Who we are

- Resource Investment Strategy Consultants
- RISC is a truly independent advisory firm.
- We provide impartial advice to a broad range of clients in the oil and gas industry, enabling them to make their business decisions with confidence.
- We work in partnership with our clients to support their interests in the oil and gas industry, offering a broad and innovative perspective on oil and gas projects around the world.
  - We have many years of practical experience and provide a bespoke service.
  - We provide insightful views on technical, commercial and strategic issues
  - We help our clients understand the uncertainties and risks associated with the oil and gas industry.
Disclaimer

- The statements and opinions attributable to the author and/or RISC in this presentation are given in good faith and in the belief that such statements are neither false nor misleading.
- In preparing this presentation the author has considered and relied solely upon information in the public domain. This information has been considered in the light of RISC’s knowledge and experience of the oil and gas industry.
- In some instances, our perspectives may differ from some of our highly valued clients.
- In some cases the views and opinions of the author may differ from those held by others within RISC.
- This presentation is the copyright of RISC and may not be reproduced, electronically or in hard copy, without the written permission of RISC.

- RISC A&D hold AFSL #457327
Contents / Objectives

- What is Natural gas?
- Why do we process gas?
- What are the main issues involved?
- How are processing systems put together?
What is Natural Gas

- Methane
  - CH4
  - C1
- Ethane
  - C2H6
  - C2
- Propane
  - C3H8
  - C3
- Octane
  - C8H18
  - C8
- ...C30+

- Non Hydrocarbons:
  - Water, Carbon Dioxide, Nitrogen, Hydrogen Sulphide, Mercury, Argon...
Natural Gas terminology

Natural Gas Well Stream

Methane
Ethane
Propane
Butane
Pentane and heavier: “Pentane Plus” “Natural Gasoline” “Condensate” “Naptha”

Non Hydrocarbons
Water, Carbon dioxide, Nitrogen
Hydrogen Sulphide, Argon, Mercury

NGL
LNG
LPG
**Natural Gas Components & Characteristics**

<table>
<thead>
<tr>
<th>Component</th>
<th>Liquid at °C</th>
<th>MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1 - Methane</td>
<td>-161</td>
<td>16</td>
</tr>
<tr>
<td>C2 - Ethane</td>
<td>-88</td>
<td>30</td>
</tr>
<tr>
<td>C3 - Propane</td>
<td>-42</td>
<td>44</td>
</tr>
<tr>
<td>C4 - Butane (iso)</td>
<td>-12</td>
<td>58</td>
</tr>
<tr>
<td>C4 - Butane (nor)</td>
<td>-0.5</td>
<td></td>
</tr>
<tr>
<td>C5 - Pentane (iso)</td>
<td>28</td>
<td>72</td>
</tr>
<tr>
<td>C5 - Pentane (nor)</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>C6 - Hextane</td>
<td>70</td>
<td>86</td>
</tr>
<tr>
<td>C7 - Heptane</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>
Main Differences - Oil & Gas Devt.

- Markets
- Economics of processing and transportation
- Efficiency of energy generation (combustion)
- Environmental impact
Why do we Process Gas?

- **Safety**
  - Protect our customers, ourselves and the general public.
  - To protect our Assets, our customers assets.
    - To manage toxicity and corrosion concerns
    - To make it dry

- **Specifications**
  - To meet customers’ specifications
  - To add value

- **Transport**
  - To allow for delivery conditions
  - To account for availability requirements
What don’t we want?

- Water (Corrosion / Hydrates)
- Heavy Hydrocarbons (2 Phase Flow)
- CO2 (Corrosion)
- H2S (Corrosion / Toxic)
## Typical Product Specifications

### Oil

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vapour Pressure</td>
<td>TVP $&lt; 83$ kPa @ T</td>
</tr>
<tr>
<td></td>
<td>RVP $&lt; 10-12$ psi</td>
</tr>
<tr>
<td>Base Sediment &amp; Water</td>
<td>BS&amp;W $&lt; 0.5%$</td>
</tr>
<tr>
<td>Salt Content</td>
<td>NaCl $&lt; 70$ g/m³</td>
</tr>
<tr>
<td>Temperature</td>
<td>$&gt; \text{PourPoint}$</td>
</tr>
<tr>
<td>Hydrogen Sulfide</td>
<td>$\text{H}_2\text{S} &lt; 70$ g/m³</td>
</tr>
</tbody>
</table>

### Water

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dispersed Oil Content</td>
<td>$&lt; 40$ g/m³</td>
</tr>
<tr>
<td>Suspended Solids Content</td>
<td>$&lt; 50$ g/m³</td>
</tr>
<tr>
<td>Hydrocarbon Dew Point</td>
<td>$-3\degree\text{C} @ &lt; 7000$ kPa</td>
</tr>
<tr>
<td>Water Dew Point</td>
<td>$-8\degree\text{C} @ &lt; 7000$ kPa</td>
</tr>
</tbody>
</table>

### Gas

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating Value</td>
<td>37-43 MJ/Sm³</td>
</tr>
<tr>
<td>Max amounts</td>
<td>Inerts, CO₂, H₂S</td>
</tr>
<tr>
<td>Delivery Pressure &amp; Temperature</td>
<td></td>
</tr>
</tbody>
</table>
Water Content of Gas

Why is water in gas?
- Hydrocarbons are normally found in conjunction with water
- Hydrocarbons and water have been in geological contact for millions of years

Water content depends on:
- Composition
- Pressure
- Temperature

Why is water an issue?
- Free water leads to
  - Corrosion in the presence of other components (CO, CO$_2$, H$_2$S etc)
  - Hydrates
- Water is non-combustible
What are Hydrates

Hydrates are:
- Deposits resembling ice, compacted snow, or wax
- Formed by combination of water and light HCs, CO2 and H2S
- Grow like crystals that build up and plug lines, valves, orifices, etc
Requirements for Hydrates

For hydrates to form the following are pre-requisites:

- Free water
- High Pressure
- Low Temperature

Different Strategies:

- Stay out of the hydrate region (keep warm)
- Ensure no free water (dry)
- Hydrate inhibition
  - MEG / Methanol
<table>
<thead>
<tr>
<th>Component</th>
<th>Liquid at</th>
<th>MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1 - Methane</td>
<td>-161 °C</td>
<td>16</td>
</tr>
<tr>
<td>C2 - Ethane</td>
<td>-88 °C</td>
<td>30</td>
</tr>
<tr>
<td>C3 - Propane</td>
<td>-42 °C</td>
<td>44</td>
</tr>
<tr>
<td>C4 - Butane (iso)</td>
<td>-12 °C</td>
<td>58</td>
</tr>
<tr>
<td>C4 - Butane (nor)</td>
<td>-0.5 °C</td>
<td></td>
</tr>
<tr>
<td>C5 - Pentane (iso)</td>
<td>28 °C</td>
<td>72</td>
</tr>
<tr>
<td>C5 - Pentane (nor)</td>
<td>36 °C</td>
<td></td>
</tr>
<tr>
<td>C6 - Hextane</td>
<td>70 °C</td>
<td>86</td>
</tr>
<tr>
<td>C7 - Heptane</td>
<td>100 °C</td>
<td>100</td>
</tr>
</tbody>
</table>
Multi-component Hydrocarbon Phase behaviour - The Phase Envelope

The diagram illustrates the phase behavior of hydrocarbons, showing the relationship between pressure and temperature. Key points include:

- **Critical Point**
- **Bubble Point**
- **Dew Point**
- **Liquid**
- **Gas**
- **Dense**

The shaded area represents the region where the hydrocarbon phase is in equilibrium, transitioning from one phase to another as pressure and temperature change.
Moving around the P-T Diagram

- Pump
- Compressor
- Cooler / Refrigerator
- Heater
- Turbo Expander
- Valves
- JT Valve

Press. vs Temp.
How do we use and change Phase Envelopes?
Separation: changing the envelope

Separator @ 70 Bar and 50°C

Separator Gas
Separator Liquid
How do we use and change Phase Envelopes?

Separator Operating Conditions
Building the Gas Processing System

Gas Spec.
- Hydrocarbon dewpoint < 0°C at all P < 100 bar
- Delivery pressure 100 bar
- Gas field with primary separator at 70 bar and 50°C
Separator Gas Phase Envelope

- Gas Out Bubble Point
- Gas Out Dew Point
Meeting specification

Temperature (°C)

Pressure (Bar)

Gas Out Bubble Point
Gas Out Dew Point
Sales Gas Bubble Point
Sales Gas Dew Point
Meeting specification through cooling
Simple cooling/refrigeration PFS 1
Alternative – Turbo Expander

![Temperature vs. Pressure Graph]

- Gas Out Bubble Point
- Gas Out Dew Point
- Sales Gas Bubble Point
- Sales Gas Dew Point
Turbo Expander PFS 3
What don’t we want?

- Water (Corrosion / Hydrates)
- Heavy Hydrocarbons (2 Phase Flow)
- CO2 (Corrosion)
- H2S (Corrosion / Toxic)
Generic Process Scheme Development

Simple (Onshore gas plant delivering to local system)

Complex (LNG Delivery system)
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Component</th>
<th>Mol % 1</th>
<th>Mol % 2</th>
<th>Mol % 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CO2</td>
<td>3.35</td>
<td>0.38</td>
<td>12.00</td>
</tr>
<tr>
<td>N2</td>
<td>Nitrogen</td>
<td>0.32</td>
<td>5.34</td>
<td>1.50</td>
</tr>
<tr>
<td>C1</td>
<td>Methane</td>
<td>74.45</td>
<td>93.85</td>
<td>77.91</td>
</tr>
<tr>
<td>C2</td>
<td>Ethane</td>
<td>10.77</td>
<td>0.41</td>
<td>3.00</td>
</tr>
<tr>
<td>C3</td>
<td>Propane</td>
<td>4.19</td>
<td>0.01</td>
<td>2.50</td>
</tr>
<tr>
<td>iC4</td>
<td>i-Butane</td>
<td>0.61</td>
<td>0.00</td>
<td>0.50</td>
</tr>
<tr>
<td>nC4</td>
<td>n-Butane</td>
<td>1.24</td>
<td>0.00</td>
<td>1.05</td>
</tr>
<tr>
<td>C5</td>
<td>neo-Pentane</td>
<td>0.01</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>iC5</td>
<td>i-Pentane</td>
<td>0.42</td>
<td>0.00</td>
<td>0.40</td>
</tr>
<tr>
<td>nC5</td>
<td>n-Pentane</td>
<td>0.47</td>
<td>0.00</td>
<td>0.60</td>
</tr>
<tr>
<td>C6</td>
<td>Hexanes</td>
<td>0.56</td>
<td>0.00</td>
<td>0.30</td>
</tr>
<tr>
<td>C7</td>
<td>Me-Cyclo-pentane</td>
<td>0.13</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Benzene</td>
<td>0.04</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cyclo-hexane</td>
<td>0.27</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heptanes</td>
<td>0.37</td>
<td>0.00</td>
<td>0.10</td>
</tr>
<tr>
<td>C8</td>
<td>Me-Cyclo-hexane</td>
<td>0.37</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Toluene</td>
<td>0.16</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Octanes</td>
<td>0.40</td>
<td>0.00</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>Ethyl-benzene</td>
<td>0.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C9</td>
<td>Meta/Para-xylene</td>
<td>0.14</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ortho-xylene</td>
<td>0.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nonanes</td>
<td>0.29</td>
<td>0.00</td>
<td>0.02</td>
</tr>
<tr>
<td>C10</td>
<td>Tri-Me-benzene</td>
<td>0.04</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Decanes</td>
<td>0.26</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>C11+</td>
<td>Undecanes +</td>
<td>1.10</td>
<td>0.00</td>
<td>0.05</td>
</tr>
<tr>
<td>H2O</td>
<td>Water mg/Sm³</td>
<td>50</td>
<td>1000</td>
<td>500</td>
</tr>
</tbody>
</table>
Comparison of NWSV and Gorgon Field Developments

NWSV

Source/Reservoir
- Hydrocarbons
- H2O
- CO2

Transport Subsea to Platforms
- Corrosion
- Flow Assurance

Primary Processing G/L Separation
- G/L Separation
- Dehydration
- Condensate Stabilisation
- Water Treatment

Transport dry gas to LNG Plant
- Flow Assurance
- Multiphase flow

Processing (LNG & other products)
- G/L Separation
- CO2 removal
- Dehydration
- Liquefaction
- LPG fractionation
- Condensate Stabilisation
- Water Treatment
- Domestic Gas

Product Transport (LNG Tankers)
- Storage and Loading
- Scheduling

Gorgon

Source/Reservoir
- Hydrocarbons
- H2O
- CO2

Initial Transport Subsea to Beach
- Corrosion
- Flow Assurance
- Hydrate inhibition

Processing LNG & other products
- G/L Separation
- CO2 removal
- Dehydration
- Liquefaction
- LPG fractionation
- Condensate Stabilisation
- Water Treatment
- MEG regeneration
- CO2 injection
- Domestic Gas

Product Transport (LNG Tankers)
- Storage and Loading
- Scheduling
Comparison of NWSV and Gorgon
The Global LNG Market is growing and changing

Source: GIIGNL
In Context...

US will be 2nd largest importer of LNG

~100MTPA of import capacity built in USA

Source: GIKNI; EIA
In Context...

US starts exports of LNG

US expects to export ~100MTPA of LNG
Renewables are not the panacea for power generation

Notional Daily Demand

- Demand
- Coal
- Gas
- VRES

Power required, % of daily maximum for different times of the day.