L 15) - ENGINES & VEHICLES: CURRENT STATUS OF BIOFUEL UTILIZATION

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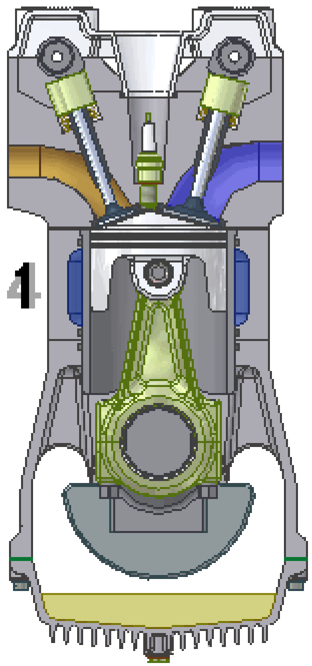
ENGINES & VEHICLES: CURRENT BIOFUEL USE

- ***BASICS OF SPARK AND COMPRESSION IGNITION ENGINES***
- ***ENGINE – BIOFUEL COMPATIBILITY***
- ***VEHICLE EVOLUTION: ENGINEERING COMPROMISES***
- ***BIOFUELS OF LIMITED COMPATIBILITY***
  - ***ETHANOL***
    - ***LOW AND MID-LEVEL BLENDS***
    - ***STRAIGHT ETHANOL AND FLEXIBLE FUEL VEHICLES***
  - ***VEGETABLE OILS AND BIODIESEL***
- ***DROP-IN BIOFUELS***
  - ***RENEWABLE DIESEL***

LAY OUT OF SPARK IGNITION (SI) ENGINE



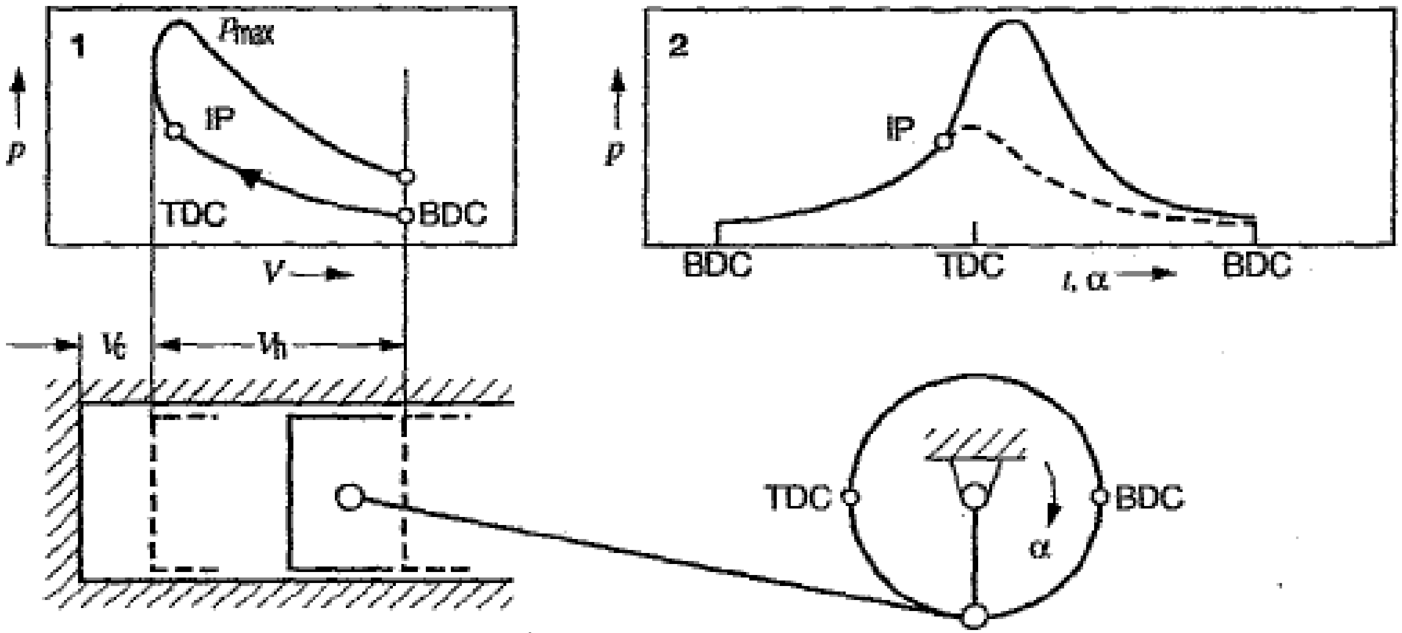
1 – ADMISSION

2 – COMPRESSION

3 – EXPANSION

4 – EXHAUST

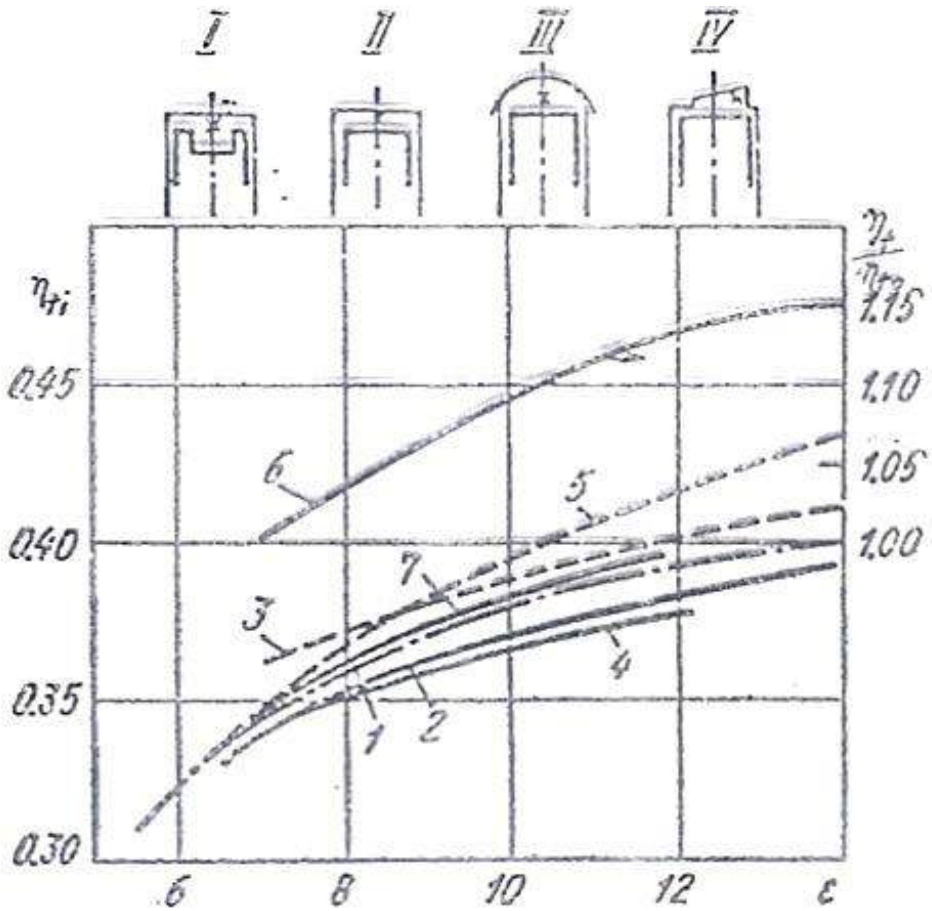
POWER GENERATION IN I.C. ENGINES



Bosch – Automotive Handbook 5th edition

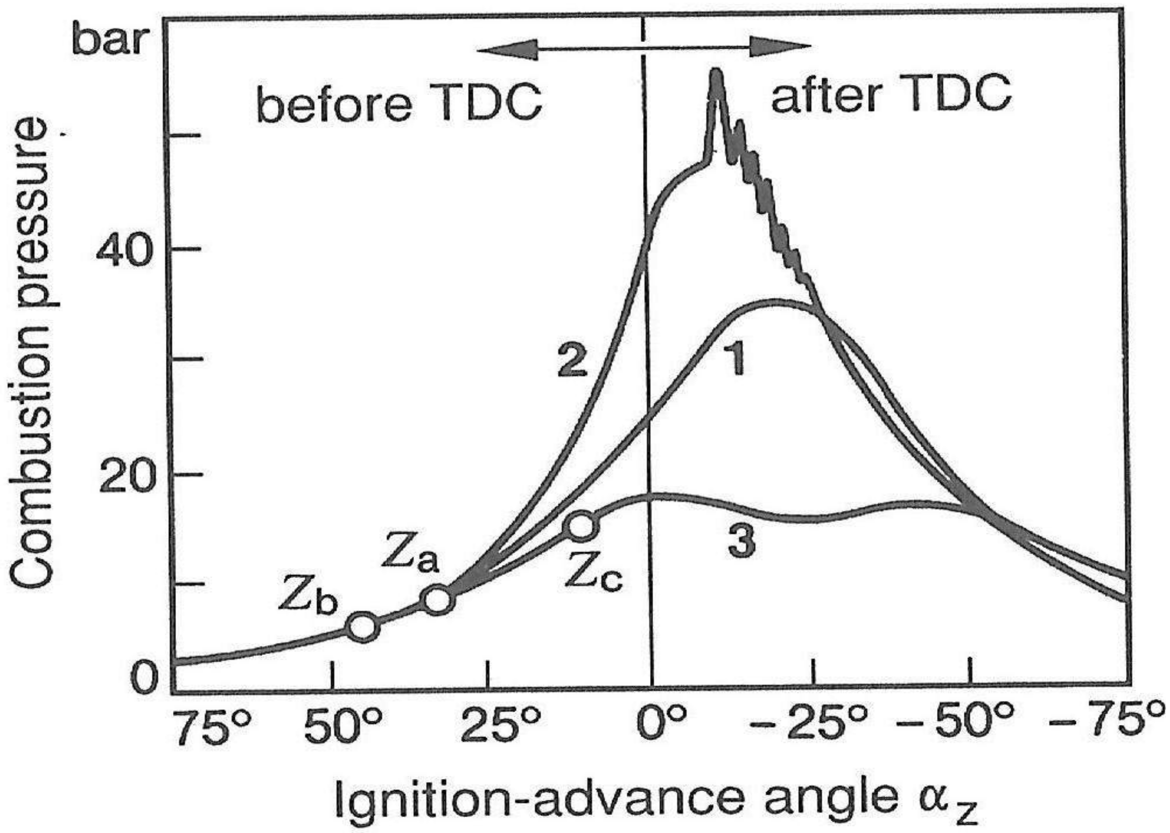
Total work produced in one cycle is limited by amount of fuel that can be burned (mass of air available)

THERMAL EFFICIENCY X COMPRESSION RATIO



Indicated thermal efficiency stands for the ratio of the work transferred by the gas in the cylinder to the piston to the net heating value of the inducted fuel. For the brake thermal efficiency one uses the work transferred by the engine flywheel to the dynamometer, taking into account the work spent to overcome friction.

COMBUSTION KNOCK IN SI ENGINES



Bosch – Automotive Handbook 5th edition

1- Correct ignition-angle (Za) & normal combustion

2- Advanced ignition-angle (Zb) & knocking combustion

3- Retarded ignition-angle (Zc) & late combustion

One seeks ignition-angle for best brake thermal efficiency (BTE) without knock

FUNDAMENTAL CHARACTERISTICS OF SI ENGINES

- **Air-fuel mixture homogenous and close to stoichiometric ratio for flame propagation (0,8< λ< 1,3);**
- **Compression of the air-fuel mixture;**
- **Load control→ throttle valve reduces the mass density of the mixture in cylinder;**
- **Combustion angular position is determined by spark timing;**
- **Combustion process is by flame propagation;**
- **Adequate fuel should have high volatility and resistance to auto-ignition to avoid "knock", under high compression ratios.**

FUEL REQUIREMENTS FOR SI ENGINES

VOLATILITY – should be high enough at low temperatures to ensure cold start of the engine, but limited to avoid evaporative emissions; maximum boiling temperature limited to avoid dilution of lubricant

"KNOCK" RESISTANCE – should be large, to permit the use of high compression ratios in order to obtain increased engine thermal efficiency (OCTANE NUMBER)

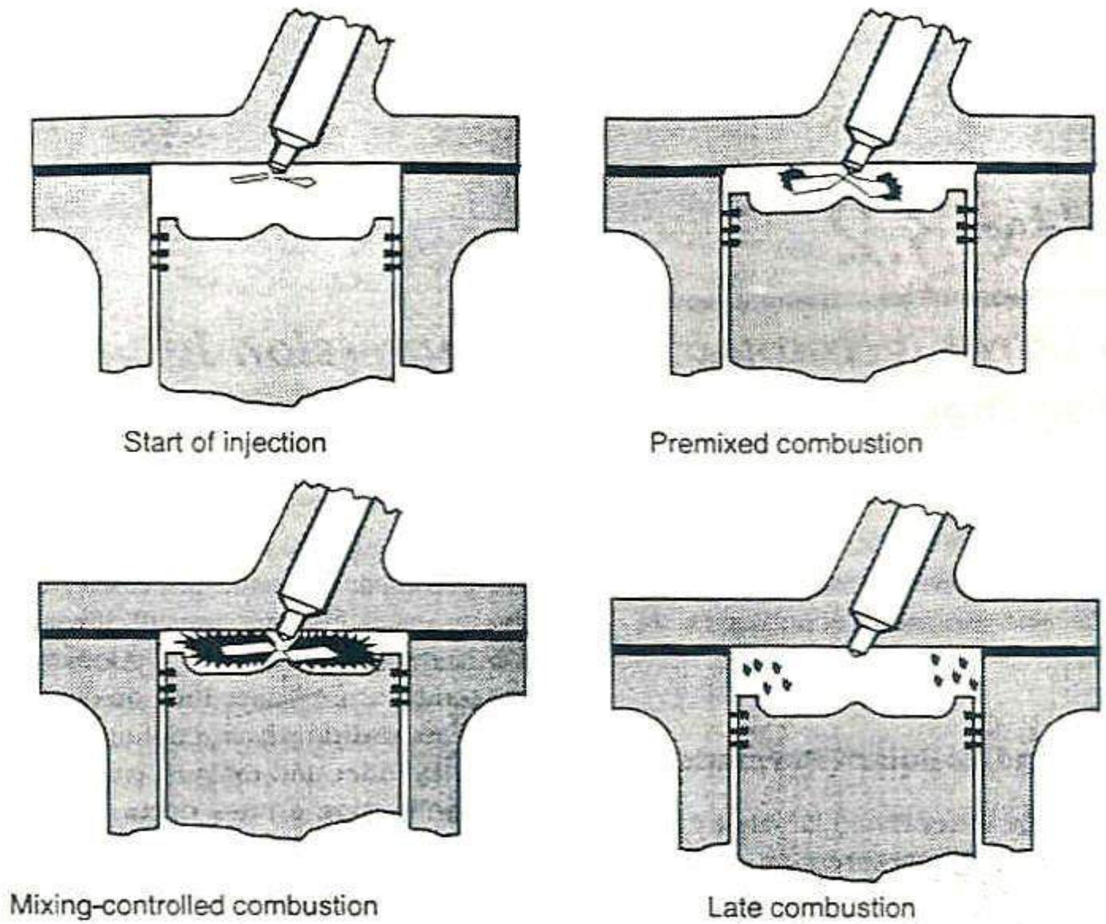
HEATING VALUE OF AIR-FUEL MIXTURE – should be large because it determines engine output (actually, for liquid fuels under stoichiometry it is almost constant – 3.5 to 3.7 MJ/m^3)

STABILITY – should not decompose to form deposits or gums

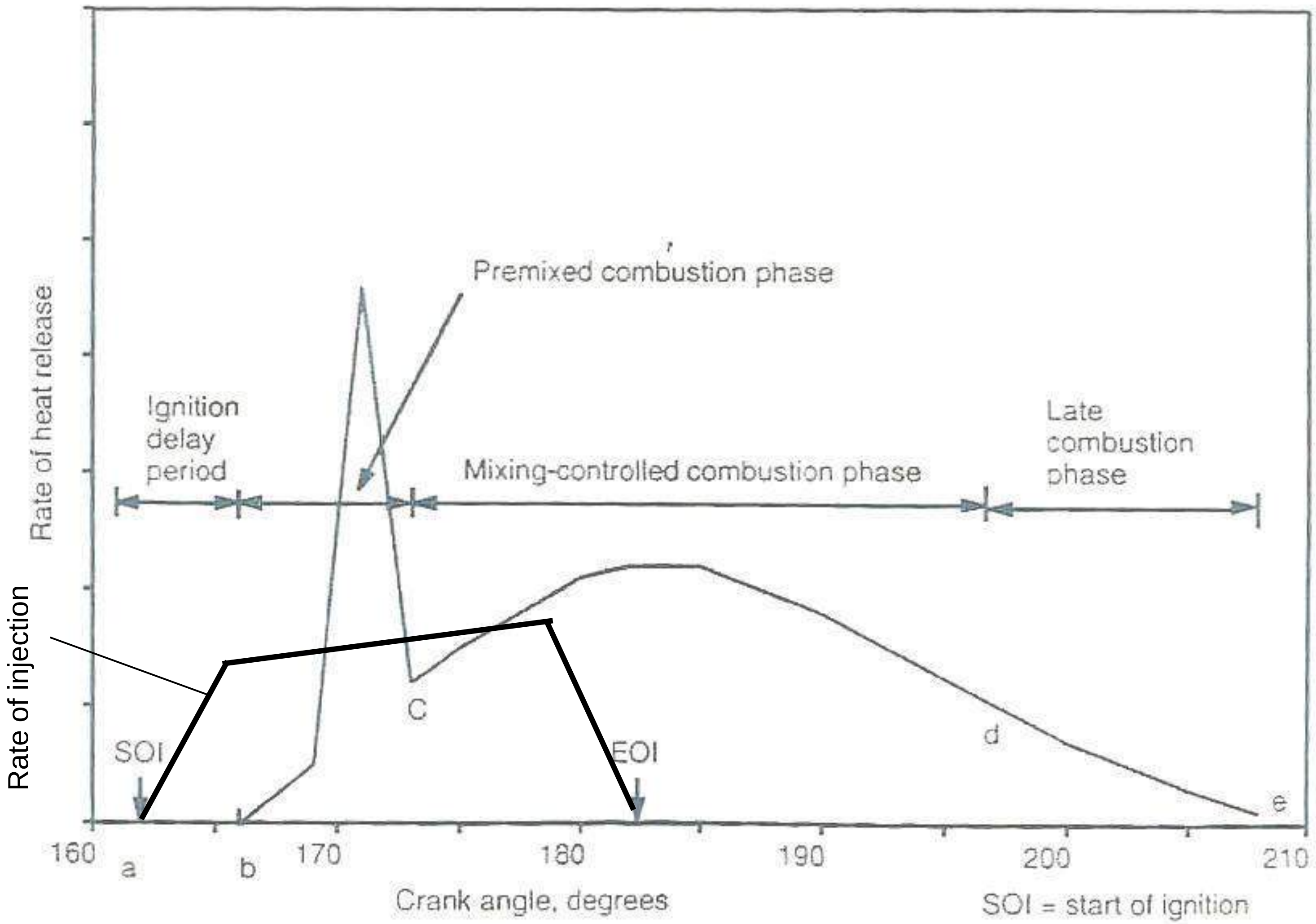
CORROSIVITY – even in the presence of moisture, should not attack fuel-system components

CHEMICAL COMPATIBILITY – should be compatible with common engineering materials

COMBUSTION PROCESS IN DIESEL ENGINES



HEAT RELEASE IN DIESEL ENGINES



FUNDAMENTAL CHARACTERISTICS OF CI ENGINES

- **Fuel is injected in compressed hot air and self-ignites;**
- **Preparation of the air-fuel mixture and its combustion are heterogeneous processes (λ>1);**
- **High pressure injection systems are very expensive;**
- **Load control by volume of injected fuel: unthrotled air flow;**
- **Combustion duration strongly dependent on turbulence**
- **High speed requires compact combustion chambers**
- **Three phase combustion process: pre-mixed, mixing-controlled and late combustion phases;**
- **Adequate fuels have to fulfill requirements of viscosity, lubricity, facility of self-ignition (CETANE NUMBER)**

PROPERTIES OF ETHANOL X GASOLINE

Property	Gasoline	Ethanol	E10	E85	E100 hydrous
Lower Heat Value LHV (MJ/kg)	42-44	27	41	29	25
Mass Density (kg/dm3)	0.72-0.77	0.79	0.75	0.78	0.81
Heat of Vaporization h_{lv} (kJ/kg)	310	885	366	836	970
$1000 \cdot h_{lv}/LHV$	7	33	9	27	39
Air/Fuel Stoichiometric Ratio	14.7	9.0	14.1	9.8	8.4
LHV/CO_2 Exhaust Emission (MJ/kg)	13.5	14.1	13.6	14.0	14.1
Cooling Potential of Intake Air (°C)	19	81	23	71	93
Laminar Flame Velocity @ 1 bar, 20°C (m/s)	0.33	0.41	-	-	-
Research Octane Number RON	86-98	110	+7- +3 [a]	105-109	111
Anti Knock Index AKI =(RON+MON)/2	87-92 [b]	100	+6- +3 [a]	97-100	101
Reid Vapor Pressure @ 37.8C (bar)	~ 0.6	0.16	~ 0.7	~ 0.4	~ 0.15

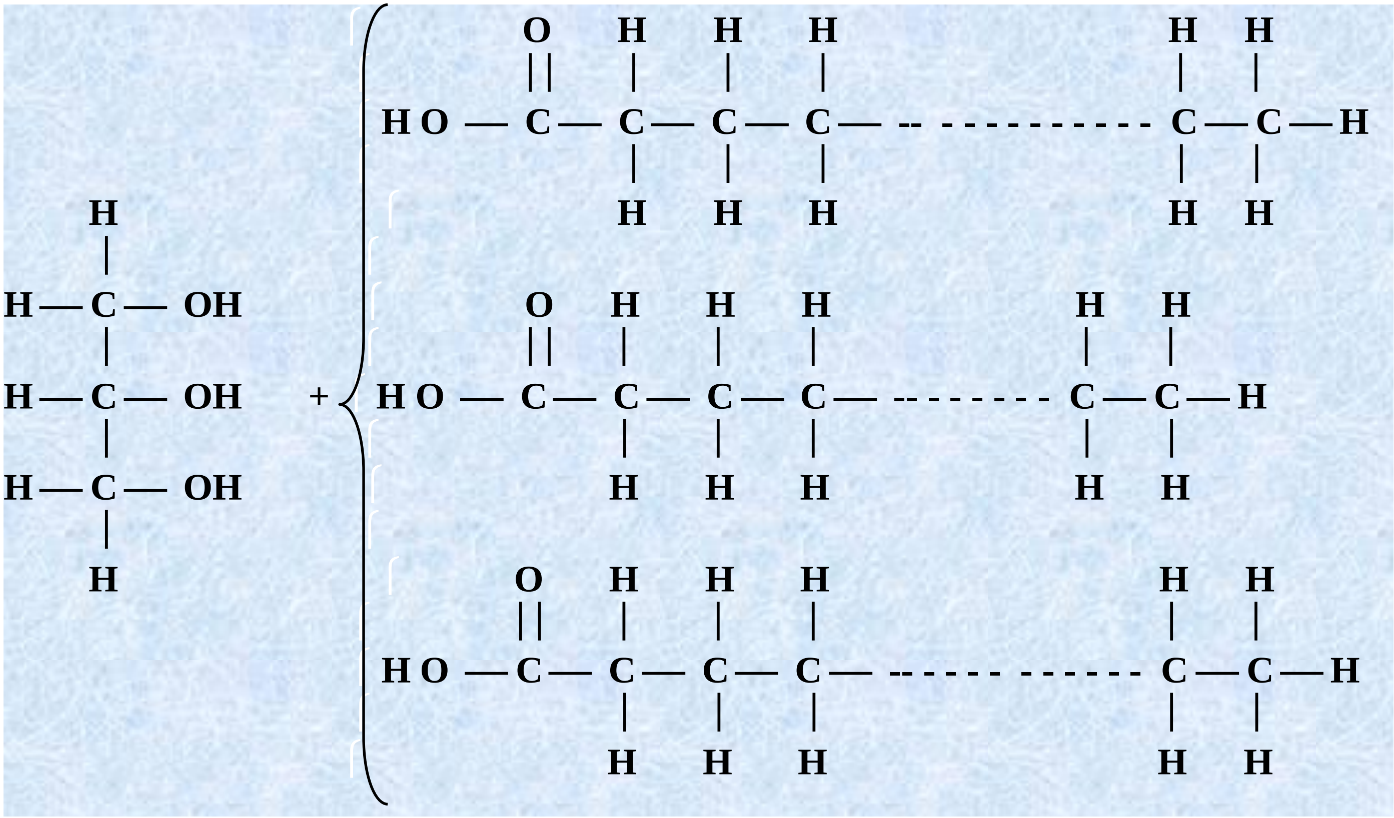
a - Incremental values of research octane number over clear gasoline for splash blending

b - Regular and Premium unleaded gasoline

Data mainly from: Kasseris E. “Knock limits in spark ignited direct injected engines using gasoline/ethanol blends” Ph.D Thesis – MIT, 2011; Larsen U., Johansen T., Schramm J. “Ethanol as a fuel for road transportation” IEA-AMF Report, May 2009; “Determination of the potential property ranges of mid-level ethanol blends” API Final Report, April 2010.

VEGETABLE OILS

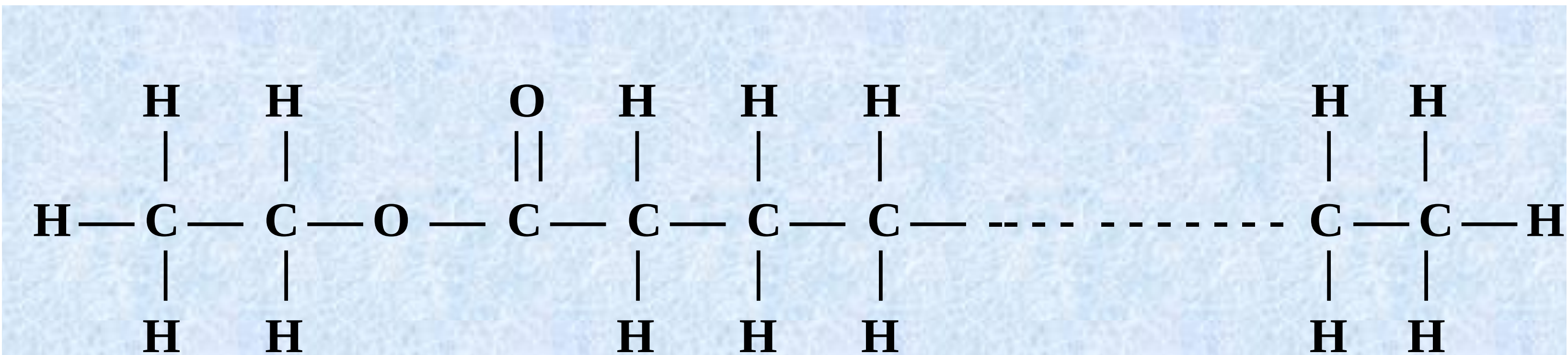
Mainly a mixture of triglycerides that are formed from combination of glycerol with linear chain fatty acids, saturated or not.



BIODIESEL

Mono-alkyl esters of fatty acids

Usually methyl-esters but, in Brazil, also ethyl-esters.

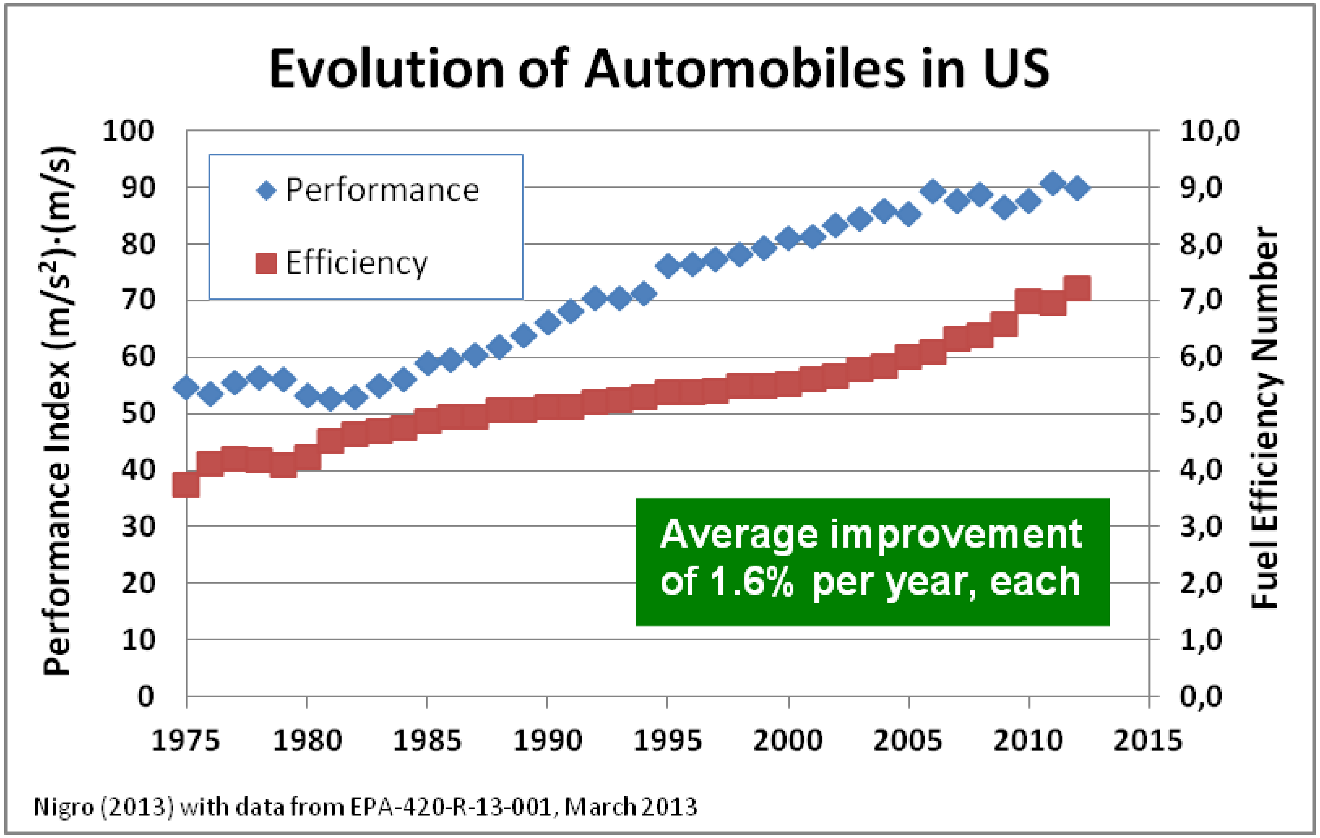


Properties

- Cetane number usually higher than diesel
- Oxigenated (~11% by weight)
- High lubricity (1% improves diesel lubricity by 65%)
- Viscosity similar to diesel

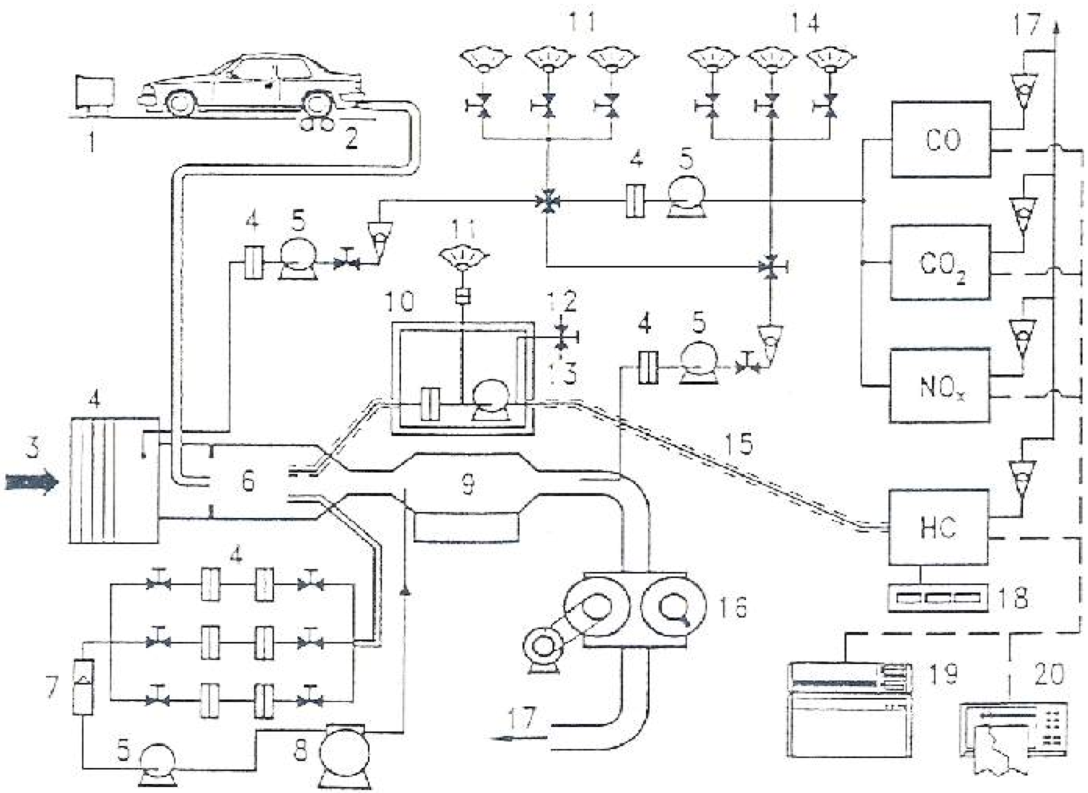
VEHICLE EVOLUTION - ENGINEERING VIEW

Compromise between Performance and Fuel Efficiency



- F.E.Number = η_{tot}/μ_{mov} ~ thermo-mechanical total efficiency/moving resistance factor (tonne · g · km/MJ) – μ_{mov} incorporates the test cycle profile (curve is for FTP combined)
- Performance Index $(m/s^2) \cdot (m/s)$ ~ capacity to accelerate at a given velocity (kW/tonne)

EXHAUST-GAS EMISSION MEASUREMENT

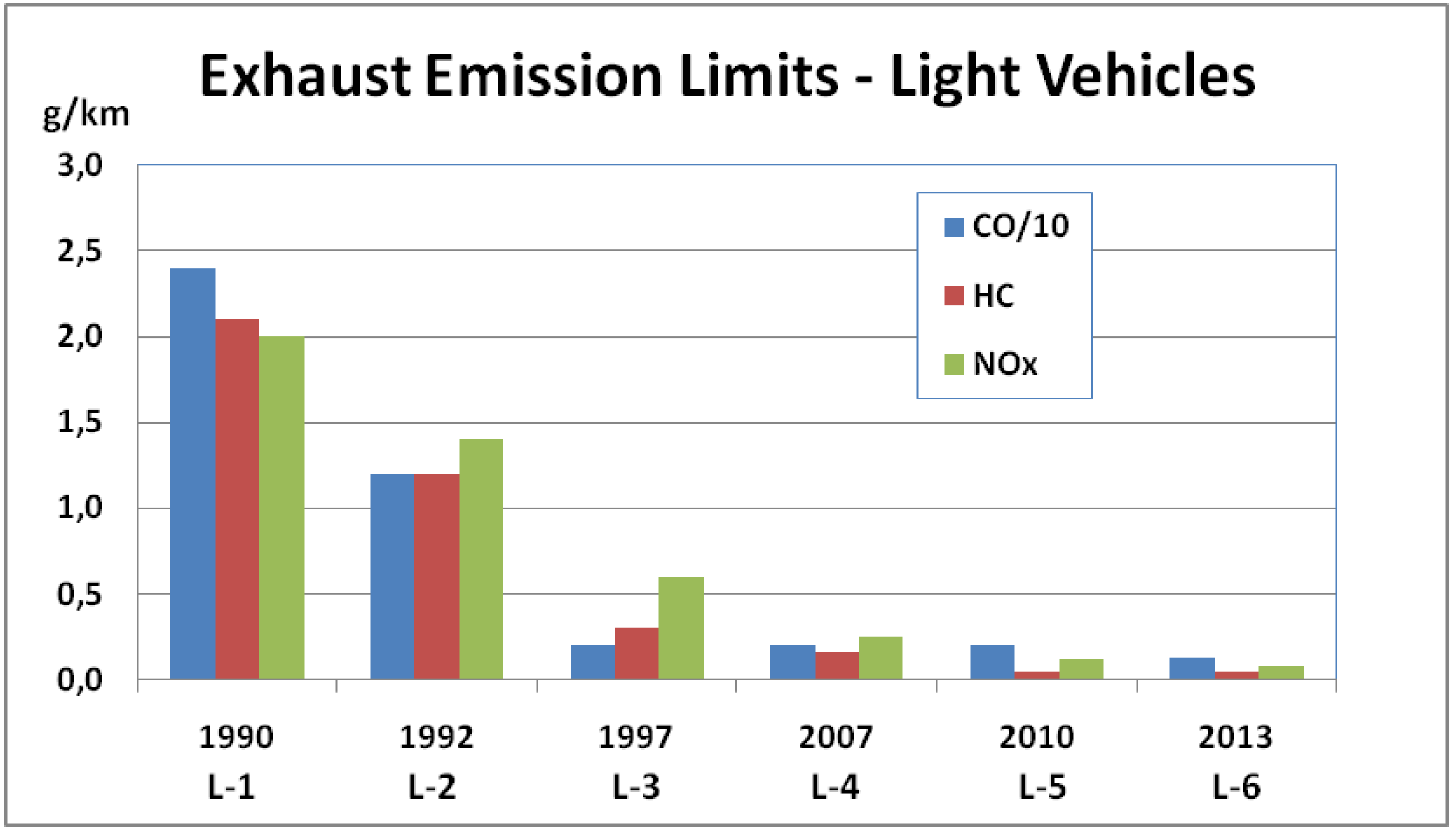


In Brazil the US FTP-75 test cycle is adopted

CVS "Continuous Volume Sampling" – Test method for passenger cars and light-duty trucks.

1- Cooling fan. 2- Chassis dynamometer 3- Air, 4- Filter, 5- Sampling pump. 6- Dilution tunnel, 7- Flow meter, 8- Gas flow-meter, 9- Heater. 10- Oven, 11- Air bags, 12- Calibration gas. 13- Zero gas. 14- sampled-gas bags, 15- Heated line, 16- Roots blower. 17- Exhaust, 18- Integrator, 19- Computer, 20- Recorder.

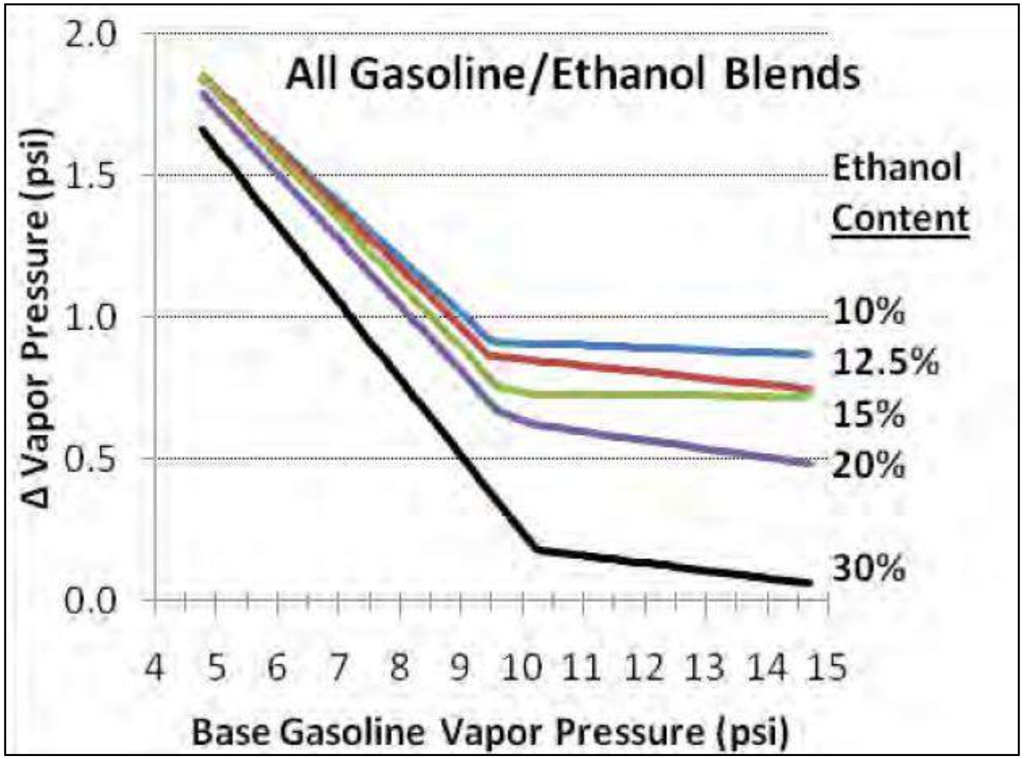
EXHAUST EMISSION LIMITS IN BRAZIL



ETHANOL: LOW AND MID-LEVEL BLENDS

- More than 50 countries have policies to use low-level blends (E5 to E10);
- In US, EPA granted waiver for E15 use in model year vehicles from 2001 and newer;
- In Brazil only gasohol (E18 to E25) is offered in gas stations and vehicles are being developed for "matched blends" since early 1980´s;
- From 83 billion liters of ethanol consumed world-wide last year, about 83% were used as low and mid-level blends;
- Most benefits are obtained if clear gasoline is prepared for the blending ("matched blend")

LOW & MID-LEVEL “SPLASH BLENDED”



Source: “Determination of the Potential Property Ranges of Mid-Level Ethanol Blends” – Final Report - American Petroleum Institute, April/2010