Refinery plants and technologies
(Introduction of Danube Refinery)

Csernik Kornél

The main goal of the refining
Driving forces

Oil growth in the transport sector – fuel quantity

World commercial energy use

Energy in transport

* Includes biofuels
Driving forces

Technology development – fuel quality

Hybrid technologies

Gasoline-technologies

VVT & Variable Valve Lift
ACP: Advanced Cam Phaser

CAI: Controlled Auto Ignition

CR: Common Rail

DI: Direct Injection

SCR: Selective Catalytic Reduction

TC: Turbocharger

Diesel technologies

Bluetec

EGR:

DI:

HCCI: Homogeneous Charge Compression Ignition

ISA: Integrated Starter Alternator

MDS: NCX Storage Converter

NSC: Multi Displacement System

SCR: Selective Catalytic Reduction

VCR: Variable Compression Ratio

VVT: Variable Valve Timing.
MOL fuel quality development: proactive steps - Euro-V compliance today

Driving forces
Environment regulations – fuel quality

- **GASOLINE**
  - aromatics
  - benzene: 5 V/V% (Not regulated) → 2 V/V% → 42 V/V%
  - lead: 0.35g/l → 0.15g/l → <1 V/V%
  - sulfur: 0.2% → 0.05% → 150 ppm → Sulfur free

- **DIESEL**
  - sulfur: 0.5% → 0.05% → 350 ppm → Sulfur free
  - PAH: Not regulated → <11 wt% → <8 wt%
  - D15: < 860 kg/m³ → < 845 kg/m³

- **OTHER PRODUCTS**
  - MOL Brand gasoil → EVO gasoil → EVO gasoline → ETBE blend → E5
  - MOL Brand gasoline → EVO gasoline → ETBE blend → E5

- **Processes and Projects**
  - PETROLEUM hydrotreater
  - REFORMATE redistillation
  - GASOLINE blending unit
  - GAS OIL blending unit
  - D15sulfur unit
  - GOK-3 hydrode-sulfurization plant
  - NEW GHDS, FCC HDS, TAME, ETBE, Hydrogen unit
  - HDS, Claus 4
  - MTBE plant
  - Gas oil blending unit
  - Gasoline blending unit
  - RESTRUCTING of gasoline production
  - Restructuring of gasoline production
  - Gas oil blending unit
  - Reformate redistillation

- **Projects**
  - Restructuring of gasoline production
  - New GHDS, FCC HDS, TAME, ETBE, Hydrogen unit
  - HDS, Claus 4
  - Petroleum hydrotreater

- **Additional Products**
  - FA60/80 Extra light heating oil
  - V-1500; V3000 softbitumens
  - 15/30 modified bitumen
  - Bitumens with adhesion improver additive
  - DDW100 shiny dipping wax
  - DWZ5860 drawable wax
  - DWZ5860 Mat dipping wax
  - AdBlue
Agenda

► General
► Crude Oil
► Products
► Refinery Operation
► History of Danube Refinery
► Position of Danube Refinery
► Sustainable Development
The Crude Oil

- Origin: organic materials

  i.e. PLANKTONS

- Burried, fossilized, and accumulated in porous rocks

- Pumped from the ground
Crude Oil Characteristics

API gravity
- Above 50 condensate
- 33-50 light crude oil
- 24-33 medium crude oil
- Below 24 heavy crude oil

Sulphur content
- Below 0.5 % low sulphur (sweet)
- 0.5 % - 1.5 % medium sulphur
- above 1.5 % high sulphur (sour)

Chemical characteristics
- Paraffinic content
- Intermediate
- Naphthenic or asphaltic

Flow properties
- Viscosity
- Pour point

These data can be found in crude oil assay
Crude Oil properties

Crudes of the World (excerpts)

- USA
- IRAN
- CANADA
- VENEZUELA
- SAUDI ARABIA
- NORTH SEA
- LIBYA
- AUSTRALIA

- heavy, sour (cheap) crudes
- Russian Export Blend
- light, sweet (expensive) crudes
Crude Transportation
Agenda

- General
- Crude Oil
- Products
- Refinery Operation
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Refinery products

Fuels
- Gasoline
- Diesel
- Jet

Chemicals
- Xylenes
- Ethylbenzene
- Toluene
- Chemical Naphta
- Sulphur
- Hydrogen
- Propylene

Lubes
- Motor oil
- Gear Oils
- Compressor oils
- Turbine oils
- Hydraulic oils
- Bearing Oil
- Plastic lubricants

Asphalts
- Road asphalts
- Construction asphalts
- Fuel oil

* These are usually distilled in a separate tower under vacuum
Product transport

- Railway: 20%
- Trucking: 7%
- Pipeline: 20%
- Shipping: 7%
Agenda

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Crude distillation curve

TBP Curve

- Light naphtha
- Med and heavy naphtha
- Kerosene
- Med and heavy gas oil
- Heavy gas oil from vacuum
- Light gas oil
- Vacuum gas oil
- Vacuum residue

Gases

°C
Temperature and pressure impact at various Refinery processes

- Coking
- Visbreaking
- Hydrovisbreaking
- Catalytic cracking
- Hydrotreating
- Hydrocracking
Conversion reached at various Refinery processes

- Hydropyrolysis
- Hydrocracking
- Hydrotreating
- Hydrovisbreaking
- Visbreaking
- Catalytic cracking
- Coking
Danube Refinery - Model of Crude Processing

- Bitumen
- Gasolines
- JET A1
- Gas oils
- Lubricants
- Paraffin and wax
- Green Coke
- LPG

Flowchart:
- CDU - 1,2,3
- Gas fractionation
- Reforming Units - 3,4
- AROMATICS EXTRACTION AND DISTILLATION
- GASOLINE BLENDING
- Gasoil blending
- Kerozene hydrotreater
- Gas oil hydrotreaters - 1,3, HDW
- HDS - MHC
- FCC
- ETBE
- ALKYLATION
- Lubricants paraffin - waxes
- H2 PLANT
- Delayed Coker
- Bitumen
Crude processing in Danube Refinery
Refinery technologies
Crude desalting

Goal
- Removal of the corrosion and catalyst poison agents from the crude oil.

Feed
- Crude oil
- Slops
- Water

Products
- Desalted crude oil
- Waste water

Parameters
- Temperature: 110 – 140°C,
- Voltage: 22 – 44kV
Refinery technologies

Crude distillation (Atmospheric and Vacuum)

Goal
- Separating the crude oil into its "fractions," the broad categories of its component hydrocarbons.

Feed
- Desalted crude, slops

Products
- Gases,
- Naphta,
- Kerosene,
- Gasoil, Vacuum Gasoils
- Vacuum residue

Parameters
- Temperature: 300-420°C,
- Pressure: atm and 50 – 100 Hgmm
Goal
• Production of gasoline blending component with high octane and aromatic feed

Feed
• Heavy Naphta

Products
• Aromatic rich fraction
• H₂ 96% vol.,
• LPG

Parameters
• Temperature: 480-520°C,
• Pressure: 0.24 – 0.7 MPa,

Catalyst
• Pt, Re on alumina + Cl
**Goal**

- Production of blending component with high octane

**Feed**

- n-C5; n-C6 fraction

**Products**

- Isomerate (ON 82 -84)

**Conditions**

- Temperature: 120 -180°C,
- Pressure: 25-30 bar,

**Catalyst**

- Pt – Al2O3 – Cl
- Pt – zeolit
- Sulphated metal-oxide
Refinery technologies
Fluid Catalytic Cracking

**Goal**
- Cracking of fuel oil to more valuable light component

**Feed**
- Desulphurized vacuum gasoil

**Products**
- Fuel gas
- LPG,
- FCC gasoline
- Middle distillate (LCO)
- Slurry
- Coke – using for energy supplying

**Conditions**
- Temperature: 480 - 540 °C
- Nyomás: 2 – 4 bar

**Catalyst**
- Zeolit (Al$_2$O$_3$ - SiO$_2$)
Refinery technologies

Alkylation

Goal
- Production of mogas blending components (i-octane)

Feed
- C4 olefins, isobutane

Products
- Alkylate (ON 92-96),
- n-butane

Techn. conditions
- T=1-40°C,
- p= 1-10 barg

Catalyst
- HFA
- H2SO4
Refinery technologies

**Oxigenate production (MTBE/ETBE)**

**Goal**
- Production of oxigenate blending mogas component

**Feed**
- C₄ unsaturated,
- Bioetanol, metanol

**Products**
- ETBE, MTBE (ON 112 - 116)

**Conditions**
- Temperature: 50-60°C,
- Pressure: 14-17 barg

**Catalyst**
- Sour resins
Refinery technologies

Hydrotreating

Goal
- Desulphurization of hydrocarbon with high level sulphur content

Feed:
- Naphtha, Kerosene, Gasoil, Vacuum gasoil

Products:
- Hydrotreated feed,
- \( \text{H}_2\text{S} \),

Conditions:
- Temperature: 280 – 420°C,
- Pressure: 15-100 bar

Catalysts
- CoMo, NiMo on Al\(_2\)O\(_3\), SiO\(_2\)
Hydrocracking

**Goal**
- Production of middle distillate from VGO/residue

**Feed:**
- VGO,
- Residue

**Products:**
- LPG, C4,
- Light Naphta (ON 80)
- Heavy Naphta (for CCR),
- Middle Distillates

**Conditions:**
- Temperature 360-430°C,
- Pressure 100-250 barg

**Catalysts**
- Ni/Mo/ SiO$_2$/Al$_2$O$_3$
**Refinery technologies**

**Coking (Delayed Coker)**

**Goal**
- Concersion of vacuum resid to more valuable products

**Feed:**
- Vacuum Resid

**Products:**
- Gases,
- Naphta,
- Gasoil,
- VGO,
- Coke

**Conditions:**
- Temperature: 480 - 520°C,
- Pressure: 1 - 5 barg
**Goal**
- Pure aromatic component production

**Feed**
- BTX from Reformer, BT fraction from TVK

**Products**
- Benzene, Toluene, MP xylenes, Ortoxyylene

**Conditions**
- Temperature: 100-150 °C,
- Pressure: 0.8-8 barg

**Solvents**
- Tetra-ethylene-glycol (TEG)
- Process Aerosolvan (NMP+MEG),
- Udex (DEG),
Refinery technologies

Hydrogen production

Goal
- High purity hydrogen production

Feed
- Methane,
- Water

Products
- Hydrogen 99.9%
- CO₂

Conditions
- Temperature 750 - 850°C,
- Pressure: 25 – 35 barg,

Catalyst
- Ni on alumina and Fe/Co

\[ \text{CH}_4 + \text{H}_2\text{O} = \text{CO} + 3\text{H}_2 \]

\[ \text{CO} + \text{H}_2\text{O} = \text{H}_2 + \text{CO}_2 \]
**Refinery technologies**  
**Sulphur production**

**Goal**
- Recovery of sulphur content from gases containing H$_2$S

**Feed**
- H$_2$S gases

**Products**
- Sulphur

**Conditions**
- Temperature: 1000-1400°C
- Pressure: atm

**Catalyst**
- Activated Al$_2$O$_3$

\[
\text{H}_2\text{S} + \frac{3}{2}\text{O}_2 = \text{SO}_2 + \text{H}_2\text{O}
\]
\[
2\text{H}_2\text{S} + \text{SO}_2 = 3\text{S} + 2\text{H}_2\text{O}
\]
Refinery technologies
Gasoil blending

- LSGO (K1)
- HDS GO (K2)
- HSGO (K3)
- LLSP (K4)
- HSP (K5)
- LSGO (K7)
- FAME (K8)
- Fuel oil (10 wppm S)
- Fuel oil (1000 wppm S)
- Fuel oil (Power Plant)
- Diesel gasoil (<10ppm S)
- EVO Diesel
- Biodiesel
- Additives
- DCS
- AFTIR
- TOPNIR
- Blend
Tank farm

Storage capacity is more than 2,000,000 m³
Refinery technologies
Baseoil and Wax Production

- Hungarian and Russian Vacuum Distillates
  - Solvent (NMP) Extraction
  - Propane Deasphalting
    - Unconverted oil UCO
      - Solvent Dewax (MEK-Toluene)
        - Vacuum Residue
          - Wax
            - Hydrofinishing
              - Wax Deoiling
                - HDS
                  - Russian Middle Distillates
                    - Hydrofinishing
                      - Clay Treatment
                        - Packing
                          - Lube Blending
                            - Lube oil
Agenda

- General
- Crude Oil
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- History of Danube Refinery
- Position of Danube Refinery
- Sustainable Development
History of Danube Refinery

1. Period
Building out of the refinery (1960-1980)
- CDUs
- Aromatic Extraction Unit
- Gasoline reforming
- Sulphur Recovery Units
- Light Naphtha Isom.Unit

2. Period
Improving product slate, increasing profitability (the ‘80s)
- FCC (Fluid catalytic cracker)

3. Period:
Starting preparation for EU membership in product quality (the ‘90s)
- Reducing sulphur, lead and benzene content of fuels

4. Period
Getting into the „upper quartile” (after 2000)
- Residual upgrading
- EU 2005 project
- Launching of the biofuels
The construction
1. period
Key drivers and outcome of Refinery Development in the ’80-s 2. period

- Realization of a Fluid Catalytic Cracker (FCC) investment in 1984, based on UOP technology
- Decreasing demand for heavy fuel oil
- Increase of demand for gasolines with good quality
- High crude oil prices

Result

additional quantity of gasoline, gasoil, liquefied gas and propylene from 1-1.2 Mt of fuel oil
Reduction of sulphur content in fuels up to 2000

3. period

**Gasolines**

<table>
<thead>
<tr>
<th>Date</th>
<th>Sulphur content (m/m) %</th>
</tr>
</thead>
<tbody>
<tr>
<td>01. 01. 1993</td>
<td>0.2</td>
</tr>
<tr>
<td>01. 01. 2000</td>
<td>0.05</td>
</tr>
<tr>
<td>01. 01. 2005</td>
<td>0.015</td>
</tr>
</tbody>
</table>

* Gas oil desulphurizer

10 ppm !!

**Gasoils**

<table>
<thead>
<tr>
<th>Date</th>
<th>Sulphur content (m/m) %</th>
</tr>
</thead>
<tbody>
<tr>
<td>01. 01. 1993</td>
<td>0.5</td>
</tr>
<tr>
<td>01. 01. 1997</td>
<td>0.2</td>
</tr>
<tr>
<td>01. 01. 2000</td>
<td>0.05</td>
</tr>
<tr>
<td>01. 01. 2005</td>
<td>0.035</td>
</tr>
</tbody>
</table>

01. 10. 1994, 01. 10. 1996, 01. 01. 2000

10 ppm !!
Reduction and phase-out of the lead content in the fuels

3. period
Reduction of benzene content in motor fuels
3. period

Only in Hungary, in the EU the regulation allowed maximum 5% until 2000
Rationalisation of distillation capacities in Hungary

4. period

Processed crude, kt
Share of light product, %

Cheap crude
Transition period
Conversion technologies, Quality improvement
Residless refining Quality improvement

Rationalisation of distillation capacities in Hungary

4. period

- original distillation capacity: 13.1 Mt/year
- shutdown before 2001: 1.5 Mt/year
- shutdown in 2001: 3.5 Mt/year
- present distillation capacity: 8.1 Mt/year

- Szóny
  - capacity: 1.2 Mt/year
  - shutdown: 1984

- Százhalombatta
  - capacity: 8.1 Mt/year

- Zalaegerszeg
  - capacity: 500 kt/year
  - shutdown: Nov. 2001

- Nyírbogdány
  - capacity: 350 kt/year
  - shutdown: 1983

- Tiszaújváros
  - capacity: 3 Mt/year
  - shutdown: July 2001
Goals of the project
To be independent from the uncertain fuel oil market
To increase the competitiveness and conversion level of the Duna Refinery
To improve environmental conditions countrywide and locally

New plants on the project
Delayed coker
Hydrogen plant
Claus-5 plan (sulphur recovery)

Investment value: about USD 250 M
In Százhalombatta the following installations were realised:

- new 800 kt/year capacity gasoline desulphuriser
- new 2.2 Mt/year capacity gasoil desulphurising plant
- new 40 th m³/h capacity hydrogen plant
- converting gasoil blending plant
- auxiliary facilities

Investment value: about USD 300 M
The Hydrocracking (HCK) project

5. Period?

Implementation of a new HCK Unit

Licensor: Chevron Lummus Global
Nominal capacity: 1.5 Mt/y
Technology scheme: two-stage recycle HCK with split feed
Operation modes:
- normal operation
- maximum conversion
- high LCO feedstock
- coker feedstock

Additional crude oil processing

An additional 1.3 Mt/y crude oil distillation capacity will provide feedstock for the HCK Unit.

The innovative concept will deliver an additional 1.3 Mt/year middle-distillate.

This capacity increase can handle the increased quantity of vacuum residues with the necessary reserve to compensate seasonality of the bitumen production.

The capacity expansion needs to be achieved with low CAPEX.
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Position of the Danube Refinery

<table>
<thead>
<tr>
<th>Key figures - 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distillation capacity:</td>
</tr>
<tr>
<td>8.1 Mt/a</td>
</tr>
<tr>
<td>Processed crude:</td>
</tr>
<tr>
<td>6.5 Mt</td>
</tr>
<tr>
<td>Share of light products:</td>
</tr>
<tr>
<td>78%</td>
</tr>
<tr>
<td>Number of plants:</td>
</tr>
<tr>
<td>49</td>
</tr>
<tr>
<td>Nelson complexity index:</td>
</tr>
<tr>
<td>10.6</td>
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</tbody>
</table>
Position of the Danube Refinery

Solomon study in every 2 years (latest in 2010)
Position of the Danube Refinery

Preliminary results of Solomon study, 2010

Energy Intensity Index (EII®)

Maintenance Cost Efficiency Index (MEI™)

Maintenance Index, US $/EDC

Mechanical Availability (Without Slowdowns), %

Preliminary results of Solomon study, 2010
Position of the Danube Refinery

Preliminary results of Solomon study, 2010

Cash Basis ROI, %

Cash Operating Expenses, US cents/UEDC

Non-Energy Operating Expenses, US $/EDC

Process Utilization, %

Volumetric Expansion Index
Utilities

Electric power demand
624.5 GWh/a

Cooling water demand
175.2 millió m³/year

Public lighting in Hungary
530 GWh/a

Lake Velence
41.1 millió m³

~1.2x

~4.3x
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HSE compliance

EU 2005 Project
Product Quality Improvement
Production of exclusively 10 ppm S motor fuels 4 years before EU regulation

New Sulphur recovery unit
Reconstruction of Waste incinerator
FCC flue gas filter

Residue Uprading project
Product Yield Improvement
Delayed Coker

Waste Water Treatment

Sustainable development
Emission reduction

Emitted oil (HC), tonnes/a

Emitted treated waste water, million m³/a
„If I were emperor of the world, I would put the pedal to the floor on energy efficiency and conservation for the next decade.“

Stephen Chu, physicist (Nobel Price 1997)
12th United States Secretary of Energy