Hydrocracking is a key enabler to maximise transportation fuels and to reduce fuel oil to less than 10% of crude
Hydrocracking Unit

- Crude Oil
  - CDU
    - Saturated Gas Plant
      - SR Kerosene
        - Naphtha Hydrotreating Unit
          - SR Light Gasoil
            - DHT Unit
              - Jet
                - Diesel
                  - Wet Gas + LPG
                    - SHC Diesel
                      - SHC VGO
                        - SDA Pitch
                          - SDA Unit
                            - VGO
                              - VDU
                                - At Res
                                  - Vac Res
                                    - SDA Pitch
                                      - Slurry HC Unit
                                        - HCU
                                          - DAO
                                            - SHC VGO
                                              - UCO
                                                - HCU Kerosene
                                                  - HCU Diesel
                                                    - HCU Diesel
                                                      - HCU Kerosene
                                                        - Bitumen Sales
                                                          - Diesel Sales
                                                            - Gasoline Sales
                                                              - Kerosene Sales
                                                                - LPG Sales
                                                                  - Natural Gas
                                                                    - Refinery Fuel Gas
                                                                      - H2
                                                                        - Hydrogen Plant
                                                                          - LPG
                                                                            - Isomerate
                                                                              - Reformate
                                                                                - CCR Unit
                                                                                  - NHT Splitter
                                                                                    - H2
                                                                                      - LPG
                                                                                       - Isom Unit
                                                                                        - UNI Naphtha
                                                                                           - SR Kerosene
                                                                                             - SR Light Gasoil
                                                                                               - Crude Oil
UOP Hydrocracking Process – Increasing Conversion and Profitability

- Hydrocracking converts low value feeds to high value transportation fuels and petrochemical feedstock
- Adds hydrogen which increases the volume of the products
- Converts heavy gas oils to clean jet and diesel,
UOP’s History of Hydrocracking Progress

UOP Lomax Hydrocracking Process

1950

UOP HDC Unibon™ Process (hydrotreating and hydrocracking)

1960

UOP HC Unibon™ Process (hydrocracking)

1970

UOP ISOMAX Process

1980

UOP Unicracking™ Process

1990

2000

Present

UOP Hydrocracking Technology - long history, sustained innovation
Hydrocracking Technology Portfolio

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Reactor Section</th>
<th>Fractionation Section</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distillate</td>
<td>Once Through</td>
<td></td>
<td>Naphtha</td>
</tr>
<tr>
<td>LCO</td>
<td>Single Stage Recycle</td>
<td></td>
<td>Kero/ Jet Fuel</td>
</tr>
<tr>
<td>VGO</td>
<td>Two Stage Recycle</td>
<td></td>
<td>Diesel Fuel</td>
</tr>
<tr>
<td>CGO</td>
<td></td>
<td></td>
<td>Lubes Base Stocks</td>
</tr>
<tr>
<td>DAO</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Customized Solutions to Meet Customer Objectives
65 years of Hydroprocessing Innovation

- 340+ Hydrotreating Units & 220+ Hydrocracking Units Licensed

- UOP Hydroprocessing Experience
  - 10 Licensed Units in Iran
  - Licensed Capacity, BPSD
  - Award Year
  - 2012 Uniflow™ Reactor Internals 5th Generation
  - 2016 Unity™ Hydroprocessing Catalysts

- 1952 1st Hydrotreating Unit
- 1960 1st Hydrocracking Unit
- 1990s/2006 HPNA Management
- 2008 E2S Process

- 1990s/2006
  - HPNA Management
- 2008
  - E2S Process

- Unity™
  - Hydroprocessing Catalysts
Comprehensive Hydroprocessing Solution

Unity
Hydroprocessing Catalysts

- Catalyst Solutions
  - Unified portfolio for hydrotreating & hydrocracking
  - Crystaphase®

Equipment Solutions
- Uniflow™ Reactor Internals
- UOP Hydrogen Purification (Polybed™ PSA)
- Callidus Combustion Equipment
- Honeywell Advanced Process Control
- Mitsui simiLe™ Metallurgy
- Filtrex® ACR Filtration

Process Technology
- Innovative flow schemes
- Unicracking Process
- Unionfining Process
- HPNA Management
- New unit & revamp experience

Expert Knowledge
- Training simulators
- Experion Solution Suites

Integrated Solutions
- Bottom of the Barrel (Uniflex™, RCD Unionfining, & SDA Processes)
- Hydrogen recovery & purification

Honeywell UOP
UOP Hydrocracking Differentiators

• Extensive experience in revamping existing Hydrocracking Units
  - Maximize value from existing assets

• Novel Fractionation
  - Reduced CAPEX and OPEX of fractionation section

• HPNA Management
  - Enabler for higher conversion

• Uniflow reactor internals
  - Maximize catalyst utilization

• Catalyst
  - Pre-treat and cracking
Improving Profitability from Existing Asset

• A challenging market demands innovative solutions
• UOP can provide a variety of revamp options to meet your objectives
  - Innovative process solutions
  - Experience with different flow schemes
  - Uniflow reactor internals
  - Complete catalyst portfolio
  - Targeted studies to resolve issues, assess future expansion or investigate different processing objectives

• UOP Worldwide Hydroprocessing Revamp experience
  - 74 Revamp Studies and 42 Revamp Schedule A’s conducted in the last 10 years
Energy Savings with Novel Fractionation

- The separation accomplished in the hot and cold separators is further improved in separate hot and cold strippers.
- Improved Diesel/UCO separation with heavy fractionator.
Novel Fractionation Benefits

- Dual Zone Stripper + Dual Fractionator
  - Improved fractionation efficiency
  - Diesel yields improved by approximately 1%
  - Produces dry diesel directly from fractionator
UOP HPNA Management Technology Enables Higher Conversion

- Heavy Polynuclear Aromatics can build up in recycle oil
- HPNA Management Solutions
  - Split shell fractionator concentrates HPNA’s in a small bleed stream
    - 15 units designed with split shell fractionator, 5 operating
  - External HPNA stripper is available as a revamp

Up to 99.5% conversion for entire catalyst cycle
Improved Distribution with UOP Uniflow Reactor Internals

- New design offering a step change in performance & speed of installation
- First sale in 2013
- Sold into 16 units (new and revamp) with 6 operating successfully

Example: Installed in 5-bed HC reactor in Nov, 2014. Unit operating at 32% higher feed rate compared to previous cycle.

<table>
<thead>
<tr>
<th>Hydrocracking Bed</th>
<th>Radial Spread (ºF) New Cycle</th>
<th>Radial Spread (ºF) Previous Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Top: 1 Bottom: 1</td>
<td>Top: 3 Bottom: 18</td>
</tr>
<tr>
<td>Bed 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Top: 4 Bottom: 3</td>
<td>Top: 2 Bottom: 6</td>
</tr>
<tr>
<td>Bed 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Top: 4 Bottom: 2</td>
<td>Top: 5 Bottom: 6</td>
</tr>
<tr>
<td>Bed 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Top: 4 Bottom: 3</td>
<td>Top: 12 Bottom: 36</td>
</tr>
<tr>
<td>Bed 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Top: 4 Bottom: 4</td>
<td>Top: 11 Bottom: 45</td>
</tr>
<tr>
<td>Bed 5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Customer Feedback:

“We would never have been able to operate this unit where it is today without these new internals. This is a step change for UOP”
Hydrocracking Catalyst System Components

Grading System
- Controls pressure drop
- Removes metals

Hydrotreating Catalyst
- Sulfur removal
- Nitrogen removal
- Aromatic saturation

Hydrocracking Catalyst
- Selective cracking to reduce boiling range
- Aromatic saturation
- Selective isomerisation
Iranian Hydrocracking Opportunities

Refineries & Crude Oil Pipelines

- Tabriz 110
- Tehran 250
- Kermanshah 21
- Arak 250
- Esfahan 375
- Shiraz 58
- Abadan 390
- Lavan 50
- Bandar Abbas 320

Length (km)
- Existing: 3831
- Future Plans: 6147
Revamp of existing Iranian units

• Key enablers for staged investment and fuel oil reduction
• Maximum utilisation of existing refinery assets
• Revamp Opportunities for increased throughput
• Phased investment for Bottom of the Barrel upgrading
• Delayed investment of major unit revamp
Existing Unit – Iranian Isomax Unit

FRESH FEED (HVGO) 10,000 BPSD

-existing Isomax Unit

LIGHT ENDS

FULL RANGE NAPHTHA

KEROSENE

DIESEL

UNCONVERTED OIL

19% Fuel Oil

RECYCLE OIL 2,000 BPSD

12,000 BPSD
Existing Unit – Iranian Isomax Unit

Phase 1 – New VDU

Original Capacity = 12,000 BPSD
Current Capacity = 12,600 BPSD

Existing Isomax Unit

FRESH FEED (HVGO)
10,000 BPSD

HVGO
2,600 BPSD

LIGHT ENDS
FULL RANGE NAPHTHA
KEROSENE
DIESEL
UNCONVERTED OIL

13% Fuel Oil

RECYCLE OIL
2,000 BPSD

FRESH FEED (HVGO)
Existing Unit – Iranian Isomax Unit
Phase 2 – New SDA

Original Capacity = 12,000 BPSD
Current Capacity = 15,600 BPSD

Existing Isomax Unit

- HVGO 2,600 BPSD
- FRESH FEED (HVGO) 10,000 BPSD
- DAO 3,000 BPSD

30% Higher than Design

Light Ends
- Fuel Oil 4%
- Diesel
- Kerosene
- Full Range Naphtha
- Unconverted Oil

Fresh Feed (HVGO) 10,000 BPSD

Recycle Oil 2,000 BPSD
Existing Unit – Iranian Isomax Unit
Phase 3 – New Slurry Hydrocracker

Original Capacity = 12,000 BPSD
Current Capacity = 16,800 BPSD

Existing Isomax Unit

40% Higher than Design

FRESH FEED (HVGO)
10,000 BPSD

DAO
3,000 BPSD

SLURRY VGO
1,200 BPSD

HVGO
2,600 BPSD

RECIRCULATED
1,876 BPSD

0% Fuel Oil

LITE ENDS

FULL RANGE NAPHTHA

KEROSENE

DIESEL

UNCONVERTED OIL
Existing Unit – Iranian Isomax Unit

Increasing Complexity

Current Operation
- 12,000 BPSD
- No Recycle
- 60-70% Conversion

Phase 1 New VDU
- 12,600 BPSD

Phase 2 Add SDA
- 15,600 BPSD

Phase 3 Add Slurry HCK
- 16,800 BPSD

Unit Revamp Required

Maximise yield of Distillates Maximum Conversion
Unit Revamp Options

New 1st Stage
16,800 BPSD

Fractionation Section

HPNA Management

Existing Isomax Unit
12,000 BPSD

Uniflow Reactor Internals

At original design capacity

HVGO, DAO and SLURRY VGO
16,800 BPSD

RECYCLE OIL
12,000 BPSD

LIGHT ENDS
NAPHTHA
KEROSENE
DIESEL

UNCONVERTED OIL

16,800 BPSD

RECYCLE OIL
12,000 BPSD
Impact on Refinery Yields

Current Performance Phase 1 - New VDU Phase 2 - New SDA Phase 3 - New Slurry Hydrocracker

PRODUCT YIELD, VOL%
## Summary of Case Study

<table>
<thead>
<tr>
<th>Hydrocracking Unit Revamp Concept</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creep of existing unit</td>
<td>+VDU</td>
<td>+SDA</td>
<td>+Slurry HCU</td>
</tr>
<tr>
<td>Add additional stage to existing unit</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Euro 5 Diesel (vol% of product)</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>43 vol%</td>
<td>52 vol%</td>
<td>61 vol%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fuel Oil (vol% of product)</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 vol%</td>
<td>4 vol%</td>
<td>0 vol%</td>
<td></td>
</tr>
</tbody>
</table>

**UOP has the knowledge and capability to provide an integrated revamp solution to phase your project to maximise transportation fuels and to reduce fuel oil to less than 10% of crude**
MIDOR Refinery Expansion Project
Boosting Refinery Capacity – 100,000 to 160,000 BPSD

Project Objectives (all achieved)
• Refinery throughput increased 60%
• Increase middle distillate yield 75%
• Meet future legislation of high quality EuroV specifications
• Zero fuel oil production
• Internal rate of return 30%

Additional Requirements
• Maximum utilisation of existing refinery units
• Minimise refinery downtime
• Limited plot space
MIDOR Refinery Expansion Project
Boosting Refinery Capacity – 100,000 to 160,000 BPSD
MIDOR Refinery Expansion Project
Current Kerosene and Diesel Processing Configuration

Current Configuration
• Targets local diesel production
• Kerosene to Jet A1 pool only
• No ability to achieve EuroV diesel specifications
MIDOR Refinery Expansion Project
Maximising Euro V Diesel Production

Unicracking Unit
Existing Configuration

33,000 BPSD
VGO+HCGO

Make-up Gas

33,000 BPSD

Separation

Fractionation

17,000 BPSD

Naphtha
Kerosene
Diesel
UCO

UOP 7432D-14
Unicracking Unit
New Configuration

Make-up Gas

50,000 BPSD
VGO+HCGO+DAO

Uniflow Reactor
Internals

New RG Scrubber

Separation

Fractionation

35,000 BPSD
UCO

Common H₂ Recovery

MUG

50,000 BPSD
VGO+HCGO+DAO

Uniflow Reactor
Internals

New RG Scrubber

Separation

Fractionation

Unicracking Unit
New Configuration

Make-up Gas

50,000 BPSD
VGO+HCGO+DAO

Uniflow Reactor
Internals

New RG Scrubber

Separation

Fractionation

35,000 BPSD
UCO

Common H₂ Recovery

MUG

50,000 BPSD
VGO+HCGO+DAO

Uniflow Reactor
Internals

New RG Scrubber

Separation

Fractionation

Naphtha
Kerosene
Diesel
MIDOR Refinery Expansion Project
Boosting Refinery Capacity – 100,000 to 160,000 BPSD

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Enhanced Two-Stage Unicracking
Tüpras Residue Upgrading Project Success Story
Enhanced Two-Stage Unicracking
Tüpras Residue Upgrading Project Success Story

- Coker Naphtha Pre-treatment
- Diesel Hydrotreating Reactor Section
- 2-Stage Hydrocracking Reactor Section
- Fractionation Section

Inputs:
- Coker Naphtha
- Distillate
- VGO HCGO

Outputs:
- LPG
- Naphtha
- Kerosene
- Diesel
- Unconverted Oil
Enhanced Two-Stage Unicracking
TÜPRAS Residue Upgrading Project Success Story

- Smooth and safe unit start-up
- On spec product with 36 hours of feed introduction
- All guarantees and met in August 2015
- One of the most profitable units in TÜPRAS
- Operating at 110% of design feed meeting all product qualities
- Forecast to exceed the catalyst cycle length
Summary – UOP Hydrocracking Technology
Upgrading Fuel Oil to Euro V Fuels

• Licensor of choice for integrated hydrocracking solutions
• Technology to enable the phasing of Iranian bottom of the barrel projects
• Existing hydrocracking units are key enablers for staged investment
• Extensive experience of revamp design to align with existing unit constraints and minimize downtime
• History of partnering with customers for successful bottom of the barrel upgrading projects
The information contained in this presentation is provided for general information purposes only and must not be relied on as specific advice in connection with any decisions you may make.