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Heavy Oil Upgrading Environment
Market and Technology

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Foster Wheeler USA Corporation
Houston, Texas
Market - where are we now?

- Continued economic growth

- After several years of under-investment in oil and gas, refining and petrochemicals, there has been significant growth in new projects

  • Investment has been by international oil companies, national oil companies and independents

And at the same time:

- Continuing investment in non-hydrocarbon sectors, e.g. hotels, airports, housing, ports

- Concurrent industrial investment in Middle East, China and India
This growth in projects has led to:

- Capex risen significantly over the past two to three years – costs still rising, but not at the same rate
- It is not just refining that has experienced this rapid growth – all business lines continue to see upward pressure on costs
- Rising costs has an impact on economics
- However, margins currently remain sufficiently high to support projects in most regions
- Therefore very important to select correct project

Looking at specific drivers to upgrade residues …
Global Heavy Oil & Residue Upgrading Projects Including Those Under Evaluation
Residue upgrading – drivers & routes

Increasing light – heavy crude differential
Declining markets for high sulfur fuel oil
Increased demand for distillates
Extra heavy crude & bitumen upgraders

Residue upgrading & conversion

Catalytic
RFCC
Residue hydrocracking

Non-catalytic
Delayed Coking
Flexicoking
Visbreaking
Solvent deasphalting
Gasification
## Residue upgrading options

<table>
<thead>
<tr>
<th>Visbreaking</th>
<th>Delayed Coking</th>
<th>Flexi coking</th>
<th>Solvent Deasphalting</th>
<th>Residue Hydrocracking</th>
<th>Gasification</th>
<th>Residue FCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low TIC</td>
<td>Moderate TIC</td>
<td>High TIC</td>
<td>Low TIC</td>
<td>High to Very high TIC</td>
<td>Very high TIC</td>
<td>Moderate TIC</td>
</tr>
<tr>
<td>Low conversion</td>
<td>Easy to integrate into refinery</td>
<td>Complex Operation</td>
<td>Expensive product treatment</td>
<td>Complex operation</td>
<td>Needs electricity market</td>
<td>Carbon Residue</td>
</tr>
<tr>
<td>Fuel oil residue</td>
<td>Readily available coke market</td>
<td>Low Btu Gas Challenge</td>
<td>Pitch residue</td>
<td>Large hydrogen demand</td>
<td>and / or Produces syngas / hydrogen</td>
<td>Limited Use with ATB or light residues</td>
</tr>
</tbody>
</table>
Processing schemes

Heavy Oils

- Steam Reformer
  - Nat Gas
- Hydrocrackers/FCC
  - Hydrogen
- Delayed Coker
- PETROPOWER℠
  - Coke
  - CFB Circulating Fluid-Bed Boiler
  - Electric Power
- Light Oils
- Heavy Oils
- Nat Gas
- Electric Power
Processing schemes

Heavy Oils

Delayed Coker / SDA

Hydrocrackers / FCC

Coke / Asphalt

POx Gasification

Combined Cycle

Electric Power

Light Oils

Heavy Oils

CO2

Syngas

IGCC
Processing solutions:
SYDEC$^{SM}$ Delayed Coking
SydecSM Delayed Coking Process
SYDEC℠ coker heaters

Foster Wheeler Double Fired Furnace
- Long heater runs
- Use with on-line decoking techniques
Benefits of delayed coking

• Proven technology
  - Past experience: large available knowledge base on design, operations and maintenance

• Strong 3rd party support services and equipment vendors

• Long turnaround periods: 5 years +

• Excellent margins
  - Fast realisation of project payback

• Anode product coke for low sulphur / metals feed

• Modern designs are safe and clean

• By-product fuel coke is easily marketed
SYDEC℠ - design for safety

- Drum switch Interlocks
- Heater Interlocks
- Advance drum unheading
- HAZOP & management of change
- Structure safety egress
- Structure fire safety systems
- Structure shelters & barriers
- Coke cutting Interlocks
- Relief systems
- Ergonomic layouts

Process & operator safety
Environmental controls

- Fines wetting and containment / collection
- Enclosed blowdown system with recovery of vent vapors and unconverted oils
- Heater NO$_x$ controls
  - SCR; low NO$_x$ burners
- Coke particulates
  - Wind barriers & wetting systems to prevent windage loss
  - Wash stations for mobile equipment
  - Coke handling
    - Enclosed conveyors or tubular conveyors
    - Covered storage ‘barns’ and reclaimers/silos
- Water reuse
- Refinery sludge disposal
Global Pet coke Uses

- By Industrial Application (Courtesy of Oxbow Carbon)

Fuel coke sells at a discount to coal and is a low profit product with no disposal issues.
Processing solutions:
Solvent Deasphalting (SDA)
**Why solvent deasphalting?**

- Physical separation of residues into:
  - Deasphalted oil (DAO)
  - Highly viscous, asphaltene-rich stream (pitch)
- Separation is by density differences
- Light liquid paraffins precipitate asphaltenes and resins from heavy oils
- Non-thermal process
- Separation of DAO and solvent by
  - Subcritical
  - Supercritical
- Can be combined with SYDEC\textsuperscript{SM} for ASCOT process
Why solvent deasphalting?

UOP/FW SDA Process Supercritical Design

Vacuum Residue Charge → Extractor → DAO Separator → DAO Stripper → Pitch Stripper → Pitch → DAO

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Why solvent deasphalting?

Typical extractor operation

- Mixing
- Initial Separation
- Feed Extraction Zone
- Settling Contacting
- DAO

- Feed + Dilution Solvent
- Main Solvent
- Pitch

- Hydroprocessing
- FCC\RFCC
- Hydrocracking
- Coking
- Residual Fuel Oil
- Road Bitumen
- Conventional Combustion
- Fluid Bed Combustion
- Visbreaking
- Gasification
- Coking
ASCOT<sup>SM</sup>: SDA and coking
Processing solutions:
Visbreaking / Thermal Cracking
UOP Foster Wheeler Visbreaking: Technology Overview

- **Mild Thermal Conversion Process**
  - Limited by Product Stability
- **Primarily used to reduce Fuel Oil Cutter Stock**
  - Can produce VB VGO for FCC or Hydrocracker
  - Utilizes relatively low-cost equipment
  - No Hydrogen, low-pressure design
- **Two (2) Types:**
  - Coil - Heater only Conversion
  - Soaker - Heater Plus Soaking Vessel with patented internals
- **Configure with Recycle Gas Oil Thermal Cracking for higher conversion (with or without Vacuum Tower)**
- **High lift Woods technology for increased gas oil production**
Typical Coil Visbreaker Layout

- **Heater**
  - **Feed**
  - **Quench**

- **Fractionator**
  - **Gas + Gasoline**
  - **Distillate Stripper**
  - **Steam**
  - **Light Gas Oil**

- **Resid**
Processing solutions:
Residue Hydrocracking
Residue Hydrocracking Technology

- **Ebullated Bed**
  - Established Process
  - Licensors: CLG, Axens, HRI
  - Achieves 75%+ Conversion with Unconverted Residue stream
  - Expensive

- **Slurry Phase**
  - Developing Technology
  - Nearly complete conversion
  - Licensors & Developers: Eni, PDVSA, UOP, Chevron
  - Very Expensive (?)
Carbon Rejection Processes: Integration With Resid HCR

- Ebullated Bed Resid HCR with Very Heavy Residues Produces Bottoms Pitch Stream
  - **Solvent Deasphalting**
    - Pitch reduction
    - Greater liquid yield
  - **Delayed Coking**
    - Pitch elimination
    - Greater liquid yield
    - Anode coke possibility
Middle East Vacuum Residue (23 CCR) 75% Conversion Residue HCR + Coking

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<tr>
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<tbody>
<tr>
<td>Gas</td>
<td>LV% FOE</td>
<td>4.16</td>
<td>1.48</td>
<td>5.64</td>
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<tr>
<td>C3 / C4</td>
<td>LV%</td>
<td>6.16</td>
<td>1.74</td>
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<tr>
<td>Naphtha</td>
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<td>17.48</td>
<td>3.06</td>
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<td>LGO</td>
<td>LV%</td>
<td>29.47</td>
<td>5.40</td>
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<tr>
<td>HGO</td>
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<td>32.27</td>
<td>6.30</td>
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<tr>
<td>Residue</td>
<td>Wt%</td>
<td>24.36</td>
<td></td>
<td>24.36</td>
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<tr>
<td>Coke</td>
<td>Wt%</td>
<td></td>
<td></td>
<td>9.38</td>
</tr>
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Processing solutions: Gasification
Gasification

Integrated gasification combined cycle

• Partial oxidation of the fuel for syngas production, syngas clean-up (upstream combustion with possible CO₂ removal for EOR) and syngas combustion in a combined cycle unit
• Suitable for both heavy oils and pet coke
• Approx. 100 t/h of pet coke are required to generate 320 MWe complex plant
• Power station with superior environmental performances
• A must if H₂ production may be foreseen in the future
Gasification

Technology Suppliers

- **Solid feed stocks (coal, petcoke):**
  GE Energy, Shell, Conoco Phillips, Siemens, Sasol, Lurgi

- **Liquid feed stocks (heavy oils, asphalts):**
  GE Energy, Shell
Potential Gasification Feeds and Products

Potential feeds:
- Natural Gas
- Refinery Gas
- Residual Oils
- Orimulsion
- Petroleum Coke
- Sewage Sludge
- Waste Oils
- Biomass
- Black Liquor
- Municipal Solid Waste
- Coal

Potential products:
- Oxygen
- Nitrogen
- Argon
- Carbon Dioxide
- Sulphur / Sulphuric Acid
- Steam
- Hot Water
- Electric Power
- Hydrogen
- Carbon Monoxide
- Fertiliser (Ammonia, Urea, Ammonium Nitrate)
- Industrial Chemicals
- Methanol / Ethanol / DME
- Acetic Acid, Acetic Anhydride
- Naphtha
- Diesel
- Jet Fuel
- Wax

Gasification Plant
- Slag for Construction Materials or Metals Recovery

Combined Cycle

Chemical Production

Fischer-Tropsch Synthesis
- Slag for Construction Materials or Metals Recovery

[Diagram showing flow of potential feeds to products through various processes]
Combination of processes

Process Attributes

- Coking completes conversion
- SDA reduces tar stream volume
- Visbreaking reduces distillate demand for Fuel Oil
- Hydrocracking provides high conversion
- Gasification allows complete utilization
Summary

• Growing need for residue conversion processes
  • Heavier feeds
  • Oil sands, Extra-heavy crude oil
  • Regulations
• Range of technologies available
  • Stand-alone
  • In combination

_Foster Wheeler – The Heavy Oils Engineering Company_