LNG (Liquefied Natural Gas)

Chapter 18

Based on presentation by Prof. Art Kidnay
Plant Block Schematic

Adapted from Figure 7.1, *Fundamentals of Natural Gas Processing*, 2nd ed. Kidnay, Parrish, & McCartney
Topics

Introduction
Liquefaction processes
LNG storage
Regasification
Introduction
Rationale for LNG

Liquefying natural gas greatly reduces volume

- Liquid density @ 1 atm – 26.37 lb/ft³
- Saturated vapor volume @ 1 atm – 8.8188 ft³/lb – 230X volume
- Standard ideal gas vapor volume – 24 ft³/lb – 625X volume
- Ideal gas volume @ 1000 psia & 60°F – 0.35 ft³/lb – 9X volume

Liquefaction makes it easier to...

- Store gas (peak shaving plants)
- Move gas to remote customers (base load plants)
Comparison of plants

Peak shaving plants
Relatively small (~0.1x10^6 tpy)
70+ in US (mainly in New England region)
Facility includes:
- Liquefaction plant
- Storage facilities
- Regasification facilities

Baseload plants
Large capacity – 3 to 10x10^6 tpy
Requires large reserves to make plant economically feasible (> 1 Tscf)
Schematic of peak-shaving facility

- Natural gas pipeline
- Gas treating
- Storage
- Odorant injection
- Regasification
- Compression liquefaction
- H$_2$S, CO$_2$ and odorant
- H$_2$O
- Heavy hydrocarbons
Energy Transmission Efficiency Over Long Distances

![Graph showing energy transmission efficiency over long distances for LNG, Pipeline, Gas-to-Liquids, and Electricity.](image-url)
Schematic of a baseload plant
LNG Trade

Figure 3.1 LNG Trade Volumes, 1990–2017

Source: IHS Markit, IEA, IGU

IGU 2018 World LNG Report
Downloaded December 24, 2018
https://www.igu.org/sites/default/files/node-document-field_file/IGU_LNG_2018_0.pdf

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LNG Trade

Figure 5.7: Major LNG Shipping Routes, 2017

IGU 2018 World LNG Report
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https://www.igu.org/sites/default/files/node-document-field_file/IGU_LNG_2018_0.pdf
LNG Facilities & Capacities

Figure 4.4: Nominal Liquefaction Capacity by Country in 2017 and 2023

Figure 6.6: Receiving Terminal Import Capacity and Regasification Utilisation Rate by Country in 2017 and 2023.
LNG Liquefaction Facilities

IGU 2018 World LNG Report
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LNG Regassification Facilities

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LNG Facility Costs

Figure 4.10: Average Liquefaction Unit Costs in $/tonne (real 2016) by Project Type, 2000–2023

Figure 6.11: Regasification Costs Based on Project Start Dates, 2006–2017

Sources: IHS Markit, Company Announcements

*Indicates the size of onshore storage relative to onshore terminal capacity.
Sources: IHS Markit, Company Announcements

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Liquefaction Processes
# Typical compositions pipeline gas vs. LNG feed

<table>
<thead>
<tr>
<th>Impurity</th>
<th>Pipeline Gas</th>
<th>LNG Feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>150 ppmv (7.0 lb/MMsc)</td>
<td>&lt; 0.1 ppmv</td>
</tr>
<tr>
<td>Hydrogen sulfide</td>
<td>0.25 gr/100 scf (4.0 ppmv)</td>
<td>&lt; 0.25 gr/100 scf (4.0 ppmv)</td>
</tr>
<tr>
<td>Total sulfur (H2S, COS, ...)</td>
<td>5–20 gr/100 scf</td>
<td>&lt; 20 ppmv</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>2–3 mol%</td>
<td>&lt; 50 ppmv</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>&lt; 3 mol%</td>
<td>&lt; 1 mol%</td>
</tr>
<tr>
<td>Mercury</td>
<td>N/A</td>
<td>&lt; 0.01 μg/Nm3</td>
</tr>
<tr>
<td>Butanes</td>
<td>N/A</td>
<td>&lt; 2 mol%</td>
</tr>
<tr>
<td>Pentanes+</td>
<td>N/A</td>
<td>&lt; 0.1 mol%</td>
</tr>
<tr>
<td>Aromatics</td>
<td></td>
<td>&lt; 2 ppmv</td>
</tr>
</tbody>
</table>
Simple JT liquefaction cycle

\[ f = \frac{\dot{m}_2}{\dot{m}_1} = \frac{\hat{H}_3 - \hat{H}_1 - q_L}{\hat{H}_3 - \hat{H}_2} \]
Simple JT liquefaction cycle – 500 psia inlet gas
JT liquefaction cycle with intermediate flash
Simple closed-cycle liquefaction process
Open-cycle expander plant

\[ f = \frac{\dot{m}_2}{\dot{m}_1} = \frac{\dot{H}_3 - \dot{H}_1 - q_L}{\dot{H}_3 - \dot{H}_2} + \frac{e(\dot{H}_4 - \dot{H}_6)}{\dot{H}_3 - \dot{H}_2} \]
FIG. 16-34
Single Mixed Refrigerant Liquefaction Process with Precooling

C3 Precooled Mixed Refrigerant

GPSA Engineering Data Book, 14th ed.
AP-X LNG Process

Fig. 16-37, GPSA Engineering Data Book, 14th ed.

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Cascade Refrigeration Process

Fig. 16-32, GPSA Engineering Data Book, 14th ed.
LNG storage
Storage of LNG

Tanks can be
- Aboveground
- Below ground

Tank material is
- Steel
- Prestressed concrete
- Hybrid (combination of both)

Typical types
- Single-containment
- Double-containment
- Full containment
- Prestressed concrete
- Frozen-earth underground storage
Single-containment tank

- Carbon Steel Outer Tank
- Perlite Insulation
- Reinforced Concrete Pad
- Electrical Heating Elements
- Suspension Deck
- Carbon Steel Roof
- 9% Nickel Steel Inner Tank
- Base Insulation
Double-containment tank

- Carbon Steel Roof
- Suspended Deck
- Carbon Steel Outer Tank
- Perlite Insulation
- 9% Nickel Steel Inner Tank
- Electrical Heating Elements
- Reinforced Concrete Pad
- Concrete Outer Shell
- Base Insulation
Full-containment tank

- Carbon Steel Outer Tank
- Perlite Insulation
- 9% Nickel Steel Inner Tank
- Reinforced Concrete Pad
- Concrete Roof
- Suspended Deck
- Electrical Heating Elements
- Concrete Outer Shell
- Base Insulation
- Reinforced Concrete Pad
Prestressed Concrete Tank

Earth Berm

Concrete

Select Fill

Insulation and Liner

Spring-loaded Trusses

Insulated Roof

Ballast
Figure 13.23  Frozen-earth storage container
Regasification
LNG regasification (simplified)

~ 40 % of HHV required to heat LNG to ambient temperatures
Summary
Summary

Natural gas can be liquefied to greatly decrease its volume & make for easier long-distance transportation.

Gas to be liquefied must be further processed from typical pipeline quality.

Two separate steps:

- Liquefaction
  - Proper heat integration necessary to minimize compression power
- Regasification