Integration of Major Liquefaction Units within Existing Import Terminals
By: Mona Setoodeh
CH·IV International
April, 2013
Overview

- North American LNG Export
- Facility Integration
- Addition of Liquefaction Trains
- Associated Hazards
- Modification of Existing Components
- Other Considerations
North American LNG Export

North American LNG Import/Export Terminals

Proposed/Potential

Import Terminal
PROPOSED TO FERC
1. Robinston, ME: 0.5 Bcf/d (Kestrel Energy - Downeast LNG)
2. Astoria, OR: 1.5 Bcf/d (Oregon LNG)
3. Corpus Christi, TX: 0.4 Bcf/d (Cheniere - Corpus Christi LNG)
POTENTIAL U.S. SITES IDENTIFIED BY PROJECT SPONSORS
4. Offshore New York: 0.4 Bcf/d (Liberty Natural Gas)

Export Terminal
PROPOSED TO FERC
5. Freeport, TX: 1.8 Bcf/d (Freeport LNG Dev/Freeport LNG Expansion/FLNG Liquefaction)
6. Corpus Christi, TX: 2.1 Bcf/d (Cheniere - Corpus Christi LNG)
7. Coos Bay, OR: 0.9 Bcf/d (Jordan Cove Energy Project)
8. Lake Charles, LA: 2.4 Bcf/d (Southern Union - Trunkline LNG)
9. Hackberry, LA: 1.7 Bcf/d (Sempra - Cameron LNG)
10. Cove Point, MD: 0.75 Bcf/d (Dominion – Cove Point LNG)
11. Astoria, OR: 1.30 Bcf/d (Oregon LNG)
12. Lavaca Bay, TX: 1.38 Bcf/d (Exocelerate Liquefaction)
13. Elba Island, GA: 0.5 Bcf/d (Southern LNG Company)
14. Sabine Pass; LA: 1.3 Bcf/d (Sabine Pass Liquefaction)
15. Lake Charles, LA: 1.07 Bcf/d (Magnolia LNG)

PROPOSED CANADIAN SITES IDENTIFIED BY PROJECT SPONSORS
16. Kitimat, BC: 0.7 Bcf/d (Apache Canada Ltd.)
17. Douglas Island, BC: 0.25 Bcf/d (BC LNG Export Cooperative)

POTENTIAL U.S. SITES IDENTIFIED BY PROJECT SPONSORS
18. Brownsville, TX: 2.8 Bcf/d (Gulf Coast LNG Export)
19. Pascagoula, MS: 1.5 Bcf/d (Gulf LNG Liquefaction)
20. Sabine Pass, TX: 2.6 Bcf/d (ExxonMobil - Golden Pass)
21. Plaquemines Parish, LA: 1.07 Bcf/d (CE FLNG)
22. Cameron Parish, LA: 0.16 Bcf/d (Waller LNG Services)
23. Ingleside, TX: 1.09 Bcf/d (Range LNG (North America))
24. Cameron Parish, LA: 0.20 Bcf/d (Gaslin Development)

U.S. - MARAD/COAST GUARD
25. Gulf of Mexico: 3.22 Bcf/d (Main Pass - Freeport-McMoRan)

POTENTIAL CANADIAN SITES IDENTIFIED BY PROJECT SPONSORS
26. Prince Rupert Island, BC: 1.0 Bcf/d (Shell Canada)
27. Goldboro, NS: 0.67 Bcf/d (Pleridoe Energy Canada)
28. Kitimat, BC: 2.0 Bcf/d (LNG Canada)

As of March 20, 2013

Office of Energy Projects
US Facility Conversion Projects

- Sabine Pass LNG Terminal, LA
- Freeport LNG Terminal, TX
- Trunkline LNG Lake Charles Terminal, LA
- Dominion Cove Point LNG, MD
- Cameron LNG, LA
- Southern LNG Company, GA
- Oregon LNG Terminal, OR
  - Design Modification

Image Courtesy of Cameron LNG
From Import to Bi-Directional

- Aiming to Realize Potential Benefits of The Shifting LNG Market

- Advantages:
  - Utilizing Available Equipment And Infrastructure
    - Storage Tanks, Marine Loading/Unloading Facilities, etc.

- Challenges:
  - Regulatory Compliant Siting
  - Integration within Existing Systems
  - Isolation and Long-Term Maintenance of Some Existing Equipment
Facility Integration

- Need to Identify:
  - New Equipment and Units
    - Pretreatment
    - Liquefaction
    - NGL Extraction/N₂ Rejection/etc.
    - Supporting Utilities & Auxiliaries
    - Hazard Detection and Mitigation Systems
  - Components Requiring Modification or Replacement
  - Systems & Components Not Further Used
Addition of Liquefaction Trains
Liquefaction Unit

- Typical Train Components
  - Feed gas booster compression
  - Refrigerant compression
  - Series of heat exchangers - Process Cooling
  - Cryogenic heat exchanger
  - LNG and Refrigerant let-down system
  - NGL extraction and potentially fractionation
  - Flare Systems
Associated Hazards

- Hazards Associated with LNG
- Hazards Associated with Hydrocarbon Refrigerants and NGLs in Process Loops
- Hazards Associated with Storage of Hydrocarbon Refrigerants and NGLs
- Hazards Associated with Chemicals
  - Amine Solutions
  - Heat Transfer Fluids
  - Aqueous Ammonia (potential)
Implications of Hazards

- Safety
- Siting Facilities
  - Regulatory Compliance
  - More Real Estate Than What Is Required for Equipment Installation
- Insurability
- Project Financing
Hazards Associated with LNG

- Common to Import and Export
- Vapor Dispersion
  - Function of:
    - Flow Rates of LNG in Pipelines
    - Dominant LNG Flow Rate & Pipe Length: Typically Loading/Unloading Lines
  - Loading Flow Rate & Pipeline Length Typically Remain The Same
    - Vapor Dispersion Modeling Is Required
      - Modifications, Tie-Ins, etc.
    - Demonstrate Compliance with Flammable Gas Dispersion Exclusion Zones
Hazards Associated with LNG

- Spill Containment Systems
  - Need To Be Re-Evaluated and Potentially Extended
    - LNG Rundown To The Tank(s)
    - Single Accidental Leak Source

- Demonstrate Compliance
  - Flammable Gas Dispersion Exclusion Zones
  - Prevent Thermal Flux Beyond Allowable Limits
    - Defined by 49 CFR Part 193 and NFPA 59A for land-based projects located in the U.S.A.
Other Hydrocarbon Hazards

- Liquefaction Introducing Additional Components to Import Facilities
  - Hydrocarbon Refrigerant Components
    - Propane – Storage, Pure
    - Ethane/Ethylene – Storage, Pure
    - Mixed Refrigerant – Mixed Component
  - NGLs
Other Hydrocarbon Hazards

- Siting Required Analyses
  - Vapor Dispersion Modeling
    - Jetting And Flashing Scenarios
      - Refrigerant and NGL
      - Single Accidental Leakage Source
    - Possible Liquid Spills
      - Refrigerant and NGL
      - Design Spills
  - Refrigerant and NGL
  - Single Accidental Leakage Source
  - Possible Liquid Spills
  - Refrigerant and NGL
  - Design Spills

- Overpressure Radii
  - From Ignition of The Vapor Clouds
  - Demonstrate No damaging effects To The Public
FLACS 3-D Plant Model
FLACS 3-D Plant Model
Refrigerant Jetting and Flashing
Overpressure Modeling
Overpressure Modeling Result
Reduced Overpressure Isopleth by Reducing Vapor Release
Onsite Refrigerant Storage

- Required Due to Expected Depletion of Refrigerants In The Refrigeration Loop

- Size of Storage Determined by:
  - Leak Rates Through The System
  - Number of Days The Owner Chooses to Keep Inventories On-Hand
    - Facility’s Proximity to Refrigerant Distribution Sources
    - Acceptable Trucking Traffic
Onsite Refrigerant Storage

- An analysis to Determine Potential for And Consequences of a Boiling Liquid Expanding Vapor Explosion (BLEVE) Associated with Refrigerant Storage Vessels May Be Required
  - Demonstrate Siting Compliance with Requirements of 49 CFR 193 and NFPA 59A – U.S. Facilities
- Potential Mitigation Measures:
  - Mounding
  - Others
Components Modifications and Replacements
Modifications and Replacements

- LNG In-Tank Pumps
  - Import Terminals
    - Lower Flow Rates
    - Discharge Pressure Depending on Plant Layout, Configuration and Hydraulics
  - Export Facilities
    - Higher Flow Rate
    - Moderate Discharge Pressures

<table>
<thead>
<tr>
<th>Facility Type</th>
<th>In-Tank Pump Sendout Rate, (m³/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LNG Import Terminal, 1 to 2 Bscfd natural gas sendout</td>
<td>1,875 to 3,750</td>
</tr>
<tr>
<td>Natural Gas Liquefaction and LNG Export Facilities</td>
<td>10,000 to 12,000</td>
</tr>
</tbody>
</table>
Modifications and Replacements

- Considerations for In-Tank Pump Replacement
  - Investigate the Limits of Expanding Operating Range for Existing Pumps
  - Determine the Number of Pumps to be Replaced
    - Contractual Agreements
    - Operability
    - Redundancy for Various Operating Modes
Modifications and Replacements

- Considerations for In-Tank Pump Replacement
  - Number and Size of Existing Columns
    - Can Limit Facility’s Maximum LNG Transfer Rate
  - Electrical Demand
  - Size of Discharge Nozzles, Type of Foot Valve, Etc.
Modifications and Replacements

- LNG Transfer System
  - Flow Rate
    - Transfer Piping
    - Transfer Arms
  - Flow Direction - LNG
  - Flow Direction - Return Vapor
Modifications and Replacements

- **Vapor Handling System**
  - **Import Terminals:**
    - Excess BOG Is Re-Condensed, Vaporized and Directed to Sendout Pipeline
    - Components: BOG Header, Onshore BOG Compressor, BOG Recondenser
  - **Export Facilities**
    - Excess BOG is compressed and Routed Upstream of Liquefaction Train(s) And / Or Blended In The Fuel System
    - Components: BOG Header, Dock BOG Blower, Onshore BOG Compressors
Modifications and Replacements

- Potential Vapor Handling System Modifications
  - Onshore BOG Compressors
    - Re-Evaluation/Optimizing Existing Capabilities
    - Addition of BOG Compressors
    - Routing Excess BOG Upstream of Liquefiers
  - Dock Blower
    - Addition of Vapor Blower(s) At The Jetty
Vapor Handling

- Design Objective: Minimizing BOG Generation
  - Lower Storage Tank Operating Pressure Compared to Import and Regasification Operations
    - Relative Saturation Pressure: LNG in Storage Tank vs. LNG Carrier
  - LNG Product Condition Entering Storage Tank(s): Slightly Subcooled
  - Minimizing Heat Leak Throughout The System:
    - Vacuum Insulated Piping vs. Mechanically Insulated Piping
    - Proper Design of In-Tank Pumps
Modifications and Replacements

- **Flare System**
  - Significantly Smaller Loads in Import Facilities for Equivalent Gas Throughput Quality
  - Typically One Flare in Import Terminals
  - Typically Two to Three Flares in Export Facilities
Export Facility Flares

- Warm (Wet) Flare or Alternatively An Atmospheric Vent Stack
  - Dedicated to Relief Systems Containing Heavy Hydrocarbons
- Cold or Dry Flare
  - Dedicated to Relief Systems Containing Light Hydrocarbons
- Optional Marine Flare or Low Pressure Flare
  - Disposal of BOG or Other Low Pressure Gases, Not Manageable by The Facility
    - Unacceptable Composition
    - Warm Temperatures/High Flow Rates
    - Gassing-In or Cooling LNG Carriers
Flare Options

- Elevated Flare
  - Smaller Equipment Footprint
  - Significantly Tall Structure

SEGAS LNG Plant,

Sakhalin LNG Plant,
Flare Options

- Ground Flare
  - Larger Equipment Footprint
  - Short Structure

Burners Distribution in a Multipoint Ground Flare

Darwin LNG Ground Flare System

Image Courtesy of Zeeco
Other Considerations

- LNG Storage Tank
  - Relief Studies
  - Roll-Over Assessment
  - Piping Hydraulic and Stress Analyses
  - Fulfillment of Existing Contractual Obligations
- Electrical Distribution System
- Control System
Summary

- Trend of The Day
- Advantages and Challenges
- Innovative Engineering Solutions to Overcome Hurdles
Thank You

Questions?

Mona Setoodeh
CH·IV International
msetoodeh@ch-iv.com