LNG Basics for Petroleum Engineers

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Present an Overview of LNG Plant

- Why LNG?
- Pre-Treatment Required
- Typical Multi-Trains Plant
- Natural Gas Liquefaction Thermodynamics
- Commercial Liquefaction Processes
- Equipment for Liquefaction
- Unique Auxiliary Facilities
- Novel Plant Concepts
- Concluding Remarks

Oman LNG Plant
Stranded Gas Looking for Markets

- LNG Proved to be Most Economic for Distances >1,500 Mile
- Volume Reduction of 600:1
- Transported in Insulated Tankers @ -162C & 1 atm.
LNG Process & Equipment?

Big Refrigeration System

- Compressor/Driver
- Refrigerant Condenser
- Evaporator (Process Heat Exchanger)

Similar to the AC System in Our Home!
**Typical 2-Train LNG Plant**

- **Gas Gathering**: 1.5 Bcf/d
- **Inlet Gas Reception**: Gas, Liquid
- **Inlet Gas Treating**: Gas
- **NGL Recovery**: NGL Fractionation
- **Liquefaction**: LNG Storage
- **LNG Storage**: 8 Mtpa (1.1 Bcf/d)
- **Fuel**: Propane (0.73 Mtpa (27 Mbd)), Butane (0.5 Mtpa (17 Mbd)), Condensate (1.2 Mtpa (34 Mbd))

**Train 1**:
- Make-Up Fuel
- Liquefaction

**Train 2**:
- Condensate Stabilization
- NGL Fractionation

**Typical 2-Train LNG Plant**

- 1.5 Bcf/d
- 8 Mtpa (1.1 Bcf/d)
- 0.73 Mtpa (27 Mbd)
- 0.5 Mtpa (17 Mbd)
- 1.2 Mtpa (34 Mbd)
Typical 2-Train LNG Plant

Inlet Gas Reception
- Pipeline Manifold
- Pig Receivers
- Inlet Separator
- Slug Catcher

Gas Gathering → Inlet Gas Reception → Inlet Gas Treating → NGL Recovery → Liquefaction → LNG Storage

Make-Up Fuel → Gas → Train 1

Train 2 → NGL Fractionation → Propane Storage → LNG
- 9 Mtpa (1.2 Bcf/d)
- .73 Mtpa (27 Mbd)
- .5 Mtpa (17 Mbd)
- 1.2 Mtpa (34 Mbd)

Fuel

- Propane
- Butane
- Condensate
Typical 2-Train LNG Plant

Condensate Stabilization

- Multi-Stage Column
- Vapor Compressor
- 10-12 psia RVP
- De-Odorized
Inlet Gas
Reception

Inlet Gas
Treating

NGL
Recovery

Liquefaction

LNG Storage

Make-Up Fuel

Gas

Fuel

LNG

9 Mtpa
(1.2 Bcfd)

Propane

.73 Mtpa
(27 Mbdp)

Butane

.5 Mtpa
(17 Mbdp)

Condensate

1.2 Mtpa
(34 Mbdp)

Typical 2-Train LNG Plant

Inlet Gas Treating

- Amine for CO₂ & H₂S Removal
  - <50 ppm & < 4 ppm
  - Sulfur Recovery Unit if H₂S
- Mol Sieve Dehydration*
  - < 100 ppb
- Mercury Vapor Removal*
  - Activated Carbon Adsorber

1.7 Bcf

Gas Gathering
Typical 2-Train LNG Plant

NGL Recovery
- Scrub Column/KO after C3 Pre-Cool
- Primarily C4+ to Prevent Freezing
- LNG Heat Value Important for US & European Markets
  - 1,070 btu/scf Max
  - Need Turbo-Expander for High C3+ Removal

<table>
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<tr>
<th>Gas Gathering</th>
<th>Inlet Gas Reception</th>
<th>Inlet Gas Treating</th>
<th>NGL Recovery</th>
<th>LNG Storage</th>
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Fuel
- LNG
  - 9 Mtpa (1.2 Bcf/d)
- Propane
  - .73 Mtpa (27 Mbpd)
- Butane
  - .5 Mtpa (17 Mbpd)
- Condensate
  - 1.2 Mtpa (34 Mbpd)
Typical 2-Train LNG Plant

NGL Fractionation
- Deethanizer
  - Vapor Compression
  - 95% & 200 psig VP
  - <.5ppm H$_2$S & <15ppm S
- Depropanizer & Treating
  - 95% & 70 psig VP @100F
  - <.5ppm H$_2$S & <15ppm S

Natural Gas Gathering (1.7 Bcf/d) → Inlet Gas Reception → Inlet Gas Treating

- Make-Up Fuel
- Gas
- Liquid

Train 1
- NGL Recovery
- Liquefaction
- LNG Storage

Fuel
- LNG
- Propane
- Butane
- Condensate

Make-Up Fuel
- LNG Storage
- Fuel

Propane Storage
- .73 Mtpa (27 Mbdp)

Butane Storage
- .5 Mtpa (17 Mbdp)

Condensate Storage
- 1.2 Mtpa (34 Mbdp)

NGL Fractionation
- Deethanizer
- Vapor Compression
- Depropanizer & Treating
- 95% & 200 psig VP
- <.5ppm H$_2$S & <15ppm S
- Debutanizer & Treating
- 95% & 70 psig VP @100F
- <.5ppm H$_2$S & <15ppm S
180,000 M³ LNG Tank

- Full-Containment Tank to Reduce Impound Area & Improve Safety
- Approx. 75M Dia x 40M H
- Insulated for <.05%/D of Boil-off
- Top Entry In-Tank Pumps

- Total Capacity Based on Tanker Size (135,000 M³)
- Plus 4+-Days Production
Inside the Tanks

Tank with Pump Caissons

Single-Stage

Multi-Stage
LNG Loading System

- 16” Chiksan Type
- 3+1 – LNG Arms
  - 3,500 M³/Hr/Ea.
  - 10,500 M³/Hr
  - 140K M³ Tanker
- 4+1 – Systems
  - 14,000 M³/Hr
  - Qmax & Qflex
  - 200K+ M³
- 1 – Vapor Return
Cost of Refrigeration

-162°C

- Methane or Nitrogen
- Ethylene
- Propane
- Air/Water

Temperature

Cost/Btu Removed

-162°C  25°C
Natural Gas Liquefaction Processes

- Temperature
- $\Delta H$ (Enthalpy - Heat Removed)

- Gas Cooling
- Condensation
- Min. DT
- Liquid Subcooling
Cascade LNG Process

- Most Straight Forward of All Processes
- Kenai Plant Continuous Operation 1969
- CoP License, Plant Build by Bechtel
C3 Precooled – Mixed Refrigerant Process

- Most Widely Used Licensed by APCI
- 1st Plant in Algeria Operating Since 1972
- Plants Built by KBR, Chiyoda, JGC, FW

Feed → C3 Precooling → Mixed Refrigerant → MRV → Mixed Refrigerant Cycle → LNG

QatarGas LNG Plant
APCI AP-X Process

- Largest Train Capacity @ 8 Mtpa
- Overcome Spiral Wound MCHE Limit
- First Unit Started in 2009 (QG-II)
- No Plants Outside of Qatar

APCI Supplies

- Process Design
- Cold Boxes
- Spiral Wound Exchanger
- Turbo-Expanders
All Processes Use Similar Equipment

- Most New Plants Use Large Gas Turbine (& Combined Cycle) to Drive Refrigerant Compressors
- Some Older & Smaller Trains Have Steam Turbine Drives
- Many Peak Shaving Plants on Electric Drives
- Use Large Process Type Centrifugal Compressors
- Main Difference is in the Cryogenic Heat Exchangers
Main Cryogenic Heat Exchanger
Use by Mixed Refrigerant Process

Air Products & Chemicals & Linde: Spiral Wound Ex.
• Max. Diameter: 5,030mm
• Height: ~55m
• Stainless Steel Core
• 25mm Aluminum Tubing
• Externally Insulated
• Chill & Liquefy Gas
  – From –34°C to –152°C
  – At 55 to 69 Barg
APCI’s MR Main Cryogenic Heat Exchanger (MCHE) Spiral Wound Design
Heat Exchanger for Cascade Process

Cold Box Configuration

Plate Fin Exchanger

- Many Manufacturers
- Use Extensively in Air Separation
- Cascade & Other LNG Processes
Advances in LNG Plants

Onshore
Conventional Design

Near-shore
GBS Design

Offshore
Steel or Concrete Floater
FLNG is about to be Reality

Shell Prelude
- Floated out of dry dock in Dec. 2013
- 3.6 mtpa of LNG capacity
- Start-up expected in 2016

Petronas Kanowit
- EPC in progress
- 1.2 mtpa of LNG Capacity
- Scheduled for deployment in 2015
Conclusions

• LNG Liquefaction Process Same as AC System in Our Home
• Pre-Treatment Facilities Can Dwarf Liquefaction System
  – Mole Sieve Dehydration & Mercury Removal Required
  – Gas Treating & NGL Extraction May be Needed
  – Stabilized Condensate & Fractionated NGL Add Value
• LNG Exchangers, Storage & Loading Systems Are Unique
• Commercial Liquefaction Processes Well Proven, Robust & Can be Optimized for Plant Size, Gas Composition, Sales & Commercial Needs
• Novel Near-Shore & Offshore Floating Concepts Are Developed
LNG ?
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