Offshore platform FEED

Yutaek Seo
Processing in offshore platforms
CPF Process General

Reservoir

- Oil Fluid (Black / Volatile Oil)

Wellbore

- Crude Oil
- Associated Gas
- Produced Water

HC Products

- Stabilized Oil
- Sales Gas
- Re-injection Gas
- Water Disposal
- Re-injection Water

Gas Fluid (Dry / Wet / Retrograde Gas)

- Gas
- Condensate
- Produced Water

- Sales Gas
- LPG (C3 & C4)
- Stabilized Condensate
- Water Disposal

Water Disposal
Typical CPF: Oil Field

1. Slug Catcher
2. Compression to HP
3. Compression to MP
4. MP Separator
5. LP Separator
6. De-salter System
7. Oil Stabilizer
8. Gas Sweetening
9. Gas Dehydration
10. Gas Refrigeration
11. Gas Exporting

- For Dew Point Control
- Re-injection for IOR / EOR or gas lifting
- Stabilized oil to tank

Streams:
- Blue: Gas Stream
- Gray: Liquid HC stream
- Black: Well Fluid Stream

- Oil Well-fluid
- Sales gas
Typical CPF: Gas Field (1)

Gas Sweetening → Gas Dehydration → Gas Refrigeration → Gas Exporting

For Dew Point Control

 Slug Catcher → Compression to HP

Condensate Stabilizer

Inlet Separator

Gas Stream

Liquid HC stream

Well Fluid Stream

Sales gas

Stabilized condensate to tank
Typical CPF: Gas Field (2)

- Gas Sweetening
- Gas Dehydration
- Gas Refrigeration
- Gas Exporting
- Slug Catcher
- Compression to HP
- Inlet Separator
- Condensate Stabilizer
- NGL Recovery

For NGL Recovery:

- Sales gas
- LPG
- Stabilized condensate to tank

Gas Well-fluid

Gas Stream

Liquid HC stream

Well Fluid Stream
Liquid Slug Problem : Normal Operation

SARB-4_Subsea Flow-line (Length = 33 km)

Inlet Flow Rate (11,562 STB/d)
Liquid Slug Problem: Pigging

SARB-4_Subsea Flow-line (Length = 33 km)

Pigging Operation / Liquid Flow Rate [bbl/d] / CPF Entrance

Severe Slugging
For Accommodation of Liquid Slug

Control vs. Big vessel

Slug Catcher → GOOOOD

Slug Catcher?

Control?
Process flow for separation

Well Fluid

HP SEPARATOR

Gas

Compr

To Flare

Surge Tank

Gas Dehydration

Export Gas

Lift Gas

Prod Water

Produced Water

Prod Wtr Conditioner

Overboard

Main Oil Line

Pump

OIL Export

OIL
Separation trains

Separation of oil, gas, and water
Multi Stage Separator

1) It is preferred for “Crude oil separation and stabilization”.

Stabilization Column

1) It is preferred for “Condensate stabilization”.
2) It is used for “Oil Stabilization” for $H_2S < 50$ ppm and lower RVP.

$R = \left( \frac{P_d}{P_i} \right)^{-1/n}$

where $R = \text{ratio per stage}$

$P_d = \text{discharge pressure, psia}$

$P_i = \text{suction pressure, psia}$

$n = \text{number of stages}$

Stage Separation Guidelines

<table>
<thead>
<tr>
<th>Initial Separator Pressure, psig</th>
<th>Number of Stages*</th>
</tr>
</thead>
<tbody>
<tr>
<td>25–125</td>
<td>1</td>
</tr>
<tr>
<td>125–300</td>
<td>1–2</td>
</tr>
<tr>
<td>300–500</td>
<td>2</td>
</tr>
<tr>
<td>500–700</td>
<td>2–3**</td>
</tr>
</tbody>
</table>

* Does not include stock tank.

** At flow rates exceeding 100,000 bopd, more stages may be appropriate.
Example for Oil Stabilization

SARB-4 Project (Oil Reservoir)

1. Multistage separation + Stabilization column (stripper type)
2. Design for 1) maximized oil production and 2) minimized H₂S ppm
3. Heavy condensate was used for striping un-stabilized oil → for preventing scale problems in the reboiler
Example for Condensate Stabilization

**Touat-Gaz Project (Gas Reservoir)**

- From Inlet Separators
- From Comp.
- From TEG Inlet Scrub.
- To Produced Water Treatment
- To Stabilized Condensate
- From Cold Separator
- To Recycled Gas
- To Produced Water Treatment

**MIDYAN Project (Gas Reservoir)**

- From Inlet Separators
- From Comp.
- From TEG Inlet Scrub.
- From Cold Separator
- From Slug Catcher.
- To Stabilized Condensate
- To Produced Water Treatment
- To Recycled Gas

**Note 1)** Touat-Gaz CPF does not have Slug Catcher.
Example for Condensate Stabilization

**Touat-Gaz Project (Gas Reservoir)**

Stabilized Condensate (RVP = 6.3 psia)

- From Inlet Separators
- From Comp.
- From TEG Inlet Scrub.
- From Cold Separator

- 44 °C
- 95 °C
- API 66
- 10 barg
- 200 °C

**MIDYAN Project (Gas Reservoir)**

Stabilized Condensate (RVP = 6.3 psia)

- From TEG Inlet Scrub.
- From Comp.
- From Cold Separator
- From Slug Catcher.

- 22 °C
- -10 °C
- 0.1 °C
- 35 °C
- 126 °C
- 9 barg
- 188 °C
Crude oil export via tanker
Water treatment
Gas collection and compression
## Gas Dehydration Unit (1)

### Factors to Determine Dehydration Method
- Initial water content of the feed
- Water spec of dried gas
- Process character
- Operational nature
- Economic aspect

<table>
<thead>
<tr>
<th>Method</th>
<th>Compression and Cooling</th>
<th>Absorption (TEG)</th>
<th>Adsorption (Molecular Sieve)</th>
<th>Membrane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>low</td>
<td>moderate</td>
<td>high</td>
<td>low</td>
</tr>
<tr>
<td>Water Spec.</td>
<td>-</td>
<td>10 ppmv</td>
<td>0.1 ppmv</td>
<td>20 ppmv</td>
</tr>
<tr>
<td>Dew Point Spec.</td>
<td>38 °C</td>
<td>-32 °C</td>
<td>-100 °C</td>
<td>-</td>
</tr>
<tr>
<td>Regen. T</td>
<td>-</td>
<td>191~204 °C</td>
<td>200~315 °C</td>
<td>-</td>
</tr>
<tr>
<td>Application</td>
<td>Field use</td>
<td>Most widely use</td>
<td>Cryogenic process</td>
<td>Offshore process</td>
</tr>
<tr>
<td>Advantage and Disadvantage</td>
<td>- Simple</td>
<td>- Economic</td>
<td>- Can obtain the lowest</td>
<td>- Light</td>
</tr>
<tr>
<td></td>
<td>- Cannot remove the</td>
<td>(glycol cost is relatively</td>
<td>water content</td>
<td>- Modular</td>
</tr>
<tr>
<td></td>
<td>water enough</td>
<td>cheap)</td>
<td>- Cost high</td>
<td>- Only</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>economic for</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>low feed flow</td>
</tr>
</tbody>
</table>

- Simple
- Cannot remove the water enough
- Economic (glycol cost is relatively cheap)
- Can obtain the lowest water content
- Cost high
- Light
- Modular
- Only economic for low feed flow
Gas Dehydration Unit (2)

For TEG Dehydration Unit Design

1. Determine Lean TEG Inlet Flow Rate (2 – 5 gal / removed water lb)
2. Determine Lean TEG Concentration
3. Determine introducing Gas Stripper or DRIZO

Most of the CPFs use TEG

Absorption (TEG)

- Economic (glycol cost is relatively cheap)

Adsorption (Molecular Sieve)

- Can obtain the lowest water content
- Cost high

Membrane

- Light
- Modular
- Only economic for low feed flow

Absorption

- moderate
- 10 ppmv
- -32 °C
- 191~204 °C

Adsorption

- high
- 0.1 ppmv
- -100 °C
- 200~315 °C

Cryogenic process

Offshore process

Advantage and Disadvantage

- Simple
- Cannot remove the water enough

Field use
Gas dehydration
Dew point control via refrigeration

- Refrigeration

  The most common method used for gas dew point control is mechanical refrigeration. This technology is suited especially when pressure is not available to be used to self-refrigerate the gas.

  Two variations exist of this process. One that recycles the stabilizer overhead to the front end of the plant, used to maximize the recovery of certain components, and a second that re-injects the stabilizer overhead in the residue gas stream.
• **J-T valve**
  - If the raw gas is at high pressure, the removal of hydrocarbons can be accomplished by refrigeration obtained through the expansion of gas by means of a Joule-Thomson valve.
  - Injection of glycol is required to prevent the formation of hydrates.
• **Turboexpander**
  : This process is a variation of the Low Temperature Separation process in which the pressure hold in the gas is used to move an expander turbine, which in the isoentropic expansion generates refrigeration and exports mechanical work.
  : This work is used to drive a compressor to partially restore the gas pressure.
In the CPF, NGL recovery unit plays a role of LPG extraction from Gas / Condensate
Design approach

Client Requirements & Onshore or Offshore?

Main Product (sales gas / stabilized oil / LPG) & EOR (or IOR) & CCS?

1) EOR: Enhanced Oil Recovery
2) IOR: Improved Oil Recovery

Well Test Data Analysis (Fluid / Flowing P & T)

Block Flow Diagram Completion

Process and Equipment Design / PFD & PID ...

CPF Design Completion
# Project Comparison

<table>
<thead>
<tr>
<th>Project</th>
<th>Reservoir Fluid</th>
<th>Product</th>
<th>IOR ¹) / EOR ²)</th>
<th>CCS ³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SARB-4 (UAE_Abu dhabi)</td>
<td>Oil</td>
<td>Stabilized Oil Reinjection Gas</td>
<td>Y (Gas/Water Injection)</td>
<td>N</td>
</tr>
<tr>
<td>TouatGaz (Algeria)</td>
<td>Gas</td>
<td>Sales Gas</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>MIDYAN (Saudi)</td>
<td>Gas</td>
<td>Sales Gas</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>AKKAS (Iraq)</td>
<td>Gas</td>
<td>Sales Gas</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>RHIP (Oman)</td>
<td>Gas</td>
<td>Sales Gas</td>
<td>Y (SG Injection)</td>
<td>Y ⁴)</td>
</tr>
</tbody>
</table>

Note ¹) IOR means “Improved Oil Recovery” as technology for 2nd and 3rd recovery

Note 2) EOR means “Enhanced Oil Recovery” as technology for 3rd recovery

Note 3) CCS means “Carbon Capture & Storage”

Note 4) RHIP process includes CO₂ EOR facilities for another oil field. CO₂ EOR plays a role of CO₂ storage role as well as enhanced production.
Ex. SARB-4 (Client: ADMO-OPCO / Abu Dahbi)

**CPF (Central Processing Facilities)**

- **Work-scope**
  1. Process Design on CPF (Zirku Island)
  2. Process Design on Artificial Islands
  3. Hydraulics on subsea pipeline
  4. Flow assurance on subsea pipelines

- **Product (CPF)**
  1. Stabilized oil (200,000 STB/d)
  2. Reinjection gas and fuel gas
  3. Reinjection water (sea water)

**Artificial Islands**

- **44 Wells**
- **42 Wells**

**Water Injection**

**Water Depth In SARB Field**

- 13.2m to 15.7m

*Artificial Islands play a role of WHP.*

Source: “Process Description”, SARB-4 FEED PKG
Ex. SARB-4 Project (Client: ADMO-OPCO)

1st Gas Compression

Gas Dehydration

2nd Gas Compression

3rd Gas Compression

Gas Sweetening

Fuel gas

Condensate Processing

Vapor Recovery

Gas (< LP)

0.3 - 0.5 barg

Stabilized oil to tank

30 barg

Oil Well fluid

8.3 barg

MP Separator

70 barg

7 barg

1 barg

Oil Stabilizer

414 barg

For IOR

Re-injection

Slug Catcher

Compression to HP

Compression to MP

De-salter System

Produced Water Treating

Sea Water Treating for IOR

Ex. SARB-4 Project (Client: ADMO-OPCO)
AKKAS Gas Field Project

Work-scope
1. Process Design on CPF
2. Hydraulics on Flowline / Trunkline / Export PL
3. Flow assurance on Flowline / Trunkline / Export PL

Product (CPF)
1. Sales Gas (480 MMSCFD)
2. LPG (8.3 MBPD)
3. Stabilized Condensate (16.8 MBPD)

Source: "Gathering System Design Philosophy", P99065-S00-PHIL-U-02, AKKAS CPF FEED Document
### Product Specification

#### Sales Gas Specification

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Dew Point @ 70 barg</td>
<td>°C</td>
<td>-12</td>
</tr>
<tr>
<td>Hydrocarbon Dew Point @ 70 barg</td>
<td>°C</td>
<td>-8</td>
</tr>
<tr>
<td>H₂S Content</td>
<td>ppm</td>
<td>7.5 max</td>
</tr>
<tr>
<td>RSH (Mercaptans) Content</td>
<td>ppm</td>
<td>15 max</td>
</tr>
<tr>
<td>CO₂ Content</td>
<td>vol %</td>
<td>2.5 max</td>
</tr>
</tbody>
</table>

#### LPG Specification

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RVP (Summer)</td>
<td>kPa</td>
<td>800</td>
</tr>
<tr>
<td>RVP (Winter)</td>
<td>kPa</td>
<td>1,000</td>
</tr>
<tr>
<td>Ethane</td>
<td>vol %</td>
<td>0.6 max</td>
</tr>
<tr>
<td>C₅+</td>
<td>vol %</td>
<td>2 max</td>
</tr>
<tr>
<td>Sulphur Content</td>
<td>mg/m³</td>
<td>343 max</td>
</tr>
<tr>
<td>Water Content</td>
<td>-</td>
<td>0 (water free)</td>
</tr>
</tbody>
</table>

#### Stabilized Condensate Specification

→ 9.6 psia (0.66 bara)
Gas processing concept

- Slug Catcher
- Inlet Separator
- Gas Dehydration
- Gas Refrigeration
- Gas Exporting
- Condensate stabilizer
- Stabilized Condensate
- Fuel Gas
- Sales Gas

- Blue arrows represent Gas Stream.
- Gray arrow represents Liquid HC stream.
- Black arrow represents Well Fluid Stream.
1. Slug Size 40 m³
2. No compositional Model
3. No transient analysis

1. De-C2 is possible to become “Condensate Stabilizer” role.
2. Condensate stabilizer for FCP-2015 is not needed.
3. RVP should be reduced from 9.6 to 6.3 psia.
1. Slug Size 40 m³
2. No compositional Model
3. No transient analysis

Flash gas compressor capacity is significantly in excess.

Free Water Formation (Pressure increase required)
## Comparison with FEED Design

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>FCP-2015</th>
<th></th>
<th>PP-2017</th>
<th></th>
<th>PP-2030</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>FEED</td>
<td>Alter</td>
<td>FEED</td>
<td>Alter</td>
<td>FEED</td>
<td>Alter</td>
</tr>
<tr>
<td><strong>LPG</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RVP</td>
<td>[kPa]</td>
<td>-</td>
<td>-</td>
<td>851.8</td>
<td>844.7</td>
<td>815.5</td>
<td>815.5</td>
</tr>
<tr>
<td>$C_2$-</td>
<td>[%]</td>
<td>-</td>
<td>-</td>
<td>0.35</td>
<td>0.37</td>
<td>0.23</td>
<td>0.37</td>
</tr>
<tr>
<td>$C_5^+$</td>
<td>[%]</td>
<td>-</td>
<td>-</td>
<td>1.60</td>
<td>1.61</td>
<td>1.57</td>
<td>1.60</td>
</tr>
<tr>
<td>Product Rate$^1)$</td>
<td>[t/d]</td>
<td>-</td>
<td>-</td>
<td>567</td>
<td>532</td>
<td>546</td>
<td>525</td>
</tr>
<tr>
<td><strong>Stabilized Condensate</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product Rate</td>
<td>[t/d]</td>
<td>530</td>
<td>526</td>
<td>1,747</td>
<td>1,743</td>
<td>732</td>
<td>717</td>
</tr>
</tbody>
</table>

Note 1) LPG production should be guaranteed as over 500 ton/d at the begging of PP-2017.
Comments from the client,

1) LPG RVP unit must be revised from \textit{psia} to \textit{kPa}.

2) LPG product must consider $C_3/C_4$ ratio according to production season.

\begin{tabular}{|c|c|l|l|}
\hline
\textbf{LPG} & \textbf{Unit} & \textbf{Before the revision} & \textbf{After the revision} \\
\hline
\multicolumn{2}{|c|}{RVP} & \multicolumn{2}{|l|}{} \\
\hline
 & - & (S) 800 psia (55 bar) & (S) 800 kPa \\
 &  & (W) 1,000 psia (68 bar) & (W) 1,000 kPa \\
\hline
\multicolumn{2}{|c|}{$C_2^-$} & 0.6 & 0.6 \\
\hline
\multicolumn{2}{|c|}{$C_{5^+}$} & 2.0 & 2.0 \\
\hline
\multicolumn{2}{|c|}{$C_3$} & No limitation & (S) 30 – 40 \\
 &  &  & (W) 60 – 70 \\
\hline
\multicolumn{2}{|c|}{$C_4$} & No limitation & (S) 60 – 70 \\
 &  &  & (W) 30 – 40 \\
\hline
\multicolumn{2}{|c|}{$C_3/C_4$} & No limitation & (S) 0.43 – 0.67 \\
 &  &  & (W) 1.50 – 2.33 \\
\hline
\end{tabular}
For client request (1) : LPG RVP unit must be revised. ((S) 800 psia, (W) 1,000 psia)

- $C_2$ removal in LPG is useless for revised RVP.
- $C_3$ content in LPG must be reduced for revised RVP.

For client request (2) : LPG product must consider $C_3/C_4$ ratio according to production season.

- Operation condition and a method for reducing $C_3$ and increasing $C_4$ should be devised.
Modification of the process

Before Revision

Gas Dehydration → Gas Refrigeration → Gas Exporting

Slug Catcher → Inlet Separator

De-C$_2$ System → De-C$_4$ System

Fuel Gas → LPG

Sales gas → Stabilized Condensate

Gas Stream
Liquid HC stream
Well Fluid Stream
Solution Devised for Client Requests

After Revision

1. Slug Catcher
2. Gas Dehydration
3. Gas Refrigeration
4. Gas Exporting
5. Inlet Separator
6. Condensate Stabilizer
7. De-C\textsubscript{2} System
8. De-C\textsubscript{4} System

- **Gas Stream**
- **Liquid HC stream**
- **Well Fluid Stream**

- Sales gas
- Fuel Gas
- LPG

For soluble water removal

Production (S) 505 ton/d
(W) 570 ton/d
Solution Devised for Client Requests

Lean TEG, 99.99 wt%
DRIZO Required for Lean TEG

Fuel Gas
Sales Gas 480 MMSCFD
Export Gas Compressor
Flash Gas Compressor

Slug Catcher
Oily Water
Inlet Separator
Produced Water

Condensate Stabilizer
De-C2
De-C4
Stabilized Condensate

De-C2 Reboiler
Duty (S) : 14.5 MW
Duty (W) : 8.8 MW

De-C4 Reboiler
Duty (S) : 10.6 MW
Duty (W) : 2.7 MW

Cond Sta Reboiler
Duty (S) : 8.4 MW
Duty (W) : 9.4 MW

Summer C3 Rec. : 0.19
C4 Rec. : 0.81
Winter C3 Rec. : 0.81
C4 Rec. : 0.94

Reflex Ratio
(S) 5.41
(W) 1.03

Production
(S) 505 ton/d
(W) 570 ton/d

480 MMSCFD

Chiller
Duty (S) : 14.1 MW
Duty (W) : 10.2 MW

52 barg

30 barg
(S)-42 °C / (W)-38 °C

Lean TEG, 99.99 wt%

Cond Sta Reboiler
Duty (S) : 8.4 MW
Duty (W) : 9.4 MW

Unstabilized Condensate

1st Cooled FS

DRIZO Required for Lean TEG
## Products summary

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>Required Spec.</th>
<th>PP-2017 FEED</th>
<th>Solution Devised</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LPG</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RVP</td>
<td>[kPa]</td>
<td>(S) 800 (W) 1,000</td>
<td>851.8</td>
<td>(S) 692 (W) 897</td>
</tr>
<tr>
<td>C&lt;sub&gt;2-&lt;/sub&gt;</td>
<td>[%]</td>
<td>0.6</td>
<td>0.35</td>
<td>(S) About 0.00 (W) 0.35</td>
</tr>
<tr>
<td>C&lt;sub&gt;5+&lt;/sub&gt;</td>
<td>[%]</td>
<td>2</td>
<td>1.60</td>
<td>(S) 1.61 (W) 1.61</td>
</tr>
<tr>
<td>Product Rate</td>
<td>[t/d]</td>
<td>&gt; 500 @ PP-2017</td>
<td>567</td>
<td>(S) 505 (W) 570</td>
</tr>
<tr>
<td>C&lt;sub&gt;3&lt;/sub&gt;/C&lt;sub&gt;4&lt;/sub&gt;</td>
<td></td>
<td>(S) 0.43 – 0.67 (W) 1.50 – 2.33</td>
<td></td>
<td>(S) 0.66 (W) 1.65</td>
</tr>
<tr>
<td><strong>Stabilized Condensate</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RVP</td>
<td>[psia]</td>
<td>9.8</td>
<td>6.433</td>
<td>(S) 6.400 (W) 6.400</td>
</tr>
<tr>
<td>Product Rate</td>
<td>[t/d]</td>
<td>-</td>
<td>1,747</td>
<td>(S) 1,770 (W) 1,754</td>
</tr>
</tbody>
</table>

- Devised solution is good to satisfy all requirements
For LPG product spec. (satisfying production rate, $C_3$/$C_4$ value, RVP and so on)

- *De-C$_2$* inlet fluid should be cooled for higher $C_3$ and $C_4$ recovery.
- $C_3$/$C_4$ and RVP control can be *De-C$_2$* re-boiler duty control and *De-C$_3$* reflux ratio.

For stable operation (preventing hydrate, water freezing and free water),

- *Water content in dehydrated gas should be 2 – 3 ppm (about 0.1 lb/mmscf).* (DRIZO)
- *Condensate stabilizer should be introduced.*
Thank you!