Energy Efficiency and Emissions Reduction using RemVue/Slipstream Technology

by Paul Slobodnik, P.Eng.
ConocoPhillips Canada

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ConocoPhillips Canada “Green” Initiatives:

• ConocoPhillips Canada Background
  – Significant Producer $\rightarrow$ #3 Fuel gas user in Alberta
  – Declining production = increasing fuel gas intensity
  – Carbon Taxes adding to Operating costs

• Strong Corporate Commitment to Emissions Reduction and Energy Efficiency

• Energy Efficiency team in place for 3 years
  – Technology evaluation and roll-out
  – Project tracking and reporting
Technology to Improve Efficiency and Reduce Emissions

• RemVue®
  – Air/Fuel Ratio Control
  – Reduced Fuel Gas (CO2, NOx) in Natural Gas Engines

• SlipStream®
  – Captures Vented Gas and Burns it in Engines
  – “Piggy-Backs” on RemVue
RemVue Air/Fuel Ratio Control

- Controls Air Fuel mixture to the engine
  - Theory – Lean fuel mixture = better combustion = less fuel gas required
  - Lower CO2e emissions

- Adaptive Control System - Air/Fuel Control alone isn’t enough
  - Must be able to operate through “upsets”
  - Load Swings, Pressure Swings, Temperature swings, low temperatures
  - Engine shut-downs not acceptable
RemVue Air/Fuel Ratio Control

Operational Regimes
1. Rich
2. Stoichiometric
* 3. Lean – Best fuel
* 4. Lean – Low NOx

In stoichiometric or rich burn engines, much of the energy goes “up the stack” or to the catalytic converter in the form of CO and unburned methane.
RemVue Air/Fuel Ratio Control

Fuel measurement
Fuel control
Air Control

Control System
RemVue Air/Fuel Ratio Control – Field Install details

- Fuel measurement
- Fuel control
- Air Control

Control System
RemVue Air/Fuel Ratio Control

• Mechanical scope of work
  – Fuel Gas Meter
  – Fuel Gas Control Valve
  – Exhaust Valve to control air-flow
  – air-intake manifold balance line (if required)

• Electrical/Instrument scope of work
  – Speed pick-up
  – Air-inlet pressure transmitter(s)
  – Fuel gas meter
  – i/p transducers for fuel and exhaust control valves
  – Manifold temperature thermocouple(s)

• Pre and Post-Audits
  – Verify performance
  – Program engine load-map and control
# RemVue Air/Fuel Ratio Control

## ConocoPhillips Canada 2008/9 Results

<table>
<thead>
<tr>
<th>Engine</th>
<th>Pre-RemVue Fuel kg/hr</th>
<th>Post-RemVue Fuel kg/hr</th>
<th>Pre-RemVue BSFC - btu/bhp-hr</th>
<th>Post-RemVue BSFC - btu/bhp-hr</th>
<th>Average Fuel Gas Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waukesha 7042GSI</td>
<td>240</td>
<td>184</td>
<td>10,122</td>
<td>7,823</td>
<td>23.0%</td>
</tr>
<tr>
<td>Waukesha 7042GSI</td>
<td>191</td>
<td>148</td>
<td>9,289</td>
<td>7,386</td>
<td>21.5%</td>
</tr>
<tr>
<td>Waukesha 7042GSI</td>
<td>192</td>
<td>163</td>
<td>8,540</td>
<td>7,460</td>
<td>13.9%</td>
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<tr>
<td>Waukesha 7042GSI</td>
<td>163</td>
<td>137</td>
<td>8,400</td>
<td>7,447</td>
<td>13.7%</td>
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<tr>
<td>Waukesha 7042GSI</td>
<td>274</td>
<td>238</td>
<td>8,661</td>
<td>7,552</td>
<td>13.0%</td>
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<tr>
<td>Waukesha 7042GSI</td>
<td>200</td>
<td>172</td>
<td>10,014</td>
<td>9,012</td>
<td>11.9%</td>
</tr>
<tr>
<td>Waukesha 7042GSI</td>
<td>170</td>
<td>148</td>
<td>8,636</td>
<td>7,678</td>
<td>11.9%</td>
</tr>
<tr>
<td>White-Superior 16G-825</td>
<td>149</td>
<td>133</td>
<td>9,892</td>
<td>9,138</td>
<td>9.2%</td>
</tr>
<tr>
<td>Waukesha 7042GSI</td>
<td>266</td>
<td>254</td>
<td>9,875</td>
<td>9,318</td>
<td>5.0%</td>
</tr>
</tbody>
</table>

Exhaust temperatures ~70 C cooler
SlipStream Vent Gas Capture System

• Captures gas that is normally vented to atmosphere and burns this as engine fuel gas
  – Instrumentation and pump gas vents
  – Compressor packing and seals
  – Tank vapours, ........

• Installed on engines that have RemVue in place
  – Vented gas is blended with engine air (non-standard operation)
  – Need Robust controls to ensure stable operation with this additional fuel source
  – SlipStream control module – minor RemVue panel addition
SlipStream Vent Gas Capture System

Fuel Gas to Engine

Air to Turbo’s

Engine with RemVue Only

Control System

Vented Gas

Misc. Equipment
SlipStream Vent Gas Capture System

- Fuel Gas to Engine
- Air to Turbo’s
- RemVue plus SlipStream
- Captured Gas
- Misc. Equipment
- Control System
SlipStream – Noel Gas Plant

• **Noel Gas Plant**
  – Located in British Columbia
  – 150 MMscfd Process Capacity
  – 4 Inlet compressors – 2200 hp each
  – 5 Sales compressor – 1478 hp each

• **Vent gas sources??**
  – Plant has instrument air – therefore no instrument vents
  – Main vented gas from compressor packing vents
Crankcase
Distance Piece
Cylinder
Reciprocating Compressors – Components

SlipStream – Noel GP
Reciprocating Compressors – Components and Vents

- **V1** – Packing vent/drain
- **V2** – Distance piece drain
- **V3** – Distance piece vent
- **V4** – Crankcase vent

**Cylinder**
**Distance Piece**
**Crankcase**
SlipStream – Noel GP – Vent Details

High Pressure Gas in Cylinder

Atmospheric Pressure

High Pressure Gas Leaks past packing rings

V1

V2

V3

V4

to V1 (90+%)
SlipStream – Noel Gas Plant – Vented Gas

- **Sales Compressors**
  - 3 @ 3-cylinder (Phase 1)
  - 2 @ 4-cylinder

- **Inlet Compressors**
  - 4 @ 6-cylinder

- **Total Plant**
  - 41 cylinders (packing leaks)
Vented Gas Stream from Compressor Packing etc.
### SlipStream – Noel Gas Plant – Vented Gas

<table>
<thead>
<tr>
<th>Gas Source</th>
<th>Vented Gas (scfh)</th>
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</thead>
<tbody>
<tr>
<td>Comp 1 Packing and Distance Piece</td>
<td>76.5</td>
</tr>
<tr>
<td>Comp 2 Packing and Distance Piece</td>
<td>57.8</td>
</tr>
<tr>
<td>Comp 3 Packing and Distance Piece</td>
<td>101.2</td>
</tr>
<tr>
<td>Comp 1 Crankcase Vent</td>
<td>30.9</td>
</tr>
<tr>
<td>Comp 2 Crankcase Vent</td>
<td>0</td>
</tr>
<tr>
<td>Comp 3 Crankcase Vent</td>
<td>109.9</td>
</tr>
<tr>
<td>Comp 4 Packing and Distance Piece</td>
<td>169.4</td>
</tr>
<tr>
<td>Comp 5 Packing and Distance Piece</td>
<td>264.3</td>
</tr>
<tr>
<td>Comp 4 Crankcase Vent</td>
<td>Not measured</td>
</tr>
<tr>
<td>Comp 5 Crankcase Vent</td>
<td>Not measured</td>
</tr>
<tr>
<td><strong>Total Gas Savings</strong></td>
<td>810 scfh</td>
</tr>
<tr>
<td><strong>Total CO2e Reduction</strong></td>
<td>2,862 Te/yr</td>
</tr>
</tbody>
</table>

**Phase 1**

**Phase 2**

![Diagram showing the position of components 1, 2, 3, 4, and 5 on the Noel Gas Plant.]
SlipStream – Noel Gas Plant – Design Basis

• Potential Gas Capture of 810 scfh
• Install SlipStream on 1 compressor – capture vents from many

• Phased Vent-Capture Scope:
  – Capture vents from 3 Sales Compressors in same building to prove-up concept
  – Capture vents from 2 other nearby Sales Compressors
  – Capture vents from 4 inlet compressors ($$ piping cost)

• Unique Design Attribute – Air Intake System
  – “Old-School” oil bath air inlet filter on engine
  – Results in negative air intake pressure of -9” WC to -27”WC
  – Decided to take advantage of this to “vaccum-up” the vents to reduce piping complexity
SlipStream – Noel GP – Vent Details

Noel Test:
If we “Vacuum-Hard” on V1 – no gas should get through to V2, V3 & V4??

to V1 (90+%)
SlipStream – Noel Gas Plant – Results

- “Vacuum” system captured about 25% of the vented gas
- Various theories – plugged lines, pressure drop, ...
- Will tie-in remainder of vents to capture 100% of gas
Next Steps

• **SlipStream – Noel Gas Plant**
  - Tie-in all vent sources to capture 100% of vented gas for the first 3 compressors
  - Evaluate tie-in of other compressors
  - Evaluate other potential vent sources on-site (compressor maintenance blow-down gas, tanks, )

• **RemVue and SlipStream Next Steps**
  - Identify other RemVue and SlipStream opportunities in our Operations
  - Low horsepower test – to meet emissions, and fuel reduction
Project Learnings

• Project Learnings
  – Many vent gas capture projects are small, retrofit projects
  – Both of these factors have significant cost escalation risk
  – Need thorough design before construction (a few dollars on paper can save many dollars in steel!)
  – Treat the construction as “maintenance” to reduce costs associated with “formal projects”
  – Local providers are best – travel can be a significant part of a small project
  – RemVue technical learnings – check air-cooler sizing, ensure all operating parameters covered by engine control map