Module No 3
Liquefied Natural Gas Markets, Consumption, Measurement & Calculation
Various LNG have different Identity

<table>
<thead>
<tr>
<th></th>
<th>Ras Laffan</th>
<th>Das Islands</th>
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<tbody>
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<td>Methane</td>
<td>CH₄</td>
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<td>Iso-Butane</td>
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</tr>
<tr>
<td>Pentane</td>
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<td>0.00%</td>
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Increment of Gas LNG Production

Figure 12. Energy production by fuel, 1980-2035 (quadrillion Btu)

(from the U.S. EIA’s Annual Energy Outlook 2012 early overview)
LNG Environment Benefit

Figure 14: Emissions across engine type

- Traditional Engine
- LS Fuel
- HFO + Scrubber
- LNG Engine

- NOx
- CO2
- SOx
- Particulates
Three Main LNG Markets

1. Henry Hub (HH) [USA]
   - A distribution hub on the natural gas pipeline system in Erath, Louisiana, owned by Sabine Pipe Line LLC, a subsidiary of Chevron Corporation
   - The pricing point for natural gas futures contracts traded on the New York Mercantile Exchange (NYMEX) and the OTC swaps traded on Inter Continental Exchange (ICE)

2. National Balancing Point (NBP) [UK]
   - Is a virtual trading location for the sale and purchase and exchange of UK natural gas
   - The pricing and delivery point for the ICE Futures Europe (InterContinental Exchange) natural gas futures contracts

3. Japan Customs-cleared Crude (JCC) [JAPAN]
   - The average price of customs-cleared crude oil imports into Japan
   - Commonly used index in long term LNG contracts in Japan, Korea and Taiwan
LNG UNIT

- LNG is traded on energy content
- MMBtu = Millions of British Thermal Units
- 1 m³ natural gas ≈ 0.0392 MMBtu
- 1 m³ LNG ≈ 23.9 MMBtu
- 1 MMBtu could heat 2,519 litres of water from 0 to 100°C
- 1 m³ LNG = 23.9 MMBtu could heat (23.9 x 2519) = 60,204 litres of water from 0 to 100°C
What’s a BTU?

1 Btu = Amount of heat needed to raise 1 lb of water by 1°F ≈1055 joules ≈252 calories

1 Calorie = 4.1868 Joules
1 BTU = 1055.056 Joules
Energy Content

Fuel Efficiency: Kilowatt-Hours per Pound

Source: Energy Information Agency, Green Econometrics research
## Energy Content

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<tr>
<td>LNG</td>
<td>53.6</td>
<td>HFO = &gt;60°C</td>
</tr>
<tr>
<td>MDO</td>
<td>45.5</td>
<td>MDO = &gt;60°C</td>
</tr>
<tr>
<td>HFO</td>
<td>42.9</td>
<td>LNG = -188°C</td>
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Volumetric Comparison

HFO

1.89 times the volume for LNG

MDO

1.75 times the volume for LNG
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Methane Number

Provides indication of knock tendency

Pure methane = 100
Pure ethane = 44
Pure propane = 32

Number varies depending on composition of LNG
Knocking

Effects low pressures 4 stroke engines

Not smooth combustion in cylinder chamber
(spontaneous combustion ahead of flame front)
If a gas mixture has a methane number of 80, its knock resistance is equivalent to that of a gas comprised of 80% methane and 20% hydrogen. There are gas constituents which have a higher methane number than 100 therefore it is also possible for a gas composite to have a higher methane number than 100.
LNG Behaviour in Air

Below – 100 Degree C
LNG is heavier than Air

Above –100 Degree C
LNG is lighter than Air

\[ \text{Ratio} = \frac{\text{Density of Methane Vapour}}{\text{Density of Air}} \]

(Density of air assumed to be 1.27 kg/m³ at 15°C)
LNG – Behaviour – density shift

Energy density: 2.5/3 times more than CNG (=9MJ/L)

About 60% of gasoline/diesel (34.2 & 37.3MJ/L)

Density = 0.41-0.5kg/L
LNG Value for Combustion

LNG quality is depending on several aspects. There needs to be a balance in order to ensure LNG Bunkered is value for money and a proper operation of engine.

– LNG will be traded in energy content
– Change in composition will affect:
  • Temp
  • Density
  • Energy content
  • Methane number
  • Price
Atmospheric Tank Filling Limit Examples

Atmospheric Tank

Max Tank pressure = 0.7 barg

Reference temp @ SVP of 0.7 barg = -154.8°C

Density at Ref Temp (-154.8°C) = 412.44 kg/m³

Loading Temp = -159°C
Density = 418.71 kg/m³
FL = 0.98 x (412.44/418.71) = 96.5%

Loading Temp = -155°C
Density = 412.72 kg/m³
FL = 0.98 x (412.44/412.72) = 97.9%
Pressurised Tank

Max Tank pressure = 10.0 barg
Reference temp @ SVP of 10.0 barg = -121.9°C
Density at Ref Temp (-121.9°C) = 355.39 kg/m³

Loading Temp = -159°C
Density = 418.71 kg/m³
FL = 0.98 x (355.39/418.71) = 83.2%

Loading Temp = -134°C
Density = 378.38 kg/m³
FL = 0.98 x (355.39/378.38) = 92.0%
Comparing Mass Loaded in 500m³ Tk.

**Atmospheric Tank**
- Max Tank pressure = 0.7 barg
- Reference temp @ SVP of 0.7 barg = -154.8°C
- Density at Ref Temp (-154.8°C) = 412.44 kg/m³

Loading Temp = -159°C
- Density = 418.71 kg/m³
- FL = 0.98 x (412.44/418.71) = 96.5%
- 0.965 x 500 = 482.5 m³
- 482.5 x 418.71 = 202.03 Tons

Loading Temp = -155°C
- Density = 412.72 kg/m³
- FL = 0.98 x (412.44/412.72) = 97.9%
- 500 x 0.979 = 489.50 m³
- 489.50 x 412.72 = 202.03 Tons

**Pressurised Tank**
- Max Tank pressure = 10.0 barg
- Reference temp @ SVP of 10.0 barg = -121.9°C
- Density at Ref Temp (-121.9°C) = 355.39 kg/m³

Loading Temp = -159°C
- Density = 418.71 kg/m³
- FL = 0.98 x (355.39/418.71) = 83.2%
- 0.832 x 500 = 416 m³
- 416 x 418.71 = 174.18 Tons

Loading Temp = -134°C
- Density = 378.38 kg/m³
- FL = 0.98 x (355.39/378.38) = 92.0%
- 500 x .920 = 460 m³
- 460 x 378.38 = 174.05 Tons

Pressure Tank loads 13.9% less than the equivalent size Atmospheric tank.
Filling Limit Formula

\[ LL = FL \frac{\rho_R}{\rho_L} \]

where:

- **LL** = Loading limit, maximum allowable liquid volume relative to the tank volume to which the tank may be loaded, expressed in percent;
- **FL** = Filling limit expressed in percent, here 98%;
- \( \rho_R \) = Relative density of fuel at the reference temperature;
- \( \rho_L \) = Relative density of fuel at the loading temperature.
Coriolis Mass Flow Meter

- Process fluid enters the sensor and flow is split with half the flow through each tube
- Drive coil vibrates tubes at natural frequency
- Pick-off coils on inlet and outlet sides
Density measurement is based on the natural frequency

- As the mass increases, the natural frequency of the system decreases
- As the mass decreases, the natural frequency of the system increases
Flow Gauge Meter Doppler Type

Doppler Flow Meter
Flow Gauge Turbine Meter

- Flow Straightener (Rotor Support)
- Magnetic Pick Up
- Turbine Rotor
- Rotor Shaft
- Turbine Meter
### MU Gas Properties

<table>
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<tr>
<th>Property</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>Temperature (°C)</td>
<td>16.68</td>
</tr>
<tr>
<td>Effective Methane (%)</td>
<td>91.11</td>
</tr>
<tr>
<td>Effective Propane (%)</td>
<td>2.42</td>
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<tr>
<td>Pressure (kPa)</td>
<td>101.87</td>
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<tr>
<td>Effective Ethane (%)</td>
<td>3.33</td>
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<tr>
<td>Carbon Dioxide (%)</td>
<td>0.78</td>
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<tr>
<td>Speed of Sound (m/s)</td>
<td>419.33</td>
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<tr>
<td>Nitrogen (%)</td>
<td>2.37</td>
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<tr>
<td>CO2 Temperature (°C)</td>
<td>16.71</td>
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<tr>
<td>Relative Density</td>
<td>0.6119</td>
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<td>CO2 Pressure (kPa)</td>
<td>101.82</td>
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<td>Density (gas)</td>
<td>0.7913</td>
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<tr>
<td>CV (Superior)</td>
<td>41.13</td>
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<tr>
<td>Compressibility</td>
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<tr>
<td>CV (Inferior)</td>
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<tr>
<td>Wobbe Index</td>
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<tr>
<td>Methane Number</td>
<td>81.59</td>
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</table>
Calculating density of the LNG loaded

The density of the LNG loaded in kg/m³ is calculated based on the composition of the LNG loaded in mole percent at a fixed temperature of –160 °C, taking into account the molar mass of each component as defined in standard ISO 6976, the molar volume of each component, the correction factors K1 and K2 as described in the revised Klosek MacKinley calculation method.
Calculating “unloaded or reloaded energy”

The calculation of the gross unloaded or reloaded energy ELNG is a function of:

- \( VLNG \): volume of LNG unloaded or reloaded
- \( pLNG \): density of the LNG unloaded or reloaded
- \( HLNG \): gross heating value (on a mass basis) of the LNG unloaded or reloaded

\[
ELNG = VLNG \cdot pLNG \cdot HLNG
\]