Compression ignition internal combustion engines

The basic principle of compression ignition consists in injecting fuel into compressed, heated air before the end of the second period just before top dead center.

Basic types of combustion chambers:

1. *Indirect injection (IDI) systems* - the combustion space is divided into two parts. First part is localized in the main cylinder and second part is in the cylinder head. The fuel injection is effected usually into the part of chamber lacated in the cylinder head. The chambers are:

A.) Swirl chamber in which compression swirl is generated.

B.) Pre-combustion chamber in which combustion swirl is induced.

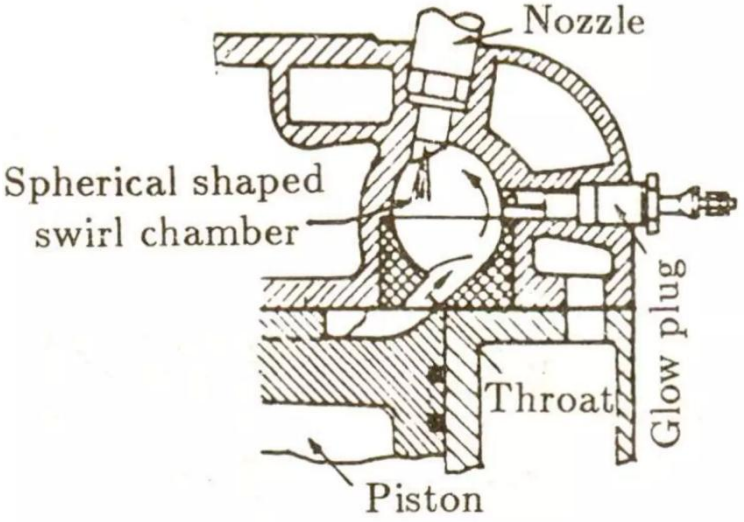
C.) Air cell in which both compression and combustion swirl are induced.

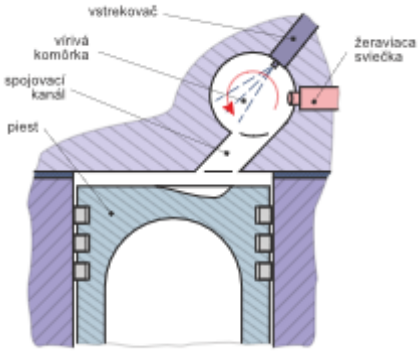
2. Direct injection (DI) systems - In this type the entire volume of combustion chamber is located in the main cylinder and fuel is injected into this volume.

Indirect injection (IDI) systems

Swirl chamber - Ricardo´s swirl chamber (disign in since 1931 ang. H. Ricardo)

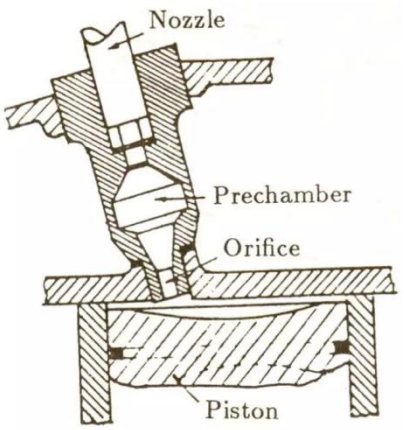
- Swirl chamber consists of a spherical shaped chamber separated from the engine cylinder and located in the cylinder head. Into this chamber, about 50% of the air is transferred during the compression stroke.
- A throat connects the chamber to the cylinder which enters the chamber in a tangential direction so that the air coming into this chamber is given a strong rotary movement inside the swirl chamber and after combustion, the products rush back into the cylinder through same throat at much higher velocity. This causes considerable heat loss to walls of the passage which can be reduced by employing a heat insulated passage.
- This type of combustion chamber finds its application where fuel quality is difficult to control, where reliability under adverse conditions is more important than fuel economy. The use of single hole of larger diameter for the fuel spray nozzle is often important consideration for the choice of swirl chamber engine.





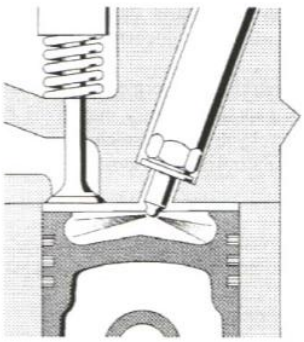
Pre-Combustion Chamber

- Typical pre-combustion chamber consists of an anti chamber connected to the main chamber through a number of small holes (compared to a relatively large passage in the swirl chamber). The pre-combustion chamber is located in the cylinder head and its volume accounts for about 40% of the total combustion, space. During the compression stroke the piston forces the air into the pre-combustion chamber.
- The fuel is injected into the pre-chamber and the combustion is initiated. The resulting pressure rise forces the flaming droplets together with some air and their combustion products to rush out into the main cylinder at high velocity through the small holes. Thus it creates both strong secondary turbulence and distributes the flaming fuel droplets throughout the air in the main combustion chamber where bulk of combustion takes place. About 80% of energy is released in main combustion chamber.
- The rate of pressure rise and the maximum pressure is lower compared to those in open type chamber. The initial shock if combustion is limited to pre-combustion chamber only. The pre-combustion chamber has multi fuel capability without any modification in the injection system because the temperature of pre-chamber. The variation in the optimum injection timing for petrol and diesel operations is only 2 deg. for this chamber compared to 8 to 10 deg in other chamber design.

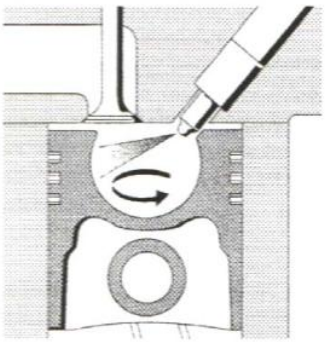


Direct injection (DI) systems

It is used in direct injection. The design of the piston head is required so that there is a perfect mixing of the air and the injected fuel.



Quiescent chamber



Swirl in chamber

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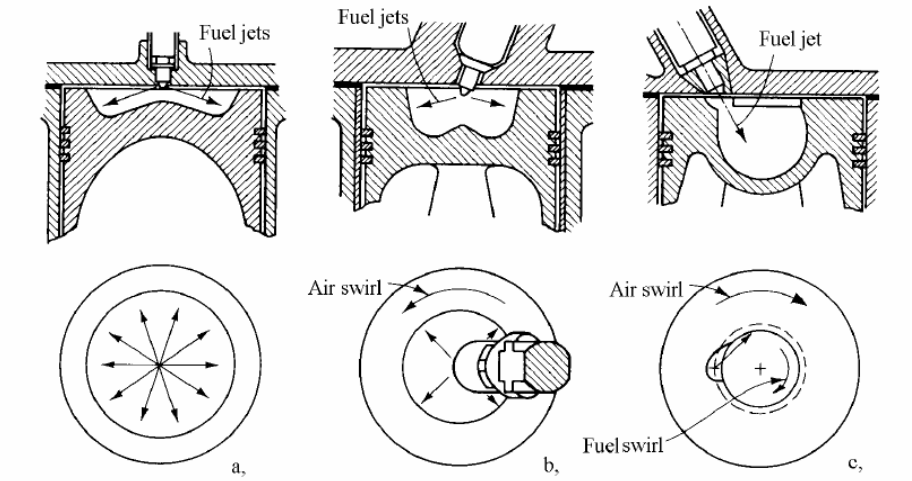
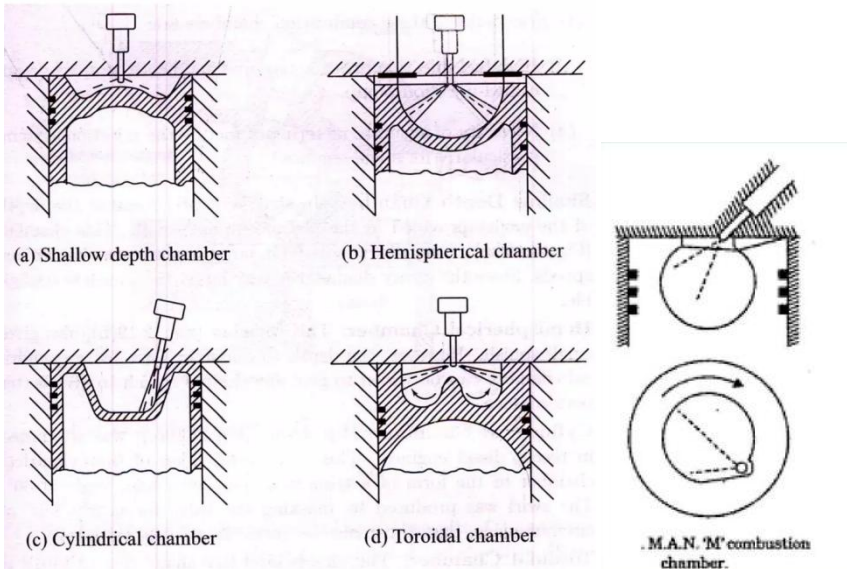


Quiescent chamber design with multihole nozzle

Bowl-in-piston chamber design with multihole nozzle

Bowl-in-piston chamber with multihole nozzle and air and fuel swirl

The typical open combustion chamber designs



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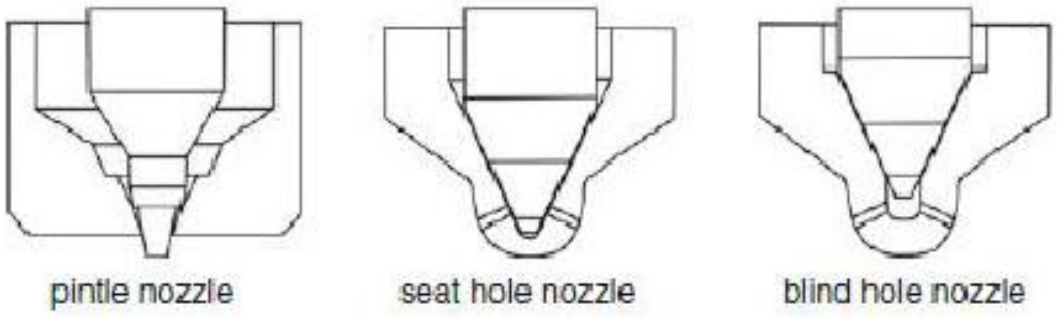
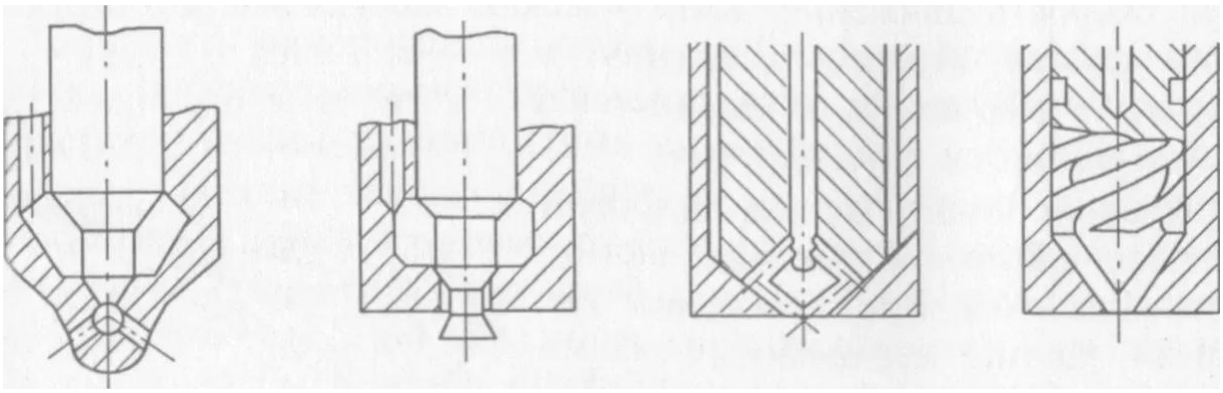
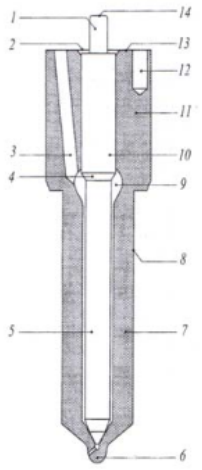
Various types of injection nozzle

Pintle type Hole type



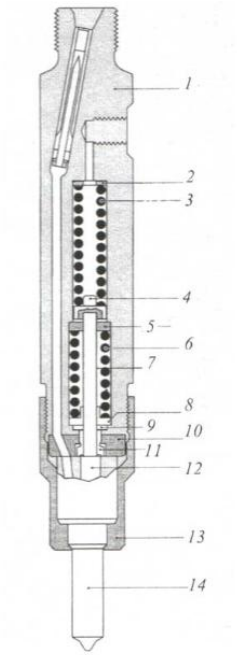


Multi hole Outward opening Spray single hole Inward opening swirl



Popis:

1 – tlačný čap
2 – plocha dorazu zdvihu
3 – prítokový otvor
4 – tlakový nábeh
5 – driek ihly
6 – zaoblený vrchol ihly
7 – driek telesa trysky
8 – povrch telesa trysky
9 – tlaková komora
10 – vedenie ihly
11 – lem telesa trysky
13 – tesniaca plocha
14 – zakončenie tlačného čapu



Popis:

1 - teleso držiaka
2 - vymedzovacia podložka
3 - tlačná pružina 1
4 - tlačný čap
5 – vodiaca podložka
6 – tlačná pružina 2
7 – tlačný kolík
8 – tanier pružiny
9 – vymedzovacia podložka
10 – medzi vložka
11 – dorazové puzdro
12 – ihla trysky
13 – napínacie matice trysky
14 – teleso trysky

Detail of injection needle of injection nozzle Dual spring injection nozzle

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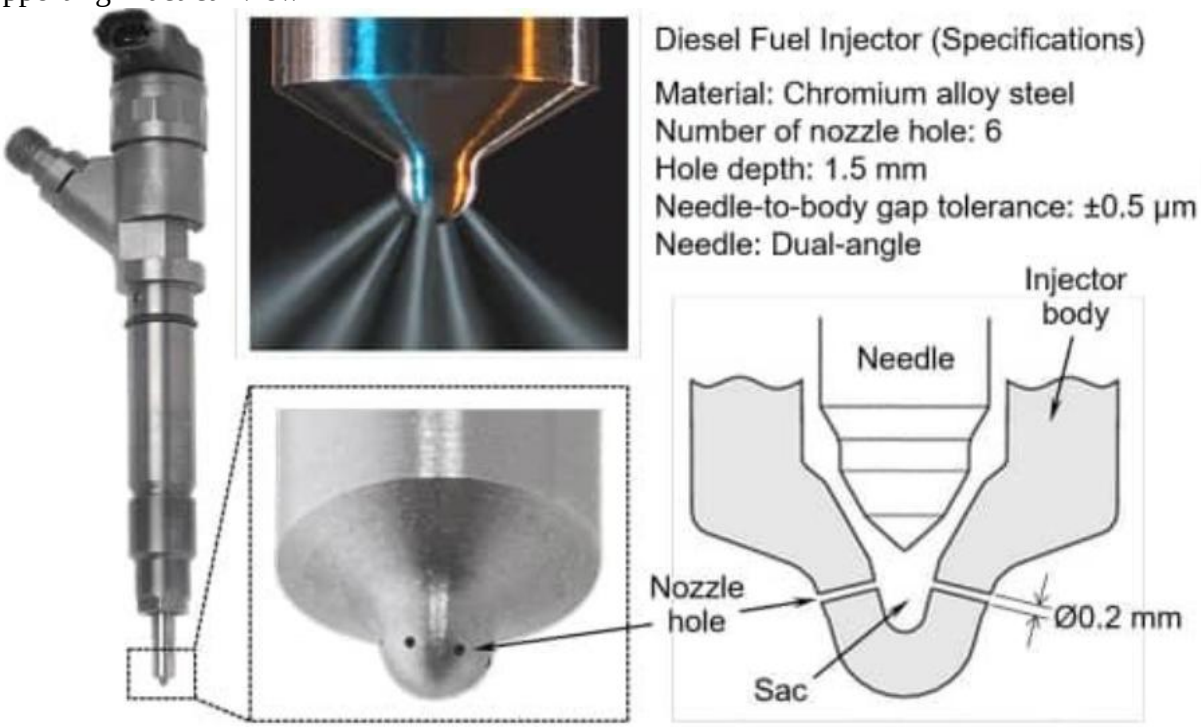
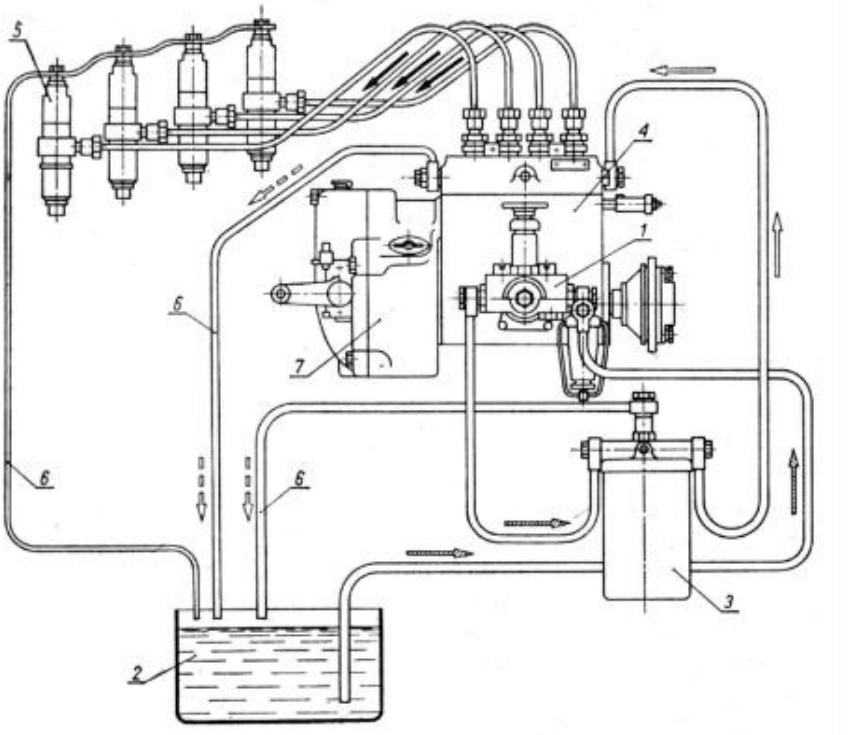
Supporting Practical view



The fuel system with mechanical fuel injection pump



1- transfer pump and preliminary filter, 2- tank, 3 - fuel filter, 4- injection pump, 5 - injection nozzle, 6 - fuel return line, 7 - control part of injection pump

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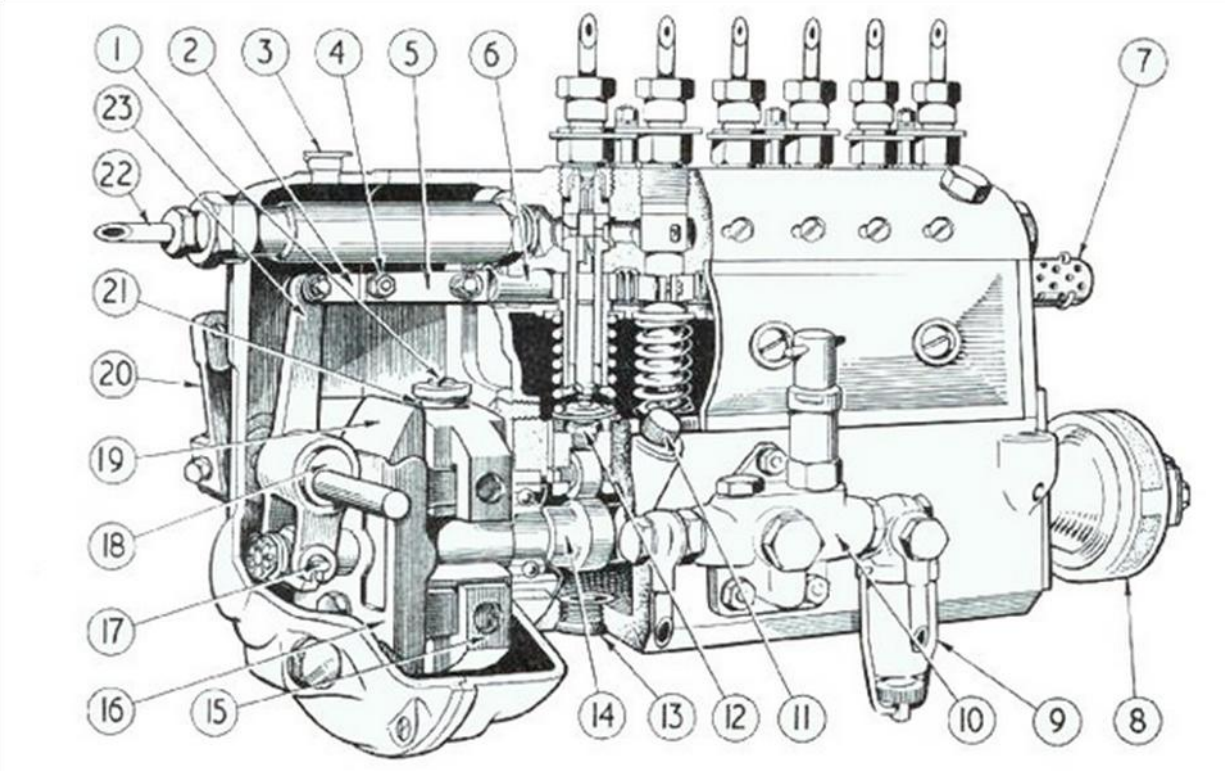
Detail of in-line fuel pump



1. Adjusting nut
2. Outer link fork
3. Oil lubricator
4. Screw for link forks
5. Inner link fork
6. Control rod
7. Control rod stop
8. Drive coupling
9. Preliminary filter
10. Plunger type feed pump
11. Oil dipstick
12. Tappet screw
13. Closing plug
14. Camshaft
15. Flyweights
16. Bell crank pin retaining cage
17. Coupling cross-head pin
18. Eccentric
19. Bell crank lever
20. Control lever
21. Governor spring
22. Fuel inlet connection
23. Floating lever

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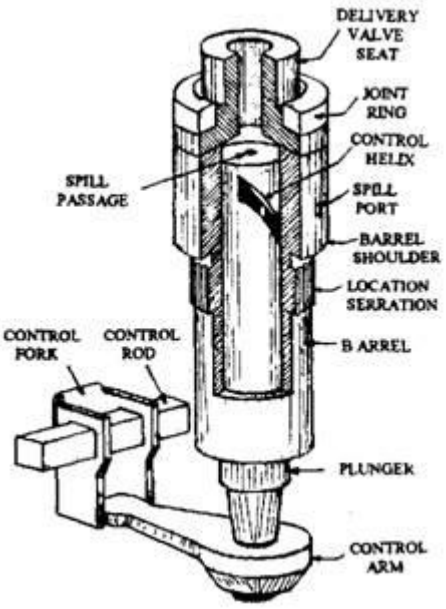
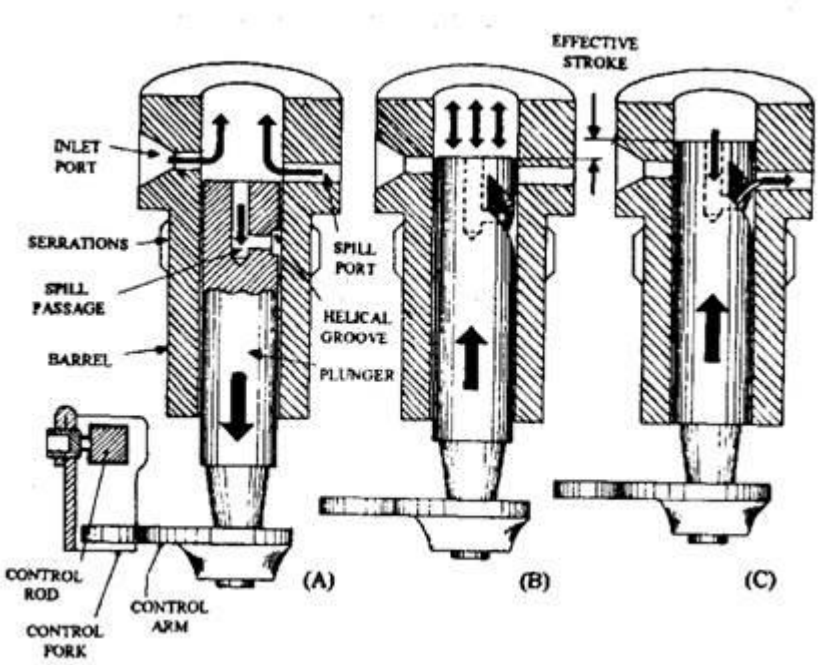
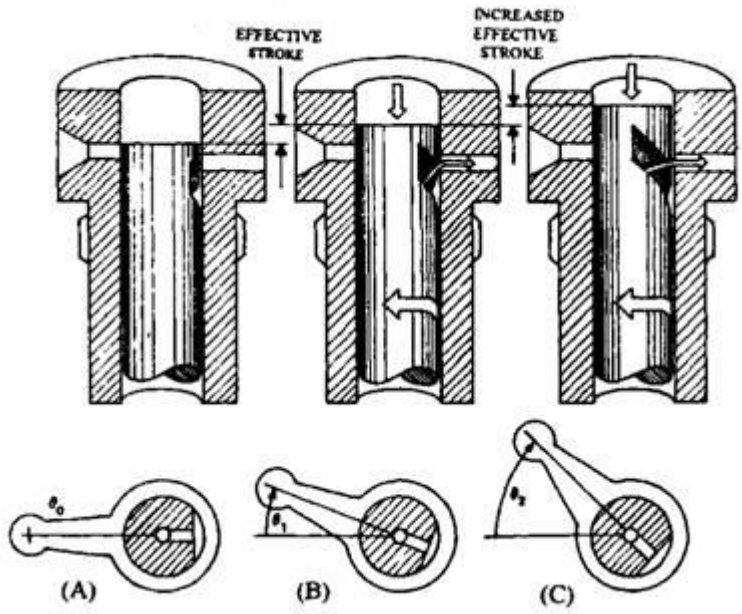
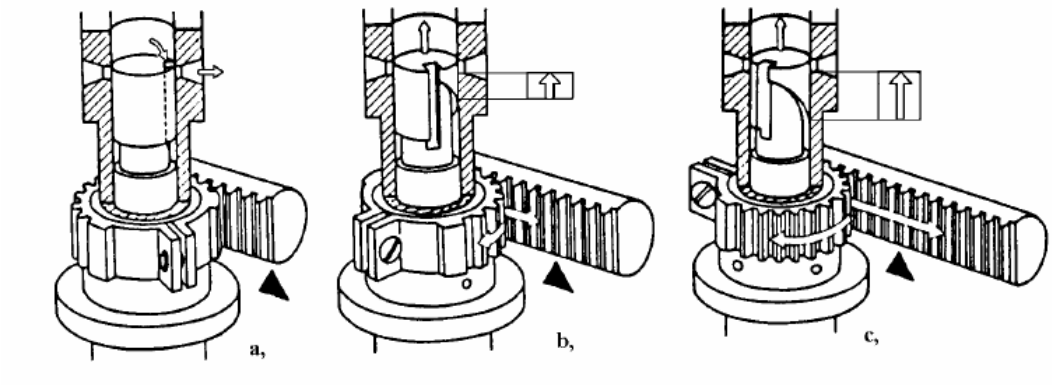
Detail of fuel-pumping element







Different type



a, stop b, part load c, full load

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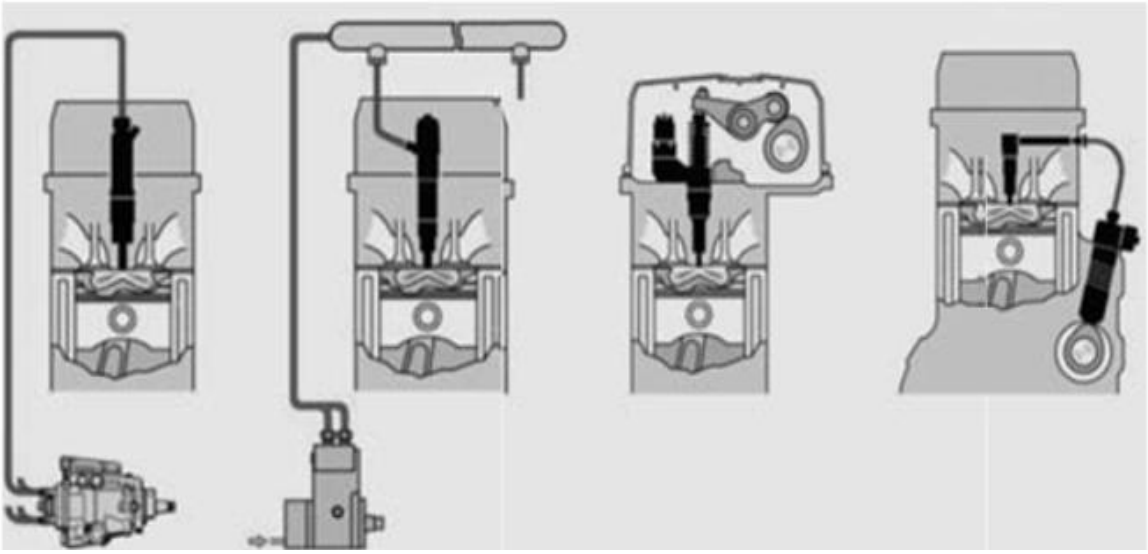
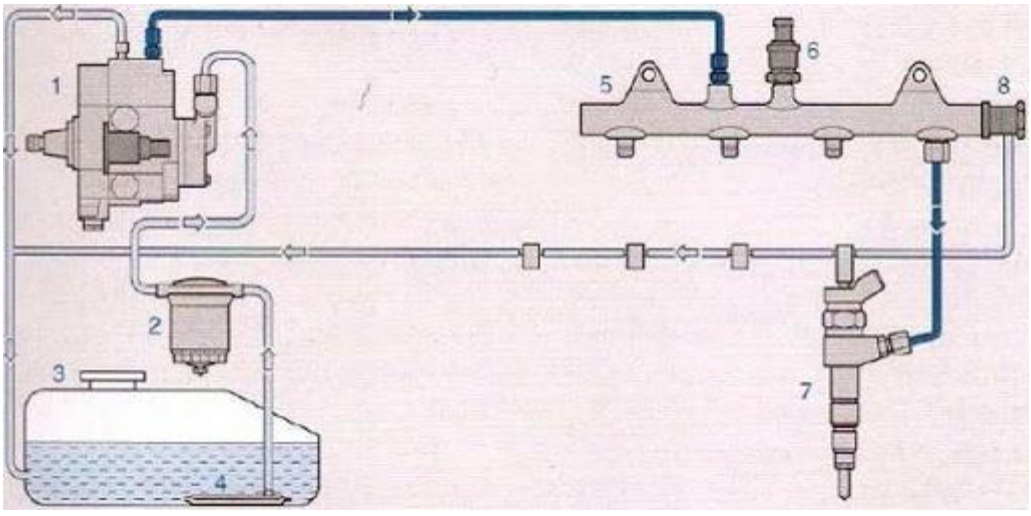
Develop Trends of direct injection systems

VP44	CRS	UIS	UPS
Rotačné vstrekovacie čerpadlo	Common-Rail	Združená vstrekovacia jednotka	Samostatné vstrekovacie čerpadlo

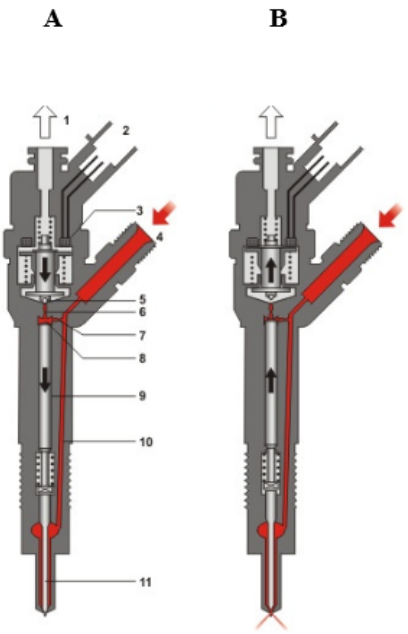


Rotary pump fuel system Common rail Unit injector system Unit Pump System

Fuel systems with control injection nozzles



Trend of control injection nozzles

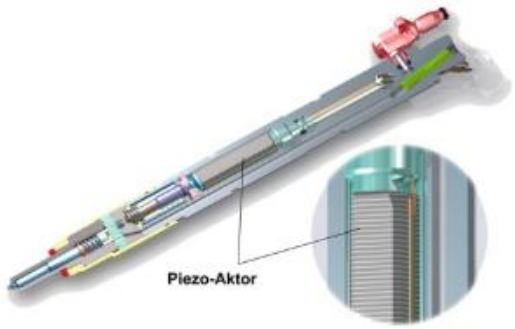


A – vstrekovač uzavretý
B – vstrekovač otvorený

Popis:

1 – spätné palivové potrubie
2 – elektrická spojka
3 – cievka elektormagnetu
4 – vysokotlaková prípojka paliva pod vysokým tlakom zo zásobníka
5 – guličkа ventilu
6 – škrtenie na prepade
7 – škrtenie na prívode
8 – riadiaca komora ventilu
9 – riadiaci piest
10 – kanál prívodu paliva do rozprašovača
11 – ihla dýz

Injection nozzles with electromagnetic coil



Injection nozzles with piezo-actuator system