Agenda

- **Gas Quality**
  - Properties of Natural Gas
  - Gas Delivery Network – Production to Market

- **Interchangeability**
  - Properties of Liquefied Natural Gas (LNG)
  - Interchangeability with Domestic Natural Gas
Properties of Natural Gas
## Natural Gas Composition
### Unprocessed

<table>
<thead>
<tr>
<th>Component</th>
<th>Typical (Mole Percent)</th>
<th>Range (Mole Percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hydrocarbons</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methane (C1)</td>
<td>92.77</td>
<td>83.74 – 98.22</td>
</tr>
<tr>
<td>Ethane (C2)</td>
<td>3.36</td>
<td>0.52 – 7.64</td>
</tr>
<tr>
<td>Propane (C3)</td>
<td>1.51</td>
<td>0.18 – 4.74</td>
</tr>
<tr>
<td>Iso-Butane (i-C4)</td>
<td>0.41</td>
<td>0.05 – 1.10</td>
</tr>
<tr>
<td>Normal Butane (n-C4)</td>
<td>0.47</td>
<td>0.06 – 1.63</td>
</tr>
<tr>
<td>Iso-Pentane (i-C5)</td>
<td>0.19</td>
<td>0.03 – 0.50</td>
</tr>
<tr>
<td>Normal Pentane (n-C5)</td>
<td>0.13</td>
<td>0.00 – 0.42</td>
</tr>
<tr>
<td>Hexane (C6)</td>
<td>0.27</td>
<td>0.09 – 0.78</td>
</tr>
<tr>
<td><strong>Inerts</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogen (N₂)</td>
<td>0.30</td>
<td>0.12 – 0.91</td>
</tr>
<tr>
<td>Helium (He)</td>
<td>Trace</td>
<td>0.00 – 0.02</td>
</tr>
<tr>
<td><strong>Impurities</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon Dioxide (CO₂)</td>
<td>0.59</td>
<td>0.13 – 1.86</td>
</tr>
<tr>
<td>Hydrogen Sulfide (H₂S)</td>
<td>Trace</td>
<td>0.00 – 0.10</td>
</tr>
<tr>
<td>Oxygen (O₂)</td>
<td>Trace</td>
<td>0.00 – 3.00</td>
</tr>
<tr>
<td>Water (H₂O)</td>
<td>Trace</td>
<td>0.00 – 0.01</td>
</tr>
</tbody>
</table>
Production Areas Prone to Gas Impurities

- Gas quality varies by production field
- Forty-one percent of gas reserves are anticipated to have excessive impurities
- Impurities are removed from the gas to meet various quality specifications to ensure it is merchantable
- Producers evaluate investment cost to produce vs. market value before deeming field commercial
Impurities Potentially Damaging to Natural Gas Facilities

- Gas is treated to reduce these impurities to acceptable levels
- Water (H₂O)
  - Enters as vapor or liquid
  - Water vapor can condense to liquid water
  - Can result in freezing of lines and equipment
  - Collects in low spots in pipeline
  - Virtually no internal corrosion occurs without liquid water

- Carbon Dioxide (CO₂), Hydrogen Sulfide (H₂S), Oxygen (O₂)
  - Reacts with liquid water and with each other potentially causing corrosion
  - Byproducts of internal corrosion can lead to wear and damage of compressors and measurement equipment
Hydrocarbon Property Measures

- **Higher Heating Value (HHV)** - measure of the energy generated by combustion (including the heat that turns the water created into steam)
  
  **Note:** HHV is the standard measure used for commercial transactions

- **Wobbe Index** – a measure of the interchangeability at the burner
# Heating Value of Components

<table>
<thead>
<tr>
<th>Hydrocarbon Component</th>
<th>Higher Heating Value @ (60 °F, 1 atm) (BTU/scf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane (C₁)</td>
<td>1010.0</td>
</tr>
<tr>
<td>Ethane (C₂)</td>
<td>1769.6</td>
</tr>
<tr>
<td>Propane (C₃)</td>
<td>2516.1</td>
</tr>
<tr>
<td>Iso-Butane (i-C₄)</td>
<td>3251.9</td>
</tr>
<tr>
<td>Normal Butane (n-C₄)</td>
<td>3262.3</td>
</tr>
<tr>
<td>Iso-Pentane (i-C₅)</td>
<td>4000.9</td>
</tr>
<tr>
<td>Normal Pentane (n-C₅)</td>
<td>4008.9</td>
</tr>
<tr>
<td>Hexane (C₆)</td>
<td>4755.9</td>
</tr>
<tr>
<td>Heptane (C₇)</td>
<td>5502.5</td>
</tr>
<tr>
<td>Octane (C₈)</td>
<td>6248.9</td>
</tr>
<tr>
<td>Decane (C₉)</td>
<td>7742.9</td>
</tr>
</tbody>
</table>

Composition of gas comprised of hydrocarbon components determines the heating value of the gas. Hydrocarbons C₁₀ and above are liquids at typical pipeline operating conditions.
Hydrocarbon Dewpoint (HDP)

Dewpoint
Temperature below which some components in a gas begin to condense and drop out as liquids

Atmosphere
When the air temperature falls below the air dewpoint it begins to rain

Pipeline
When the gas temperature falls below the hydrocarbon dewpoint it begins to “rain” hydrocarbons in the pipeline. Highly dependant on C6+ concentration
Impact of Gas Processing

Gas processing typically reduces the natural gas HHV and HDP.

Liquid Hydrocarbons will form within this envelope.

Cricondentherm
-10.3 °F
57.1 °F

Gas Phase Only

Liquid Phase Only

Unprocessed Gas
HHV = 1096

Processed Gas
HHV = 1029

Cricondentherm

Processed Gas
HHV = 1029

Unprocessed Gas
HHV = 1096
Gas Delivery Network

Production to Market
Gas Delivery Network Example

HHV = 1096
Wobbe = 1393
HDP = 57.1 °F

May be owned/operated by:
- Producers
- Mid-stream
- Gas Pipelines

Gas Composition
- Methane (C₃) 92.77%
- Ethane (C₂) 3.36%
- Propane (C₃) 1.51%
- Butane (C₄) 0.88%
- Pentane (C₅) 0.31%
- Hexane + (C₆) 0.27%
- Carbon Dioxide 0.59%
- Nitrogen (N₂) 0.31%

HHV = 1029
Wobbe = 1382
HDP = -10.3 °F

Gas Composition
- Methane (C₁) 96.33%
- Ethane (C₂) 2.50%
- Propane (C₃) 0.20%
- Butane (C₄) 0.07%
- Pentane (C₅) 0.03%
- Hexane + (C₆) 0.03%
- Carbon Dioxide 0.59%
- Nitrogen (N₂) 0.25%
Gas Pipeline Network

Free liquid hydrocarbons may:
- Form due to pressure drop at regulators
- Freeze regulators and controllers
- Interrupt the reliability of instrumentation, controllers and safety devices
- Contaminate equipment fuel lines leading to major damage to engines and compressors
- Cause increased pressure drop and loss of capacity
- Other

Compressor Station

Fuel Regulator

Optional

City Gate

Heater  Meter  Regulator
Liquefied Natural Gas

Interchangeability with

Domestic Natural Gas
Liquefied Natural Gas (LNG)

- Natural gas liquefied by cooling to minus 260°F
- Shipped and stored at near atmospheric pressure
- Volume reduction of approximately 600 to one
## LNG Properties

### Historical LNG Cargoes

<table>
<thead>
<tr>
<th></th>
<th>Trinidad</th>
<th>Algeria</th>
<th>Oman</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HHV (BTU/scf)</strong></td>
<td>1048</td>
<td>1103</td>
<td>1168</td>
<td>1045</td>
<td>1064</td>
</tr>
<tr>
<td><strong>Interchangeability Index (Wobbe)</strong></td>
<td>1380</td>
<td>1406</td>
<td>1444</td>
<td>1379</td>
<td>1390</td>
</tr>
<tr>
<td><strong>HDP (°F)</strong></td>
<td>-94.6</td>
<td>-49.7</td>
<td>+3.68</td>
<td>-88.4</td>
<td>-87.2</td>
</tr>
</tbody>
</table>

### Composition

<table>
<thead>
<tr>
<th></th>
<th>Trinidad</th>
<th>Algeria</th>
<th>Oman</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane (C₁)</td>
<td>96.13%</td>
<td>89.57%</td>
<td>86.52%</td>
</tr>
<tr>
<td>Ethane (C₂)</td>
<td>3.40%</td>
<td>8.61%</td>
<td>8.31%</td>
</tr>
<tr>
<td>Propane (C₃)</td>
<td>0.39%</td>
<td>1.18%</td>
<td>3.32%</td>
</tr>
<tr>
<td>Iso-Butane (i-C₄)</td>
<td>0.04%</td>
<td>0.13%</td>
<td>0.85%</td>
</tr>
<tr>
<td>n-Butane (n-C₄)</td>
<td>0.03%</td>
<td>0.18%</td>
<td>0.85%</td>
</tr>
<tr>
<td>Iso-Pentane (i-C₅)</td>
<td>–</td>
<td>0.01%</td>
<td>0.06%</td>
</tr>
<tr>
<td>n-Pentane (n-C₅)</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Hexane (C₆)</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Nitrogen (N₂)</td>
<td>0.01%</td>
<td>0.32%</td>
<td>0.09%</td>
</tr>
</tbody>
</table>

### Source
1. Source: GTI - Gas Interchangeability Tests, April 2003
2. Represents a large percentage of future LNG imports from BG LNG Services starting in 2005
   - LNG contains no impurities - H₂S, O₂, CO₂ or H₂O
LNG Production to Market

LNG Production can be managed by:

- Processing at LNG production
- Processing at LNG vaporization
- Injecting inert gases
- Blending with domestic natural gas