Preparation of the mixture in spark ignition internal combustion engines

In order to form an inflammable mixture, it is necessary that this mixture consists of fuel and air (especially oxygen) in a ratio of 1:15.
It is known that there is 23% oxygen in the air, then we can determine the theoretical amount of air L_t to burn 1 kg of fuel as:

$$L_t = L_o/23$$

When: L_o - the amount of oxygen needed for perfect combustion
recommended stoichiometric mixture: for gasoline engines: L_t =14,7-15,0 kg_{air}/kg_{fuel}
for diesel engines: L_t =14,3-14,5 kg_{air}/kg_{fuel}
For practice, it is much more important to assess the composition of the mixture according to the coefficient of excess air λ defined as follows :

$$\lambda = M_{air}/M_{airteor}$$

M_{air}- actual amount of air
$M_{airteor}$ - theoretical amount of air
If : $\lambda = 1$ - ideal mixture - Stoichiometric mixture
$\lambda < 1$ - rich mixture (little air - excess fuel - effect of burning the mixture on the exhaust)
$\lambda > 1$ - lean mixture (lots of air - lack of fuel - effect of oxygen cutting)

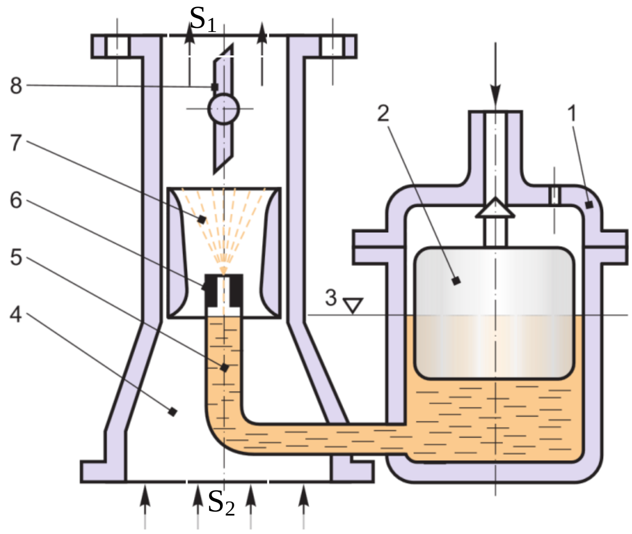
Carburetor
There are various fuel systems for an engine available. Discussed below are carburettor and injection systems.

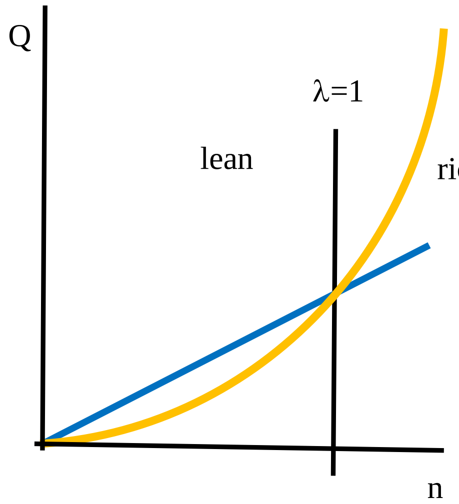
Carburettor System:
A carburettor is a relatively cheap component device used in an internal combustion engine which sprays liquid fuel, controlling its mixture with air when the engine piston moves downwards on the intake stroke, and regulates this mixture into the engine cylinders. This is done by bringing in air from the cylinder and intake manifold. This creates a vacuum and draws in air from the carburettor. In turn, this draws fuel in from the carburettor, via the intake manifold, valves and into the cylinder. A filter is used which clears the air brought into the system. The air to fuel ratio is measured by the venturi. As air flows through the venturi, its velocity and pressure decreases. This causes an adverse pressure gradient allowing fuel to be sucked into the air stream.

Liquid fuel is delivered to the carburettor via a mechanical or electrical (depending on the system) pump and is stored in a float/fuel bowl. This keeps the level of fuel stored constant via a needle valve and seat at the inlet. If the fuel drops below a determined level, the needle valve opens and allows in more fuel.

$$p_1 + \frac{1}{2}\rho . v_1^2 = p_2 + \frac{1}{2}\rho . v_2^2$$

S_1 - area of enter
S_2 - area of exit,
$S_2 > S_1$ - effect of the reducing the pressure and increasing the speed





1- float chamber
2- float
3- level of fuel
4 - air tube - air port
5- fuel tube
6- main nozzle
7 - venturi tube (diffuser)
8- throttle valve

In a single-chamber carburetor, it is possible to achieve the ideal mixture in only one speed mode. Negative impact of emissions due to imperfect combustion. Necessary change of the main nozzle depending on the altitude.

Solution:
1. Reduce emissions by using catalysts - demanding on earth resources.
2. Fuel charge control - the need to control the amount of residual air in the exhaust.
3. Combination

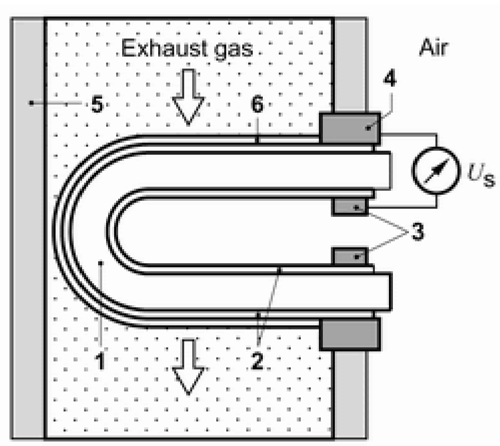
Catalysts

Basic types of catalysts
1. loose - the catalytic mass is in the form of balls, granules and the like.
2. ceramic monolithic - porous material based on Mg Al Si - belongs to the most widespread and as the active layer is used platinum, palladium, radium. The combustion of CO and hydrocarbons is accelerated.
3. metal monolithic

In terms of the resulting effect, we divide the catalysts into:
oxidizing: used if $\lambda > 1$ and the catalyst adds secondary air and reduces CO and HC to CO_2 and H_2O
reducing: ensures the conversion of NO_x to N_2 and CO_2 if $\lambda < 1$
two-way: it is a combination of oxidation and reduction catalyst and the engine works with a rich mixture $\lambda = 0.9$.
three-way: they neutralize the three main components of pollutants, namely CO, HC and NO_x. Regul probe control is required.

Lambda sensor

The lambda sensor is a device located in the exhaust pipe and is used to detect the amount of oxygen in the exhaust gases.
According to the principle, it can be:
voltage - if heated it works from 200 ° C (optimal working temperature 600 ° C)
resistive - change of resistance depends on O_2 concentration (optimal working temperature 500 ° C)



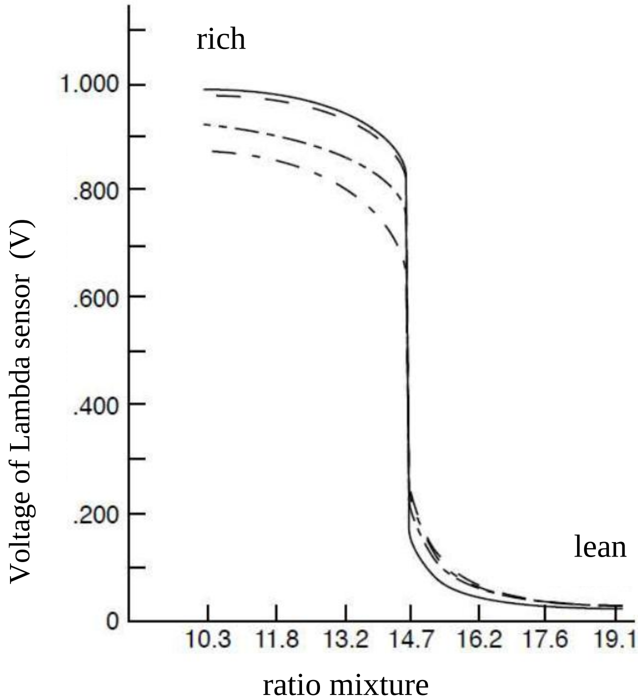
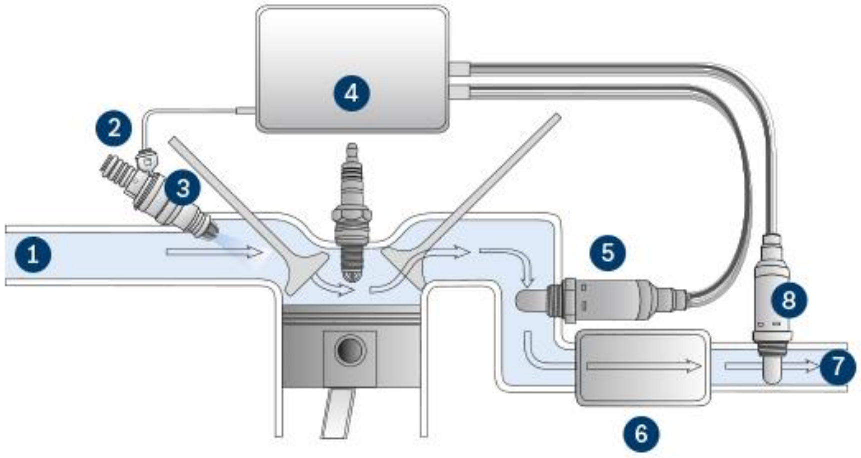


Fig. Scheme of Voltage Lambda sensor and graph of result voltage

Modern vehicles use electric control systems to monitor every parameter of a vehicle with an Engine Control Unit (ECU) at its heart. The ECU controls a plethora of actuators to ensure optimal performance. This is done by gathering data from various sensors, interpreting the data and sending data back to the actuators, adjusting them to gain the desired result; Essentially Input-process-output. One such sensor on a vehicle which is monitored closely is a lambda Sensor.

Located in exhaust systems, a lambda sensor monitors the concentration of residual oxygen present in exhaust gasses. The data received allows manufacturers to keep a close eye on vehicle emissions and, if needed, reduce them in order to meet emission regulations put in place. Collecting data on oxygen levels present in exhaust gasses, the lambda sensor provides the ECU with this information where the ECU will then determine the action required in order to keep the air:fuel ratio at an 'ideal' constant so to reduce engine emissions.

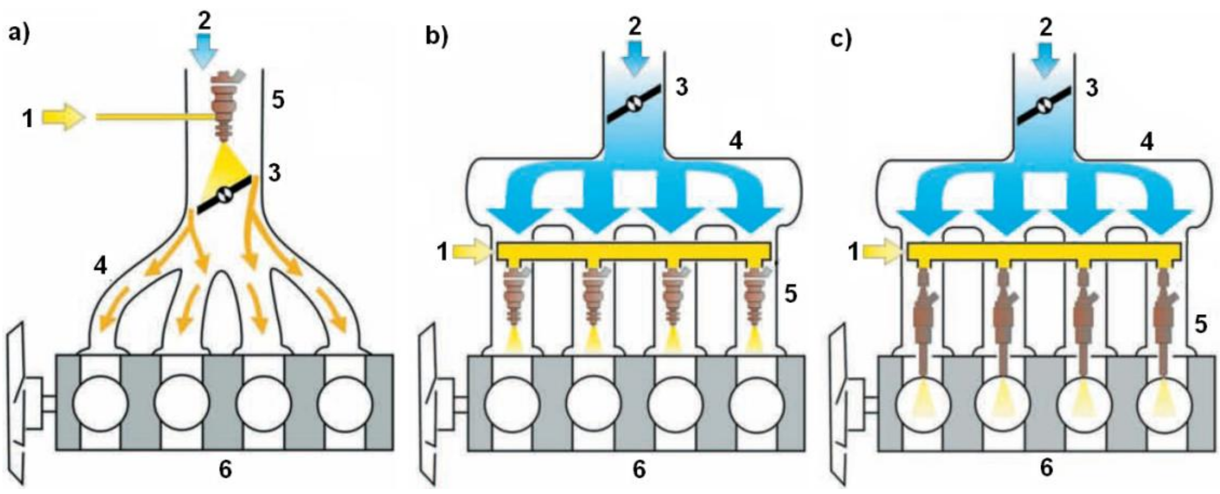
1 - air tube
2 - fuel tube
3 - fuel injector
4 - PCM (ECU)
5 - Upstream Lambda sensor (primary control sensor)
6 - Catalytic converter
7 - exhaust gas
8- Downsteam lambda sensor (diagnostic sensor)



Development of mixture preparation systems

<u> Injection Systems:</u>

In modern day technology, there are four types of fuel injection systems; Single point Inlet, Multi point inlet, Direct. These are discussed below.



a) Single Point Injection b) Multi Point Injection c) Direct Injection

<u>Single-point Inlet Injection System: </u>fuel injection pressure reaches 0.1 to 0.15 MPa (1 to 1.5 bar)

Single Point injection systems used to be common place on engines of up to 2L capacity. It now only has worth on low price solutions as modern technologies have replaced it and caused it to only be used on engines up to half the size of a 2L. The main cause of this is due to emission regulations; the fact that a single inlet system cannot differentiate between individual cylinders causes gasses to increase and therefore a large value of emissions is created.

The advantages of single point injection are:

- Only one injection nozzle/valve required
- No regulation of the systems pressure, depending on the inlet manifold pressure
- Only requires a throttle potentiometer rather than an air: volume meter
- Possesses a lower supply pressure, lower vapour development and a cheaper fuel supply pump as there is a larger distance between the components under heat-stress.

Single point injection systems used a turbine pump due to the low supply pressure. The pressure regulator does not possess a vacuum connection as the system is independent of the vacuum pressure. As the fuel injection takes place above the throttle valve, the amount injected is dependent on the systems injection time. The two most important sensors in the system are the lambda sensor and the throttle valve potentiometer. These determine the amount of fuel injected.

<u>Multi-point Inlet Injection System:</u> fuel injection pressure 0.2 to 0.3 MPa (2 to 3 bar)

Multi-Point injection systems provide far better results than single injection system. However, these systems are more complex. They involve multiple injector nozzles, one for each cylinder. As shown in the above diagram, the fuel is injected into the intake port directly before the cylinders. This is opposed to single point injection which injects the fuel into the intake manifold. There are three types of multi-point injection systems; a simultaneous injection system, sequential system and a batched sequential system.

- A simultaneous multi-injection simply injects the fuel into the system to each cylinder simultaneously.
- A sequential multi-injection system uses timed injections to match with the intake stroke of each cylinder.
- A batched sequential multi-injection system injects the fuel in ‘groups’ with no synchronising in each cylinder.

A multi-point injection system, unlike single-point, can differentiate between each cylinder (due to each cylinder having its own injection of fuel). From this, no fuel is inefficiently unburnt therefore reducing the level of emissions when compared to a single point injection system.

<u>Direct Injection System:</u> fuel injection pressure 2 to 5 MPa (20 to 50 bar)

A direct injection system introduces the directly into the combustion chamber, creating the air: fuel mix instantly. This is done by only combustion air being drawn into the system through the intake valve during the intake stroke and the liquid fuel being directly injected at a high pressure into the chamber simultaneously.
The high pressure when injecting the fuel into the system is produced via a high-pressure pump compressing the liquid fuel to level of pressure that is required in the systems fuel rail. The best possible mixture for the systems combustion chamber is determined by the injectors which meter and atomize the fuel under high pressure.

Arguably, direct injection is the best option for engine designers as the precise metering, distribution of air and injected fuel for each stroke can provide up to 5% more torque, low emission values and a reduced fuel consumption of up to 15%.