Liquefied Natural Gas Emissions Reduction Opportunities

Lessons Learned from Natural Gas STAR

Producers and Processors Technology Transfer Workshop

ConocoPhillips and EPA’s Natural Gas STAR Program
Kenai, AK
May 25, 2006

Liquefied Natural Gas (LNG): Agenda

LNG Sources of Emissions
- Methane Losses
- Methane Recovery
- Is Recovery Profitable?
- Industry Experience
- Discussion Questions
US LNG Facilities

Methane Losses: LNG Facilities

Source: EIA, "US LNG Markets and Uses: June 2004 Update"
Emission Sources

<table>
<thead>
<tr>
<th>LNG Emission Sources (Combined Sources by Type)</th>
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</thead>
<tbody>
<tr>
<td>Export Terminal</td>
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<tr>
<td>Ship in Transit</td>
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<tr>
<td>Ship Unloading</td>
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<tr>
<td>Ship Loading</td>
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<tr>
<td>Terminal Operations</td>
</tr>
<tr>
<td>Storage Tanks</td>
</tr>
<tr>
<td>Boiloff Gas Recovery</td>
</tr>
<tr>
<td>Sendout (pumps, vaporizers)</td>
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<tr>
<td>Liquefaction</td>
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<tr>
<td>Vehicle Fuel</td>
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</tbody>
</table>

LNG Operations

- Natural gas liquefaction
  - Compression and cryogenic cooling
- LNG storage tanks
- LNG marine terminals
  - Loading and unloading LNG from large tankers
- LNG tankers
  - Vessels for import and export of LNG
- LNG send-out
  - Vaporization and injection into pipelines
Liquefaction Equipment

- **Description**
  - Progressively lower temperature refrigeration loops
  - Phillips cascade (3 refrigerants)
  - Mixed refrigerants

- **Possible sources of methane emissions**
  - Compressor seals
  - CO$_2$ removal systems
  - Dehydration systems
  - Tank overpressure
  - Ship loading displacement vapors
  - Loading arm disconnection

LNG Storage tanks

- **Tank vapors**
  - 99+% methane
  - Near atmospheric pressure
  - Cold - visible leaks

- **Possible emission sources - venting of vapors**
  - Tank overpressure venting
  - Leaks from pressure relief valves
  - Vapor recovery compressors

Source: FERC
LNG Marine Terminals

- Special equipment beyond an LNG storage facility
  - Vessel loading arms
  - Vapor return blowers

- Possible emissions sources
  - Fugitives
  - Venting, if boil-off vapor cannot be consumed as fuel

Source: ConocoPhillips

Source: EIA, "US LNG Markets and Uses: June 2004 Update"
LNG Tankers

- Long distance transport of LNG
  - Fleet approaching 200
  - Kenai, AK exports LNG to Pacific rim, Japan (1969)
  - Cargos to US in 2005: 197
  - 5 existing US terminals
  - 1 new terminal every 2 years starting 2008

Possible emissions sources

- Flange and fitting leaks during cool down
- Leaking vapor recovery systems, not operating
- Leaking cargo tank relief valves
- Cargo tank venting during delays

LNG Sendout

- LNG from tanks is pumped to pipeline pressure and then vaporized

Possible emission sources

- Vaporizer fuel system leaks
- Pressure relief valves
Methane Savings from Compressors

- Centrifugal compressor seals
  - Wet seal oil degassing vents methane to the atmosphere
    - Typical wet seal emissions of 40 cf/min to 200 cf/min
  - Dry seals pump gas between the seal rings creating a high pressure barrier to leakage
    - Typical dry seal emissions of 0.5 cf/min to 3.0 cf/min
  - Gas savings translate to approximately $112,000 to $651,000 per year at $7/Mcf

Methane Savings from DI&M

- Fugitive losses can be dramatically reduced by implementing a DI&M program
  - Voluntary program to identify and fix leaks that are cost effective to repair
  - Survey cost typically pay out in the first year
  - Provides valuable data on leakers with information of where to look
Is Recovery through DI&M Profitable?

<table>
<thead>
<tr>
<th>Component</th>
<th>Value of Lost Gas ($)</th>
<th>Estimated Repair Cost ($)</th>
<th>Payback (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plug Valve: Valve Body</td>
<td>29,496</td>
<td>200</td>
<td>0.1</td>
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<tr>
<td>Union: Fuel Gas Line</td>
<td>28,362</td>
<td>100</td>
<td>0.0</td>
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<td>Threaded Connection</td>
<td>24,374</td>
<td>10</td>
<td>0.0</td>
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<tr>
<td>Open-Ended Line</td>
<td>16,238</td>
<td>60</td>
<td>0.0</td>
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<tr>
<td>Compressor Seals</td>
<td>13,493</td>
<td>2,000</td>
<td>1.8</td>
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<tr>
<td>Gate Valve</td>
<td>11,034</td>
<td>60</td>
<td>0.1</td>
</tr>
</tbody>
</table>

1Based on $7/Mcf gas price

LNG Emission Prevention Opportunities

- Improved connect/disconnect practices
- Improved tank pressure management
- Improved vapor recovery system maintenance and availability
- Strict enforcement of ship venting rules
Summary

LNG Sources of Emissions - *Operations and equipment*
- Methane Losses – *Compressor seals and leaks*
- Methane Recovery – *Alternative seals and DI&M*
- Is Recovery Profitable? - *Probably*
- Industry Experience – *ConocoPhillips Presentation*
- Time for Discussion & Questions