LIQIUD FUELS

TYPES OF LIQUID FUELS

- **fossil** (crude oil and derived fuels, oil shale, tar shale),
- **synthetic** (alcohols, product of coal liquefaction, vegetable oils).

OTHER RAW MATERIALS FOR LUQUID FUELS PROCESSING

- oil shale
- tar shale
- oil sand

CRUDE OIL AND DERIVED FUELS

GAS and OIL FIELDS in POLAND

DEPOSITS OF NATURAL GAS

DEPOSITS OF CRUDE OIL

DEPOSITS OF OIL & GAS

BORDERS OF GEOLOGICAL UNITS

NON-PROSPECT REGIONS

REACH OF ROTLIEGEND

CONGLOMERATE

SANDSTONE

MUDSTONE AND SHALE WITH SANDSTONE INSERT

ORIGINS OF CRUDE OIL

- Crude oil is the only natural liquid fuel.
- The origins of oil are organic, probably.
- More than half of oil belongs to the Tertiary formation (1-60 mln year b.n.e.)

The beginnings of crude oil exploitation are connected with Łukasiewicz (1853), who invented the oil lamp.

OIL COMPOUNDS

Oil is the mixture of more than 3000 of hydrocarbons (C_mH_n)

COMPOSITION OF CRUDE OIL

- fractional (contents of fractions different with respect to boiling temperature),
- chemical (contents hydrocarbon groups),
- elementary (contents of particular elements).

FRACTIONS OF CRUDE OIL

Fractions of oil from distillation:

- light petrol: 313-433 K,
- heavy petrol: 433-473 K,
- kerosene: 473-590 K,
- Diesel oil: 590-633 K,
- light residual oil: 633-813 K,
- heavy residual oil: above 813 K.

TYPES OF HYDROCARBONS

- Paraffins: saturated hydrocarbons (C_nH_{2n+2}) present in all fractions of oil (methane CH_4, ethane C_2H_6, propane, C_3H_8).
- Naphthenes are cyclic saturated hydrocarbons (C_nH_{2n}) present in heavy crude oils (cyclopropane C_3H_6, cyclopentane C_5H_{10}) .
- Aromatics are ring compounds containing one or more six-membered rings (C_6H_6 – benzene).
- Olefins unsaturated hydrocarbons (C_nH_{2n}) – they do not exist normally in crude oil, but are produced during oil processing in refinery ethylene C_2H_4, propylene C_3H_6).
- Heterogenic compounds of:
  - sulfur (hydrogen sulfide, mercaptans, tiophenes),
  - nitrogen (piridine, amines)
  - oxygen (acids, esters, phenoles)
  - alcohols, ketones.

BASIC ELEMENTS IN CRUDE OIL

- Pure hydrocarbons are compounds of two elements only, carbon C and hydrogen H.
- In crude oil there are other three basic elements.

Element	Content, % wt.	Element	Content, % wt.
Carbon **Hydrogen** **Sulfur**	83–87 12–14 0.01–8	**Nitrogen** **Oxygen**	0.01–1.2 0.05–4

Other elements present in crude oil, like: vanadium, iron, manganese, cobalt, phosphor and microelements are in concentration of order of 10^{-3}–10^{-5}%.

CLASSIFICATION OF CRUDE OIL

There is no single method of oil classification

The primary simple systems of oil classification used the easily to measure parameters:

- density,
- sulfur content,
- content of resins and asphalts groups,
- content of paraffines

CLASSIFICATION OF CRUDE OIL REGARDING SULFUR CONTENT

a) low-sulfur oil: S < 0.5%

b) sulfur oil: S = 0.5–2%

c) high-sulfur oil: S > 2%

CLASSIFICATION OF CRUDE OIL REGARDING DENSITY

a) light oil: $\rho < 0.87$ kg/m^3

b) medium oil: $\rho = 0.87$–0.91 kg/m^3

c) heavy oil: $\rho > 0.91$ kg/m^3

CLASSIFICATION OF CRUDE OIL REGARDING PARAFFINES

a) low-paraffin oil: paraffin< 5%

b) paraffine oil: paraffin 5-10%

c) high-paraffin oil: paraffin >10%

SACHANEN CLASSIFICATION OF CRUDE OIL

Type of oil	Composition
Paraffine	Paraffins > 75%
Naphthene	Naphthene > 70%
Aromatic	Aromatics > 50%
Asphalt	Resins and asphaltes > 60%
Paraffine -naphthene	Paraffines = 60-70%, naphthenes > 20%
Paraffine-naphthene-aromatic	Paraffins, naphthenes and aromatics approx. equal content
Naphthene-Aromatic	Naphthenes or aromatics > 35%
Naphthene-aromatic-asphalt	Naphthenes, aromatics or asphalts > 25%
Aromatic-asphalt	Aromatics or resins > 35%

PETROLEUM PRODUCTS

- LPG (liquid petroleum gas),
- engine fuels (petrol, Diesel oil),
- gas turbine fuels (wide-cut gasoline, kerosene, Diesel oil)
- heavy oils,
- solid petroleum hydrocarbons (paraffin, ceresine, vaseline),
- road and industrial asphalts,
- raw materials (hydrocarbons) for chemical synthesis.

PETROLEUM PROCESSING

Distillation

Catalytic cracking

Catalytic reforming

Hydrogenation

Pyrolysis

Hydroreforming

PETROLEUM DERIVED FUELS

Name		LCV kJ/kg	Application
Gasoline	Aircraft gasoline	42 900–46 500	Aircraft piston engines with spark inition
	Car gasoline	42 900–46 500	Car piston engines with spark inition
	Tractor gasoline	43 500–45 250	Tractor piston engines with spark ignition
Kerosene	Aircraft kerosene	42 400–45 700	Aircraft gas turbines
Oil	Diesel oil	41 800–42 750	Diesel engines, gas turbines
	Heating oil	39 400–39 800	Boilers, burners

HEATING FUEL- OILS

Heavy oils are residue products of crude oil distillation, their mixture with crude oil or oil fractions of distillation.

According to Polish Standard PN-C-96024:2001 there are two types of heating fuel-oils:

- **light oils** (L1, L2),
- **heavy oils** (C1, C2, C3).

LIGHT OILS: L-1, L2

Parameter	Requrements	
	L-1	L-2
Density at °C, max, kg/m^3	860	890
Temperature of ignition, min, °C	56	
Viscosity (kin.) at 20 °C, max, cSt	6.0	8.0
Temperature of flow, max., °C	– 20	
Content of sulfur, max. (m/m) %	0.20	0.3
Content of water, max., mg/kg	200	500
Content of wastes, max., mg/kg	24	
Ash, max., (m/m) %	0.01	
Color	-	red
LCV, min., MJ/kg	42.6	41.5

HEAVY OILS: C-1, C-2, C-3

Parameter	Value		
	C-1	C-2	C-3
Viscosity (kinematic) at 50 °C max., cSt (mm^2/s) at 100 °C max., cSt (mm^2/s)	 90 –	 180 –	 – 55
Ash, max, %	0.1	0.15	0.20
Sulfur, max, %	0.5÷2.0	0.5÷2.5	0.5÷3.0
Water, max, (V/V) %	1,0	1,0	1,0
Vanadium, max, mg/kg	100	150	
Temperature of ignition, min, °C	62		
LCV, min, MJ/kg	41.3	39. 9	39.7

HEAVY OIL C-3

Heavy oil C-3 is the residue after the distillation process of crude oil.

There are two types of heavy oil C-3

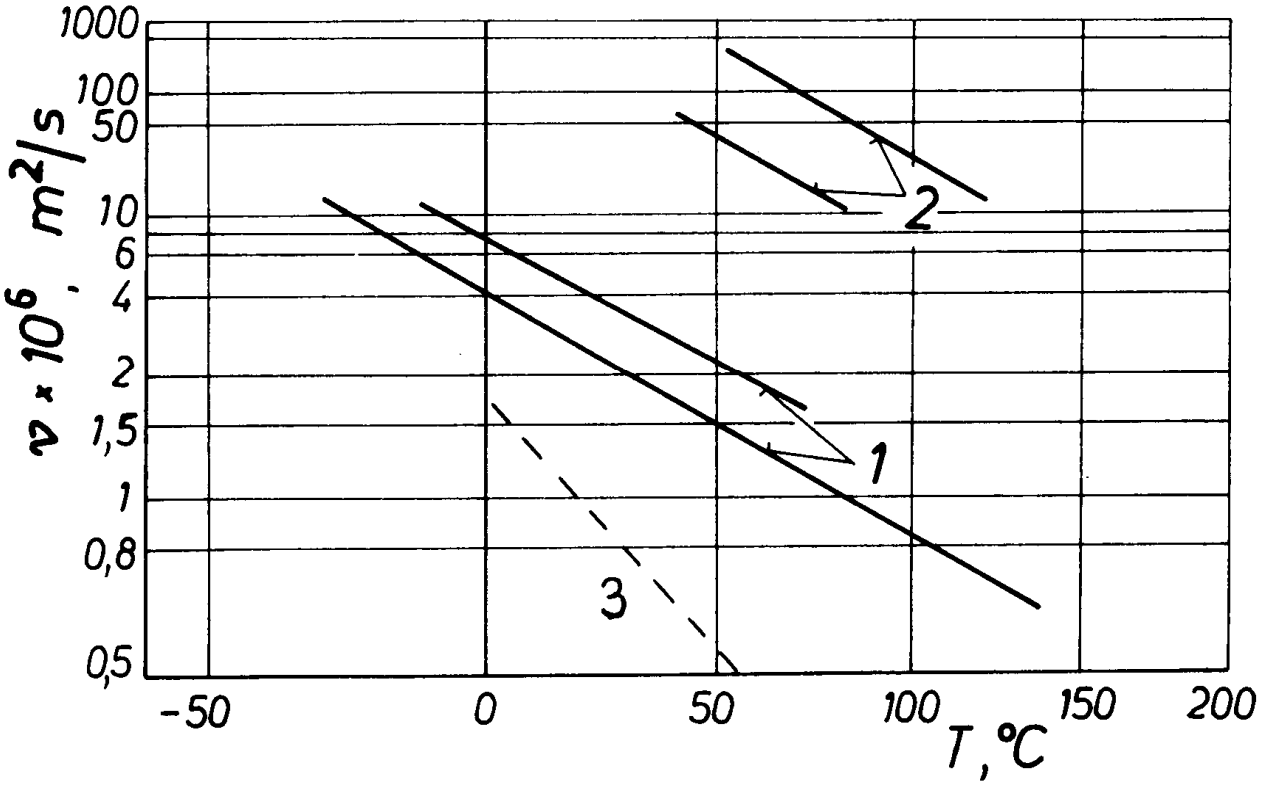
- Mazut: residue after atmospheric distillation of crude oil.
- Gudron: residue after vacuum distillation of crude oil.

The heavy heating oil (C-3) has high viscosity, which cause that for transportation and atomisation; it requires **heating** up to the temperature of **65-90 °C.**

DISADVANTAGES OF MAZUT

1. High viscosity: which requires heating of mazut to the temperature of 65- 90 °C for transportation.
2. High density: storage of mazut requires heating it up to 55 °C
3. High content of sulfur: high emission of SO_2
4. High content of solid pollutants: requires the use of filters.

VISCOSITY OF HEAVY OIL no. 3



Viscosity of : 1 – Diesel oil, 2 – heavy oil, 3 – water *versus* temperature

VISCOSITY UNITS

Basic:

$$m^2/s$$

Auxiliary units:

$$cSt = mm^2/s$$

$$1\ cSt = 10^{-6}\ m^2/s$$

EXAMPLE OF MAZOUT PARAMETERS AS A FUEL FOR POWER PLANT

- **LCV: 39380 kJ/kg,**
- **temperature of ignition: 438 K (165 °C),**
- **freezing point: 303 K (30 °C),**
- **viscosity at temperature of 353 K: (30 °C): 110 cSt,**
- **max. temperature of heating: 363-398 K (90-125 °C),**
- **sulfur content < 3%,**
- **ash content < 0.3%,**
- **water content < 1.5%,**
- **solid bodies content < 0.5%.**

OP 650

LIGHT HEATING OIL (EL)

Requirements (Parameters)	Values
LHV, ≥	42.0 MJ/kg
Density at temperature of 15 °C, ≤	0.860 kg/l
Temperature of ignition, ≥	55 °C
Kinetic viscosity at temperature of 20 °C, ≤	6.0 cSt
Freezing point, ≤	–6 °C
Water, % wt., ≤	0.05
Ash, % wt., ≤	0.01
Sulfur, % wt., ≤	0.20
Char (Conradson), % wt., ≤	0.1
Other compounds, % wt., ≤	0.05

DERIVED FUELS

TAR DERIVED OILS

Heating oils are produced with:

- **raw coke tar,**
- **gas tar, generator tar**
- **pyrolysis tar.**

Coke tar is produced in the process of coal coking in coke batteries at the temperature of 1000 °C. Tar removed from coke gas during its cleaning.

Heating oil is obtained from the fraction of distillation of tar. Its components mostly are aromatic hydrocarbons.

PROPERTIES OF TAR DERIVED OILS

Requirements	Sort	
	I	II
Density, kg/m^3	0.96–1.09	0.96–1.12
Water (%), ≤	1	1
Ash (%), ≤	0.05	0.5
Temperature of ignition (Markusson) (°C), ≥	70	65
LCV, (kJ/kg), ≥	35 600 (ca. 8500 kcal/kg)	33 500 (ca. 8000 kcal/kg)

ALCOHOLS

» methyl alcohol

» ethyl alcohol

APPLICATIONS OF ALCOHOLS

Methyl and ethyl alcohols can be used as motor fuels replacing hydrocarbon liquid fuels in:

- spark ignition piston engines (2 – and - 4 stroke)
- Diesel engines (methanol)

PRODUCTION OF ALCOHOLS

Methods of alcohols manufacturing:

Methanol: is produced by Fisher-Tropsch chemical synthesis from synthetic gas received from natural gas and from gases obtained via gasification of coal, wood and wastes.

Ethanol: is produced from biomass by its alcohol fermentation and distillation.

SOME PROPERTIES OF ALCOHOLS AS A FUEL

Parameter	Methanol	Ethanol
Chemical formula	CH_3OH	C_2H_5OH
LCV, kJ/kg	19 000	27 000
Air, kg/kg	6.45	9.01
Viscosity at temp. of 293 K, cSt	0.75	1.51
ON (octane number)	96	94

VEGETABLE OILS

TYPES OF VEGETABLE OILS

- Rapeseed
- Sunflower
- Palm
- Soya

Esters fat acids

COMPARISON OF RAPESEED OIL AND METHYL ESTER PROPERTIES

Properties	Type of oil		
	ONM	Rapeseed oil	ROKMET
Density at temp. of 20 °C, g/cm^3	0.817	0.914	0.882
Viscosity at temp. of 40 °C, mm^2/s	1.83	34.56	4.61
Cetane number (LC)	51.7	49	52
Temperature of ignition, °C	67	200	130
LCV, MJ/kg	≈ 42	37.7	36.7

BASIC PARAMETERS OF LIQUID FUELS

1. Composition
2. HCV (Q_s) and LCV (Q_i) (MJ/kg)
3. Density ρ (kg/m^3)
4. Viscosity ν (m^2/s)
5. Temperature of ignition (K)
6. Freezing point (K)
7. Heat of vaporization (J/kg)
8. Ash
9. Sulfur
10. Octane number (ON)
11. Cetane number (CN)

CETANE NUMBER (CN)

Cetane number CN is the measure of ability of Diesel fuel to selfignition.

CN of a particular fuel blend is determined under specific operating conditions in a CFR single cylinder engine at variable CR.

CFR – Co-operative Fuel Research
CR – Compression Ratio

The reference fuel: mixture of n-cetane, $C_{16}H_{34,}$ and α-methyl-naphtalene

n-cetane has CN = 100
α-methyl-naphtalene has CN = 0

CN = content of cetane in %. (40-50)

CALORIC VALUES OF SELECTED LIQUID FUELS

Type of fuel	Name	LCV MJ/kg	HCV MJ/kg
Liquid	Ethanol	26.8	29.7
	Petrol	42.0	45.2
	Diesel oil	41.8	44.7
	Heating oil	42.1	44.8

WORLD RESERVES OF CRUDE OIL

Total reserves:	370 bln Mg.
Recoverable reserves:	137 bln Mg
Time of consumption:	44 years

RESERVES, PRODUCTION AND IMPORT OF CRUDE OIL IN POLAND

Total reserves:	12 mln Mg
Production:	0.728 mln Mg/year
Import of petroleum:	18 mln Mg
Import of petrol:	0.627 mln Mg
Import of Diesel oil:	0.968 mln Mg

Structure of liquid fuels use in Poland