Internal Combustion Engines

Diesel Engines - Facts

- The diesel engine is a type of internal combustion engine (more specific ally, a compression ignition engine) in which the fuel is ignited by being suddenly exposed to the high temperature and pressure of a compressed gas containing oxygen (usually atmospheric air), rather than a separate source of ignition energy (such as a spark plug), as is the case in the petrol engine.

- This is known as the diesel cycle, after German engineer Rudolf Diesel, who invented it in 1892 and received the patent on February 23, 1893.

Diesel Engines - Facts

- Initial CI engines were large and slow.
- Heavy distillate petroleum was forced into the cylinder using compressed air.
- Robert Bosch began producing injection systems in 1927.

CI vs. SI Engines

- SI engines draw fuel and air into the cylinder.
- Fuel must be injected into the cylinder at the desired time of combustion in CI engines.
- Air intake is throttled to the SI engine -- no throttling in CI engines.
- Compression ratios must be high enough to cause auto-ignition in CI engines.
- Upper compression ratio in SI engines is limited by the auto-ignition temperature.
- Flame front in SI engines smooth and controlled.
- CI combustion is rapid and uncontrolled at the beginning.

Diesel Engines - Facts

- In very cold weather, diesel fuel thickens and increases in viscosity and forms wax crystals or a gel. This can make it difficult for the fuel injector to get fuel into the cylinder in an effective manner, making cold weather starts difficult at times, though recent advances in diesel fuel technology have made these difficulties rare.

Diesel Engines - Facts

- A common method to electric ally heat the fuel filter and fuel lines. Other engines utilize small electric heaters called glow plugs inside the cylinder to warm the cylinders prior to starting. A small number use resistive grid heaters in the intake manifold to warm the inlet air until the engine reaches operating temperature.

Diesel Engines - Facts

- A vital component of any diesel engine system is the governor, which limits the speed of the engine by controlling the rate of fuel delivery.

- Older governors were driven by a gear system from the engine (and thus supplied fuel only linearly with engine speed.)

- Modern electronically-controlled engines achieve this through the electronic control module (ECM) or electronic control unit (ECU).

Diesel Engines - Facts

- The addition of a turbocharger or supercharger (boost pressures can be higher on diesels) to the engine greatly assists in incre asing fuel economy and power output.

- The higher compression ratio allows a diesel engine to be more efficient than a comparable spark ignition engine, although the calorific value of the fuel is slightly lower at 45.3 MJ/ kg to gasoline at 45.8 MJ/ kg.

Diesel Engines - Applic ations

- High-Speed (approximately 1200 rpm and greater) engines are used to power lorries (trucks), buses, tra ctors, cars, yachts, compressors, pumps and small generators.
- Large electric al generators are driven by medium speed engines, (approx. 300 to 1200 rpm) optimized to run at a set speed and provide a rapid response to load changes.
- The largest diesel engines are used to power ships. These engines have power outputs over 80,000 kW, turn at about 60 to 100 rpm, and are up to 15 m tall. They often run on cheap low-grade fuel, which require extra heat treatment in the ship for tanking and before injection due to their low volatility.

Fuel Injection System -Requirements

- The fuel injection should occur at the correct moment
- It should supply the fuel in correct quantity as required by the varying engine loads
- The injected fuel must be broken into very fine droplets
- The spray pattern should ensure rapid mixing of fuel and air
- It should supply equal quantities of metered fuel to all the cylinders in a multi cylinder engines
- The beginning and the end of injection should be sharp

Elements of Fuel Injection System

- **Pumping elements:** to supply fuel from fuel tank to cylinder

- **Metering elements:** to meter fuel supply as per load and speed

- **Distribution elements:** to divide the metered fuel equally among the cylinders

- **Timing controls:** to adjust the start and the stop of injection

- **Mixing elements:** to atomize and distribute the fuel within the combustion chamber

Types of Injection Systems

- **Air (Blast) Injection System:** In air blast injection system, fuel is forced into the cylinder by means of compressed air.

- This system is little used universally at present, because it requires a multistage air compressor, which incre ases engine weight and reduces brake power.

- This method is capable of producing better atomization and penetration of fuel resulting in higher brake mean effective pressure.

Types of Injection Systems – Contd.

- **Solid Injection System:** In solid injection, the liquid fuel is injected directly into the combustion chamber without the aid of compressed air. Hence, it is termed as airless mechanical injection or solid injection.

- **Every solid injection system must have**

  - a pressuring unit (the pump)

  and

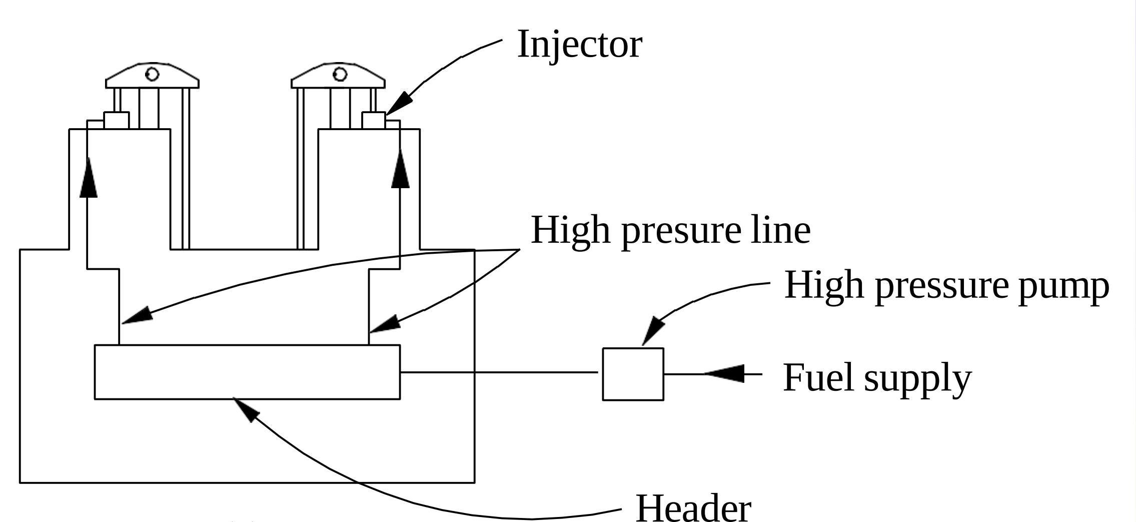
  - an atomizing unit (the injector).

Solid Injection - Classification

- Depending upon the location of the pumps and injectors, and the manner of their operations, solid injection systems may be further classified as follows:

  - Common Rail System
  - Unit Injection System
  - Individual Pump and Nozzle System
  - Distributor System

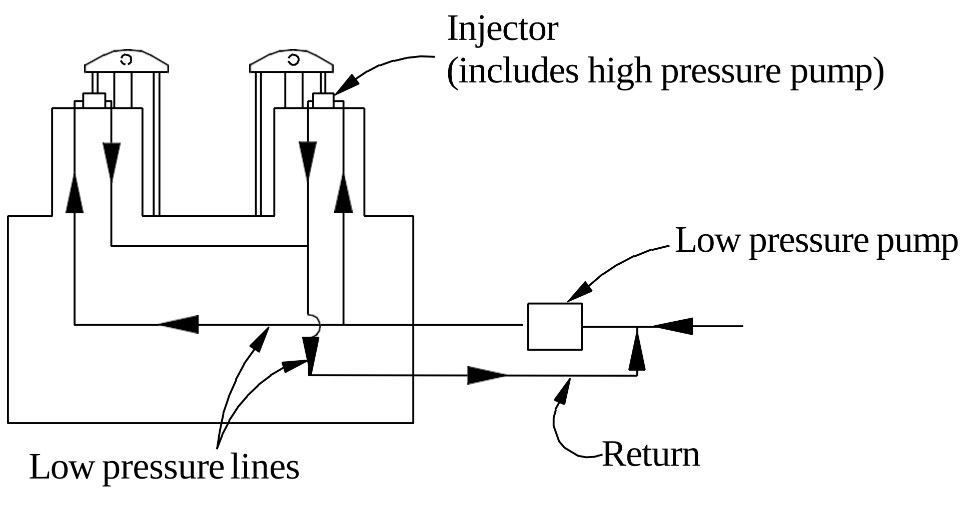
Common Rail System



(a)

❖In this system, a high-pressure pump supplies fuel to a fuel header as shown. The high-pressure in the header forces the fuel to each of the nozzles located in the cylinders. At the proper time, a mechanic ally operated (by means of push rod and rocker arm) valve allows the fuel to enter the cylinder through nozzle.

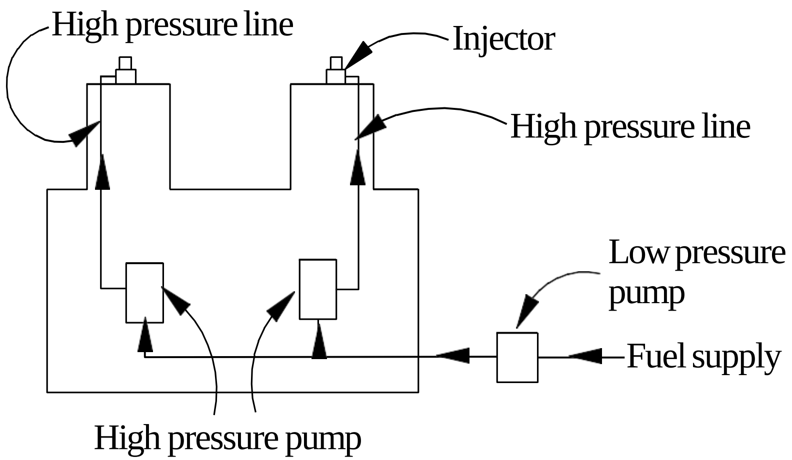
Unit Injection System



(b)

❖Here, the pump and nozzle are combined in one housing. Each cylinder is provided with one of these unit injectors. Fuel is brought up to the injector by a low-pressure pump, where at the proper time, a rocker arm activates the plunger and thus injects the fuel into the cylinder. The quantity of fuel injected is controlled by the effective stroke of the plunger.

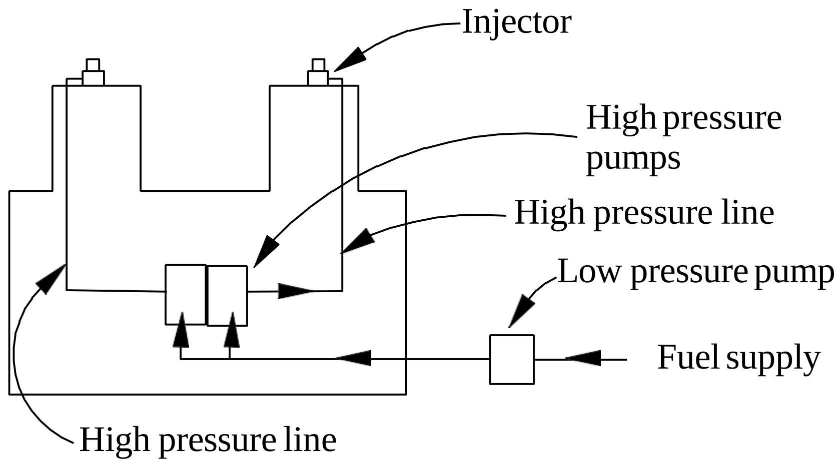
Individual Pump and Nozzle Systems



(c)

Separate pumps

Pumps in Clusters

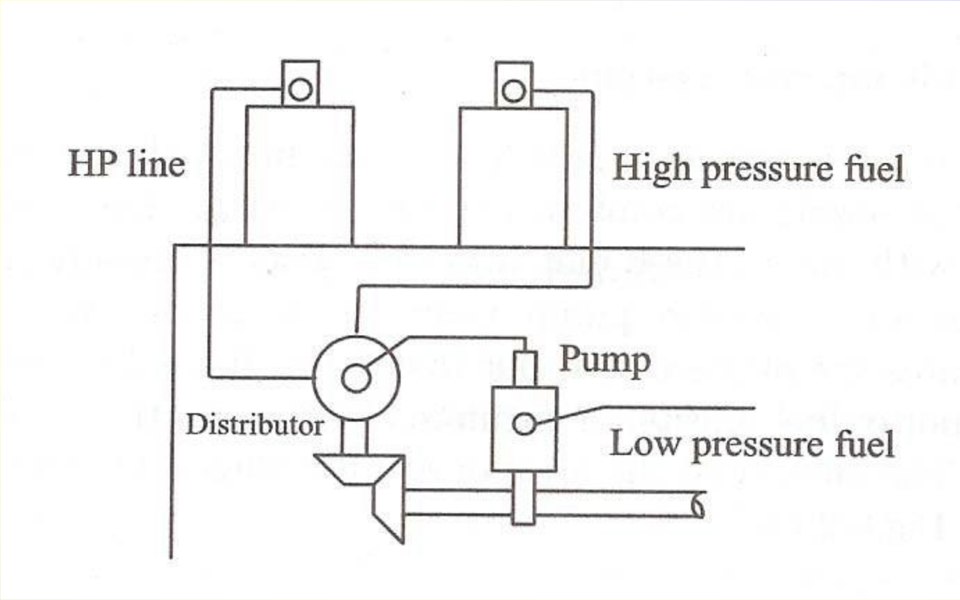


(d)

Individual Pump & Nozzle Systems – contd.

- In this system, each cylinder is provided with one pump and one injector. This type differs from the unit injector in that the pump and injector are separated from each other, i.e., the injector is located on the cylinder, while the pump is placed on the side of the engine. Each pump may be placed close to the cylinder, or may be arranged in a cluster. The high-pressure pump plunger is actuated by a cam, and produces the fuel pressure necessary to open the injector valve at the correct time. The quantity of fuel injected is again controlled by the effective stroke of the plunger.

Distributor System



❖Here, the pump which pressurizes the fuel also meters and times it. The fuel pump after metering the required quantity of fuel supplies it to a rotating distributor at the correct time for supply to each cylinder. Since there is one metering element in each pump, a uniform distribution is ensured.

Injection Pump and Governor

- The main objective of the fuel injection pump is to deliver accurately a metered quantity of fuel under high pressure at the correct instant to the injector fitted on each cylinder. Two types of pumps are generally used viz., jerk type and distributor type.

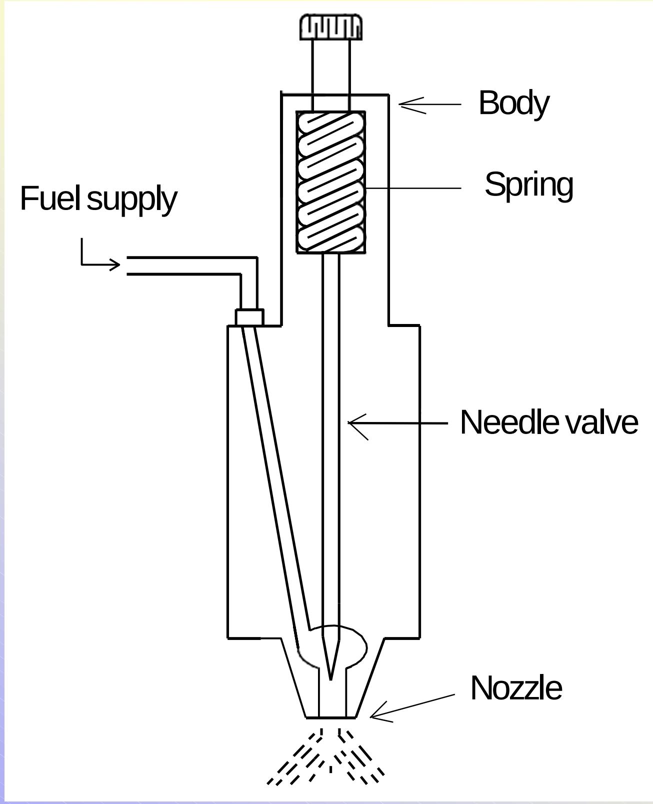
- Fuel delivered by a pump increases with speed while the opposite is true about the air intake. This results in over fueling at higher speeds. At low speeds, the engine tends to stall due to insufficiency of fuel. To overcome this, injector pump governors are generally used. Two types of governors are found in applications viz., (a) mechanical governor and (b) pneumatic governor.

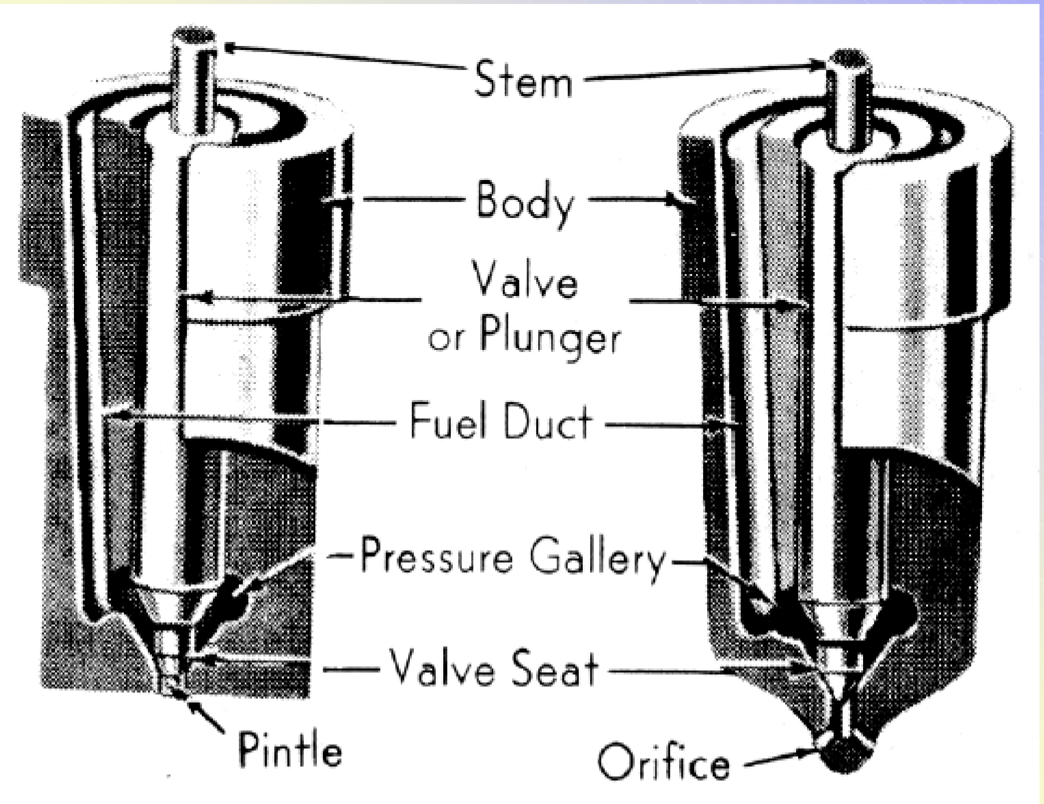
Fuel Injectors and Nozzles

- Quick and complete combustion is ensured by a well designed fuel injector. By atomizing the fuel into very fine droplets, it increases the surface area of the droplets resulting in better mixing and subsequent combustion. Atomization is done by forcing the fuel through a small orifice under high pressure. An injector assembly consists of the following components.

  - a needle valve
  - a compression spring
  - a nozzle
  - an injector body

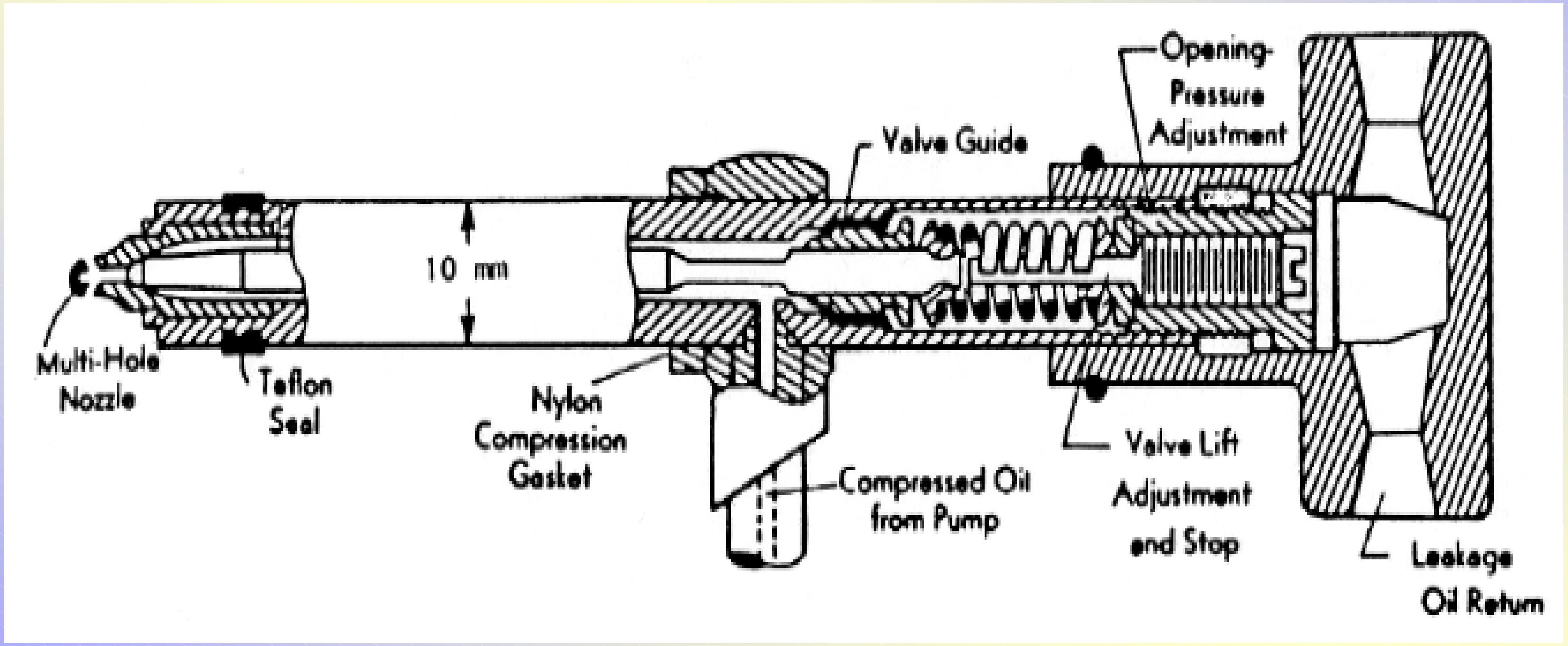
Conventional Injection Nozzles





Components of injector nozzle

Cutaway of Conventional Injection Nozzle



Operation

- Fuel is injected by a pump. The pump exerts sufficient pressure / force that lifts the nozzle valve.

- When the nozzle valve is lifted up, fuel is sprayed into the combustion chamber. As the fuel supply is exhausted, the spring pushes the valve back on its seat.

- The spring tension and hence the valve operating pressure is controlled by adjusting the screw at the top.

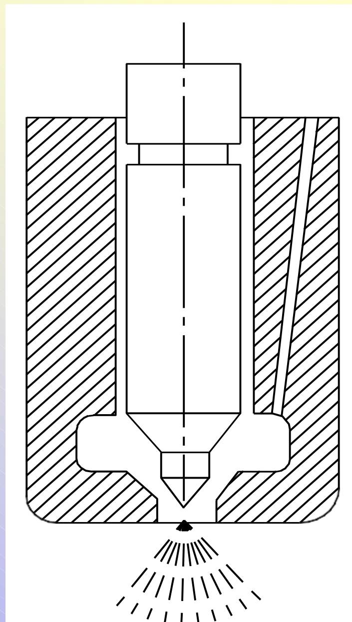
Nozzle

- The nozzle sprays the liquid fuel. The functions of the nozzle are: (a) atomization, (b) distribution of fuel to the required area, (c) non-impingement on the walls, and (d) no dribbling.

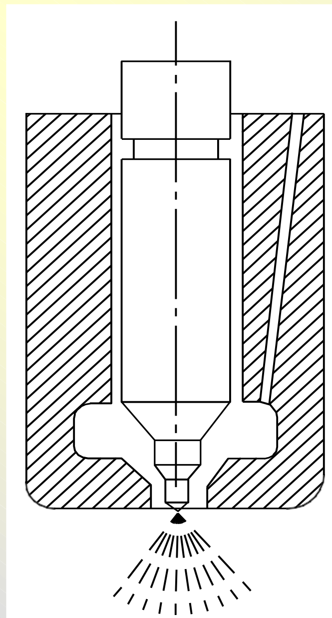
Note: High injection pressure allows better dispersion and penetration into the combustion chamber. High air density in the cylinder gives high resistance to the droplets. This further causes dispersion.

Note: The fuel striking on the walls decomposes and produces carbon deposits. This causes smoky exhaust and incre ases fuel consumption.

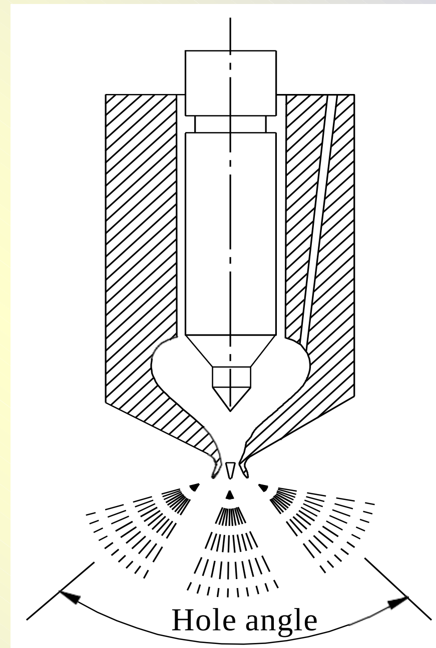
Types of Nozzles



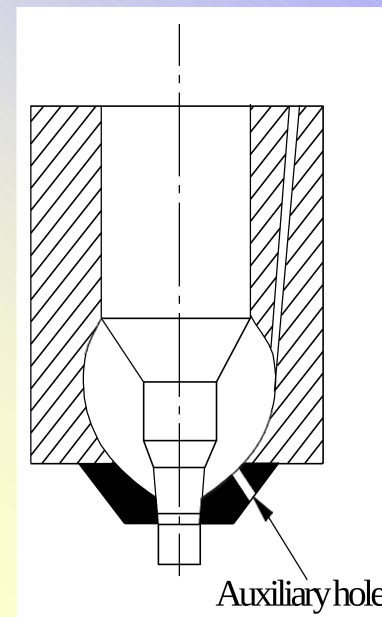
(a) Single hole



(b) Pintle nozzle



(c) Multiple hole



(d) Pintaux nozzle

15^0
18 Mpa

60^0
8-10 Mpa

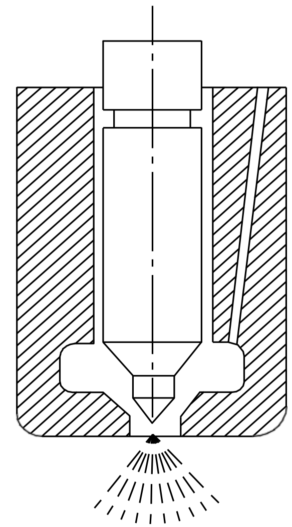
20^0
18 Mpa

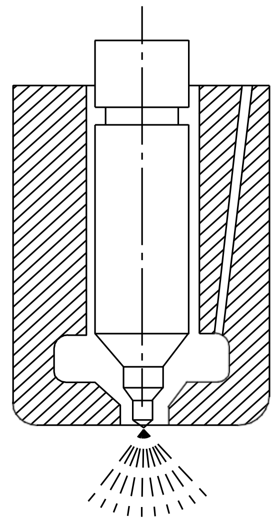
Nozzles

Nozzle Holder

Types of Nozzles

- The single hole nozzle requires a high injection pressure and this type of nozzle has a tendency to dribble. The spray cone angle is usually narrow, and this gives poor mixing unless the velocity is high.

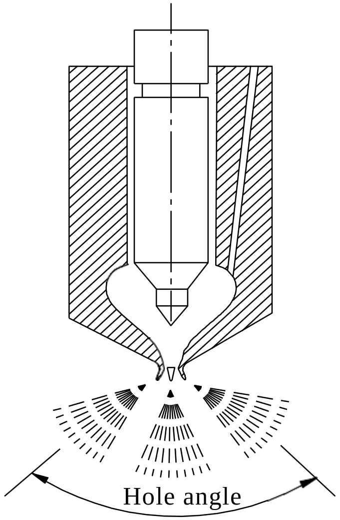

(a) Single hole


(b) Pintle nozzle

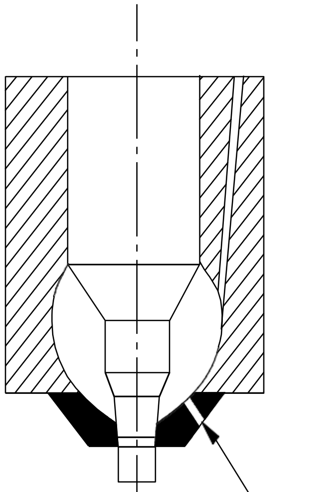
- The pintle nozzle has been developed to avoid weak injection and dribbling. The spindle is provided with a pintle capable of protruding in and out. Pintle nozzle results in good atomization and reduced penetration.

Types of Nozzles

❑A multihole nozzle, where the number of holes may vary from 4 to 18, allows a proper mixing of air and fuel. The advantage lies with the ability to distribute the fuel properly even with lower air motion within the chamber.

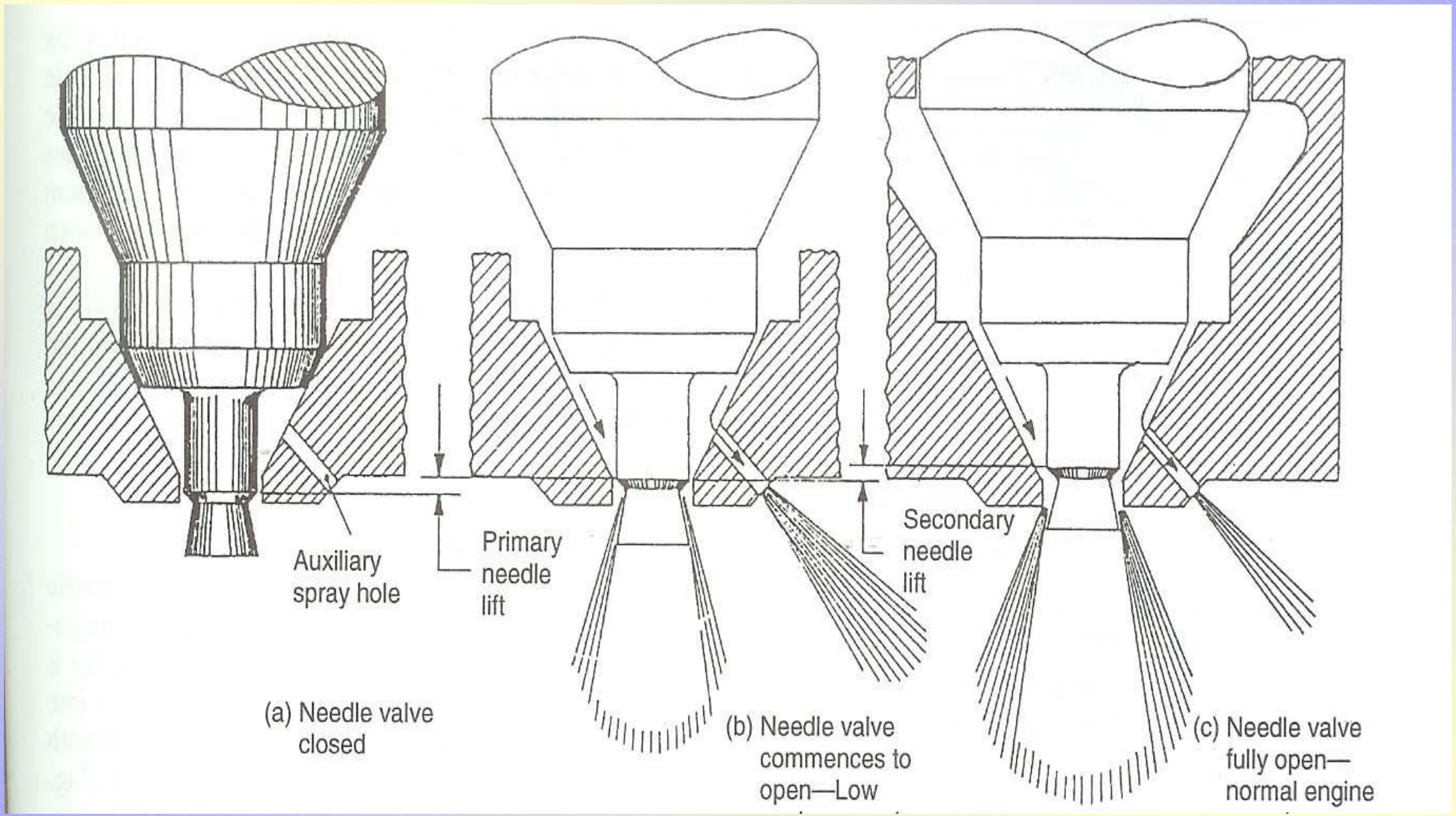


(c) Multiple hole



(d) Pintaux nozzle

❑ The pintaux nozzle is a pintle nozzle with an auxiliary hole drilled into the nozzle body. At low speeds, the needle valve does not lift fully and most of the fuel is injected through this auxiliary hole.


Auxiliary
spray hole
Primary
needle
lift
Secondary
needle
lift
(a) Needle valve
closed
(b) Needle valve
commences to
open—Low
(c) Needle valve
fully open—
normal engine

V_f = the fuel jet velocity at the orifice exit

$$\therefore V_f = C_d \sqrt{2\left(\frac{p_{inj} - p_{cyl}}{\rho_f}\right)}$$

$where\ \ p_{inj} = injection\ \ pressure$

$p_{cyl} = cylinder\ \ pressure$

$\rho_f = density\ of\ \ fuel$

$C_d = coefficient\ of\ discharge\ for\ orifice$

Volume of flow injected per second, Q

$$\therefore Q = \left(\frac{\pi}{4} d^2 n\right) V_f \left(\frac{\theta}{360} \frac{60}{N}\right) \left(\frac{N_i}{60}\right)$$

Area of all orifices

Time of one injection

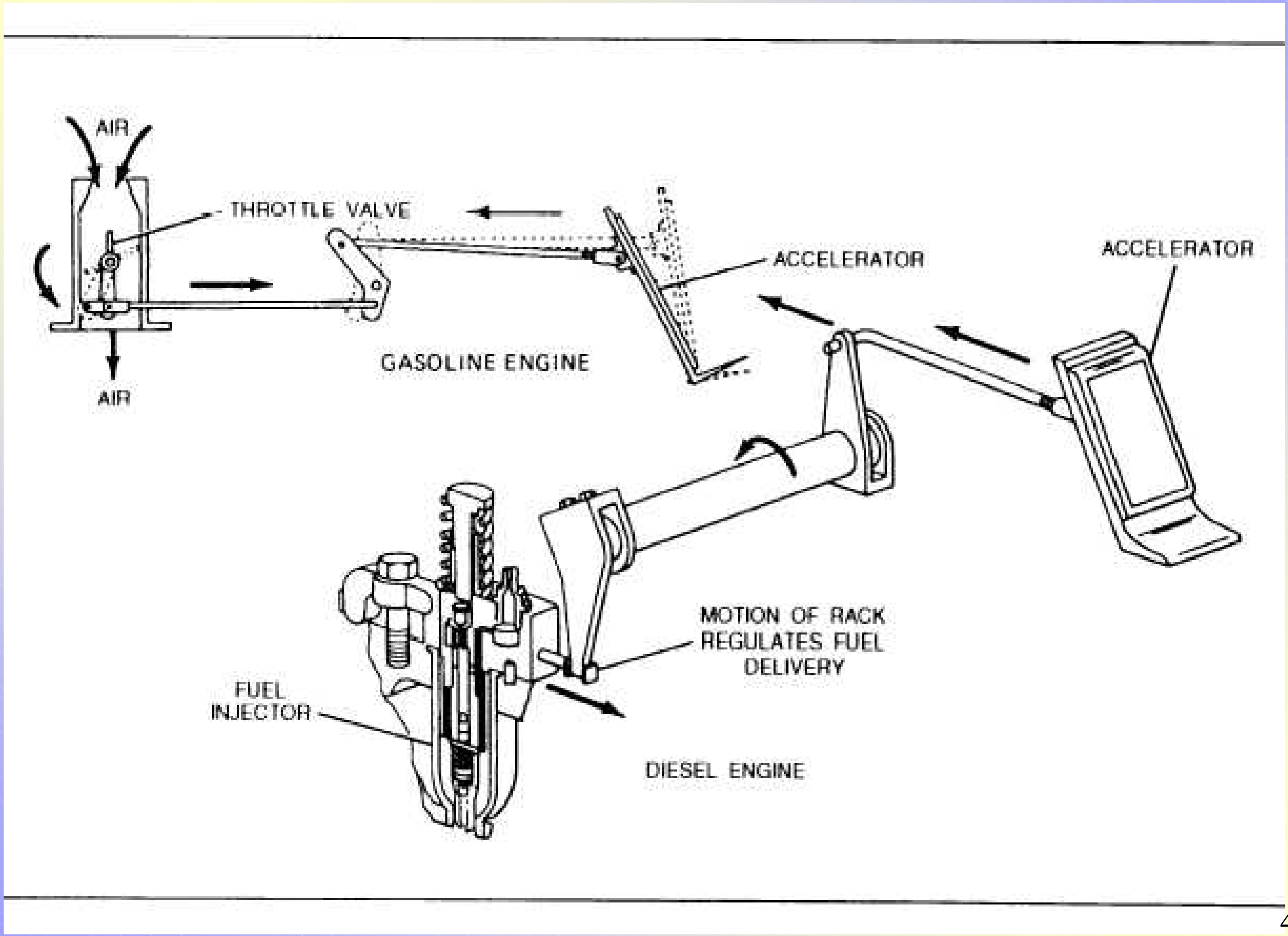
No. of injection per sec for one orifice

d = diameter of orifice
n = no. of orifices
θ = duration of injection in crank angle degrees
N = rpm/ 2 for four stroke
 = rpm for two stroke
N_i = no. of injection per minute

Diesel Engines - Facts

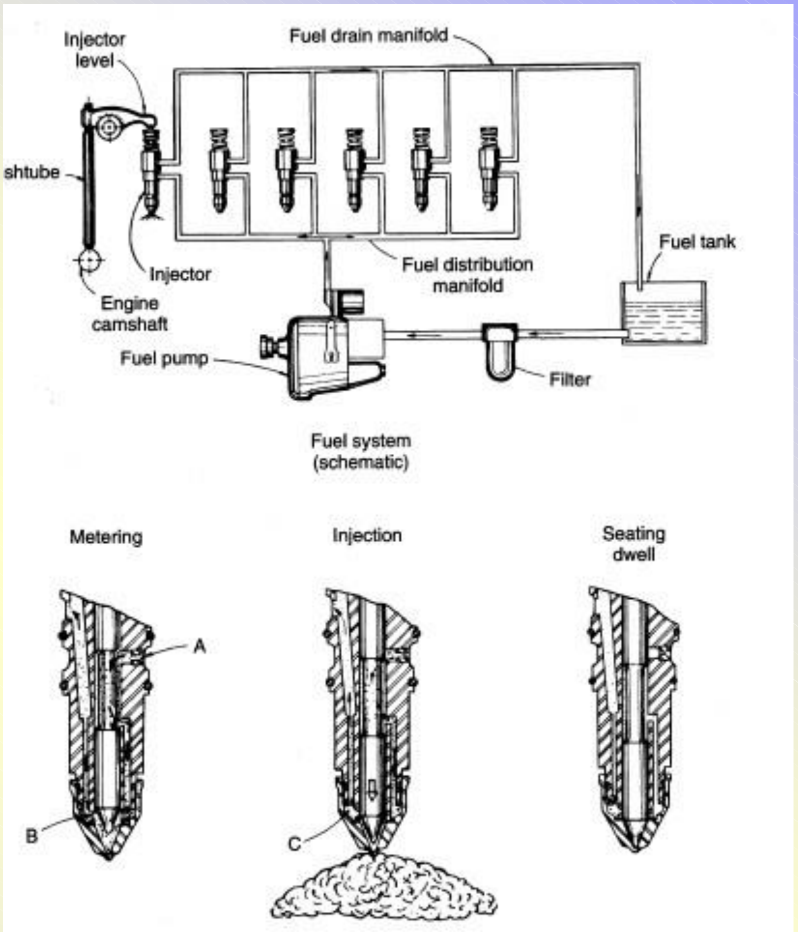
- Diesel engines are rather unpopular in the United States, often being thought of as loud and dirty. Worldwide, however, diesel engines are very well established in a wide variety of applications, as they are much more efficient than gasoline engines and generally longer lasting.

Petrol & Diesel Engines



Diesel Fuel Injection System

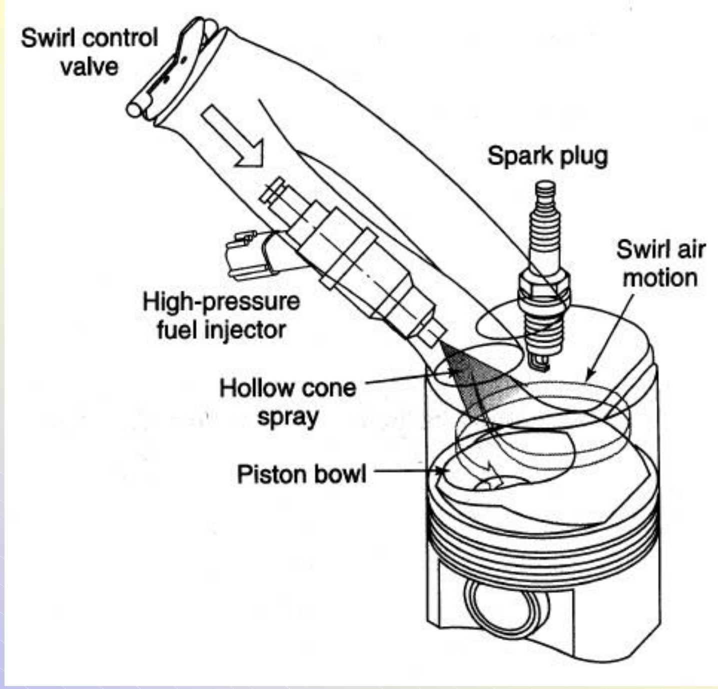
With diesel engines fuel is sprayed directly into the cylinders power is varied by metering the amount of fuel added (no throttle). Diesel fuel injection systems operate at high-pressure, e.g., 100 Mpa. In this system, fuel pressure must be greater than the compression pressure, and the system needs high fuel jet speed to atomize droplets small enough for rapid evaporation.



- **Traditional Diesels high pressure produced locally within the injector**
- **Latest Diesels use high pressure common rail with solenoid actuated injectors**

Gasoline Direct Injection (GDI) Engine

- Fuel is injected directly into the cylinder during the intake stroke or the compression stroke
- High pressure injector required, 5-10 MPa
- Need bowl in piston design to direct the fuel spray towards the spark plug



Benefits of GDI Engine

Engine that combines the best features of SI and CI engines:

- **Operate at optimum compression ratio (12-15) for efficiency by injecting fuel directly into engine during compression (avoiding knock associated with SI engines with premixed charge)**
- **Ignite the fuel as it mixes (avoid fuel-quality requirement of diesel fuel)**
- **Control engine power by fuel added (no throttling ⓪ no pumping work)**
- **During intake stroke fuel cools the cylinder wall allowing more air into the cylinder due to higher density**

Direct-Injection Stratified-Charge Engines

- Create easily ignitable fuel-air mixture at the spark plug and a leaner fuel-air mixture in the rest of the cylinder.
- Lean burn results in lower emissions and higher energy efficiency

Example:

Mitsubishi GDI engine achieves complete combustion with an air-fuel ratio of 40:1 compared to 15:1 for conventional engines

This results in a 20% improvement in overall fuel efficiency and CO2 production, and reduces NOx emissions by 95% with special catalyst

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Web Resources

1. http://www.mne.psu.edu/simpson/courses
2. http://me.queensu.ca/courses
3. http://www.eng.fsu.edu
4. http://www.personal.utulsa.edu
5. http://www.glenroseffa.org/
6. http://www.howstuffworks.com
7. http://www.me.psu.edu
8. http://www.uic.edu/classes/me/ me429/lecture-air-cyc-web%5B1%5D.ppt
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10. http://www.rmi.org/sitepages/pid457.php
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