Agenda

- Nitrogen Contamination in Natural Gas
- Methane Losses from Nitrogen Rejection
- Methane Recovery
- Partner Experience
- Is Recovery Profitable?
- Discussion Questions
Nitrogen Contamination in Natural Gas

★ 16% of US gas reserves contain large volumes of nitrogen*

◆ Gas with high nitrogen must be processed to meet heat content specifications (about 4% nitrogen by volume)

★ Wellhead gas can have well over 15% nitrogen, especially in associated gas production

◆ Nitrogen is sometimes injected for enhanced oil recovery operations and for pressure maintenance

★ Unacceptable levels of nitrogen can be removed with a Nitrogen Rejection Unit (NRU)

*www.engelhard.com
Reducing Emissions, Increasing Efficiency, Maximizing Profits

Methane losses from NRUs are included in blowdown venting and plant fugitives.

- Blowdowns: 2 Bcf
- Centrifugal Compressors: 6 Bcf
- Gas Engine Exhaust: 7 Bcf
- Reciprocating Compressors: 17 Bcf
- Plant Fugitives: 2 Bcf
- Dehydrators and Pumps: 1 Bcf
- Other Sources: 1 Bcf
Methane Losses from Nitrogen Rejection

★ NRU fugitives
  ◆ Methane leaks occur at valves, piping connectors and open ended lines
  ◆ Natural Gas STAR accounts for these leaks in processing plant fugitive emissions

★ Nitrogen reject vent
  ◆ Reject stream usually contains some methane, 1 to 5%
  ◆ Natural Gas STAR accounts for these vents in processing plant blowdown/venting emissions
NRU Fugitives

Clearstone study of 4 processing plants measured NRU fugitives

<table>
<thead>
<tr>
<th>Component</th>
<th>Emission Factor (Mcf/yr/component)</th>
<th>Activity Factor (components/plant)</th>
<th>Emissions (Mcf/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NRU Valves</td>
<td>11.37</td>
<td>101</td>
<td>1,148.70</td>
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<tr>
<td>NRU Connectors</td>
<td>2.50</td>
<td>242</td>
<td>604.04</td>
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<tr>
<td>NRU PRVs</td>
<td>0.00</td>
<td>2</td>
<td>0.00</td>
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<tr>
<td>NRU Comp Seals</td>
<td>0.00</td>
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<td>0.00</td>
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<tr>
<td>NRU OELs</td>
<td>7.77</td>
<td>8</td>
<td>62.15</td>
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<tr>
<td>Total NRU Fugitive Emissions</td>
<td></td>
<td></td>
<td>1,815</td>
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<tr>
<td>Total Gas Plant Fugitive Emissions</td>
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<td>41,116</td>
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NRU Vented Methane

★ Methane is lost in the nitrogen reject stream

◆ On-line gas chromatograph can alert operators to the methane content of the reject stream

★ Over a year, the small fraction of methane in the reject stream can add up to significant methane loss

★ NRU optimization can reduce product loss in the reject stream, with a payback of <1 year
Nitrogen Rejection Unit

★ Large gas feeds with nitrogen content of 10% or greater are best processed with cryogenic NRUs

◆ All sulfur, water, and mercury must be removed first to avoid corrosion
◆ Dry gas then cooled to cryogenic temperatures where methane condenses
◆ Non-condensable gases purged and vented to the atmosphere
NRU Setup

Feed Gas >10% N₂ → Methane Preseparation Column → Nitrogen Rejection Columns → Nitrogen Reject ~98.5% N₂

Nitrogen Reject ~98.5% N₂ → Plate-fin Heat Exchangers → Cold Box 2

Cold Box 2 → Methane Pumps

Methane Pumps → Centrifugal Gas Compressor

Centrifugal Gas Compressor → Cold Box 1

Cold Box 1 → Plate-fin Heat Exchangers

Plate-fin Heat Exchangers → Methane Pumps

To Pipeline <5% N₂

NRU Bypass

Reducing Emissions, Increasing Efficiency, Maximizing Profits
Methane Recovery: Optimizing NRU

- Building a process-specific model of your NRU is crucial to optimization
  - Model all equipment in the process
  - Include all input material and energy streams and typical variations for those streams
- Sensitivity calculations can help to develop recommendations for maintenance and process modification
- Prioritize recommendations and develop a maintenance schedule
Optimization Activities

★ Depends on the process model results
  ◆ Adjust temperature/pressure in nitrogen reject columns
  ◆ Inspect and clean heat exchangers
  ◆ Re-tray nitrogen reject columns

★ Prioritize activities
  ◆ Temperature/pressure adjustments can be made by control systems
  ◆ Replacing column trays requires unit to be taken out of service
Partner Experience

☆ One Gas STAR partner operating an older NRU took steps to optimize their process

◆ NRU was 20+ years old
◆ High nitrogen composition gas (60% N₂)
◆ On-line chromatograph showed 5% methane in reject stream

☆ Contractor hired to develop a process model and provide process optimization recommendations
Optimization Recommendations

☆ Change control settings
  ◆ Adjust nitrogen reject column reflux

☆ Perform maintenance
  ◆ Fix leaking valve that had iced over

☆ Change process equipment
  ◆ Re-tray columns with higher efficiency trays
    ▪ Scheduled at a later date
After performing recommended activities (aside from replacing column trays) methane in the reject stream was reduced from 5% to 2%

- 50 MMcf/day NRU with 60% inlet nitrogen saved over 200,000 Mcf/yr

- Additional savings are anticipated from replacing column trays
Is Recovery Profitable?

- Gas savings of 200,000 Mcf/yr
- Optimization costs
  - $35,000 for process model development on existing software
  - $15,000/yr for plant maintenance

<table>
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<th>Gas Price ($/Mcf)</th>
<th>2.00</th>
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<tbody>
<tr>
<td>Gas Saved (Mcf/yr)</td>
<td>200,000</td>
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<td>Annual Savings ($/yr)</td>
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<tr>
<td>Installed Cost</td>
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<tr>
<td>Operating Cost</td>
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<td>Payback Period (months)</td>
<td>1.1</td>
<td>0.7</td>
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Discussion Questions

★ Is the methane content of the nitrogen reject stream continuously monitored in your NRU?
★ How can this presentation be improved to help you determine your opportunities for NRU methane savings?
★ What other activities have you undertaken to increase the efficiency of your NRU?