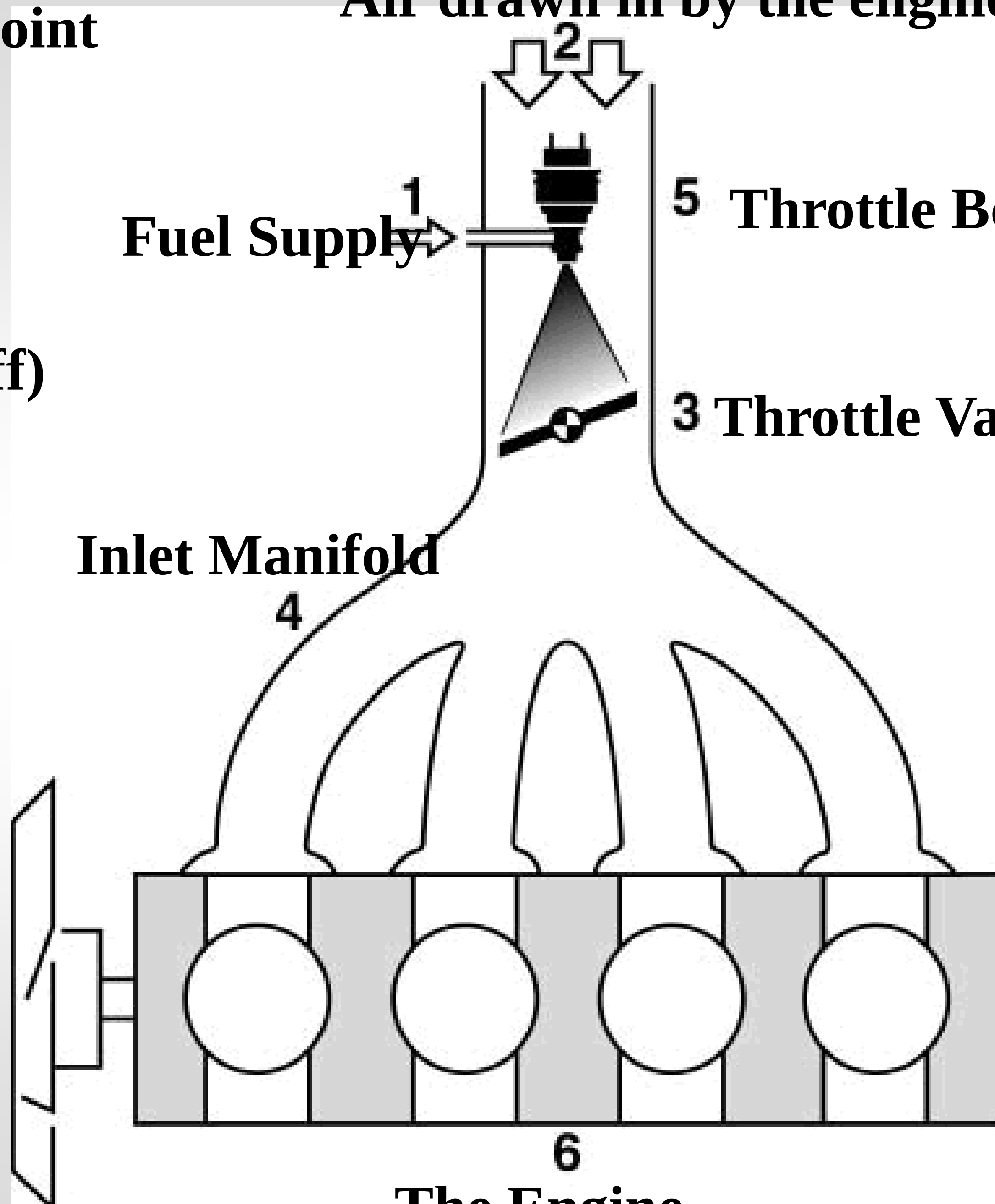
**Smoother engine operation and greater power**

**Automatic adjustment of the air/fuel ratio to keep the vehicles emissions (pollution) to a minimum.**

# Throttle Body/Single Point S.I. Fuel Injection

Fuel Injector (one off)





# Single Point Electronic Fuel Injection (EFI) Systems

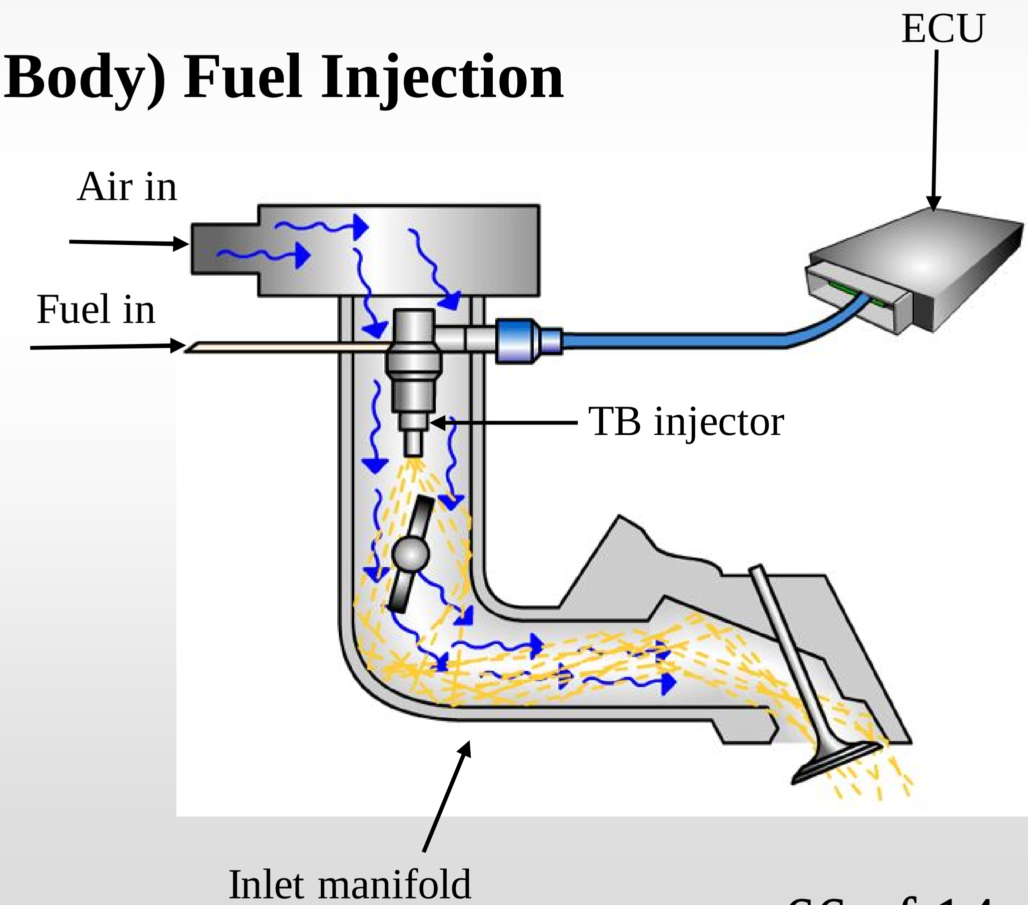
EFI systems are classified by using the point of injection.

**Single Point (Throttle Body) Fuel Injection**

A fuel injector (may be 2) is located in a throttle body assembly that sits on top of the inlet manifold.

Fuel is sprayed into the inlet manifold from above the throttle valve, mixing with incoming air.

Fuel quantity, how much feul is injected is controlled by an



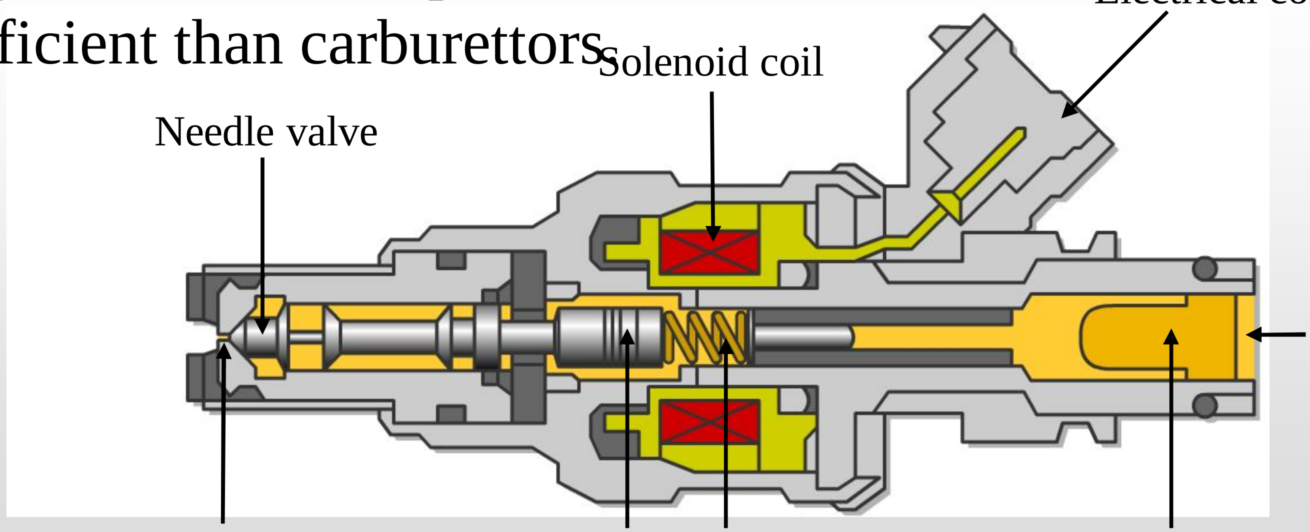
# Electronic Fuel Injector Operation

An injector sprays fuel into the inlet manifold by use of a solenoid coil.

When the coil is switch on by the ECU, it pulls the armature/needle valve away from the nozzle, allowing pressurized fuel into the engine.

When the coil is not switched on, the spring pushes the armature/needle against the nozzle, no fuel is injected into the inlet manifold

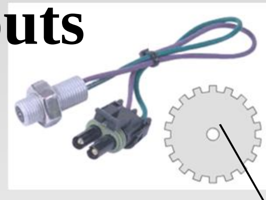
Injectors are more precise and efficient than carburettors.



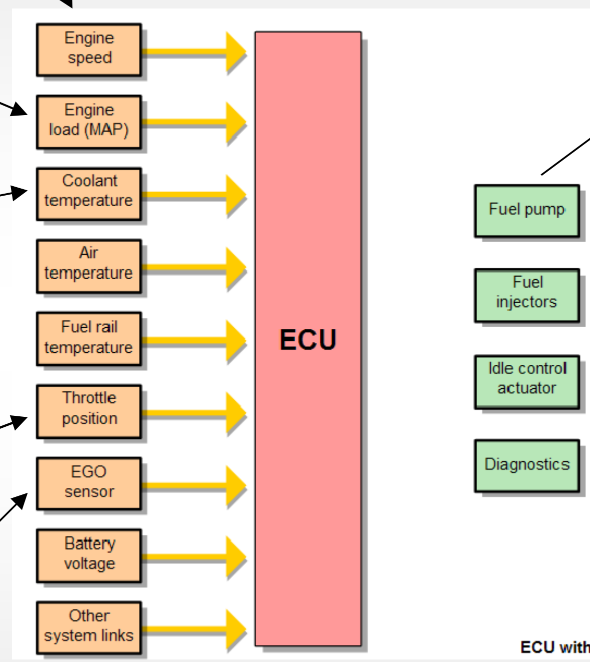
# SensorInputs

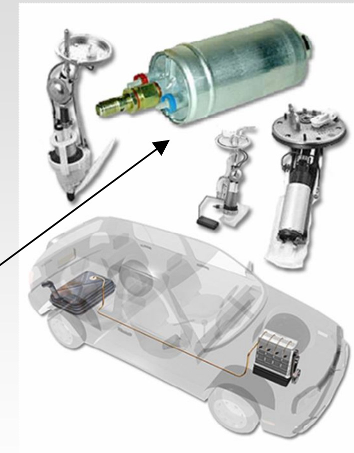
# Single Point Injection

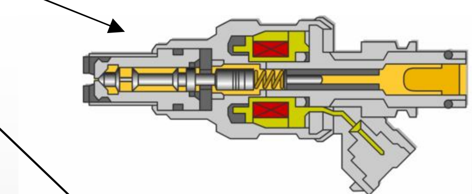
# Outputs

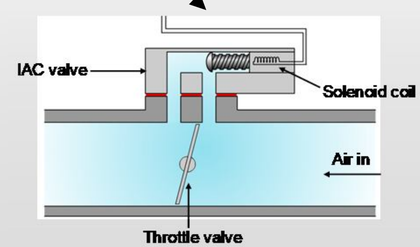






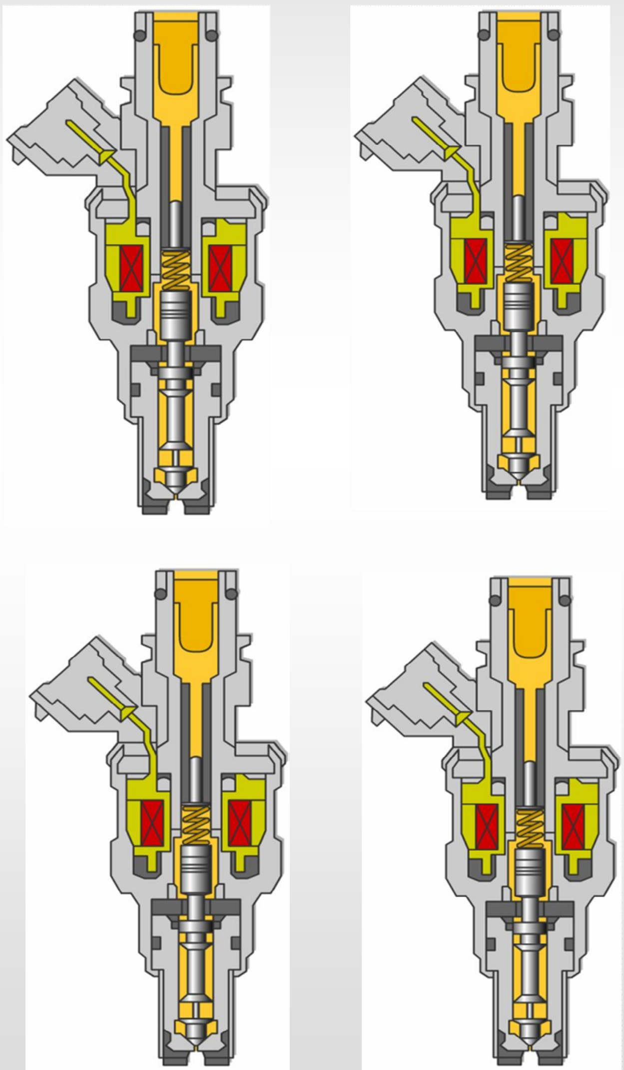


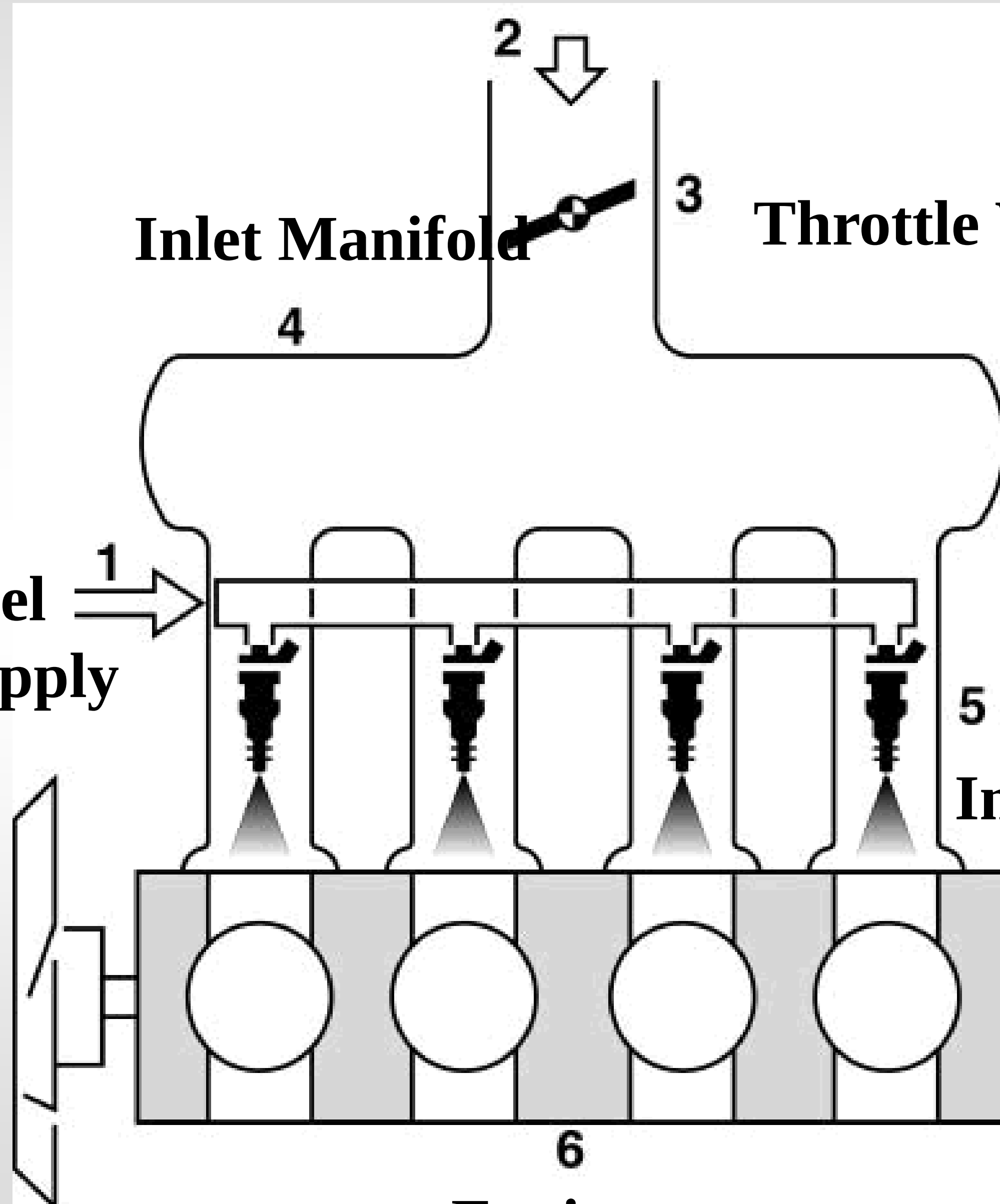



**The ECU (Brain) receives Information from varies sensors. From this information it works out how much fuel the engine needs**

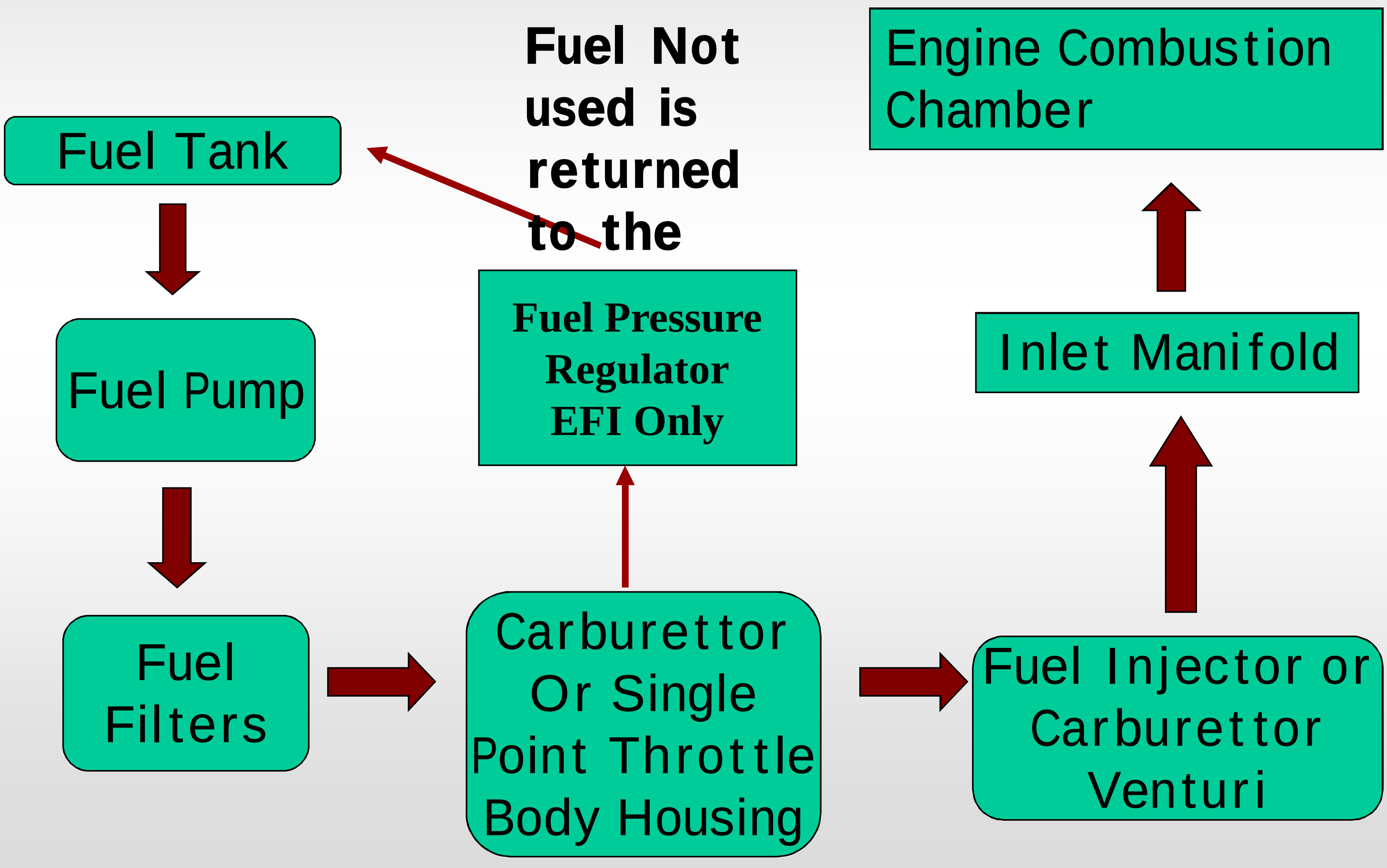
# Multi – Point S.I. Fuel Injection

**Fuel Injectors**

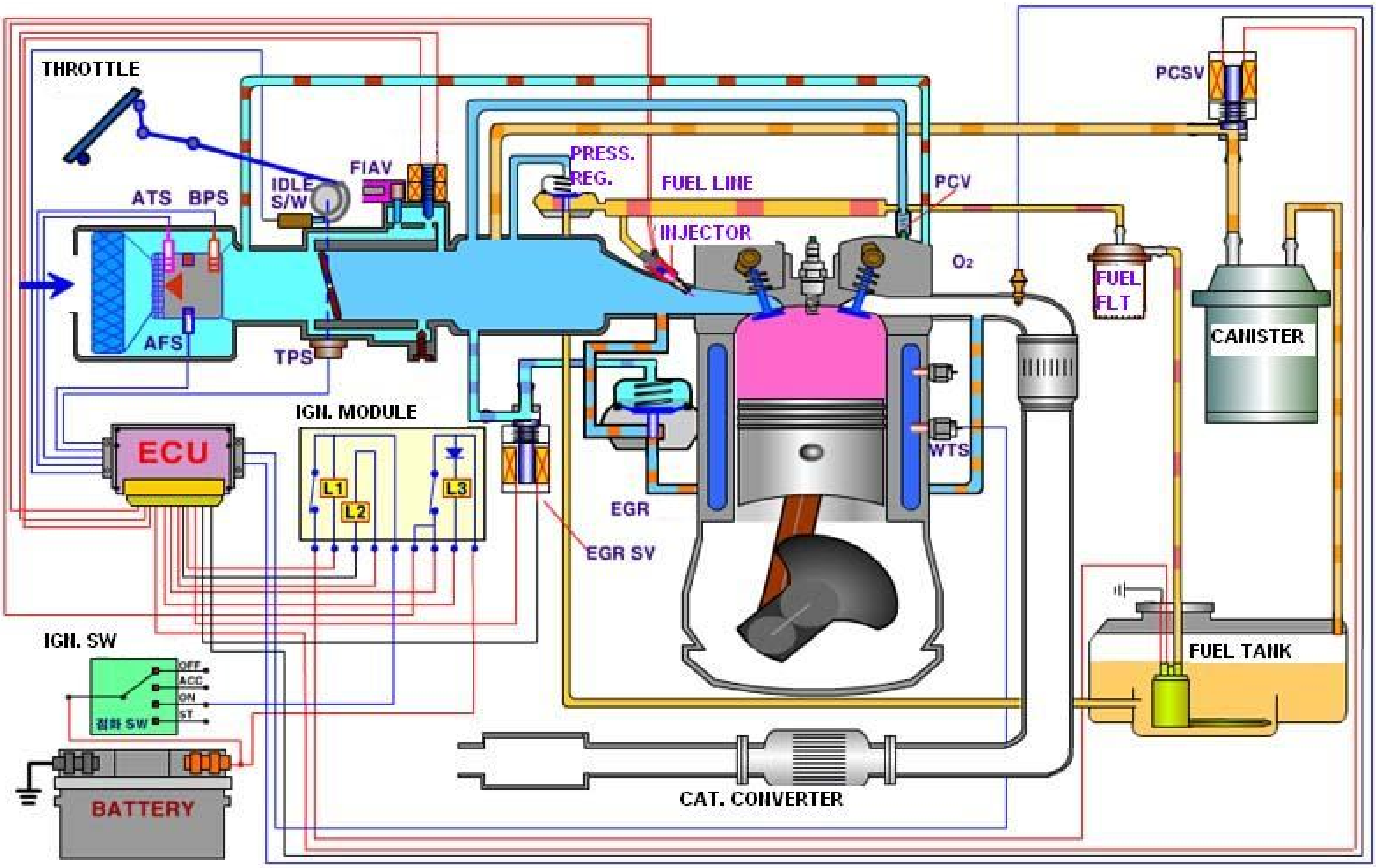




# Typical S.I. Fuel System Layout (Simplified)



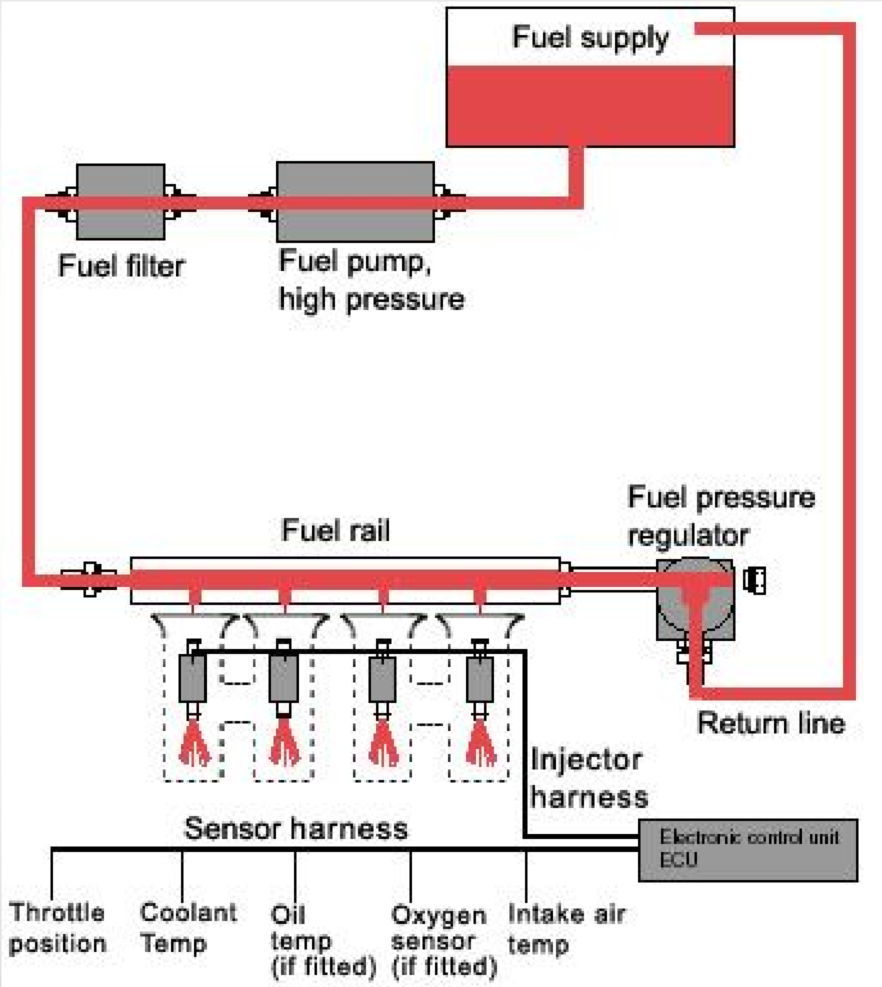
# Fuel Injection System



# Fuel Injection System

•Uses pressure (not Vacuum) from an electrical pump to spray fuel into the intake manifold.

•Provides the engine with proper air-fuel ratio (14.7 : 1)



# Fuel Injection System

**Advantages**

- Improved Atomization
- Better fuel flow
- Smoother idle
- Improved fuel economy
- Lower emissions
- Better cold weather drivability
- Increased engine power
- Simpler

# Fuel Injection System

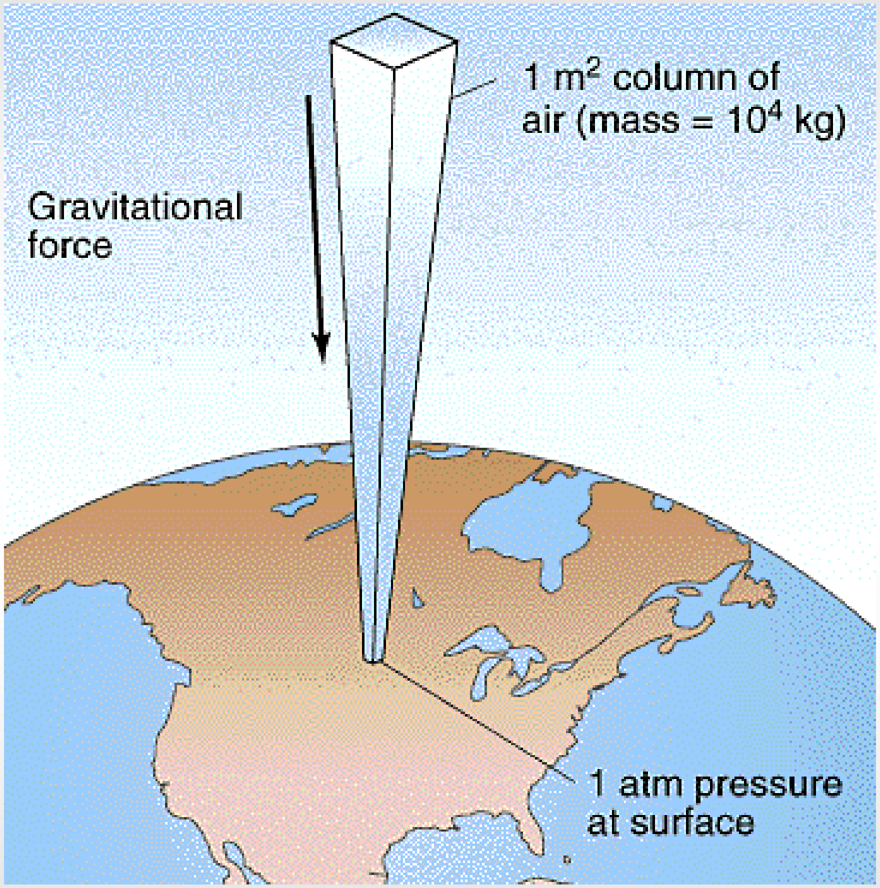
<u>**Atmospheric Pressure**</u>

- Pressure formed by the air surrounding the earth.

- Atmospheric pressure is 14.7psi at sea level.

- Any space with less than 14.7psi at sea level has vacuum.

- Engine acts as a vacuum pump, producing vacuum in the intake manifold.



# Fuel Injection System

**Engine Throttle Valve**


•Controls air flow and gasoline to power engine.

•When butterfly valve is closed it restricts air-flow and the resulting flow of fuel into the engine.

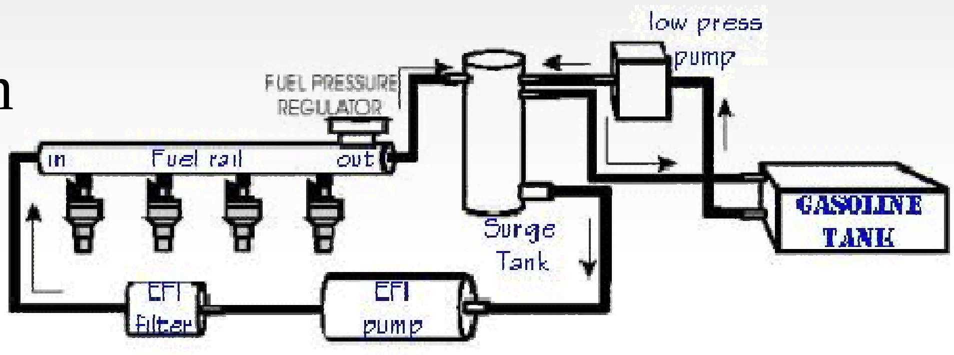
•When accelerator is pressed, the air-flow is increased in the intake manifold.

•Engine sensors detect the resulting changes and increase fuel flow through the injectors.

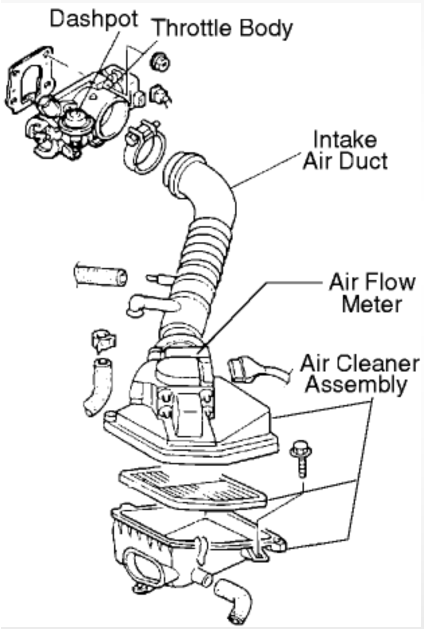
# Fuel Injection System

**<u>Electronic Fuel Injection</u>** uses various engine sensors and control module to regulate the opening and closing of injector valve.

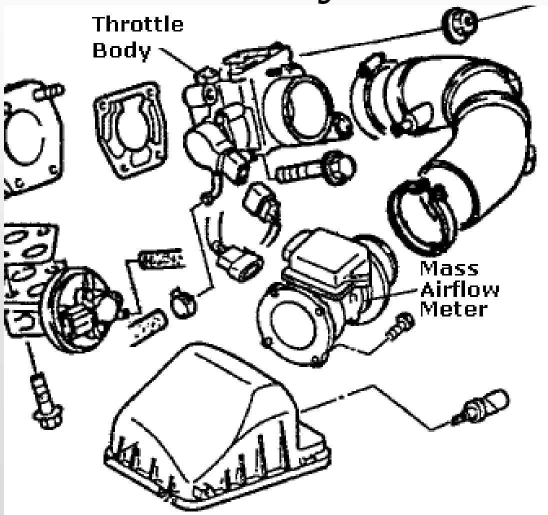
•Fuel delivery system



FUEL SYSTEM USING ANTI-SURGE TANK




•Air induction system



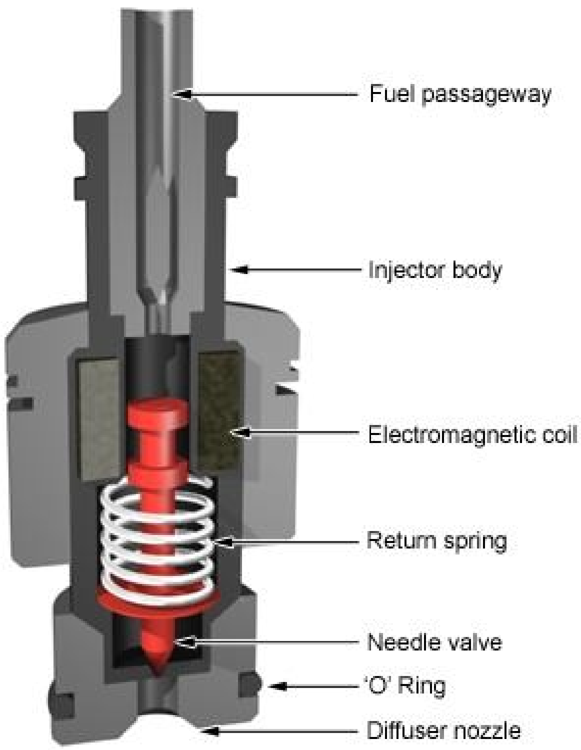

•Sensor system

•Computer control system

# Fuel Delivery system

•**Electrical Fuel Pump** draws fuel from tank and forces it into the regulator.

•**Pressure Regulator** controls the amount of pressure that enters the injector and any extra fuel is returned to the fuel tank.




•**Fuel Injector** is simply a coil or solenoid operated valve.

•Spring pressure holds the injector closed.

•When engaged, the injector sprays fuel into the engine.

**Injector Pulse Width** indicates the time each Injector is energized (*Kept Open*).

# Air Induction System


- Air filter

- Throttle valve

- Sensors

- Connecting ducts

# Sensor System

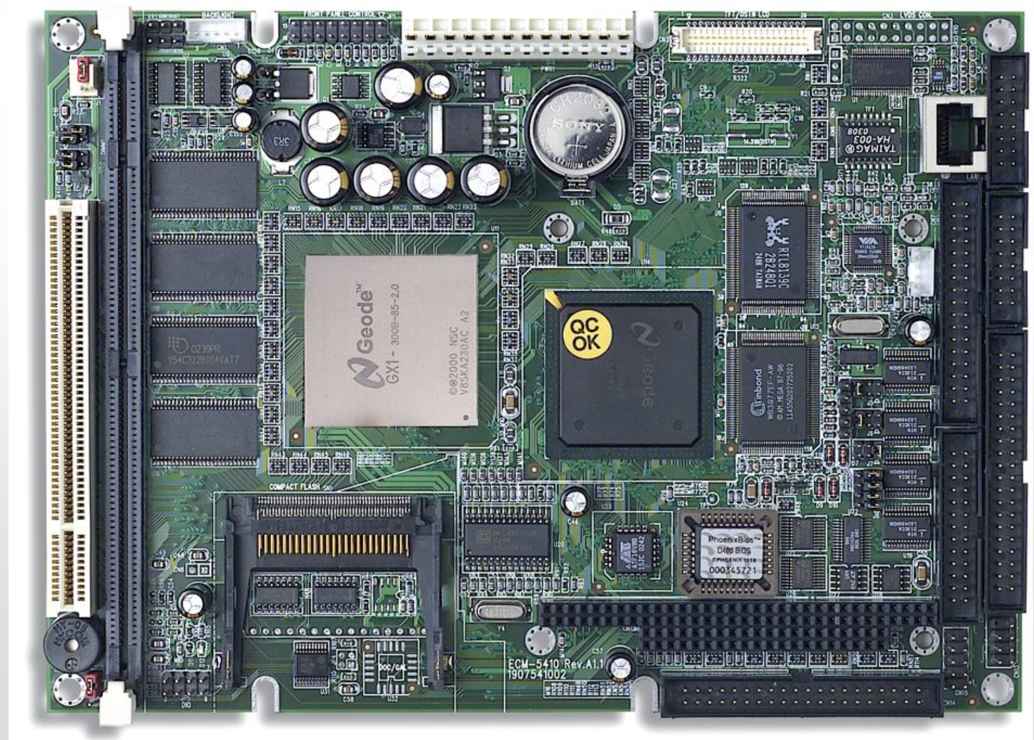

•Monitors engine operating condition and reports this information to ECM (computer).

•Sensors are electrical devices that change resistance or voltage with change in condition such as temperature, pressure and position.

# Computer Control System

•Uses electrical data from the sensors to control the operation of the fuel injectors.

•Engine Control Module (ECM)- “Brain” of the electronic fuel injection.



# Engine Sensors

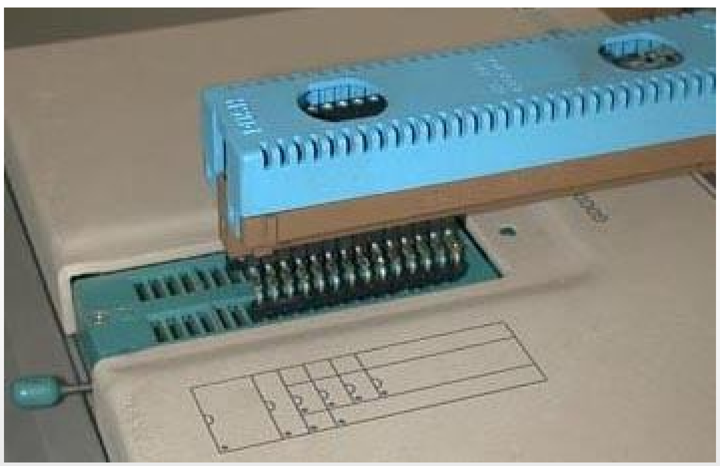
**Oxygen Sensor** measures the oxygen content in engine exhaust.

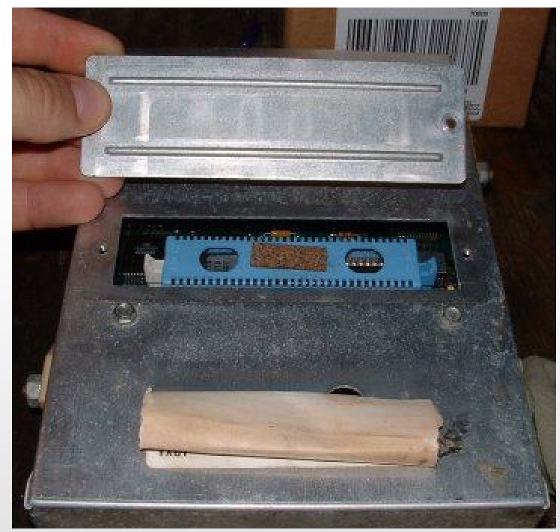

- Mounted on the exhaust system before the catalytic converter.
- Voltage out-put of O2 sensor changes with the change in oxygen content of exhaust.
- Lean mixture decreases the voltage.
- Rich mixture increases the voltage.
- Signal is sent to ECM and the ECM changes the time that an injector is open or close.

# Engine Sensors

**<u>Open Loop</u>**

- When the electronic injection system doesn't use the input from the engine exhaust.
- System operates on information stored in the computer (PROM).
- Computer ignores the sensors when the engine is cold.



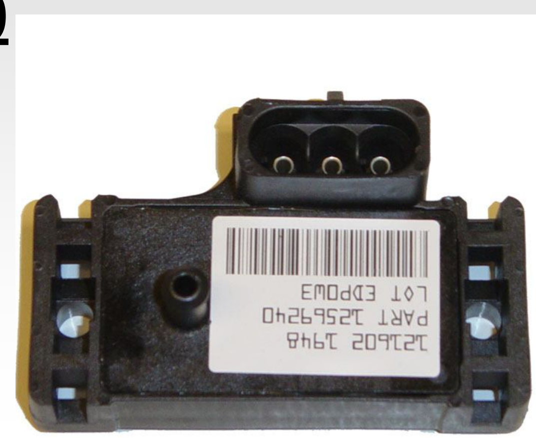


**<u>Closed Loop</u>**

- Ones engine reaches the operating temperature, computer uses information from oxygen sensor and the other sensors.

# Engine Sensors

**Manifold Absolute Pressure Sensor (MAP)**



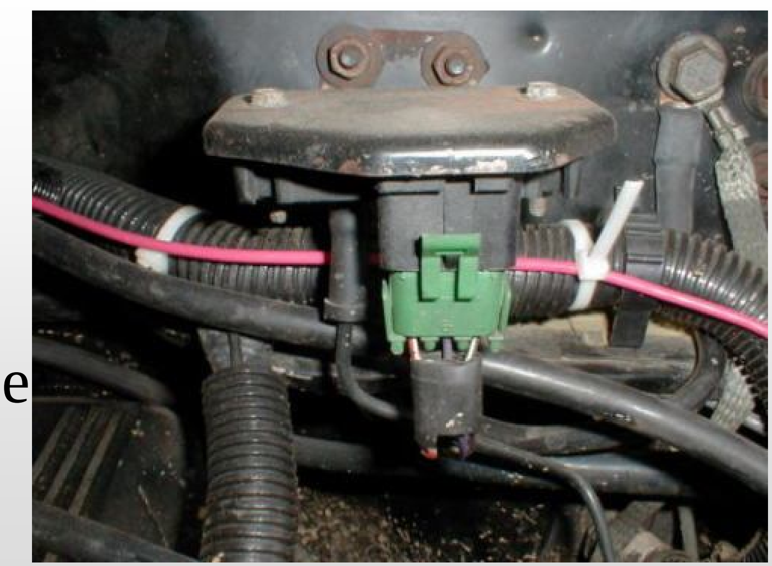
- Measures the pressure, or vacuum inside the engine intake manifold.

- Manifold pressure = Engine load

- High pressure (low intake vacuum) = High load = Rich mixture

- Low pressure (high intake vacuum) = Little load = Lean mixture

- Computer senses the change in resistance and alters the fuel mixture.



# Engine Sensors

**<u>Throttle Position Sensor (TPS)</u>**

•Variable resister connected to the throttle plate.

•Change in throttle angle = change in resistance.

•Based on the resistance, ECM richens or leans the mixture.


# Engine Sensors

**Engine Temperature Sensor**

•Monitors the operating temperature of the engine.

•Exposed to engine coolant.

•Engine cold = Low Resistance = Rich Mixture

•Engine Hot = High Resistance = Lean Mixture.

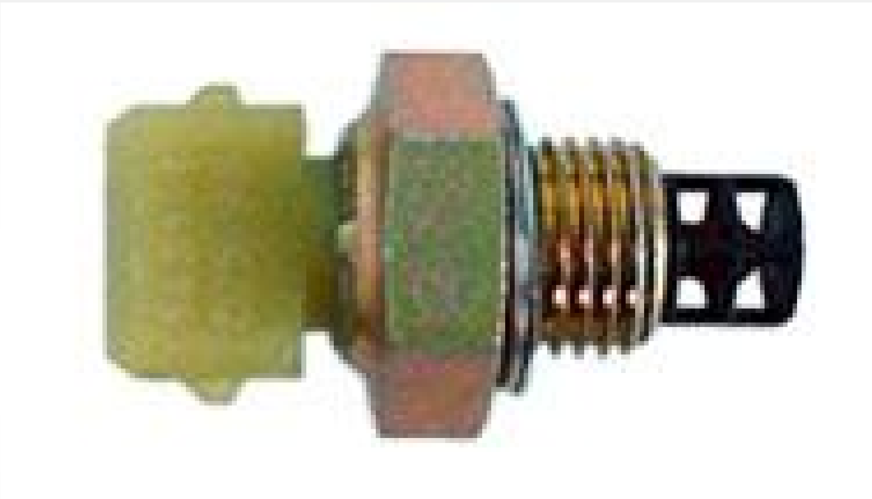
# Engine Sensors

**Mass Air Flow Sensor (MAF)**

- Measures the amount of outside air entering the engine.
- Contains an air flap or door that operates a variable resistor.
- Helps computer to determine how much fuel is needed.

# Engine Sensors

**<u>Inlet Air Temperature Sensor</u>**



•Measures the temperature of air entering the engine.

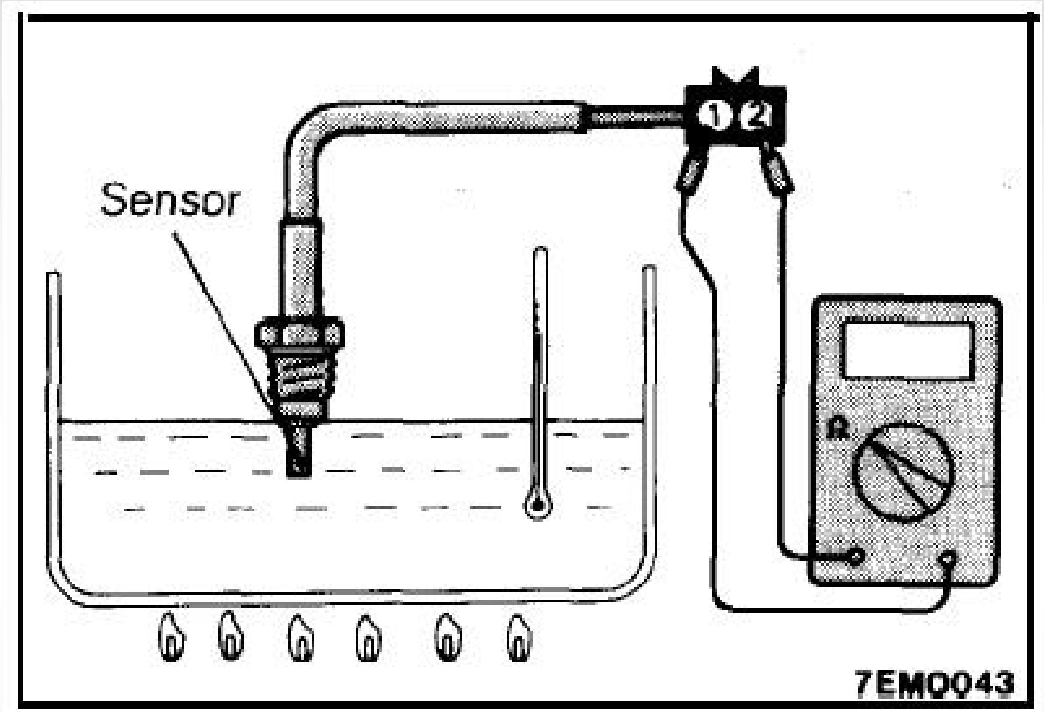
•Cold air (*more dense*) = More fuel for proper AF ratio.

# Engine Sensors

**Crankshaft Position Sensor**

- Detects engine speed.
- Changes injector timing and duration.
- Higher engine speed = More fuel

# Temperature Sensors




•Resistance can be checked by dipping it in hot Vs cold water.

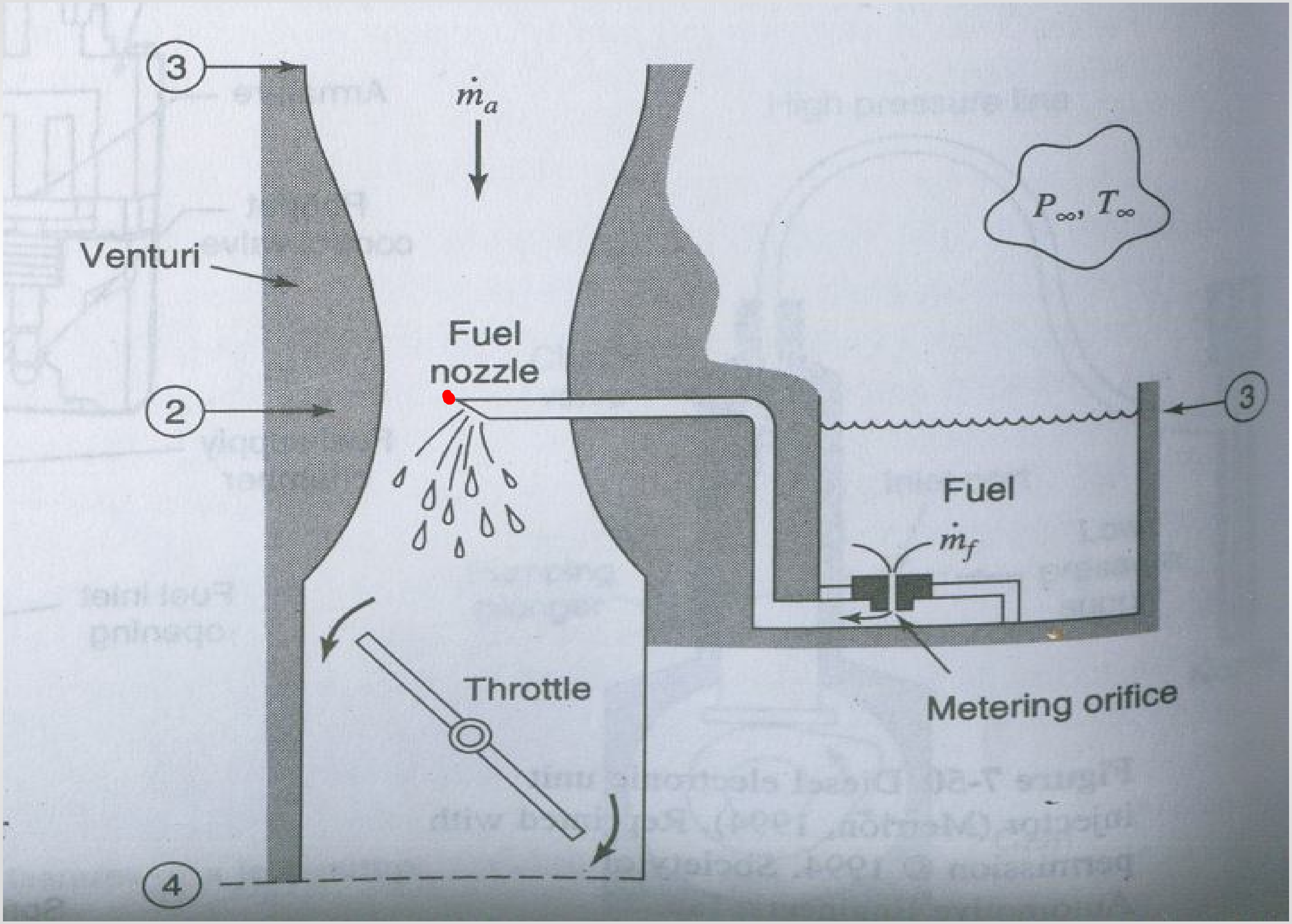
Cold = Low resistance.

Hot = High resistance.

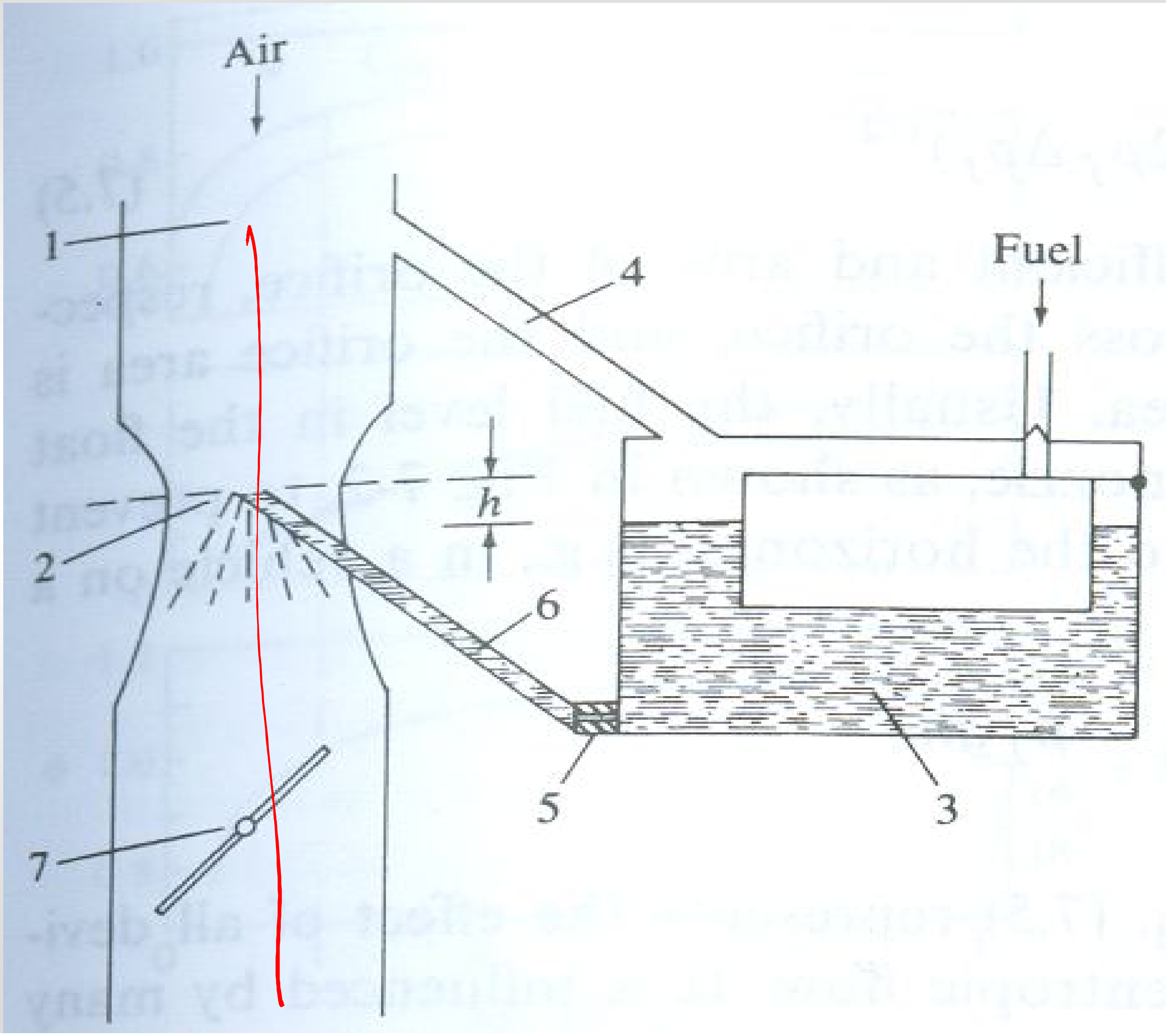
# Induction of Fuel in SI Engine

- The task of the engine induction and fuel systems is to prepare from ambient air and fuel in the tank an air-fuel mixture that satisfies the requirement of the engine.
- This preparation is to be carried out over entire engine operating regime.
- In principle, the optimum air-fuel ratio for an engine is that which give the required power output with the lowest fuel consumption.
- It should also ensure smooth and reliable operation.
- The fuel Induction systems for SI engine are classified as:
- Carburetors.
- Throttle body Fuel Injection Systems.
- Multi Point Fuel Injection Systems.

# The Carburetor: A Natural Fuel Induction System



# Practical Carburetor Venturi

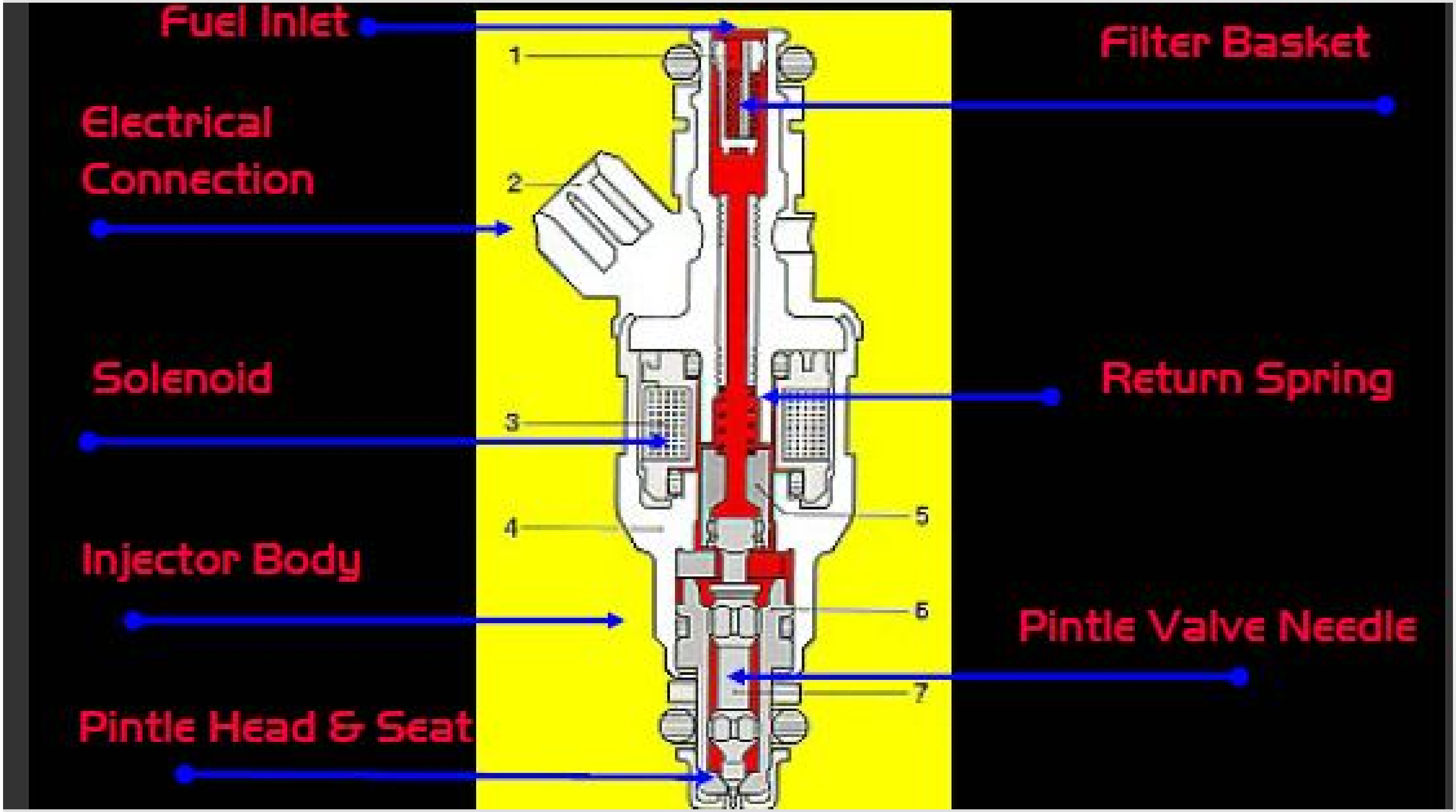


# Fuel Injection Systems

- The fuel-injection systems for conventional spark-ignition engines inject the fuel.
- There are both mechanical and electronically controlled injection systems.
- The main advantages of port fuel injection are increased power and torque.
- Better volumetric efficiency
- More uniform fuel distribution
- More rapid response to changes in loading conditions
- More precise control of the equivalence ratio.

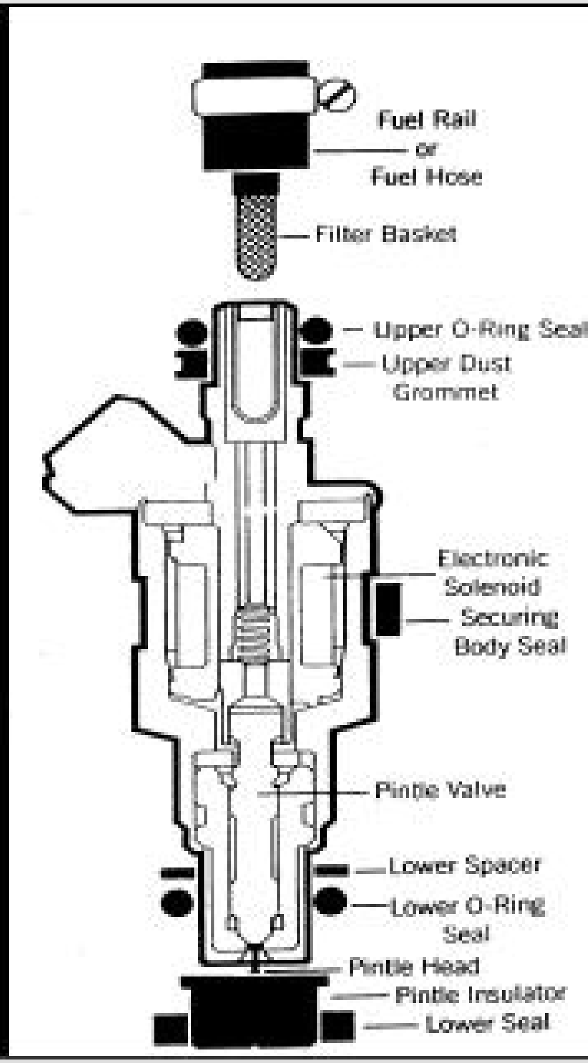
# Standard Gasoline Injectors

# Anatomy of EFI



# Serviceable Parts of A EFI

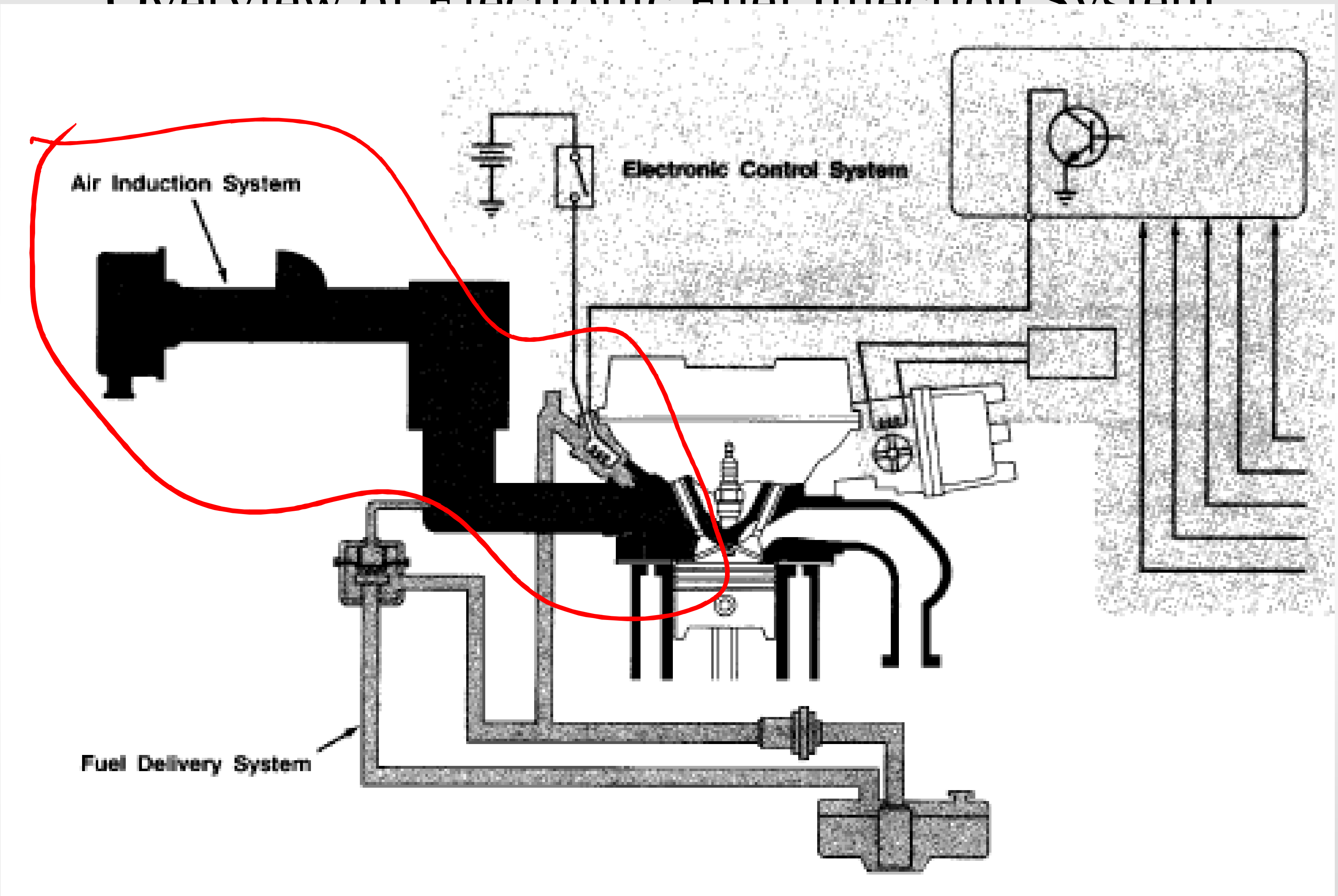
The Electronic Injector is a sealed unit and cannot be dismantled or have any of its internal components replaced.



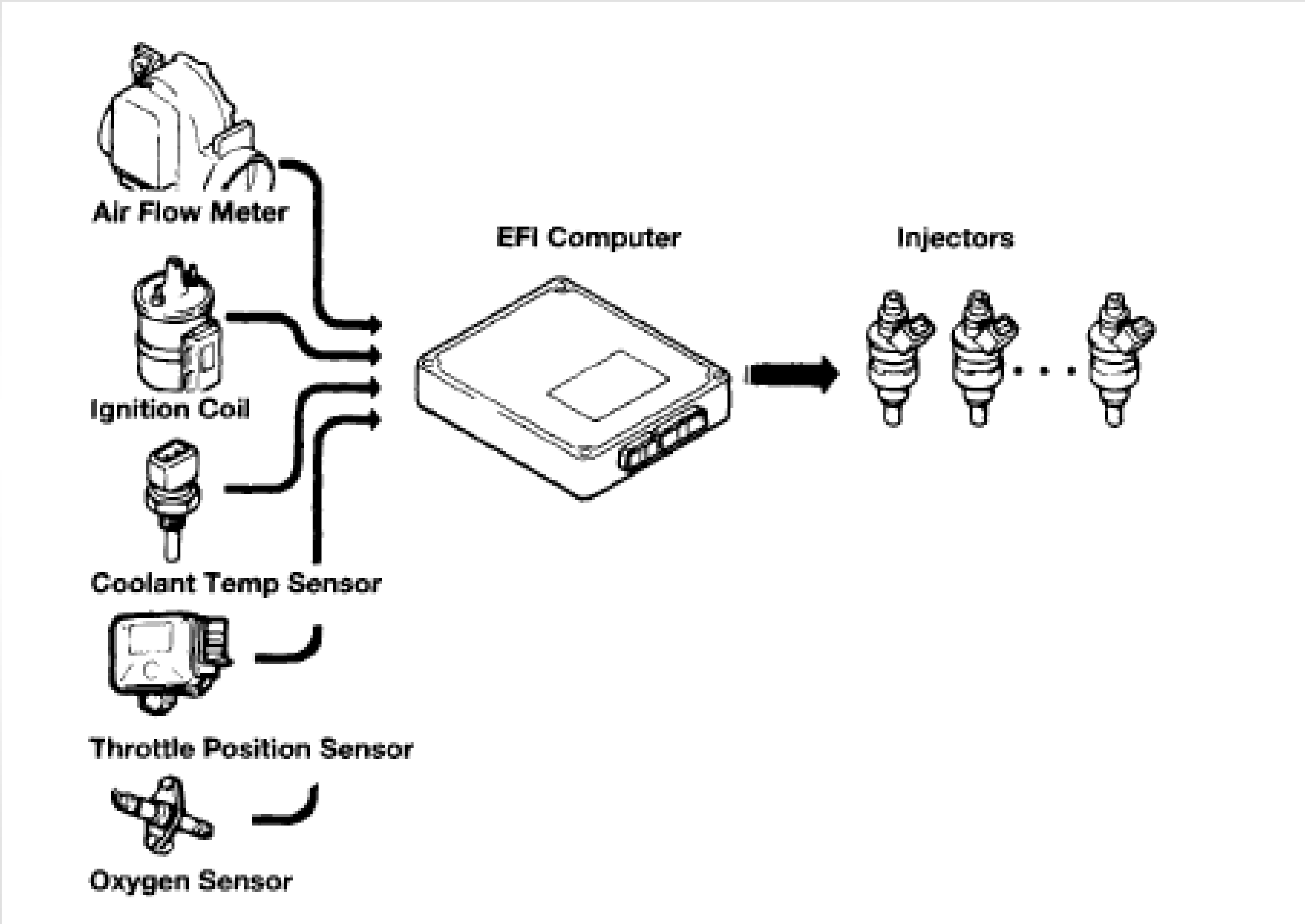

Only the external components and internal filter can be replaced. All rubber Fuel & Air seals should be replaced if injector are removed from engine

# Filters for EFI

# Overview of Electronic Fuel Injection System



# ECU Data Map



Air Flow Meter
EFI Computer
Injectors
Ignition Coil
Coolant Temp Sensor
Throttle Position Sensor
Oxygen Sensor

# Merits of Fuel Injection in the SI Engine

- Absence of Venturi – No Restriction in Air Flow/Higher Vol. Eff./Torque/Power
- Hot Spots for Preheating cold air eliminated/Denser air enters
- Manifold Branch Pipes Not concerned with Mixture Preparation (MPI)
- Better Acceleration Response (MPI)
- Fuel Atomization Generally Improved.
- Use of Greater Valve Overlap
- Use of Sensors to Monitor Operating Parameters/Gives Accurate Matching of Air/fuel Requirements: Improves Power, Reduces fuel consumption and Emissions
- Precise in Metering Fuel in Ports
- Precise Fuel Distribution Between Cylinders (MPI

# Merits (Continued)

- Fuel Transportation in Manifold not required (MPI) so no Wall Wetting
- Fuel Surge During Fast Cornering or Heavy Braking Eliminated
- Adaptable and Suitable For Supercharging (SPI and MPI)

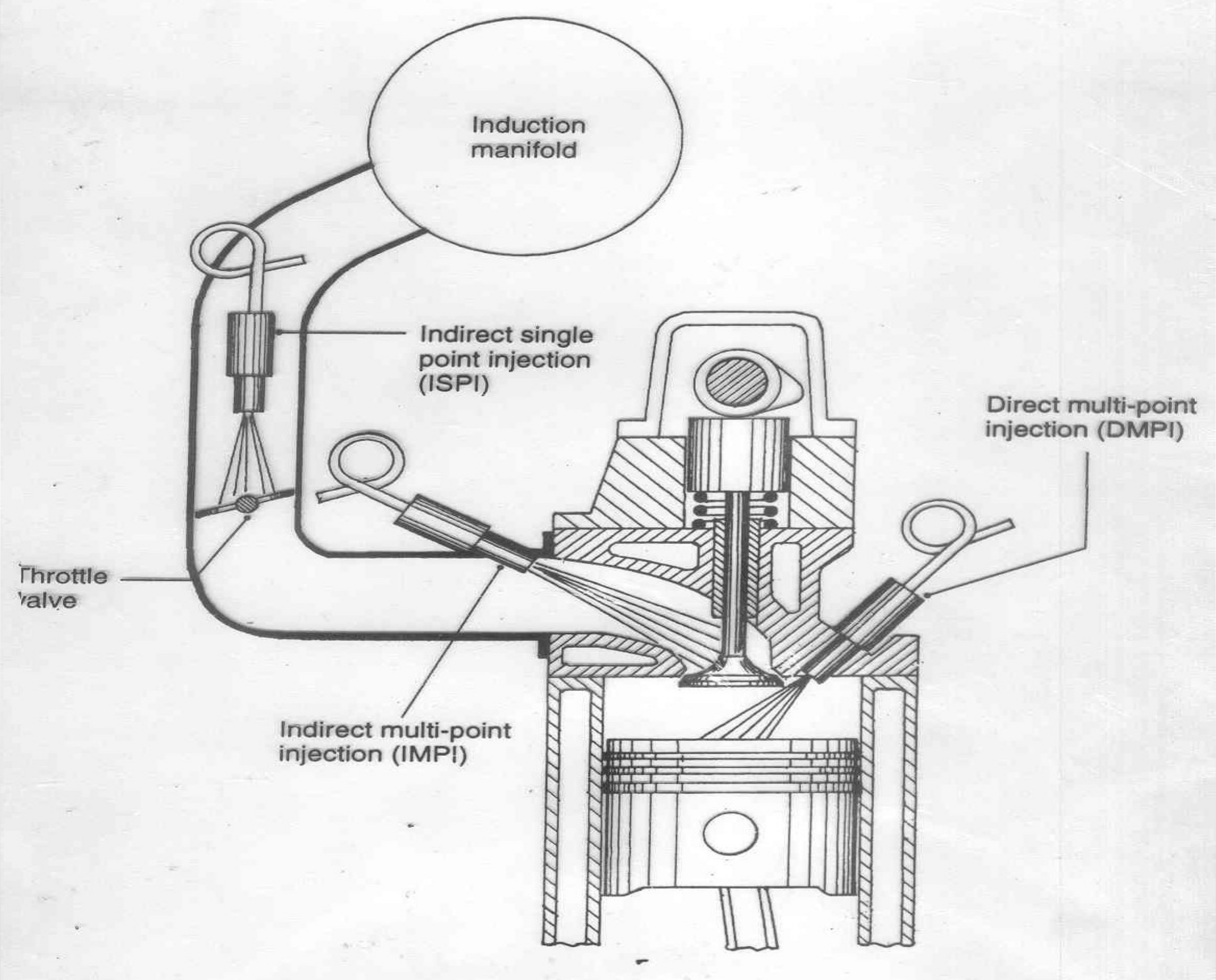
# Limitations of Petrol Injection

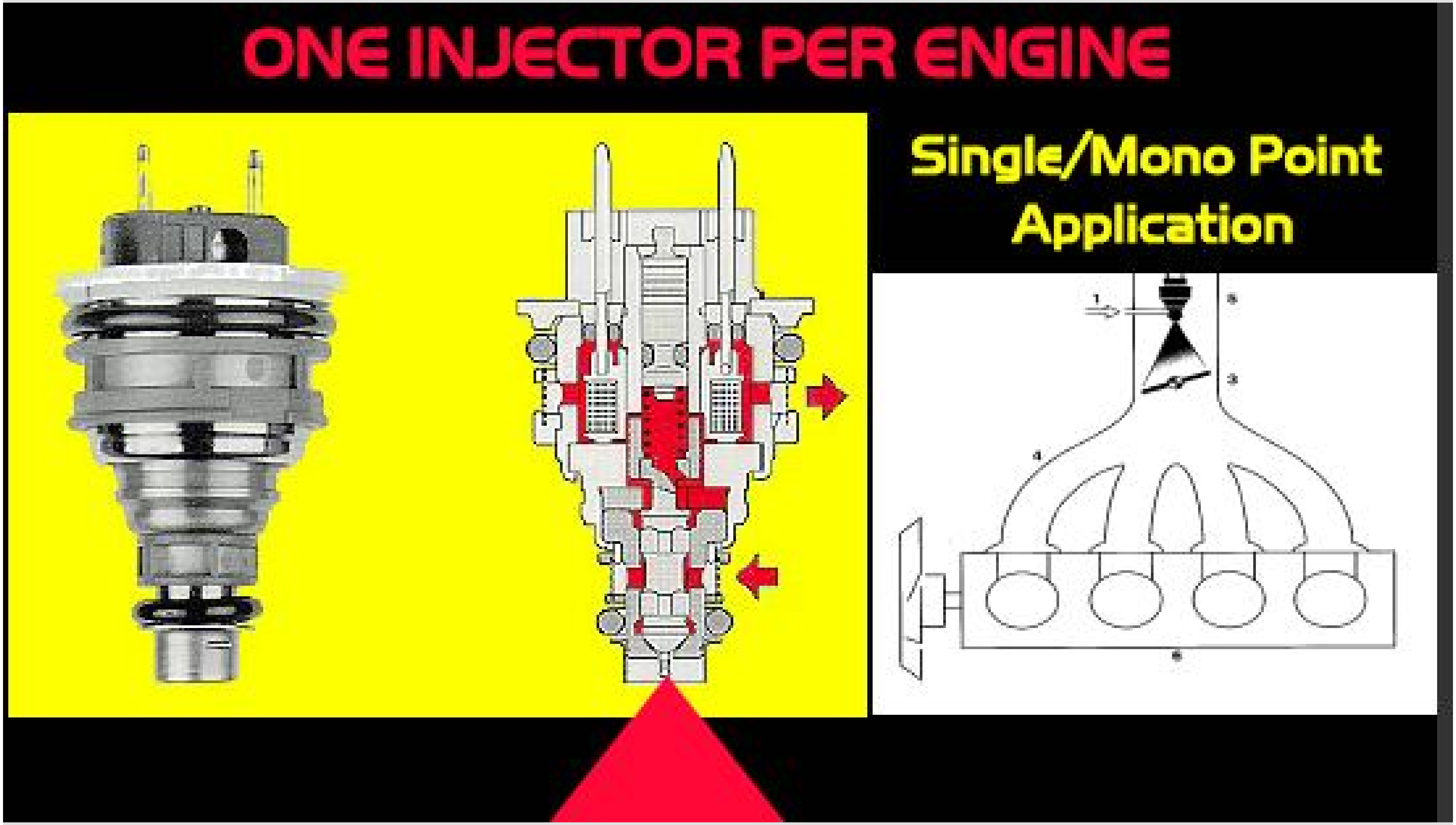
- High Initial Cost/High Replacement Cost
- Increased Care and Attention/More Servicing Problems
- Requires Special Servicing Equipment to Diagnose Faults and Failures
- Special Knowledge of Mechanical and Electrical Systems Needed to Diagnose and Rectify Faults
- Injection Equipment Complicated, Delicate to Handle and Impossible to Service by Roadside Service Units
- Contain More Mechanical and Electrical Components Which May Go Wrong
- Increased Hydraulic and Mechanical Noise Due to Pumping and Metering of Fuel

# Limitations of Petrol Injection (Continued)

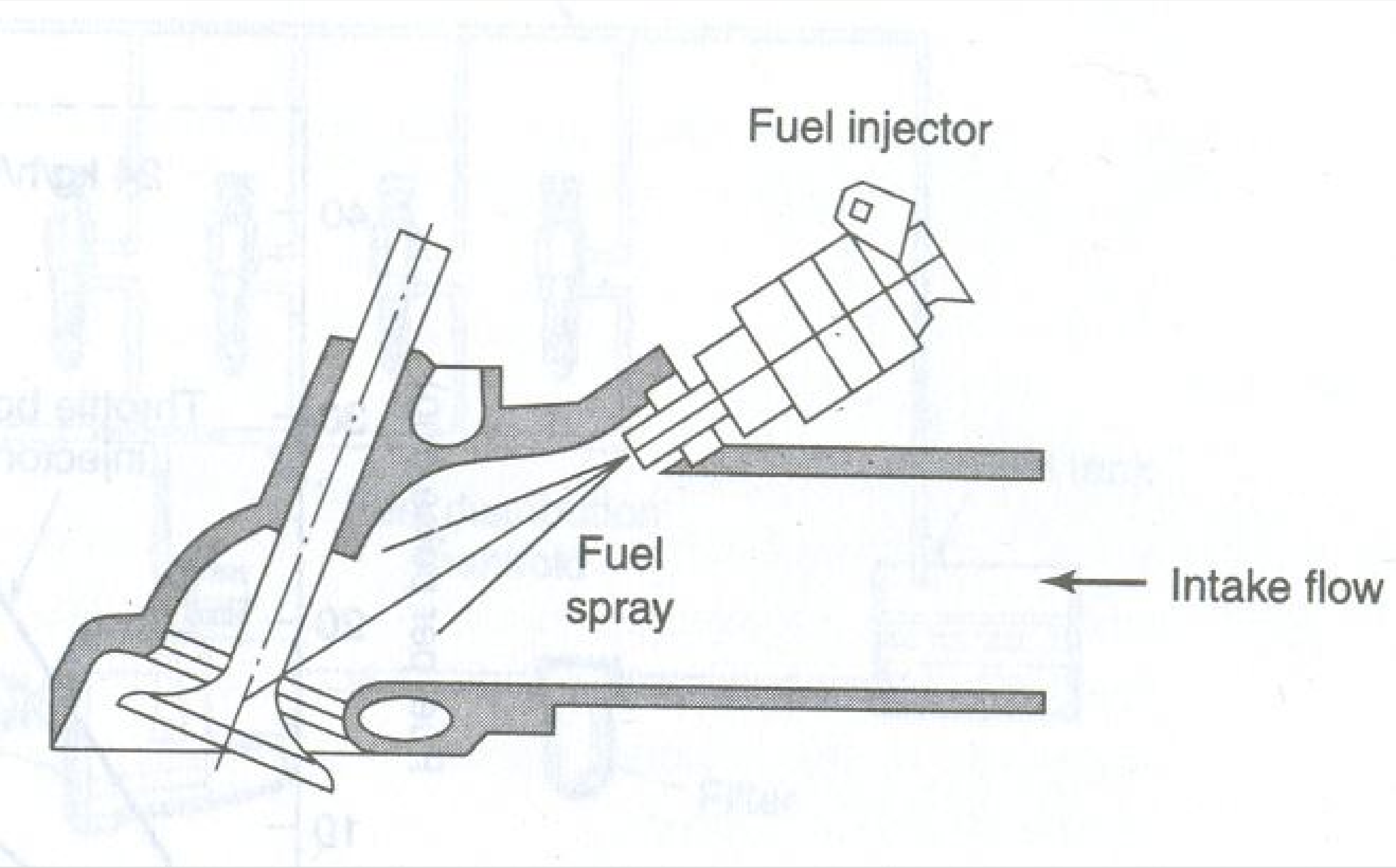
- Very Careful Filtration Needed Due to Fine Tolerances of Metering and Discharging Components
- More Electrical/Mechanical Power Needed to Drive Fuel Pump and/or Injection Devices
- More Fuel Pumping/Injection Equipment and Pipe Plumbing Required- May be Awkwardly Placed and Bulky

# Options for Injector Location




ONE INJECTOR PER ENGINE
Single/Mono Point
Application

# Port Fuel Injection System



# Principle of Operation of EFI

- The EFI operates based on three main factors.
- The amount of fuel delivered through a fuel injector is based on rpm, throttle position, and oxygen remaining within the exhaust.
- The distributor triggering contacts relay the engine speed to the Electronic Control Unit (ECU).
- The load on the engine is taken from the intake air pressure sensor.
- These factors influence how long the injectors remain on for.
- When the engine is first started, the starter is on; additional gas is pumped through the intake manifold.
- When the car is accelerating, throttle position is closer to wide open, the amount of time the injectors remain on is longer.
- When decelerating the fuel injectors remain turned off until the rpm's drop below 1,000, when the injectors open again to allow the engine to run in the idle mode.

- The accuracy of the correct amount of fuel used and stepping up the voltage increases proper timing.
- The battery of a car produces 12V and that is stepped up to 100V to allow the injector to minimize the open/close delay.
- An inductive coil step up the voltage and stores it in a capacitor until it is needed to activate the solenoid, when it is discharged.
- A square wave is used to drive the electronic control unit.
- The square wave is either on or off, 1 or 0.
- The major concern is to reduce the lag between when the electric pulse is received and when the solenoid is discharged.
- By increasing the pressure of the fuel coming into the injector and reducing the air gap you can accomplish this goal of reducing lag.
- The air gap is based on the distance between the needle of the fuel injector when it's fully closed compared to when it's fully open.
- The more pressure you have the less time it takes for the correct amount of fuel to be distributed and also reduces the size of the hole needed to allow the fuel into the manifold.

# Types of EFIS

- There are two types of injector systems:
- throttle body injection system (TBI), which is located above the throttle plate; and
- port fuel injection system (PFI), which is located below the throttle plate.
- When the injectors are located above the throttle plate, they are not subjected to the variations in manifold pressure, which result from the continual opening and closing of the throttle butterfly.
- On the other hand, injectors located below the throttle plate see a continuously changing pressure into which they must squirt their accurate spray.

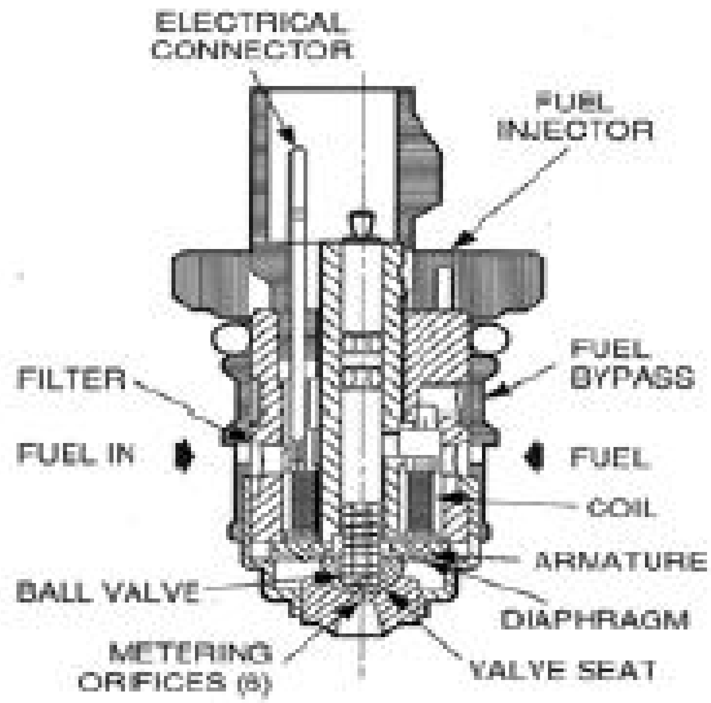
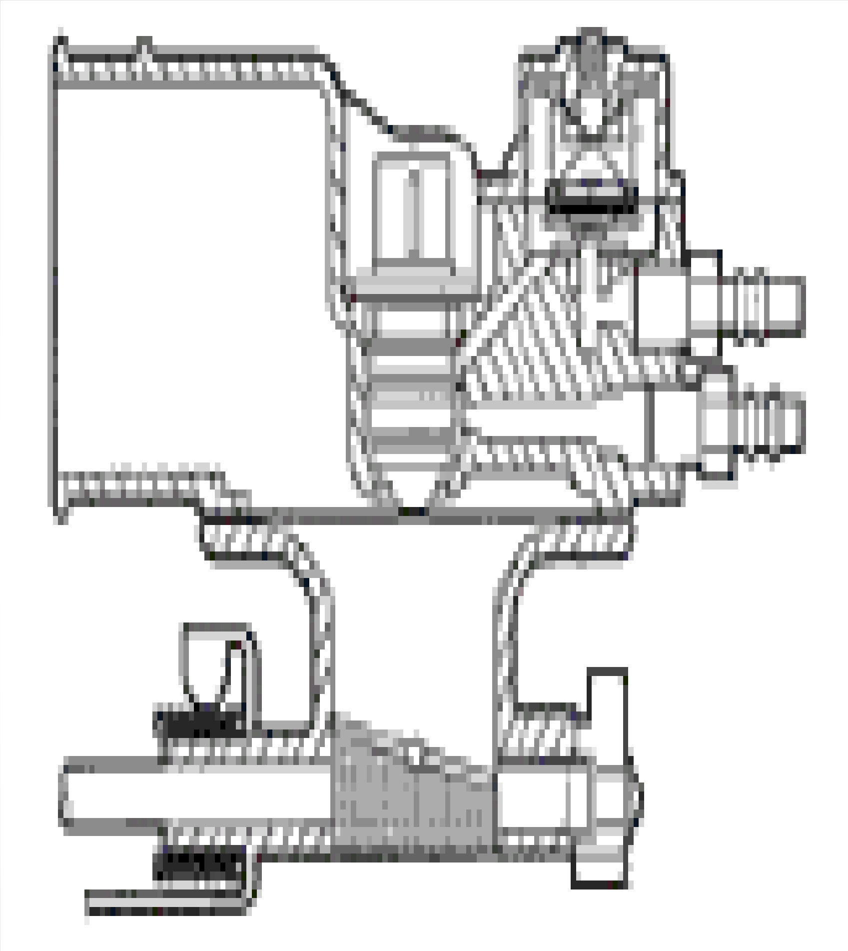


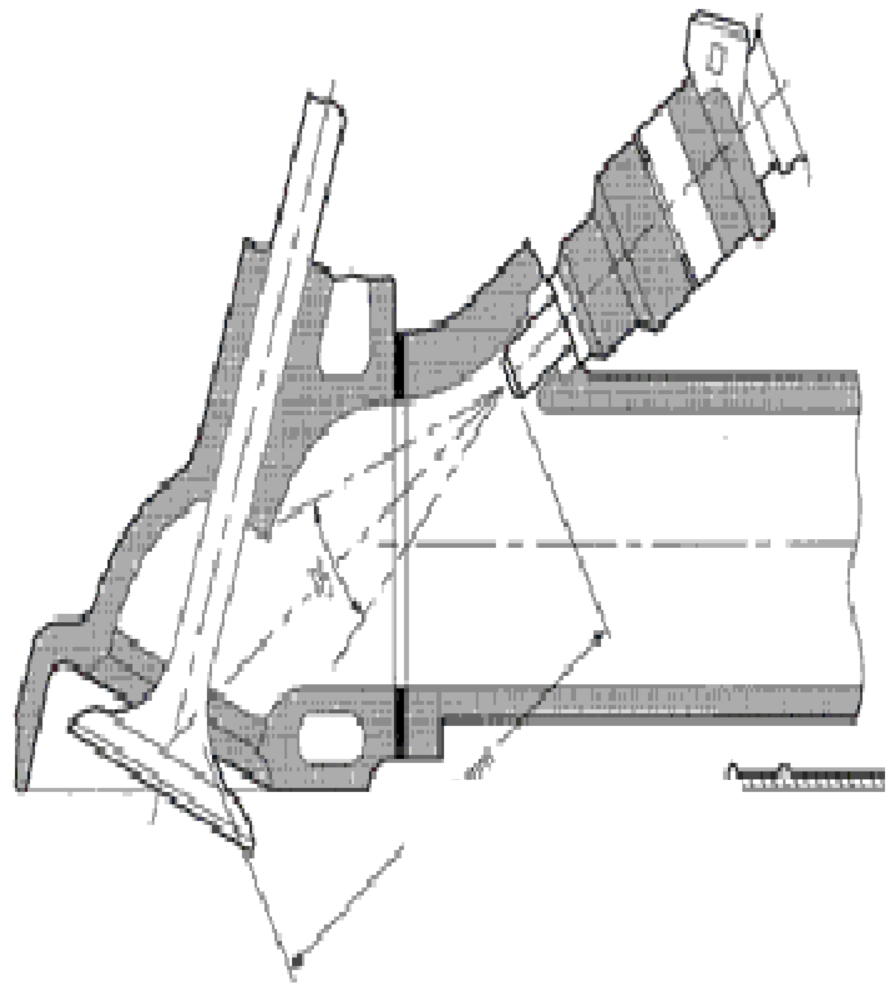

Figure 14
Throttle Body Injector

- The throttle body injection (TBI) system has its spray pattern formed by the metering orifice and the surrounding spray opening.
- A ball valve, which bears against a seat, opens and closes to start and top the flow of fuel.
- This valve is held closed by a small spring.
- To open to nozzle, the ball must be pulled off the seat.
- This is done through the use of an electric solenoid.
- When energized by an electric signal from the computer, the wound wire solenoid creates a magnetic field, which the pulls the ballvalve completely off its seat as far as it can open.

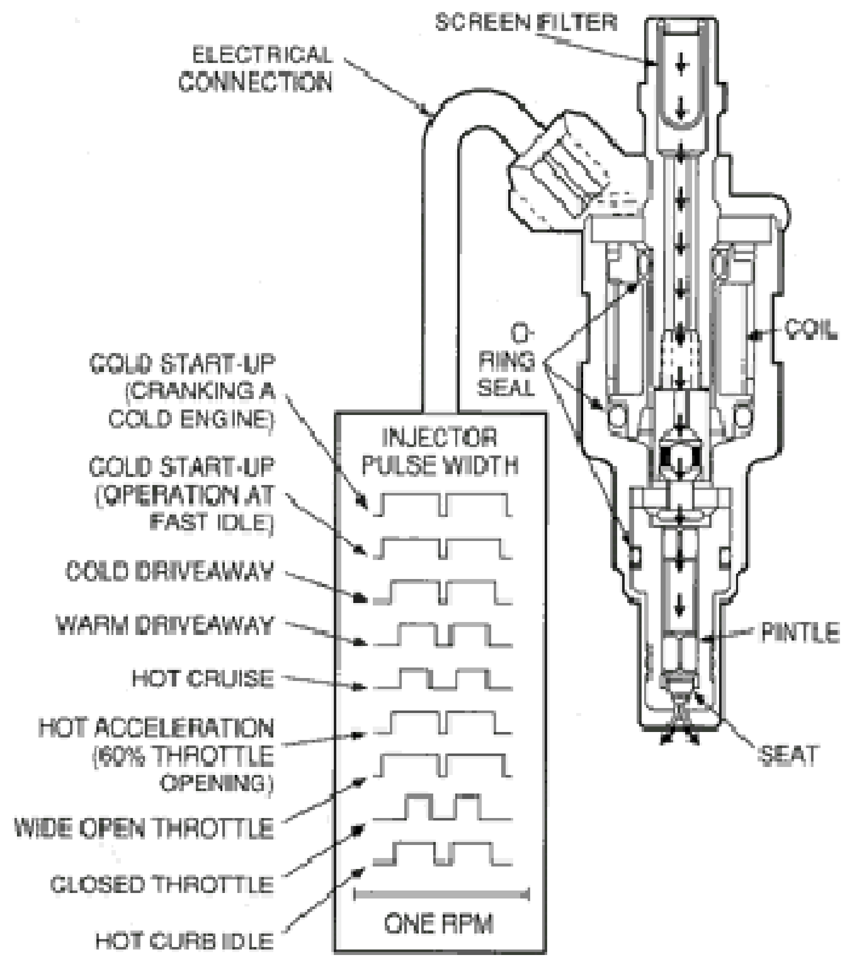


# EFI in Port

- In the typical port injection type of electronic systems (PFI), the injector uses an armature and pintle assembly rather than a ball valve to open and close the flow of fuel and create the spray pattern for the fuel flowing through the nozzle.
- The nozzle and pintle are designed to produce a definite spray pattern.
- Like the TBI, the pintle assembly is held against its seat by a small spring.
- The force that pulls on the armature to open the pintle is provided by an electric solenoid.
- When an electric current is passed through the winding, a magnetic force is created, which pulls the assembly off of its seat.



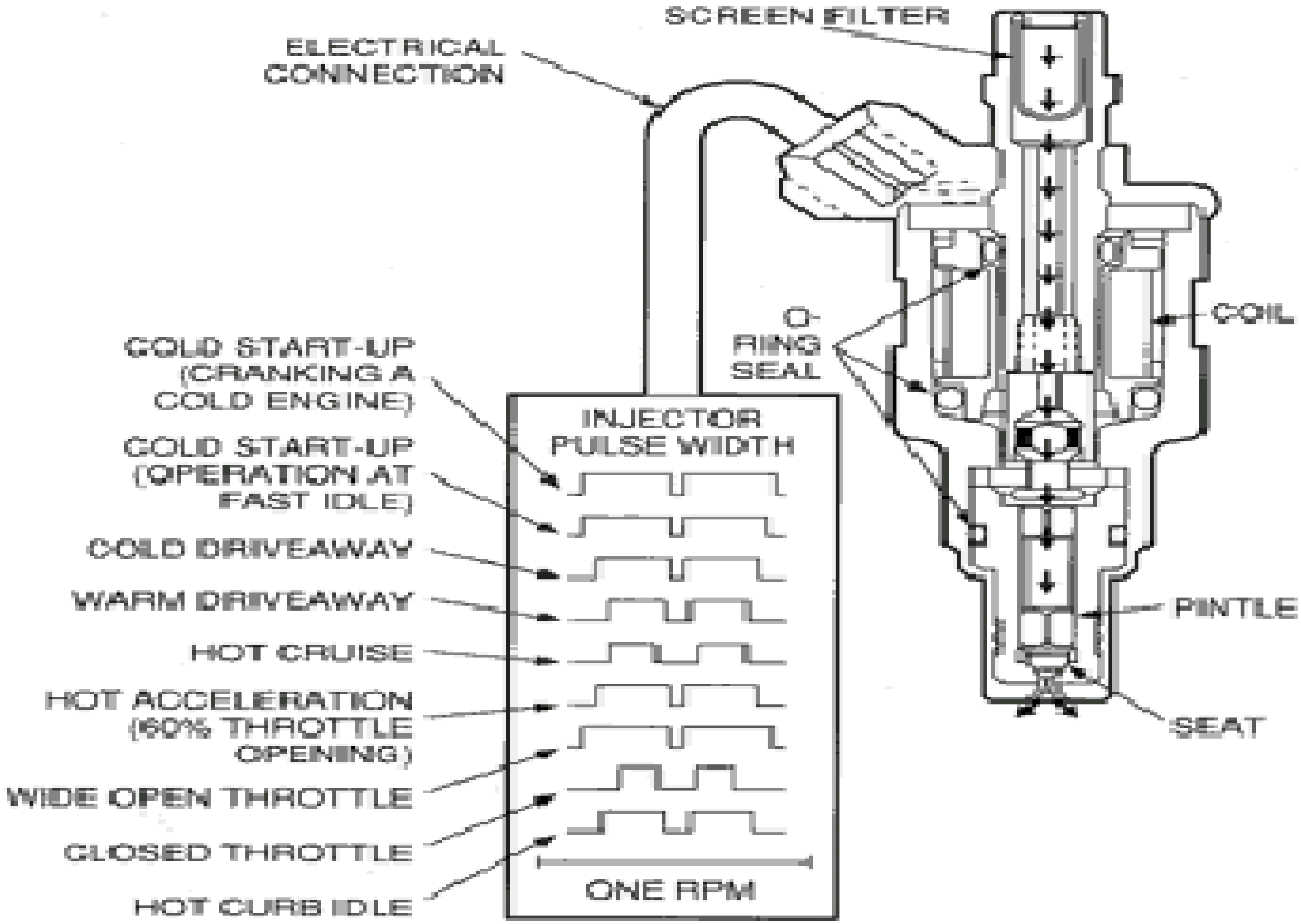
- Thus, every time the solenoid is energized in both TBI and port injectors, the fuel flow area is
- opened to its full potential.
- The actual amount of fuel flow and the amount of fuel forced through the nozzle are governed by the length of time during which the pintle assembly or ball valve is off the seat.
- Clearly, the longer either the pintle assembly or ball valve is off its seat, the more time is for fuel to flow.
- The shorter the time either is off its seat, the quicker it closes and the less time is for fuel to flow.



# Injection Pulse

- The length of time an injector is open and squirting fuel is called the "pulse width," and it is measured in milliseconds (MS).
- As rpm increase, an injector can only be held open for so long before it needs to be held open again for the next engine revolution -- this is called its "duty cycle."
- Even though a fuel injector's flow rate is measured at its maximum duty cycle (100%), fuel injectors should never be operated at 100% duty cycle.
- Instead, a typical maximum duty cycle is around 80%.
- Fuel pressure plays a big role in the operation of a fuel injection system.
- Because the injector is essentially a gate valve for fuel delivery, increasing fuel pressure can allow you to cram more fuel into the intake tract for a given injector pulse width.

# Injector Electrical Input



# Speed Density Electronic MPFI

- Speed-density system uses engine speed, manifold pressure and air temperature to calculate the engine air flow.
- The electrically driven fuel pump delivers the fuel through a filter to the fuel line.
- A pressure regulator maintains the pressure in the line at a fixed value (270 kPa).
- Branch line leads to each injector, the excess fuel returns to the tank vial a second line.
- Typical injection times for automobile applications range from 1.5 to 10 ms.
- The appropriate coil excitation pulse duration or width is set by the electronic control unit (ECU).
- In speed-density system the primary inputs to the ECU are the outputs from the manifold pressure sensor, the engine speed sensor and temperature sensors installed in intake manifold.

# Diagnosis of EFI Health : Quality of Injection

# Mechanical MPFI with Air-flow Meter