Compare the different options for NGL Recovery from Natural Gas

Henri Paradowski, Andre Le Gall and Benoît Laflotte
Process Division Technip France

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1 Market
2 Gas and NGL chains from wellhead to the consumer
3 Dehydration: Mol sieves or TEG?
4 Ethane recovery: which process?
5 NGL fractionation: how to save energy?
6 NGL refrigeration: which cycle use?
1. Market driven?

- Gas / NGL's market prices translate into an extraction margin in the US
- Similar situation in North Sea
- C₃ / C₄'s recovery justified in most instances
- C₂ recovery only worth if a petro-chemical market is at hand

Sources: EIA / Barnes and Click
2. Gas and NGL chains: from wellhead to the consumer

- **Plant complexity function of**
  - Gas characteristics and targeted products
  - Plant geographical location

- **Example: Western Libya Gas Project**
  - Treated Gas / Treated Crude / Propane / Butane
  - Onshore
    - Wafa Desert Plant: Gas Sweetening, Liquids extraction (blended with stabilized Crude)
    - Oil and Gas Pipeline to coast (over 500 km)
    - Liquids fractionation at Wafa Coastal Plant
  - Offshore
    - Gas and Condensate sent to shore (Mellitah) for treatment and fractionation.

*Source: ENI web site (Investor Relations), October 2004*
3. Pre-treatment options: focus on dehydration

### 3.1 Hydrates formation temperature

<table>
<thead>
<tr>
<th>Water content ppm mole</th>
<th>Natural gas at 62 bar</th>
<th>Natural gas at 30 bar</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>-20</td>
<td>-26</td>
</tr>
<tr>
<td>10</td>
<td>-27</td>
<td>-32</td>
</tr>
<tr>
<td>5</td>
<td>-33</td>
<td>-39</td>
</tr>
<tr>
<td>2</td>
<td>-42</td>
<td>-47</td>
</tr>
<tr>
<td>1</td>
<td>-49</td>
<td>-53</td>
</tr>
<tr>
<td>.5</td>
<td>-55</td>
<td>-59</td>
</tr>
<tr>
<td>.2</td>
<td>-64</td>
<td>-66</td>
</tr>
<tr>
<td>.1</td>
<td>-70</td>
<td>-72</td>
</tr>
</tbody>
</table>
3. Pre-treatment options: focus on dehydration

3.2 Mole Sieves: a standard option for deep NGL recovery

- Achieve 0.1 ppm water content
- Capital intensive and energy intensive
- May be troublesome in operation
- Design with care
  - Upstream separation of utmost importance,
  - Regeneration sequence to be carefully studied,
  - Mole sieve binder to be carefully selected.
3. Pre-treatment options: focus on dehydration

3.3 TEG dehydration: a valid option in most cases

- Achieve 1 to 10 ppm water content in dry gas
- Minimizes CAPEX and OPEX
- Less maintenance and operational issues
- Design Issues
  - Sensitive to Absorber feed gas temperature
  - Design Absorber with vendor of internals: packing, distributors,..
  - Design outlet separators to avoid TEG carry over
  - Pure TEG melting point is –5 °C
3. Pre-treatment options: focus on dehydration

### 3.4 TEG dehydration sensitivity: dehydration at 62 bars

<table>
<thead>
<tr>
<th>Natural gas Temperature °C</th>
<th>Number of stages</th>
<th>TEG water content % weight</th>
<th>Dry gas water content ppm mole</th>
</tr>
</thead>
<tbody>
<tr>
<td>34</td>
<td>4</td>
<td>0.1</td>
<td>6.3</td>
</tr>
<tr>
<td>24</td>
<td>3</td>
<td>0.1</td>
<td>4.0</td>
</tr>
<tr>
<td>24</td>
<td>4</td>
<td>0.1</td>
<td>2.9</td>
</tr>
<tr>
<td>24</td>
<td>4</td>
<td>0.2</td>
<td>5.5</td>
</tr>
</tbody>
</table>
4. Ethane recovery: which process choose

■ 4.1

- Propane market accepts additional low sulfur LPG
- No world wide Ethane market
- Ethane production: constant or Variable?
- Feed Gas and Sales gas constant or variable?
4. NGL Recovery process: Constant Ethane

4.2 Constant Ethane with variable Feed Gas

- Situation met in Europe: Lacq from 1987 to 2000
  - High sales production during winter and reduced gas production in summer, constant ethane production to meet the ethylene production

- Option 1: reject
- Option 2: modify recovery rate

- Dual Reflux Process is an attractive solution:
Single Reflux Ethane Recovery

Ethane recovery 72.4% : 47900 kg/h
Power 180 kW.h / t NGL

7600 kW
738 mmscfd
23600 kW

738 mmscfd

60 bar
34°C

25 bars
-94°C

7600 kW

129700 kg/h

NGL (C2+)

GT

Sales gas

Feed gas

60 bar

800 mmscfd

-34°C

E1

K1

K2

C1

E2

V1

Power 180 kW.h / t NGL

Ethane recovery 72.4% : 47900 kg/h
Ethane recovery: 84.8% 49100 kg/h
Power 195 kW.h / t NGL

Dual Reflux Ethane Recovery

Feed gas
60 bar

T1
K1
K2

7100 kW
725 mm Scf/d
23600 kW

recycle

Sales gas
641 mm Scf/d
60 bar

GT
25 bars
-99°C

C1
121200 kg/h

NGL (C2+)
700 mm Scf/d

E1
V1
-34°C

Ethane recovery: 84.8% 49100 kg/h
Power 195 kW.h / t NGL
Dual Reflux Ethane Recovery

Ethane recovery: 96% 47,650 kg/h
Power: 215 kW.h/t NGL

- Feed gas: 60 bar, 600 mmscfd
- T1: 25 bars, -102°C
- K1: 6800 kW
- K2: 168 mmscfd, 714 mmscfd, 23,400 kW
- E1: -34°C
- E2: recycle
- GT: 60 bar
- Sales gas: 546 mmscfd
- C1: 25 bars, -102°C
- NGL (C2+): 109,500 kg/h
- Power: 6,800 kW
- 546 mmscfd
- 168 mmscfd, 714 mmscfd, 23,400 kW
- 25 bars, -102°C
- 109,500 kg/h
- Power: 6,800 kW
Multiple Reflux Ethane Recovery

Ethane recovery 88.6% 51300 kg/h
Power 191 kW.h / t NGL

Feed gas 700 mmscfd

7100 kW

84 mmscfd
724 mmscfd
23600 kW

recycle

640 mmscfd
Sales gas

60 bar

25 bars
-100°C

123400 kg/h
NGL (C2+)

GT

C1

V1 -34 °C

V2

E1

E2
4. Ethane recovery : Variable Ethane production

4.3 Variable Ethane (with constant Feed Gas)

- **Option 1**: recover $C_2$ and reject $C_2$ to sales gas
  - Effective easy to operate but costly in fuel

- **Option 2**: limit recovery and possibly loose some $C_3$
  - Easy to operate but not economic if $C_3$ price is high

- **Option 3**: switch from a high $C_2$ recovery scheme to a low $C_2$ and high $C_3$ recovery scheme
  - Efficient but needs skilled operators

- **Option 4**: change operating conditions: slowly go from a high $C_2$ recovery to low $C_2$ and high $C_3$ recovery
  - Efficient and easy to operate but higher CAPEX
4. The ethane recovery dilemma

4.4 Conclusion

■ To choose the best scheme
  ● The different options have to be compared
  ● Some options shall be left open in design competition for LSTK
  ● Client has to evaluate different production scenarios

■ It is always possible to modify a Propane recovery scheme to obtain an Ethane recovery scheme
  ● Some provisions have to be taken
5. NGL Fractionation: an energy sink

5.1 Observation

- High energy demand for NGL fractionation

Example in Jose, Venezuela

<table>
<thead>
<tr>
<th></th>
<th>Duty Reboiler (kW)</th>
<th>Product (t/h)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Deethaniser</td>
<td>21700</td>
<td>65</td>
<td>Ethane</td>
</tr>
<tr>
<td>Depropaniser</td>
<td>17800</td>
<td>80</td>
<td>Propane</td>
</tr>
<tr>
<td>Debutanizer</td>
<td>11500</td>
<td>45</td>
<td>C5+</td>
</tr>
<tr>
<td>C4 Splitter</td>
<td>20000</td>
<td>55</td>
<td>i+n C4</td>
</tr>
<tr>
<td>TOTAL</td>
<td>71000</td>
<td>245</td>
<td></td>
</tr>
</tbody>
</table>

Reboiling Heat
300 kW.h / t of NGL
Fuel 360 kW.h / t of NGL

5.2 Solutions to minimize this energy consumption

- Study heat integration
- Combine fractionation with cogeneration
5. NGL Fractionation: an energy sink

5.3 NGL Fractionation with Heat Integration

- Ethane 65 t/h
- Propane 80 t/h
- i-Butane 20 t/h
- n-Butane 35 t/h

NGL Feed 245 t/h

Deethaniser

Depropaniser

Debutaniser

C4 splitter

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5. NGL Fractionation: an energy sink

5.4 NGL Fractionation with Cogeneration

NGL Feed 245 t/h

- Deethaniser
- Depropaniser
- Debutaniser
- C4 splitter

- LP Steam
- LP Steam
- LP Steam
- LP Steam

- Ethane 65 t/h
- Propane 80 t/h
- C5+ 45 t/h
- n-Butane 35 t/h

- i-Butane 20 t/h
5. NGL Fractionation: an energy sink

5.5 Cogeneration

- **Boiler(s)**
  - 110 t/h
  - 63 bar abs
  - 440°C

- **Preheaters**
  - 150°C

- **Reboilers**
  - 5 bar abs

- **G 14 MW**
## 5.6 Comparison

<table>
<thead>
<tr>
<th></th>
<th>No integration</th>
<th>Process integration</th>
<th>Cogeneration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highest column bottom temperature (°C)</td>
<td>125°C</td>
<td>170°C</td>
<td>125°C</td>
</tr>
<tr>
<td>Heating Medium for reboilers</td>
<td>Hot Water</td>
<td>Hot Oil</td>
<td>LP Steam</td>
</tr>
<tr>
<td>Fuel consumption kW</td>
<td>88 000</td>
<td>88 000</td>
<td>88 000</td>
</tr>
<tr>
<td>Electrical Power Production kW</td>
<td>N/A</td>
<td>N/A</td>
<td>14 000</td>
</tr>
<tr>
<td>Efficiency</td>
<td>N/A</td>
<td>N/A</td>
<td>high</td>
</tr>
<tr>
<td>Possible use of GT exhaust gases</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>CAPEX</td>
<td>low</td>
<td>medium</td>
<td>high</td>
</tr>
</tbody>
</table>
6. C\textsubscript{3} Refrigeration and Atmospheric Storage: which cycle?

- 6.1 : 3 options considered

- \(C_3\) Boil Off Gas compressor, closed propane loop and \(C_3\) compressor with 1st stage suction under vacuum,

- \(C_3\) Boil Off Gas compressor, closed propane loop and \(C_3\) compressor with 1st stage suction above atmospheric pressure,

- Semi open propane loop, single propane compressor with suction at atmospheric pressure, for Boil Off Gas and \(C_3\) refrigerant.
6. C₃ Refrigeration and Atmospheric Storage: which cycle?

6.2 Closed Loop

Overall Power Consumption: 5700 kW

Propane

Rundown
160 t/h

8.5 bar

2.4 bar

0.7 bar

1.3 t/h

Propane BOG

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6. C₃ Refrigeration and Atmospheric Storage: which cycle?

6.3 Semi-Open Loop
Overall Power Consumption: 5400 kW

Propane

8.9 bar

2.7 bar

1.0 bar

Propane BOG

10 t/h

Propane Rundown
160 t/h

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## 6. C₃ Refrigeration and Atmospheric Storage: which cycle?

### 6.4 Comparison

<table>
<thead>
<tr>
<th></th>
<th>CLOSED LOOP Vacuum</th>
<th>CLOSED LOOP Atmospheric</th>
<th>SEMI-OPEN Atmospheric</th>
</tr>
</thead>
<tbody>
<tr>
<td>LP C3 Suction Pressure</td>
<td>0.7 bar a</td>
<td>1.2 bar a</td>
<td>1.0 bar a</td>
</tr>
<tr>
<td>CAPEX</td>
<td></td>
<td></td>
<td>lower</td>
</tr>
<tr>
<td>Safety</td>
<td></td>
<td>good</td>
<td></td>
</tr>
</tbody>
</table>
7. Conclusion

- **To design, build and operate the best NGL plant**
  - Many options are available and have to be compared

- **Success factors**
  - Understand the requirements
  - Operability comes first

- **Collaboration between Client-Contractor-Suppliers**