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GREEN AND SAFE ROAD TRANSPORT IN LOCAL COMMUNITIES

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Fuel Combustion

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Engine

An engine or motor is a machine designed to convert energy into useful mechanical motion

Types of Engines

- Heat engines: internal or external combustion engines - burn a fuel to create heat, which then creates motion.
- Electric motors
- Pneumatic motors
- and others.....- clocwork motors, molecular motors

History of the heat engines

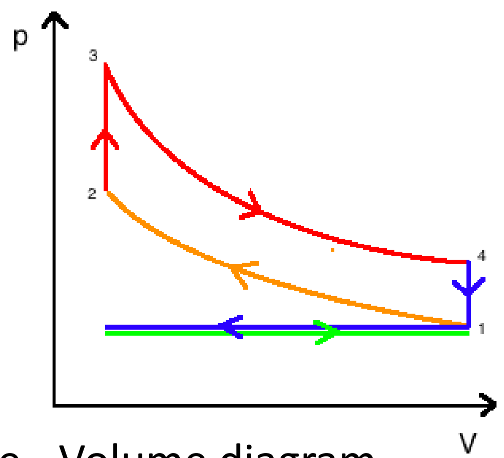
Boulton & Watt engine - 1788

The internal combustion piston engines were tested in France in 1807 by de Rivaz. They were theoretically advanced by Carnot in 1824 and Otto in 1877

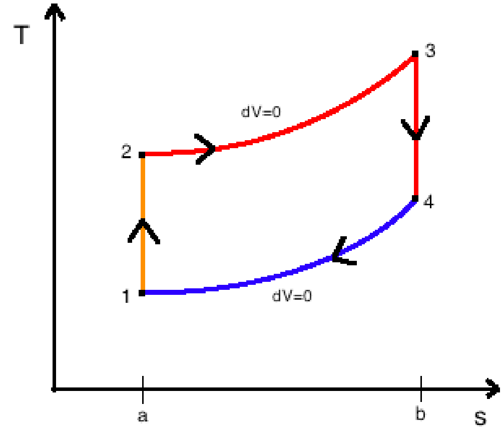
The Diesel engine was developed by German inventor Rudolf Diesel in 1893

The first commercially successful automobile, created by Karl Benz. In 1896, Karl Benz was granted a patent for his design of the first engine with horizontally opposed pistons

An **Otto cycle** is an idealized thermodynamic cycle which describes the functioning of a typical spark ignition reciprocating piston engine



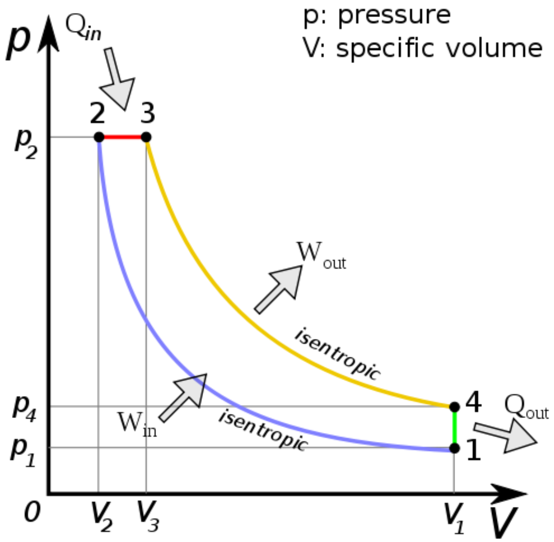
Pressure - Volume diagram



Temperature - Entropy diagram

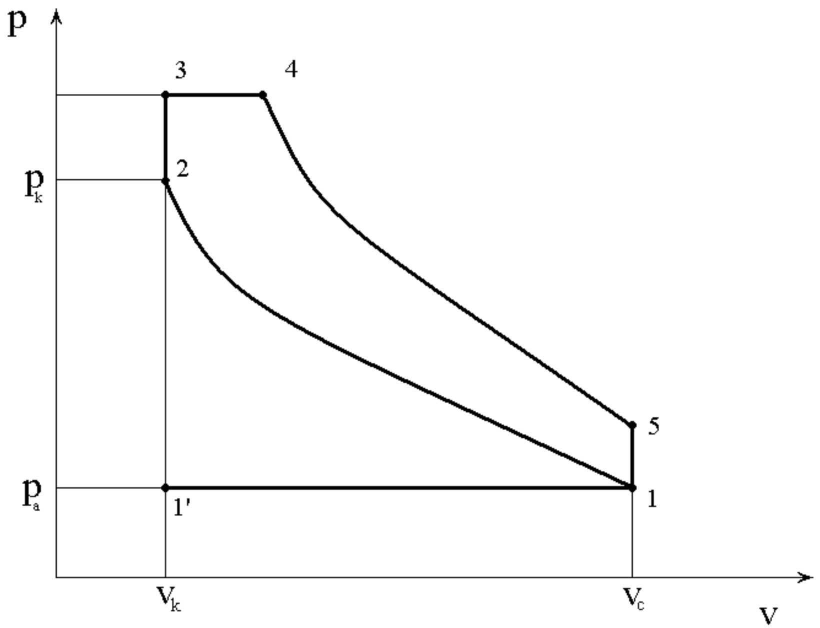
Process 1-2 is an isentropic compression of the air as the piston moves from bottom dead centre (BDC) to top dead centre (TDC).
Process 2-3 is a constant-volume heat transfer to the air from an external source while the piston is at top dead centre. This process is intended to represent the ignition of the fuel-air mixture and the subsequent rapid burning.
Process 3-4 is an isentropic expansion (power stroke).
Process 4-1 completes the cycle by a constant-volume process in which heat is rejected from the air while the piston is a bottom dead centre.

The **Diesel cycle** is an idealized thermodynamic cycle which approximates the pressure and volume of the combustion chamber of the Diesel engine, invented by Rudolph Diesel



Process 1 to 2 is isentropic compression of the fluid (blue colour)
Process 2 to 3 is reversible constant pressure heating (red)
Process 3 to 4 is isentropic expansion (yellow)
Process 4 to 1 is reversible constant volume cooling (green)

The **dual combustion cycle** (also known as the **limited pressure** or **mixed cycle**, **Trinkler cycle**, **Seiliger cycle** or **Sabathe cycle**) is a thermal cycle that is a combination of the Otto cycle and the Diesel cycle, first introduced by Russian-German engineer Gustav Trinkler. Heat is added partly at constant volume and partly at constant pressure, the advantage of which is that more time is available for the fuel to completely combust. Because of lagging characteristics of fuel this cycle is invariably used for diesel and hot spot ignition engines.



1-2 Adiabatic compression
2-3 Addition of heat at constant volume.
3-4 Addition of heat at constant pressure.
4-5 Adiabatic expansion.
5-1 Rejection of heat at constant volume.

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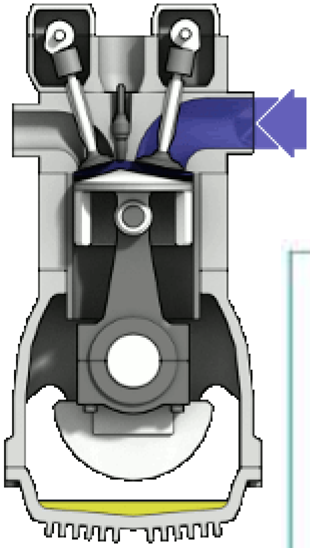
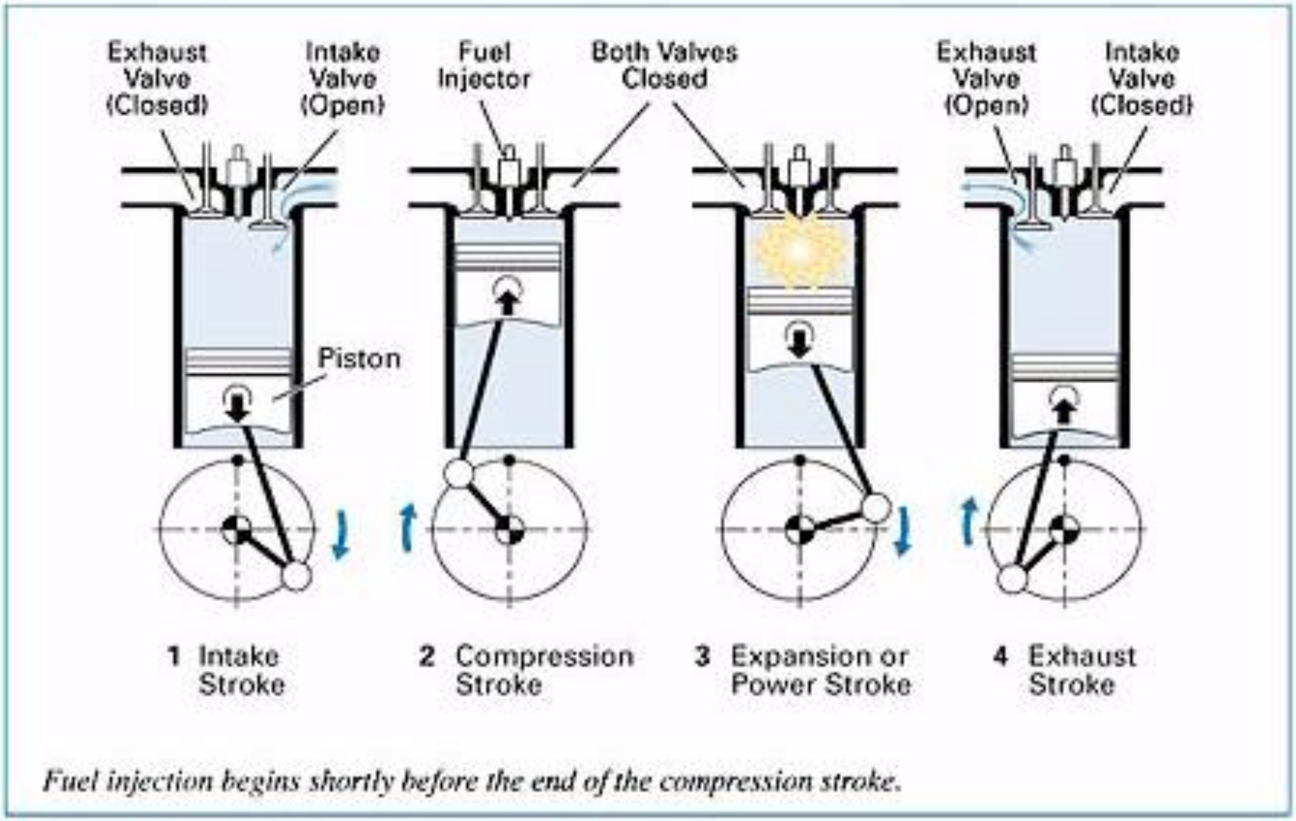


Four Stroke Engine



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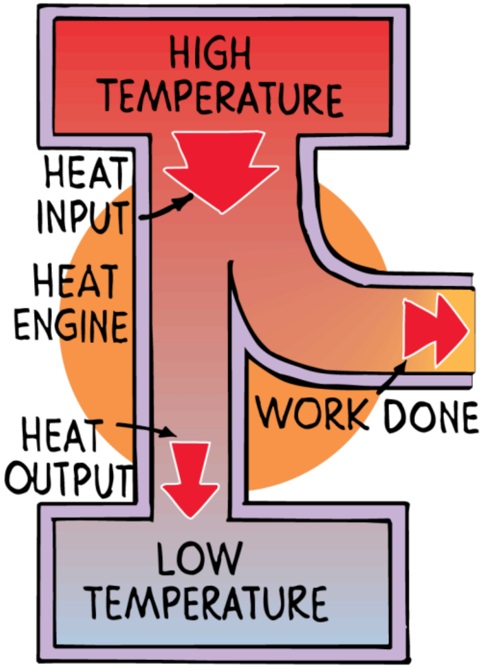
According to the second law of thermodynamics, no heat engine can convert all heat input to mechanical energy output.



When heat energy flows in any heat engine from a high-temperature place to a low-temperature place, part of this energy is transformed into work output.

The **Carnot efficiency,** or ideal efficiency, of a heat engine is the ideal maximum percentage of input energy that the engine can convert to work.

$$\text{Ideal efficiency} = \frac{T_{\text{hot}} - T_{\text{cold}}}{T_{\text{hot}}}$$

T_{hot} is the temperature of the hot reservoir.
T_{cold} is the temperature of the cold.

Important engines characteristics

1. The engine's performance over its operating range
2. The engine's fuel consumption within this operating range and the cost of the required fuel
3. The engine's noise and air pollutant emissions within this operating range
4. The initial cost of the engine and its installation
5. The reliability and durability of the engine, its maintenance requirements, and how these affect engine availability and operating costs

Theoretical combustion air requirements – L_0

$$L_o = \frac{1}{0,233} \cdot \left(\frac{8 \cdot C}{12} + 8 \cdot H - O + S\right)$$ kg/kg of fuel

The massive participation C,H, O, S in the fuel

$L_{o\ petrol}$ = 14,9 kg/kg
$L_{o\ diesel\ fuel}$ = 14,5 kg/kg

Normally in engines, fuels are burned with air. Dry air is a mixture of gases that has a representative composition by volume of 20.95 percent **oxygen**, 78.09 percent **nitrogen**, 0.93 percent **argon**, and trace amounts of **carbon dioxide**, **neon**, **helium**, **methane**, and other gases.

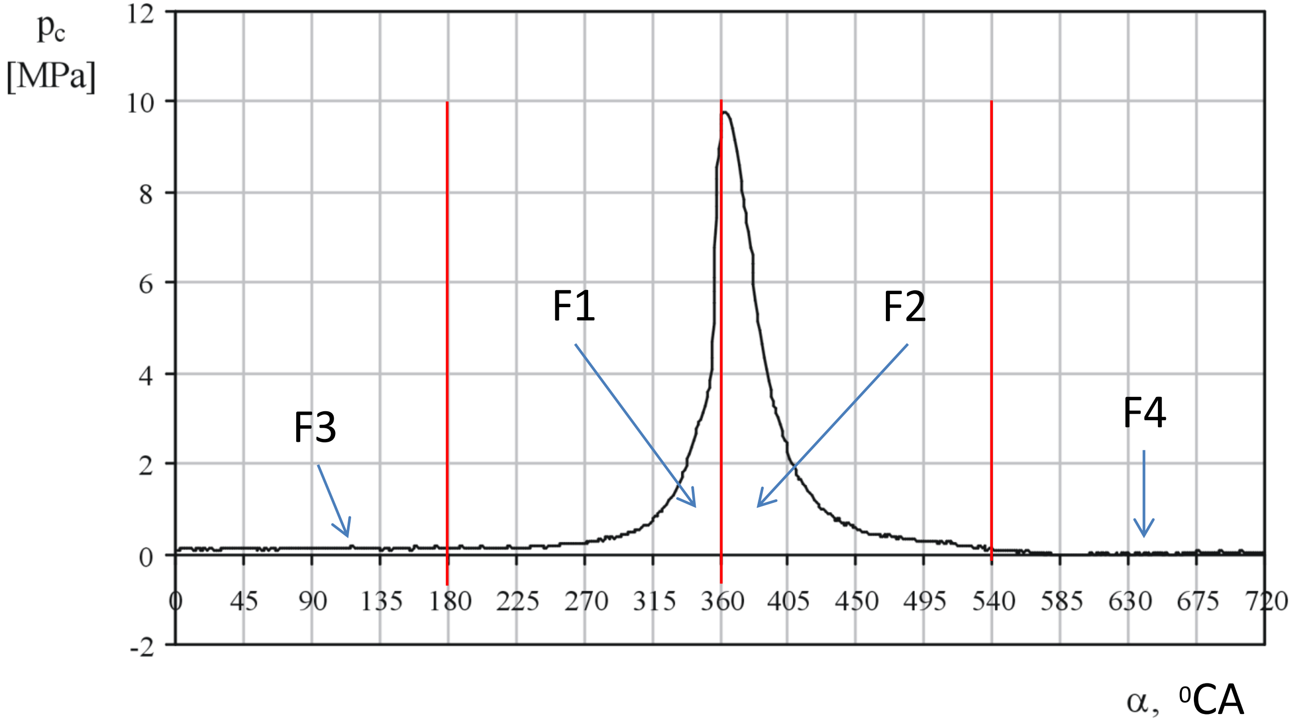
Mean Indicated Pressure - MIP

MIP is defined as a constant alternative pressure which acting on the piston during the whole expansion stroke performs the same amount of work as the real variable pressure in the cylinder. Consequently, the MIP can be expressed as:

$$MIP = \frac{L_i}{V_s}$$

where L_i is the amount work indicated in the cylinder, and V_s is the piston displacement volume of the cylinder. The work Li is estimated numerically by integration of the measured pressure.

The MIP is directly proportional to the effective power of the engine



The MIP is directly proportional to the $(F_2 - F_1) - (F_4 - F_3)$

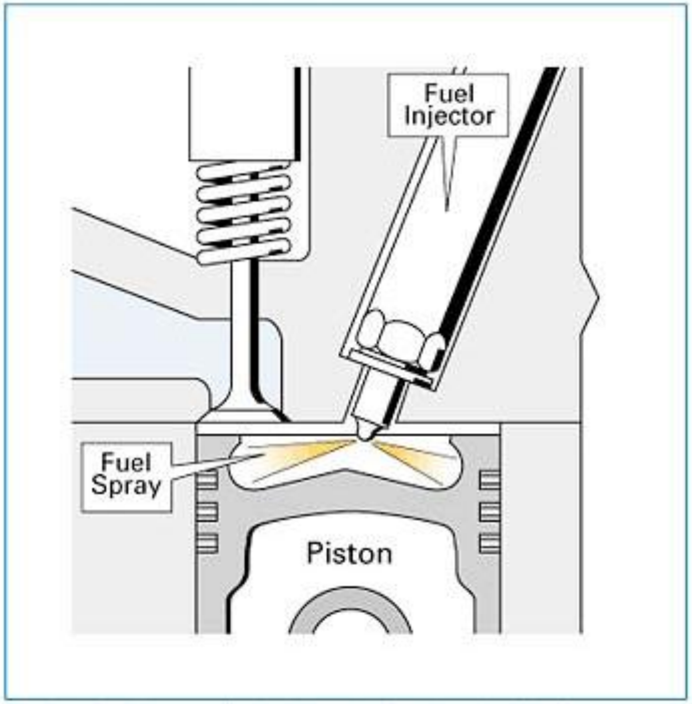
Ignition Delay

The **ignition delay** in a diesel engine was defined as the time (or crank angle) interval between the start of injection and the start the combustion.

If injection starts earlier, the initial air temperature and pressure are lower so the delay will increase. If injection starts later (closer to TC) the temperature and pressure are initially slightly higher but then decrease as the delay proceeds

If injection starts earlier the pressure growing maximum velocity increase

Direct-Injection (DI) Process



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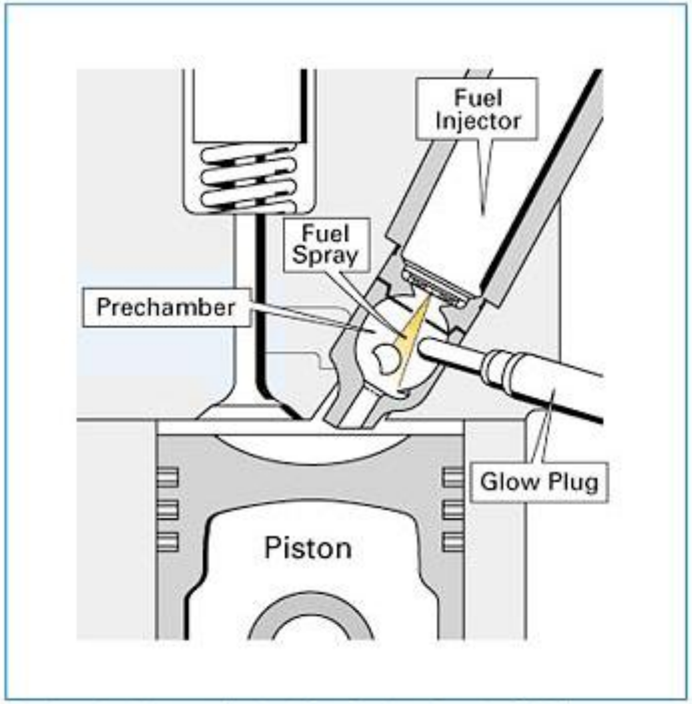
Indirect-Injection (IDI) Process



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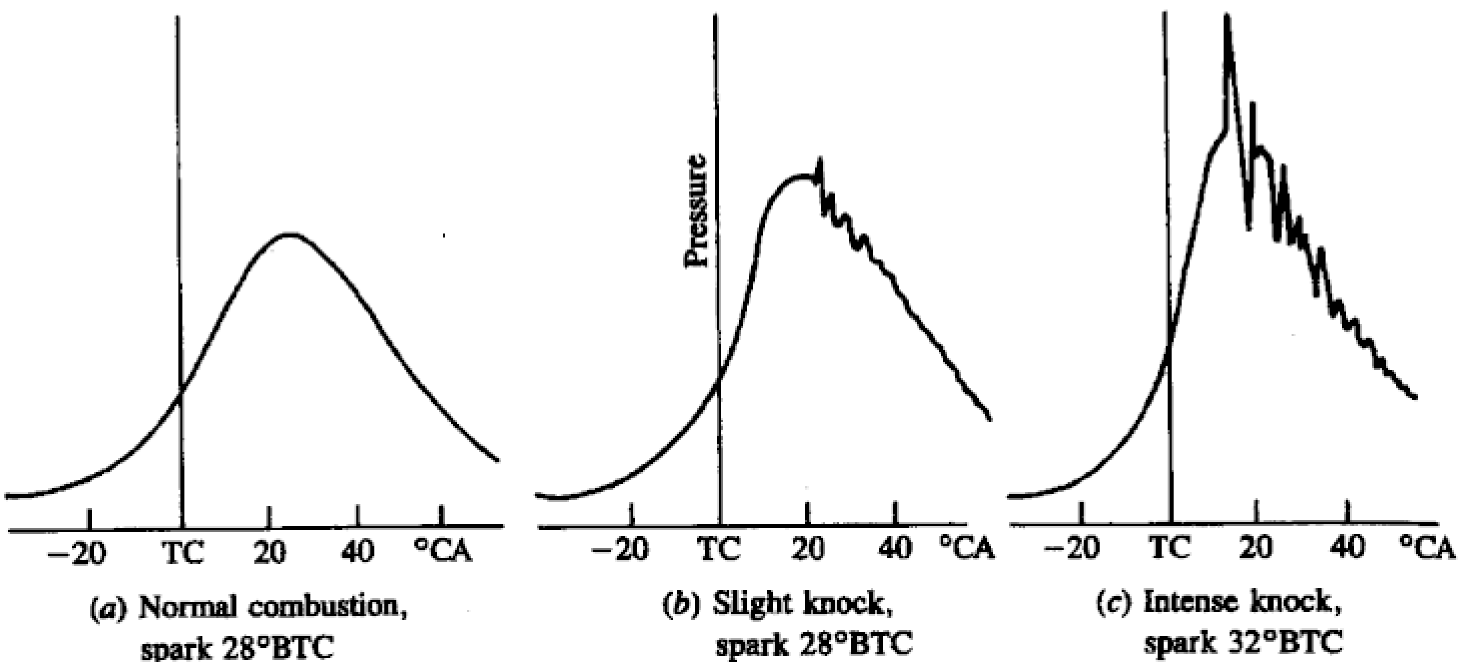
Knock is the name of the noise transmitted through the engine structure when essentially spontaneous ignition of a portion of end-gas – the fuel, air, residual gas, mixture ahead of the flame front – occurs. When knock takes place, there is an extremely rapid release of much of the chemical energy in the end-gas, causing very high local pressures and the propagation of pressure waves of substantial amplitude across the combustion chamber.



Knock Reduction

Temperature Factors in SI Knock Reduction

Increasing the temperature of the unburned mixture by any of the following factors will increase the possibility of SI engine knock:

- Raising the compression ratio
- Raising the inlet air temperature
- Raising the coolant temperature
- Raising the temperatures of the cylinder and chamber walls
- Advancing the spark timing.

★ The temperature of the exhaust valve is relatively high and therefore it should be located near the spark plug and not in the end-gas region.

Time Factors in SI Knock Reduction

Increasing the time of exposure of the unburned mixture to autoigniting conditions by any of the following factors will **increase** the possibility of SI engine knock:

- Increasing the distance the flame has to travel in order to traverse the combustion chamber
- Decreasing the turbulence of the mixture and thus decreasing the flame speed
- Decreasing engine speed: thus
  - decreasing the turbulence of the mixture
  - increasing the time available for preflame reactions

★ If the chamber width is great, the end-gas may have time to reach a self-ignition temperature and pass though the ignition delay period before the flame flame has completed its travel.

Density Factors in SI Knock Reduction

Increasing the density of unburned mixture by any of the following will **increase** the possibility of SI engine knock:

- Opening the throttle (increasing the load)
- Supercharging the engine
- Advancing the spark timing

★ Opening the throttle does not appreciably change the gas temperatures when the air-fuel ratio is constant. However, total energy release is proportional to the mass of the mixture in the cylinder, and therefore opening the throttle tends to raise wall temperatures and raise mixture & end-gas temperatures.

Composition Factors in SI Knock Reduction

The properties of the fuel and fuel-air ratio are the primary means for controlling knock, once the compression ratio and engine dimensions are selected. The possibility of knock is decreased by

- Increasing the octane rating of the fuel
- Either rich or lean mixtures
- Stratifying the mixture so that the end gas is less reactive
- Increasing the humidity of the entering air.

★ A rich/lean mixture is effective in reducing knock because of:

- the longer delay
- the lower combustion temperature

Thank you for attention