Routing Centrifugal Compressor Seal Oil De-gassing Emissions to Fuel Gas as an Alternative to Installing Dry Seals

Global Methane Initiative All-Partnership Meeting

Oil and Gas Subcommittee – Technical and Policy Sessions

October 14, 2011
Krakow, Poland

Reid Smith
BP, Senior GHG and Air Quality Advisor
Agenda

- Natural Gas STAR Program Background
- Centrifugal Compressor Wet Seals
- Retrofitting/Installing Dry Seals
- Background and Summary of North Slope Study
- Overview of North Slope Operations
  - Central Gas Facility
  - Central Compressor Plant
- Sour Seal Oil Vapor Recovery System
- Early Results: BP Measurements of CCP
- Preliminary Results: Velocity Measurements
- Applicability/Benefits
- Conclusions and Next Steps
- Contact Information
Natural Gas STAR Program Background

- The Natural Gas STAR Program is a flexible, voluntary partnership with oil and natural gas companies—both in the United States and internationally to promote cost-effective technologies and practices that reduce emissions of methane.
- The main goal of Natural Gas STAR is to work with Partner companies to develop technical information and then facilitate the implementation of mitigation practices across the industry.
- As both a potent greenhouse gas and clean energy source, reducing methane emissions has both environmental and economic benefits.
- BP has been an active Partner since 1995, contributing to the Natural Gas STAR Program’s technical information and technology transfer efforts.
Centrifugal Compressor Wet Seals

- High pressure seal oil circulates between rings around the compressor shaft
- Oil absorbs the gas on the inboard side
  - Little gas leaks through the oil seal
  - Seal oil degassing vents methane to the atmosphere
- Wet seals leak little gas at the seal face
- Most emissions are from seal oil degassing
- Seal oil degassing may vent 1.1 to 5.7 m³/minute
- One Natural Gas STAR Partner reported emissions as high as 2,124 m³/day

Source: PEMEX
Traditional Solution: Retrofitting/Installing Dry Seals

- **Dry seals:**
  - 0.8 to 5.1 m$^3$/hour (0.01 to 0.08 m$^3$/minute) leak rate
  - Significantly less than the 1.1 to 5.7 m$^3$/minute emissions from wet seals
- Very cost-effective option for new compressors
- Significant capital costs and downtime for retrofitting compressors
  - See *Lessons Learned* for more info
- Alternative exists for more cost-effective seal oil degassing and vapor recovery retrofit with less downtime

Dry seals keep gas from escaping while rotating with the shaft

Tandem dry seals

Source: PEMEX
Background of North Slope Study

- Natural Gas STAR learned of anecdotal information on this potential mitigation opportunity a few years back
  - Developed a theoretical example and presented to Natural Gas STAR Partners at workshops and in the Spring 2009 Newsletter

- In taking measurements, BP discovered their wet seal recovery system on centrifugal compressors at its North Slope facilities
  - BP’s initial results showed recovery of >99% of seal oil gas that would be otherwise vented to atmosphere from degassing tank

- Led to BP and Natural Gas STAR collaboration on detailed measurement study of alternative wet seal capture mitigation opportunity
  - Recovery system that separates gas from the sour seal oil before being sent to the degassing tank
  - Recovered gas sent to various outlets: flare, low pressure fuel, turbine fuel ~273 psig (18.6 Bar), compressor suction
  - System leads to lower emissions from degassing tank vent (more details on following slide)
Summary of North Slope Study

**Purpose:**
Evaluate methane emissions capture from sour seal oil vapor recovery systems on centrifugal compressors at the North Slope. Systems show evidence of reducing wet seal degassing emissions.

**The Team:**
- Natural Gas STAR
- BP local and global staff
- North Slope facility operators
- North Slope emissions measurement specialists

**Goals:**
A detailed evaluation and review of all sour seal oil recovery systems on the North Slope with:
- Real-time measurement data from one facility (CCP)
- Engineering calculations from CGF and other facilities as applicable
Comprehensive characterization of wet seal degassing recovery system including process/operating requirements, applicability, limitations, emission reduction potential, costs, and economics.

**The Tools:**
- In-depth understanding of compressor wet seal recovery system design and layout
- FLIR IR camera
- Vent anemometer
- P&IDs and operational data
- Complete readouts of compressor operating conditions and key parameters

This presentation is focusing on preliminary results from Central Compressor Plant (CCP) only; final results will be available at a later date.
Overview of North Slope Operations

Prudhoe Bay

How we get the oil from the ground to the Trans-Alaska pipeline.

Crude oil at Prudhoe Bay is located in the Sablechit zone, a sandstone formation at approximately 9,000 feet below the earth’s surface. Pressure from the formation pushes the crude up a well to the surface where a wellhead controls the flow of crude. Wellheads are located on gravel drill sites and are covered by a well house for worker and equipment protection against the harsh arctic environment. From here the crude flows through the manifold building, also located on the drill site, where oil/gas/water ratio is determined. Crude then travels to a processing center and is separated into oil, gas, and water. Natural gas is sent to the gas handling facilities for reinjection back into the field. Produced water is sent back to the drill sites and reinjected into the formation to help in the oil recovery. Oil continues its journey to Alyeska’s Pump Station 1 to begin its 800 mile trip to Valdez.
Overview of North Slope Operations

~100 Centrifugal Compressors
All but a few with Wet Seals
All Wet Seal machines equipped with recovery system
Pressures: 3 psi suction => 4,700 psi discharge

Prudhoe Bay process flow and volumes
Overview of North Slope Operations

Key facilities visited

Start of TAPS
Central Gas Facility (CGF)

- World’s largest gas processing plant (max feed of 246 MMcm/day)
- Processes all gas from Prudhoe Bay gathering & boosting stations (except local fuel)
- Products:
  - Residue gas
  - Natural gas liquids (blended with oil and delivered to TAPS)
  - Miscible injectant (used for EOR purposes)
- 11 compressors (totaling over 500,000 HP)
  - Three boosters
  - Two refrigerant
  - Two MI
  - Four tandems
- Seal oil vapor recovery lines sent to flare
Central Compressor Plant (CCP)

- World’s largest compressor station (~238 MMcm/day capacity)
- Receives residue gas from CGF, compresses to higher pressures, and sends to gas injection wellpads (~200 MMcm/day at 3,600 to 4,000 psig)
- 15 compressors (totaling 537,000 HP)
  - Nine low pressure (1st stage) compressors in parallel
  - Four high pressure (2nd stage) compressors in parallel
  - Two tandem compressors (1st and 2nd stages) in parallel
- Seal oil vapor recovery lines sent to flare or fuel gas (for compressor turbines, heaters, and blanket gas)
Sour Seal Oil Vapor Recovery System

1. New fuel pressure seal oil degassing drum and demister ("sour seal oil trap")
2. Atmospheric seal oil degassing drum
3. Less gas vented to atmosphere
4. Seal oil circulation pump

4 OPTIONS
- FLARE
- 18.0 atm
- 1.8 atm
- 4.4 atm

*Note: New equipment in red*
Sour Seal Oil Vapor Recovery System: CCP

Restrictive Orifice 1/16”
Seal Oil Degassing Separators
Seal Oil Degassing Separators
Seal Oil Degassing Separator/System

Restrictive Orifice
(note frost from expansion cooling)
Seal Oil Degassing Separators
CCP Fuel Gas Layout

CCP Fuel Gas Schematic
Early Results: BP Measurements of CCP

- Table shows initial measurements taken by BP from a low- and high-pressure compressor at CCP before study.
- Used nitrogen as “tracer gas” to calculate methane and total hydrocarbon flow-rates.
- Recovered Gas: 0.92 MMSCFD LP; 3.7 MMSCFD HP Turbine Fuel.

<table>
<thead>
<tr>
<th></th>
<th>High-Pressure Compressor</th>
<th>Low-Pressure Compressor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen Purge Rate (SCF/Hr)</td>
<td>33</td>
<td>25</td>
</tr>
<tr>
<td>Vent Analysis (mole%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogen</td>
<td>43.846</td>
<td>86.734</td>
</tr>
<tr>
<td>Methane</td>
<td>37.872</td>
<td>6.93</td>
</tr>
<tr>
<td>Total Hydrocarbon + CO2</td>
<td>56.1540</td>
<td>13.2660</td>
</tr>
<tr>
<td>Total Methane Flow (SCFM)</td>
<td>0.4751</td>
<td>0.0333</td>
</tr>
<tr>
<td>Total Process Gas Flow (SCFM)</td>
<td>0.7044</td>
<td>0.0637</td>
</tr>
<tr>
<td>Number of Seals</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Total Methane Flow (SCFM/Seal)</td>
<td>0.2375</td>
<td>0.0166</td>
</tr>
<tr>
<td>Total Process Gas Flow (SCFM/Seal)</td>
<td>0.3522</td>
<td>0.0319</td>
</tr>
<tr>
<td>&quot;Average&quot; Total Gas/Seal (SCFM)</td>
<td>108</td>
<td>108</td>
</tr>
<tr>
<td>Control Percentage</td>
<td>0.997</td>
<td>1.000</td>
</tr>
</tbody>
</table>
Preliminary Results: Velocity Measurements

Table shows vane anemometer measurements taken prior to and during the study.

Full results of study are not yet final, but initial results from CCP measurements show generally consistent with BP’s results from before the study.
CCP Compressor Vent Measurement
Close-up
FLIR Camera Verification
Applicability/Benefits to Oil and Gas Companies

Based on the results of this study, this sour seal oil vapor recovery system could prove to be an economic alternative to dry seal retrofits on centrifugal compressors:

- Dry seals on new compressors are now more prevalent in industry—typically cheaper than wet seals.
- Dry seal retrofits on older compressors are still very high in cost; ~$250,000 to $1 million per compressor.
- Sour seal oil vapor recovery system on wet seals compressors much lower in capital cost, requires short-duration compressor shutdown or interruption in gas service.

Project characterization could provide companies with a way to both reduce methane emissions and utilize recovered gas cost-effectively.
Applicability/Benefits

- Investment includes cost of:
  - Intermediate degassing drum ("sour seal oil trap")
  - New piping
  - Gas demister/filter
  - Pressure regulator for fuel gas line

- Project summary:
  - Less expensive capital costs compared to dry seals
  - Prevents most seal oil gas emissions from venting to atmosphere while also improving site efficiency
  - Positive cash flow after less than a month

<table>
<thead>
<tr>
<th>PROJECT SUMMARY: CAPTURE AND USE OF SEAL OIL DEGASSING EMISSIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Requirements</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Capital &amp; Installation Costs</td>
</tr>
<tr>
<td>Annual Labor &amp; Maintenance Costs</td>
</tr>
<tr>
<td>Methane saved</td>
</tr>
<tr>
<td>Gas Price per Mcm</td>
</tr>
<tr>
<td>Value of Gas Saved</td>
</tr>
<tr>
<td>Payback Period in Months</td>
</tr>
</tbody>
</table>

¹Assuming a typical seal oil flow rate of 14.20 liters/minute (3.75 gallons/minute)
Conclusions and Next Steps

Preliminary results are promising and indicate that sour seal oil vapor recovery from centrifugal compressors can be a viable project option for companies.

BP and Natural Gas STAR currently analyzing data obtained during study.

BP and Natural Gas STAR will continue to collaborate on this study to fully characterize the seal oil vapor recovery system seen on the North Slope.

Team to publish more detailed results of study in a future article.
Contact Information

For further details, direct questions to:

**Suzie Waltzer**  
EPA Natural Gas STAR Program  
waltzer.suzanne@epa.gov  
+1 (202) 343-9544

**Reid Smith**  
BP  
gordon-reid.smith@bp.com  
+1 (281) 384-3583

**Don Robinson**  
ICF International  
drobinson@icfi.com  
+1 (703) 218-2512