BP Background

- BP Canada operates in AB and NE BC. >90% of its production is natural gas.
- Compressor combustion emissions are our #1 emitter. Fugitives are #2.
- Significant push for quantifying and reducing its fugitive and vented emissions.
- BP Canada has over 250 compressor engines. ~20% have REMVue® control panels, most with Air Fuel management control.
BP Canada E&P Operations

720 miles

760 miles
Emission Projections Provincial

http://environment.gov.ab.ca/info/library/5892.ppt
SlipStream™ is the REM Technology product* designed for utilizing vented hydrocarbons as a supplementary fuel source for natural gas engines.
Design Objectives for SlipStream™

- Develop a technology that would allow vented hydrocarbons to be used as supplementary fuel for natural gas engines
- Must not reduce performance or reliability of engine
- Must be scaleable from low volumes of supplementary fuel to high volumes
- Must be able to compensate (Air-Fuel Ratio and Governor) for variable flow and BTU value of the supplementary fuel
- Must be able to handle diluted and undiluted sources
- Must be safe — Safety First
Pilot Site Selection

- Engaged workforce
- Has a source that can be easily captured
- Site with existing REMVue® AFR control Panel
- Minimally affect production during testing and commissioning
Initial Site Details

SlipStream™ Sources:

- **Packing Vent Gas** *(Diluted)*
  - Available from 3 units
  - Includes packing/distance piece vents and drains
  - Process gas is sweet natural gas
  - Headers located in main building adjacent to compressors

- **VRU Gas** *(Undiluted)*
  - Flash gas collected from Gas Boot feeds 1st stage suction of VRU (more than 2x btu value)
  - Make-up gas system supplements VRU when there is insufficient gas from the Gas Boot
  - VRU building located ≈ 45 m from Waukesha compressor building
  - Existing pipe and pipe rack
**Initial Site Details**

Unit 2 – Waukesha 9390 GSI with REMVue® Rich-to-Lean AFR

- Three Waukesha 9390 engines (2× GSI, 1× GL)
- Two units running continuously ≈ 50–60 % loaded
- Third unit functions as backup
- Adjacent White-Superior no longer used
- Pre-existing REMVue® – 500/AS system on Unit #2
Installation Details
Installation

**VRU Gas**
- 2” Sch. 80 pipe
- Liquids drop out vessel
- Manual isolation valves
- Control valve and I/P
- Shutoff valve and solenoid
- Pressure transmitter
- Flow meter
- Screen
- Sampling ports
- Low point drain
Installation

- Packing Vent Gas
  - 1” Sch. 80 pipe
  - Control valve and I/P
  - Manual isolation valve
  - Sampling ports
  - Packing vent filter (optional)
  - Packing vent thermocouple
  - Wide range lambda sensor hardware
Installation
Safety Review
Safety

- Any given SlipStream™ system may have one or more undiluted and/or diluted sources that may interface with any number of existing site processes and associated equipment.
- Given the diversity of processes and equipment in the field, it is crucial that a site-specific HAZOP is conducted.
- The complexity of the SlipStream™ design will depend on the type of SlipStream™ system, amount of flow, gas quality, expected process fluctuations, upstream equipment, etc.
- The safe operation of the SlipStream™ System is the primary design objective.
Safety

Gas Concentration

If the air-fuel mixture remains below the Lower Explosive Limit for that mixture, an explosion cannot occur.

Combustion

Fuel + Oxidizer + Energy Source

Lower Explosive Limit

The minimum percent by volume of a gas in air which forms a flammable mixture at normal temperatures and pressures.\(^2\)

Table 1 Gas Mixture and LEL Percentages

<table>
<thead>
<tr>
<th>FUEL</th>
<th>FUEL SPECIFIC GRAVITY (REL. TO AIR)</th>
<th>STOICHIOMETRIC % OF FUEL IN MIXTURE</th>
<th>LEAN ((\lambda = 1.5)) % OF FUEL IN MIXTURE</th>
<th>LEL %</th>
<th>SLIPSTREAM % OF FUEL IN AIR LEVEL 3 – 50% OF ENGINE FUEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>0.56</td>
<td>10.1</td>
<td>6.7</td>
<td>5</td>
<td>3.4</td>
</tr>
<tr>
<td>Ethane</td>
<td>1.04</td>
<td>5.3</td>
<td>3.6</td>
<td>3</td>
<td>1.8</td>
</tr>
<tr>
<td>Propane</td>
<td>1.52</td>
<td>3.7</td>
<td>2.4</td>
<td>2.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Butane</td>
<td>2.02</td>
<td>2.75</td>
<td>1.8</td>
<td>1.8</td>
<td>0.9</td>
</tr>
</tbody>
</table>


BP SlipStream™

PRELIMINARY RESULTS AND LESSONS LEARNED
Engine Fuel Flows

- SlipStream Flow (VRU)
- Main Fuel Flow
- Total Fuel Flow

SlipStream flow turned off
SlipStream flow turned on

Time hh:mm:ss
Flow kg/h

[Graph showing fuel flow over time with annotations for SlipStream flow turned on and off]
Overnight run shown above for the VRU overflow (anything causing the suction pressure before the VRU to exceed 12 kPa). The make-up gas regulator opens to supply the VRU at 10 kPa
Control Test Results
(from first SS installation at another CDN gas company)

- This next graph shows a trend of the engine RPM, SlipStream™ Flow and main fuel flow
- The SlipStream™ flow is turned off and on abruptly to observe how the REMVue® control system handles this sudden change in fuel to the engine
- In addition to the trend graph, two videos of these events were taken with a FLIR infrared camera
- The videos show the vent pipe at the top of the engine building when the SlipStream™ Flow is turn on and off per the trend graph
- This FLIR shows methane leaks that are invisible to the naked eye.
Full vented flow turned off abruptly, then on abruptly

Minimal engine RPM change
Control

- SlipStream™ uses advanced control algorithms to anticipate changes in SlipStream flow and adjusts the governor and air-fuel ratio control accordingly.

- The result — no impact to engine reliability or speed from:
  - Load changes
  - SlipStream™ Flow
  - Fuel gas or SlipStream™ gas BTU swings
  - Ambient air temperature or pressure
Real-time Graph on REMVue® HMI
BP Preliminary Results

- AFR upgrade and SlipStream™ installation complete
- AFR Control
  - Relocation of governor control, addition of a DVC, and the implementation of new tuning techniques have led to significant improvement in engine governor response
- Packing Vent Gas
  - Diluted flow control implementation is a success!
  - By collecting the packing vent gas from only one unit, 4 kg/hr or approximately 2% of the engine’s normal fuel flow was saved
  - Equates to approximately $11,000/yr in potential fuel cost savings and a reduction of 625 tonnes CO2(e)/yr
- VRU Gas
  - SlipStream fuel rates of up to 50 kg/hr or approximately 25% were achieved using gas from the VRU suction
  - Equates to approximately $137,500/yr* in potential fuel cost savings
Lessons Learned

- An audit of each unit’s “as found” operational and health issues is required prior to SlipStream™ implementation.
- Need for improved site coordination and project documentation during system installation.
- SlipStream™ source characteristics — amount, pressure, BTU content, etc. must be clearly understood.
- More specific pipe routing instructions are required to minimize flow restrictions.
- Fast governor response is necessary to minimize speed upsets due to SlipStream™ transients.
- Main fuel flow meter selection — Thermal vs. Coriolis.
- SlipStream™ flow meter placement and control valve selection.
What’s Next for BP and SlipStream™

- Identify SlipStream opportunities in BP fleet
- Develop business proposal to management for SlipStream deployment
- Participate in new PTAC study to quantify impact of SlipStream deployment on upstream Canadian gas industry
Thank You