Optimization of the Bottom of the Barrel Complex – UOP Solutions to Process Mazut
Agenda

1. MARPOL specs
2. Fiscal Incentive for Residue Conversion
3. What can affected refiners do?
4. Example of no fuel oil refinery
5. SDA and Uniflex MC Technologies
6. Conclusion
MARPOL Annex VI Regulation Affecting Shippers and Refineries

2016 Study
Marpol review in Oct 2016 has defined 2020 implementation

MARPOL Annex VI implementation schedule

2020: 0.5% S limit for world-wide Open Sea bunkers results in surplus residue and this will affect Russian Residue exports
Key Changes in Russian Oil Tax System

• Introduction of new tax rules in 2011 that aim to transform Russian refining landscape by providing refineries with the incentive to invest in more advanced refining processes
  – Excise tax changes driving Class-5 transport fuels production
  – Mineral Export Tax (MET) changes
  – Fuel products and crude export tax changes with heavy oil products export duty increased to 100% in 2017
  – Additionally Class-5 fuels specification implementation mandatory as of 1st July 2016

The overall refinery margins have reduced as a result and CDU/VDU refineries will need to be upgraded to remain profitable.
Refinery Options to Process Mazut

1) Vacuum distillation and optionally Solvent DeAsphalting (SDA) to maximise hydrocracker (HCU)/FCC feed

2) Conversion of VR/SDA pitch to valuable light products via

Slurry bed process such as Uniflex MC™ process
- High capex but good payback
- Newer technology but has operated 15 years in commercial unit

Coking process such as AMEC FW DCU process
- High capex if products treating and environmental aspects of making coke are accounted for. Lower conversion and payback
- Established technology

Ebullated bed process
- High capex, complexity and potential operability issues with difficult feeds eg Urals. Lower conversion and payback
- Established technology

RCD Unionfining™ / RFCC processes
- High capex, for gasoline oriented market, may be less attractive for more difficult Atmospheric Residues eg Urals
- Established technology

Slurry Bed Hydrocracking Processes have the Best Payback
Case Study

**Base case:**
Typical complex refinery

**Investment**
CDU / VDU
HCU/FCCU
VBU

Add SDA and Uniflex units

*Note: Other Configurations are possible – with or without SDA unit depending on individual refinery situation*
Example Base Case: Typical refinery (flows in Thousand Tons Per Annum)

Base case HSFO Production
~30% on Atmospheric Residue

Refinery Before Investment

- **GS**
- **Distillates**
- **Cutter**

### Base Case HSFO Production

- **3500 AR**
- **2100 VGO**
- **1400 VR**
- **FCC/HCU** Gasoline / Distillates / Cutter
- **VDU**
- **VBU**
- **Bitumen** 300
- **HSFO** 950
Investment to Eliminate HSFO

Heavy Oil Complex: add SDA and Uniflex Unit (flows 1000T/a)
## Economic and Product Summary

<table>
<thead>
<tr>
<th>Options</th>
<th>Base</th>
<th>SDA + Debottleneck HCU/FCC + Uniflex Unit</th>
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<tbody>
<tr>
<td>Capex m$ Total Installed Cost incl. OSBL</td>
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<tr>
<td>Margin m$/a</td>
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<td>Simple payback yrs</td>
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<tr>
<td>Bitumen kt/a</td>
<td>300</td>
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</table>

Above values are only for illustration purposes.
UOP / FWUSA Solvent Deasphalting

De-Asphalted Oil (DAO) feed to:
- FCC
- HCU
- Hydrotreater

Vacuum Residue (VR)

SDA

SDA Pitch feed to:
- Bitumen
- Boiler / Power
- DCU
- Uniflex Unit

- Not a catalytic process, but a solvent based separation process
- 3 cut SDA if Bitumen is to be produced

DAO yield typically 30 - 70% limited by DAO quality and at very high lifts by pitch quality
DAO Quality vs DAO Lift

- DAO quality at lifts below 70% shows relatively low metals content
- DAO quality below 50% shows lower CCR content
- Asphaltenes levels in DAO are extremely low
- Nitrogen and sulphur are more evenly distributed
DAO Processing in Unicracking™ Process

• Extensive experience of processing DAO in high conversion recycle hydrocrackers and FCC units
• UOP has experience of processing DAO in hydrocrackers at high conversion >95%
• Higher the SDA lift, more the guard bed and reactor volume of the hydrocracker has to be increased to maintain conversion and cycle length
• UOP has proprietary technology to prevent HPNA build up in recycle hydrocrackers and extend cycle length, thus maximizing conversion and minimizing catalyst volume
• Optimization of VDU, SDA and FCCU / HCU operation will realize additional revenues
Enhanced Two-Stage (E2S) Unicracking Process units started since 2015
All designed to process high proportions of heavy feedstocks – HCGO, DAO

E2S advancements delivered
- Diesel yields increased by up to 7 wt-% with maximum distillates production
- Commercially proven HPNA management to allow full conversion, constant throughout cycle
- Hydrogen consumption reduced
- Catalyst volumes reduced significantly
- Lower energy consumption

Strong commercial interest shown
- First license signed in April 2009

13 units licensed since launch

Unicracking Process with 99.5% Conversion
Proven Solution for Heavy Feeds

Hydrocracking technology designed for bottom of the barrel upgrading
Why Uniflex™ Process?

**Commercially Proven Operation:**
- Commercial unit that operated for 15 years with high onstream factor.
- 6 Uniflex licenses awarded to date

**Significant Yield Improvements vs. Other Technologies:**
- Low value streams such as FCC CSO can be upgraded to high value products
- 95-98 % conversion of residue
- High yields of Euro V middle distillate
- Low yields of VGO which can be processed in existing conversion units
“Deep Oil Processing Complex” (DPC) Flowscheme – Example From a Russian Project

Distillation
- CDU
- VDU
- SDA

Upgrading
- Unicracking™ Unit
- Merox™ unit PSA

Product Improvement /Treating
- Unionfining™ unit
- CCR Platforming™ + Par-Isom™ Units

- Gasoline
- Diesel
- UCO
- Crude Oil
- Natural Gas

Utilities & Power
- H₂ & S
- P & S
- Power Steam
- SRU
Deep Oil Processing Complex Product Structure

Based on Urals Crude Oil Feed

Product Yield (Wt-% on Crude)

New Deep Oil Processing Complex

- Fuel Gas
- LPG
- ~20% Gasoline/Xylenes
- ~72% Kero/Diesel
- Pitch to Utilities

The yield of Light Fuels will be >90 Wt-% of crude oil feed
Uniflex Process - Continuous Improvement

Comprehensive development program
• New catalyst innovations
• Process enhancements

Responding to customer and market needs
• High conversion to valued products
• Process design for sustained operability and reliability
• Economically efficient catalyst systems, and manufacturing capability
• Economically advantaged disposition for all products
• Robust feed and product characterization

Further improvements to a commercially proven process
<table>
<thead>
<tr>
<th>Name</th>
<th>Location</th>
<th>Capacity, MMTA</th>
<th>Feeds</th>
<th>Start-up</th>
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<tbody>
<tr>
<td>Petro-Canada, Montreal</td>
<td>Canada</td>
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<td>Venezuelan, Mexican, North Sea, Cold Lake, Visbroken VR</td>
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<td>Med Arab, Merey, Russian Export</td>
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<tr>
<td>Undisclosed</td>
<td>China</td>
<td>0.8</td>
<td>Arab Light, Russian Export</td>
<td>Delayed</td>
</tr>
</tbody>
</table>
Next Generation Uniflex MC Process Features

Feed

Microcat Catalyst Preparation Section

Catalyst Made by refiner on site

VR
Matrix

Recycle H₂

2 Reactors w Interstage Sep

No Quench or Anti-foam

Makeup H₂

Pump-Around

VTB & Slop Wax Recycle

HVGO

No Heater

Flash Gas

Diesel

Naphtha

C₄-

Diesel

LVGO

no net HVGO

Solids Recovery

Made by refiner on site

no net HVGO
Uniflex MC Process – Enhancement Benefits

• Enables 95 to 98 Wt-% conversion (525°C+ material)
  – 95% base conversion
  – 98% conversion with solids recovery option

• Reduced catalyst addition rate
  – Injection rate in ppm of fresh feed
  – Highly efficient molybdenum based catalyst
  – On-site catalyst manufacturing capability

• Improved VTB (Vacuum Tower Bottoms) quality
  – Low solids content, low sulfur level, and no iron
  – Fungible product (e.g. fuel, low sulfur petcoke, asphalt production)

• Solids recovery from VTB
  – Recovered oil product quality upgraded, or
  – Recycle operation in unit for higher conversion and yields
  – Recovered solids to metals recovery
UOP Heavy Oil Development Center

• Expanded capabilities to support Bottom of Barrel Technology Development
• New facility for pilot plant expansion at UOP Riverside, Illinois
  – Feed and Product handling area:
    • Handling, sampling, and blending of bulk heavy feeds and products
  – High throughput Feed Preparation / Fractionation:
    • 3 BPD capacity multi-column fractionation unit
  – Uniflex pilot plant:
    • High capacity operation with multiple reactors capable of staged operation
  – Solvent De-asphalting (SDA) pilot plant:
    • Multi solvent capability: Propane, Butane, Pentane.
  – Flexible Heavy Oil Hydroprocessing pilot plant:
    • Heavy Oil Technologies fully integrated with UOP Unicracking™ and Unionfining™ (RCD and Distillate) pilot plant
    • Capable of high pressure (5000 psi) operation with reactor configurable in all Hydrocracking and Hydrotreating modes
Conclusions

Fiscal rules adds incentive to build residue conversion capacity in Russia. The optimization of any bottom of the barrel complex is key to ensuring the highest return on investment.

UOP offers a full technology portfolio and can help optimize a Heavy Oil complex offering with VDU, SDA, HCU/ FCCU and Uniflex MC process to help maximize distillates and project economics.

SDA is a low cost solution to upgrade excess VR to DAO and Bitumen.

Unicracking process is the proven technology for VGO, HCGO and DAO upgrading.

Uniflex MC process can be used to process VR/SDA pitch as a second phase investment to help maximize valuable distillates.