PETROBRAS’ Delayed Coking Unit: a new concept

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Current Refining Scenario

- Increase in processing capacity of heavy oil and national oil.
- New profile of oil products demand.
- Demand for high quality products.
- Growth of environmental concerns.
- Growth of biofuel demand.
Typical Petroleum Distillation Curve

Heavy oil: 58 % resid

Light oil: 18% resid
Product Demand
Internal Market / Brazil (1000 bpd)

Increase of 32% compared with 2006
Typical refining scheme
Target to gasoline market and low fuel oil production
Refining scheme

Target to diesel market and low investment

- Marlim 16° API
- Carabobo 16° API (synthetic crude)

What can we expect of a DCU in terms of yields?

Flexibility for future installation of Vacuum Unit and Hydrocracking Unit to attend the market

Scheme of Abreu e Lima Refinery (230,000 bpd)
Pilot Unit Informations
Patent: PI 0603024-6A (Petrobras)

Feed Streams

<table>
<thead>
<tr>
<th>Properties</th>
<th>VR</th>
<th>AR</th>
<th>HVGO</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCR, %wt</td>
<td>15.0</td>
<td>7.3</td>
<td>0.59</td>
</tr>
<tr>
<td>°API</td>
<td>9.5</td>
<td>14.3</td>
<td>18.4</td>
</tr>
<tr>
<td>Sulfur, %wt</td>
<td>0.74</td>
<td>0.67</td>
<td>0.54</td>
</tr>
</tbody>
</table>

Operating Conditions

<table>
<thead>
<tr>
<th>Heater outlet temperature, °C</th>
<th>500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coke Drum pressure, kgf/cm²</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Yields

<table>
<thead>
<tr>
<th>Products</th>
<th>VR</th>
<th>VR + 20% HVGO</th>
<th>AR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel, %v</td>
<td>51.3</td>
<td>52.2</td>
<td>53.5</td>
</tr>
<tr>
<td>HCGO, %v</td>
<td>20.2</td>
<td>23.2</td>
<td>27.7</td>
</tr>
<tr>
<td>Coke, %wt</td>
<td>24.5</td>
<td>20.3</td>
<td>13.5</td>
</tr>
</tbody>
</table>
Pilot Unit Informations
Patent: PI 0603024-6A (Petrobras)

100 AR → VDU → 50 VR → DCU → 50 HCGO (% v/v)
60.1% HGO (% v/v)
20.2 HCGO (% v/v)
24.5 Coke (% wt/wt)
25.7% diesel (% v/v)
12.3 % coke (% wt/wt)

100 AR → DCU → 27.7 HCGO (% v/v)
27.7 HCGO (% v/v)
53.5 Diesel (% v/v)
13.5 Coke (% wt/wt)
12.3 % coke (% wt/wt)
Operating Variables Selection

1. Heavy oil samples
2. Fractionation to obtain the residue
3. Marlim crude
4. Industrial tests
5. Pilot plant tests
6. Premises
7. Results evaluation
8. Refining scheme
9. Operating variables selection
Operating Variables
Coke Drum Pressure

- Heavy gasoil yield
- Middle distillates and coke yields
- Heavy gasoil quality
- Shot coke formation
- Coke drum diameter
- Gas Compressor power

PRESSURE
Operating Variables
Heater Temperature

- Liquids yields
- Coke yield
- VCM content
- Shot coke formation
- Heater tubes coking rate
Operating Variables
Recycle Ratio

<table>
<thead>
<tr>
<th>RECYCLE</th>
<th>Heavy liquid fraction due to feedstock’s cracking.</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="" alt="" /></td>
<td>High boiling point and high carbon residue compared with other coker distillates.</td>
</tr>
<tr>
<td><img src="" alt="" /></td>
<td>When recycle is incorporated into fresh feed, this fraction is cracked one more time while passing through furnace and drum.</td>
</tr>
<tr>
<td><img src="" alt="" /></td>
<td>When recycle isn’t incorporated into fresh feed, it is taken back with HGO, increasing the production of HGO and worsening its quality.</td>
</tr>
</tbody>
</table>

The recycle ratio is defined by the temperature control in the Fractionator bottom.
Operating Variables

Recycle Ratio

- Total distillates yields
- Middle distillates in diesel range
- HCGO quality
- Coke quality
Operating Variables Definition

✓ High Recycle Ratio: > 20% v/v;
✓ High Coke Drum Pressure: 2.0 kgf/cm² g;
✓ High Heater outlet temperature: > 500°C

These conditions meet the main goal of maximizing diesel production and minimizing fuel oil production.
New Petrobras’ DCU to Abreu e Lima Refinery

Capacity: 11,915 m³/d
Driving Forces for New DCU

- Maximizing diesel production.
- Minimizing fuel oil production.
- Minimizing investment cost;
- Minimizing water consumption;
- Minimizing emissions;
- Increase safety and operational continuity.
Reaction and Fractionation Sections

Reaction

Fractionation

150°C  292°C

Heat integration

Administrator
CENPES/EB AB-G&E/CS
Public Information
June-2009
Gas Recovery Section

- Stripped sour water
- High pressure steam produced in the unit

Heat integration

Diagram showing the process of gas recovery with various components such as condensate, light naphtha, gas, sponge oil, rich oil, primary absorber, secondary absorber, naptha stripper, debutanizer, high pressure vessel, and sour water.
Fractionation and Gas Recovery Sections

The designed process scheme meets environmental and operational requirements:

- energy recovery optimization;
- operational stability;
- minimum fresh water consumption;
- flexibility to process:
  - external streams;
  - off spec products.
Fractionation and Gas Recovery Sections

- Heat integration studies based on:
  - tools and softwares like PETROBRAS simulators and others using “pinch technology” concept;
  - PETROBRAS experience in DCU project and operation.

- Upsets due to coke drum batch operation controlled by:
  - project criteria to minimize impacts at Fractionation and Gas Recovery Sections;
  - instrumentation and advanced control tools.
Fractionation and Gas Recovery Sections

- Environmental impact reduced by:
  - minimizing fresh water consumption.
  - actions to meet minimum emissions: closed pump-out system, maximum number of PSV relief aligned to internal DCU systems, etc.
  - processing off-spec products and external streams, minimizing refinery residues generation.
Fractionation and Gas Recovery Sections

- Maximum use of air coolers instead of cooling water exchangers:

<table>
<thead>
<tr>
<th>Heat exchangers</th>
<th>% DUTY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using cooling water</td>
<td>51.7</td>
</tr>
<tr>
<td>Air coolers</td>
<td>25.3</td>
</tr>
<tr>
<td>Using process streams</td>
<td>23.0</td>
</tr>
</tbody>
</table>

- Use of stripped sour water to wash compressor gases.

maximized air cooler use instead of cooling water

heat integration
Closed Blowdown System

- Reduced residue generation from DCU
- Disposal of external slop inside DCU
- Vapour to Fractionator Overhead
- Light Slop Oil to Fractionator
- Refinery Slop
- Heavy Slop Oil to Coke Drum
- Quench (Steam / Water)
- Heavy Gasoil
- OIL/WATER SEPARATOR DRUM
- BLOWDOWN TOWER
- SLOP DRUM
- Sour Water to Treatment
Closed Blowdown System

Main goals
- Receiving coke drum effluent from steam purge and water quench steps.
- Recovering steam and hydrocarbon vapors as sour water, gas and slop oil streams to be processed in DCU:
  • minimizing residue generation.

Main design and operation issues:
- Formation of water/oil emulsion phase.
- Separation of hydrocarbon streams in order to enable the best routing inside DCU.
Closed Blowdown System

- Desing improvements
  - Defined pressure and temperature profile in order to improve heavy and light slop oil fractionation:
    - better reuse of these streams in DCU, recovering them as distillate products.
  - Blowdown designed to damp fluctuation of light and heavy slop oil production:
    - minimum upset at Fractionator operation.
  - Disposal of refinery residue in the Blowdown.
Closed Blowdown System

Desing improvements

- Operating temperature that minimizes emulsion formation:
  - significant reduction of mechanical damage risk caused by severe water vaporization inside Fractionator and coke drum overhead line.
- Off-line coke drum effluent quenched mainly by the heavy slop oil recovered in this system:
  - reduction of residue generation.
- Maximized air cooler use.
Closed Blowdown System

Heavy slop oil to quench vapors from off-line coke drum
Conclusions

The new Petrobras’ Delayed Coking Unit considers:

- Operating conditions in order to maximize diesel production.
- Operational stability by the use of advanced control tools.
- Strong heat integration, reducing utilities consumption.
- Reduced slop and waste generation.
- Flexibility to process refinery residue and off-spec products.