SlipStream™ *

BP Pilot — Project Review

* *Patents Pending*

REMVue®

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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 REM*Vue*® control panels, most with Air Fuel management control.

BP Canada E&P Operations

760 miles

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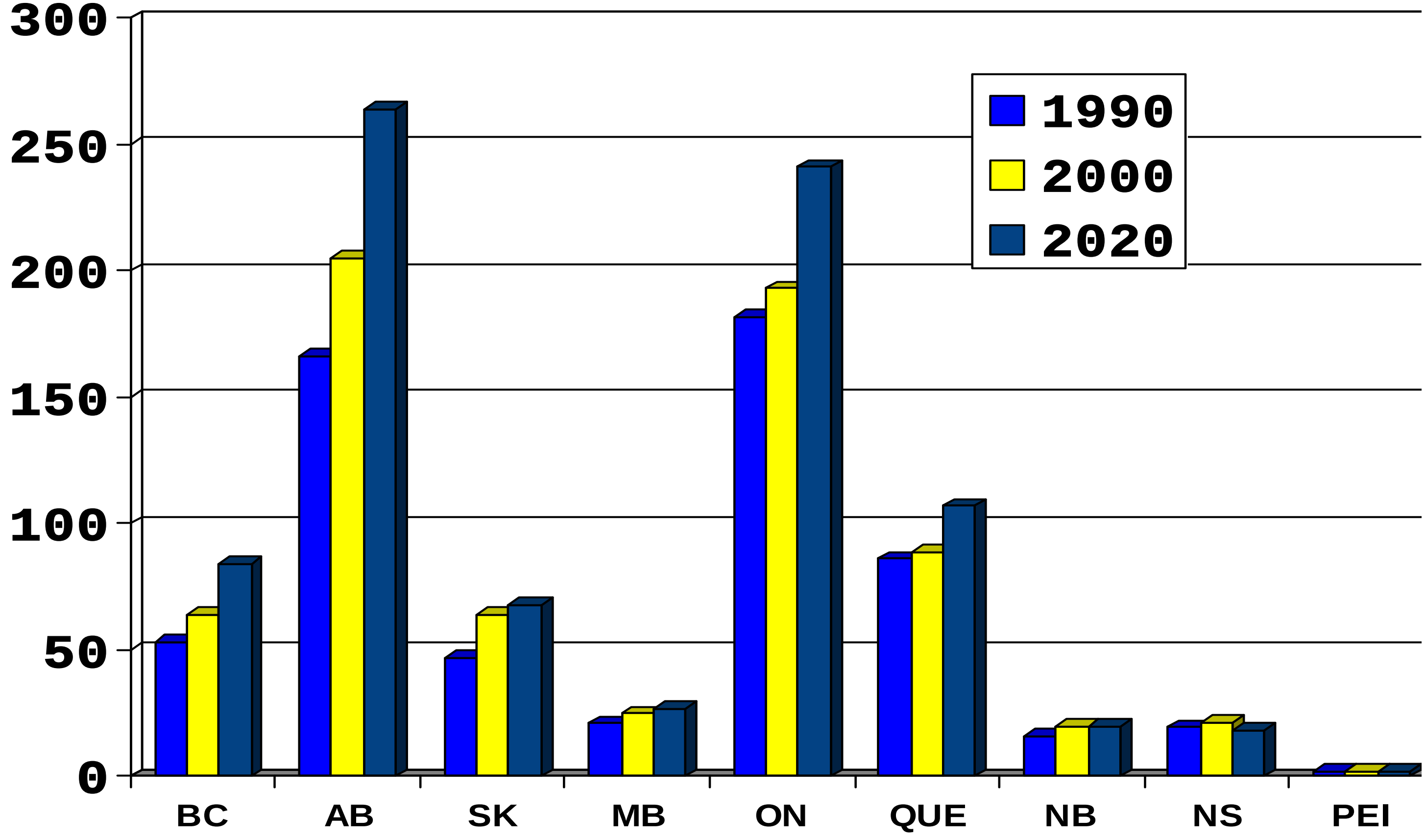
720 miles

Emission Projections Provincial



http://environment.gov.ab.ca/info/library/5892.ppt

SlipStream™

- 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*

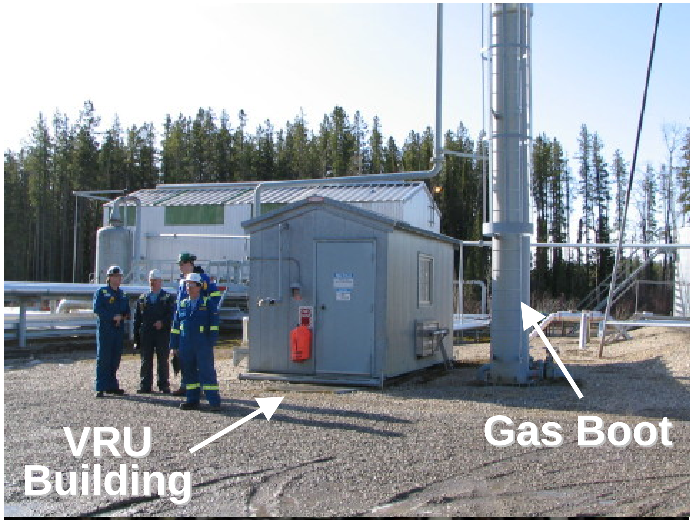
Pilot Site Selection

- Engaged workforce
- Has a source that can be easily captured
- Site with existing REM*Vue*® 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

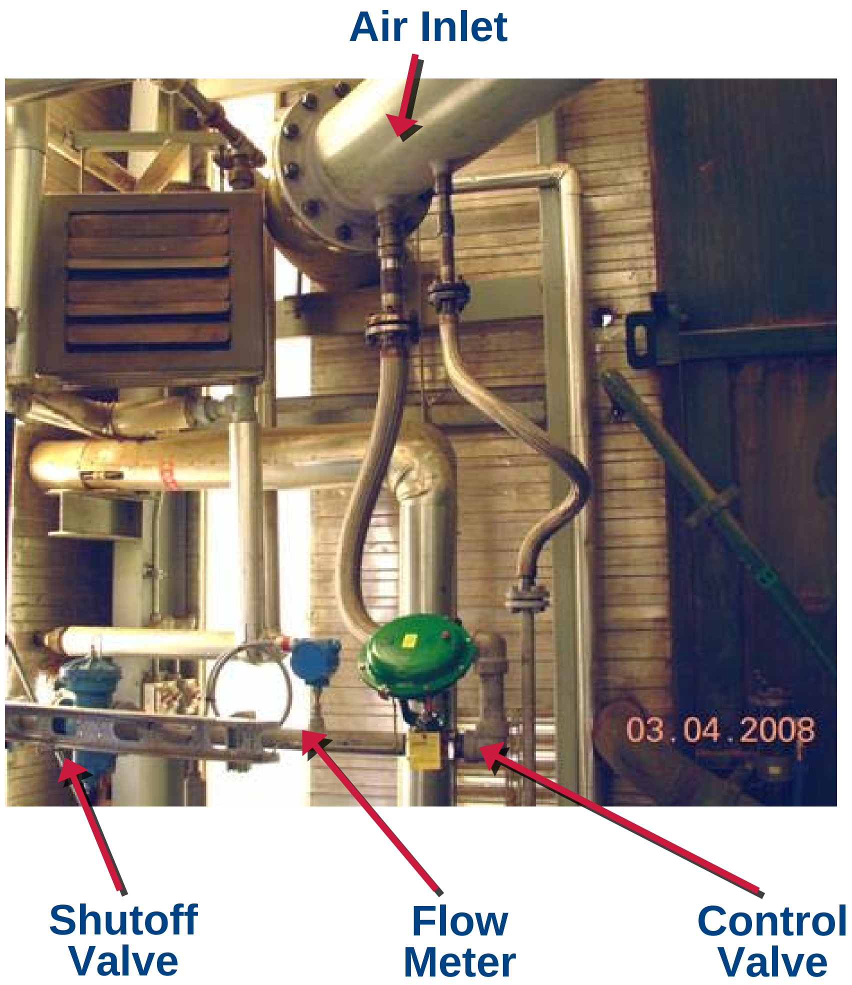
Unit 2 – Waukesha 9390 GSI with REM*Vue*® Rich-to-Lean AFR

- 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 REM*Vue*®– *500/AS* system on Unit #2

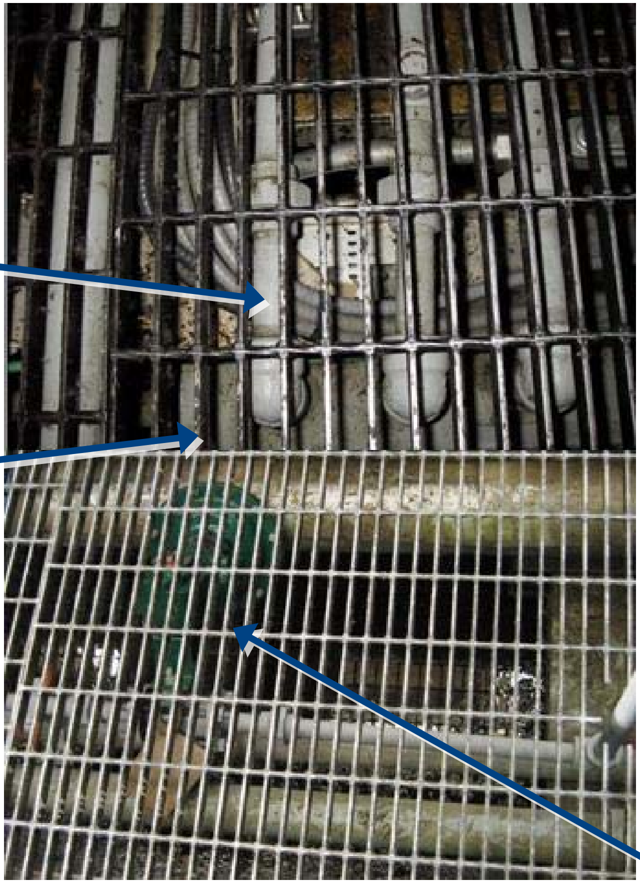
Installation Details

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

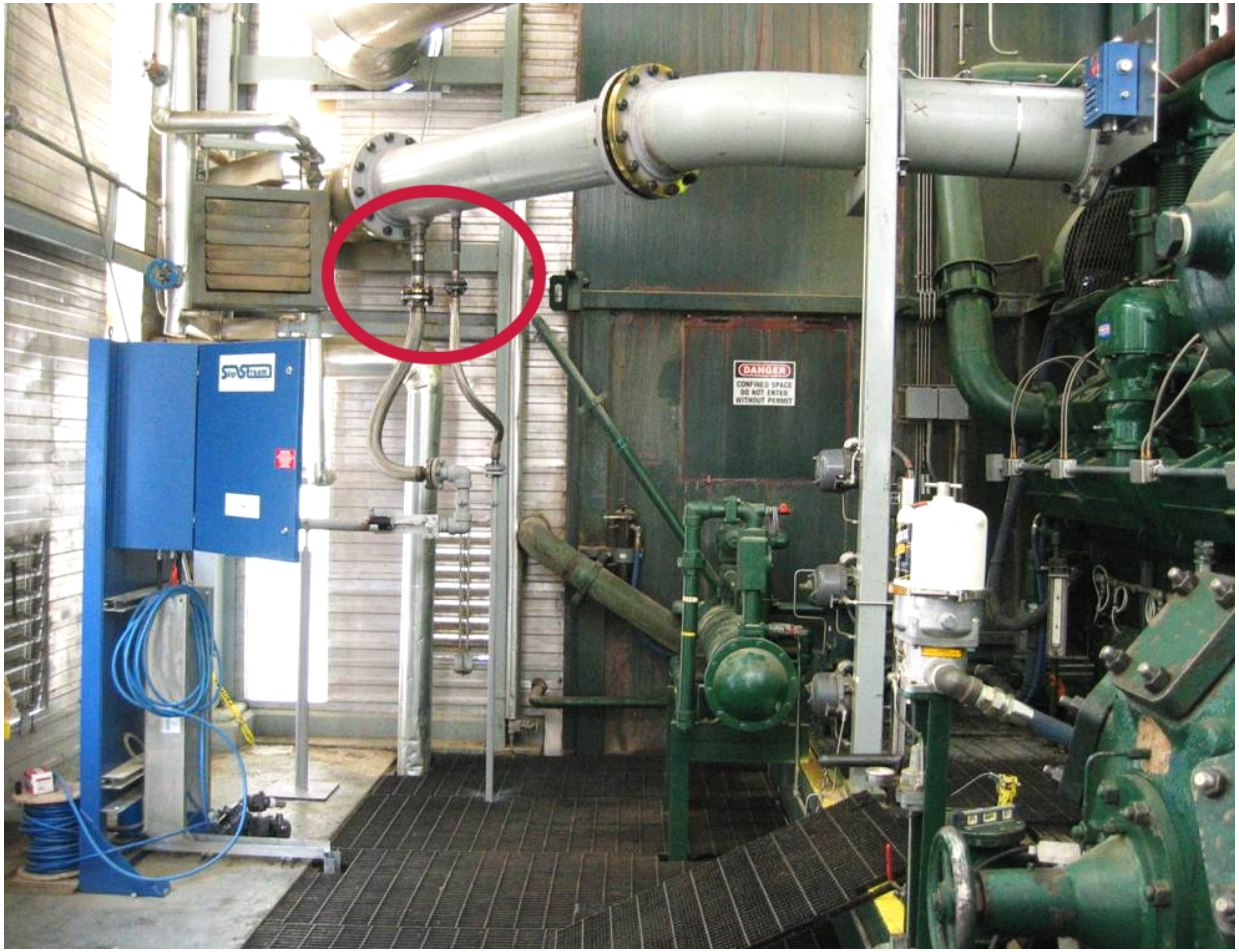


Installation



- **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 can not 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

Fuel	Fuel specific gravity (rel. to air)	Stoichiometric % of fuel in mixture	Lean (λ =1.5) % of fuel in mixture	LEL[1]%	SlipStream % of fuel in air Level 3 – 50% of engine fuel
Methane	0.56	10.1	6.7	5	3.4
Ethane	1.04	5.3	3.6	3	1.8
Propane	1.52	3.7	2.4	2.2	1.2
Butane	2.02	2.75	1.8	1.8	0.9

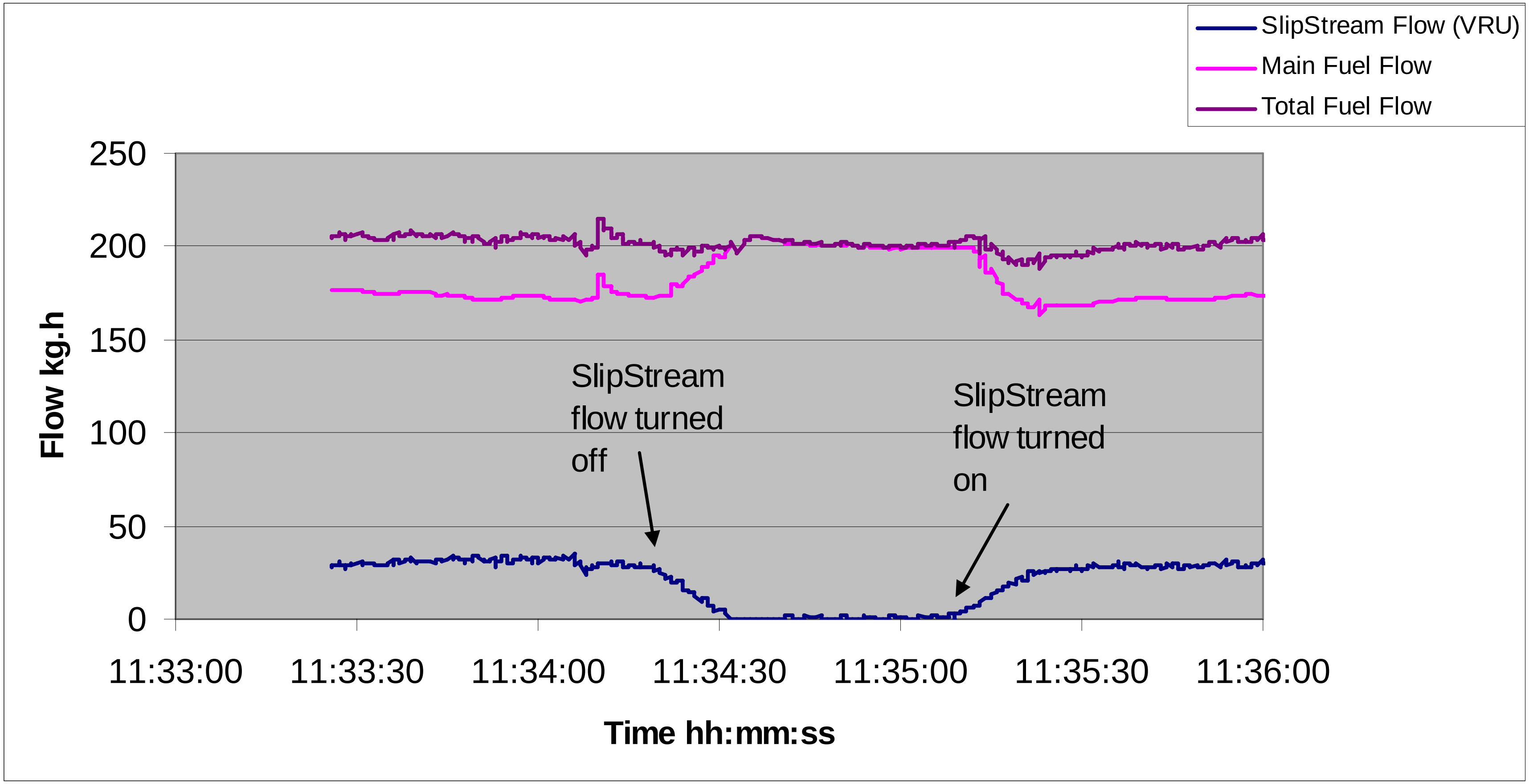
1. LEL from *CRC Handbook of Chemistry and Physics, 72nd edition*; CRC Press; Boca Raton, Florida; 1991; ISBN 0-8493-0565-9 and MSDS (Material Safety Data Sheets) from www.msdssearch.com

2. *"Glossary of Specialty Gas Terminology,"* 2002, AIR LIQUIDE GROUP. http://www.airliquide.cl/medias/pdf/business/industry/laboratories/glossary.pdf

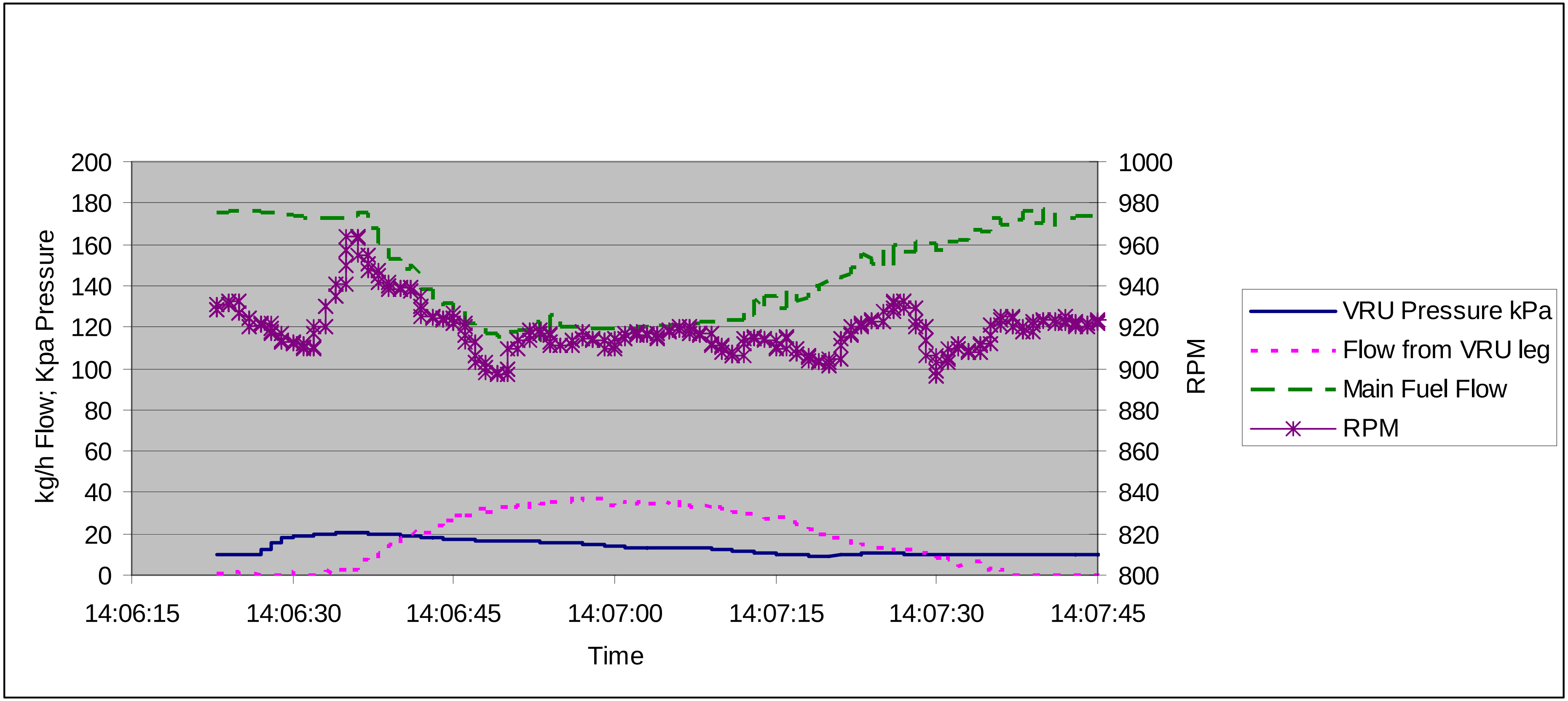
BP SlipStream™

PRELIMINARY RESULTS AND LESSONS LEARNED

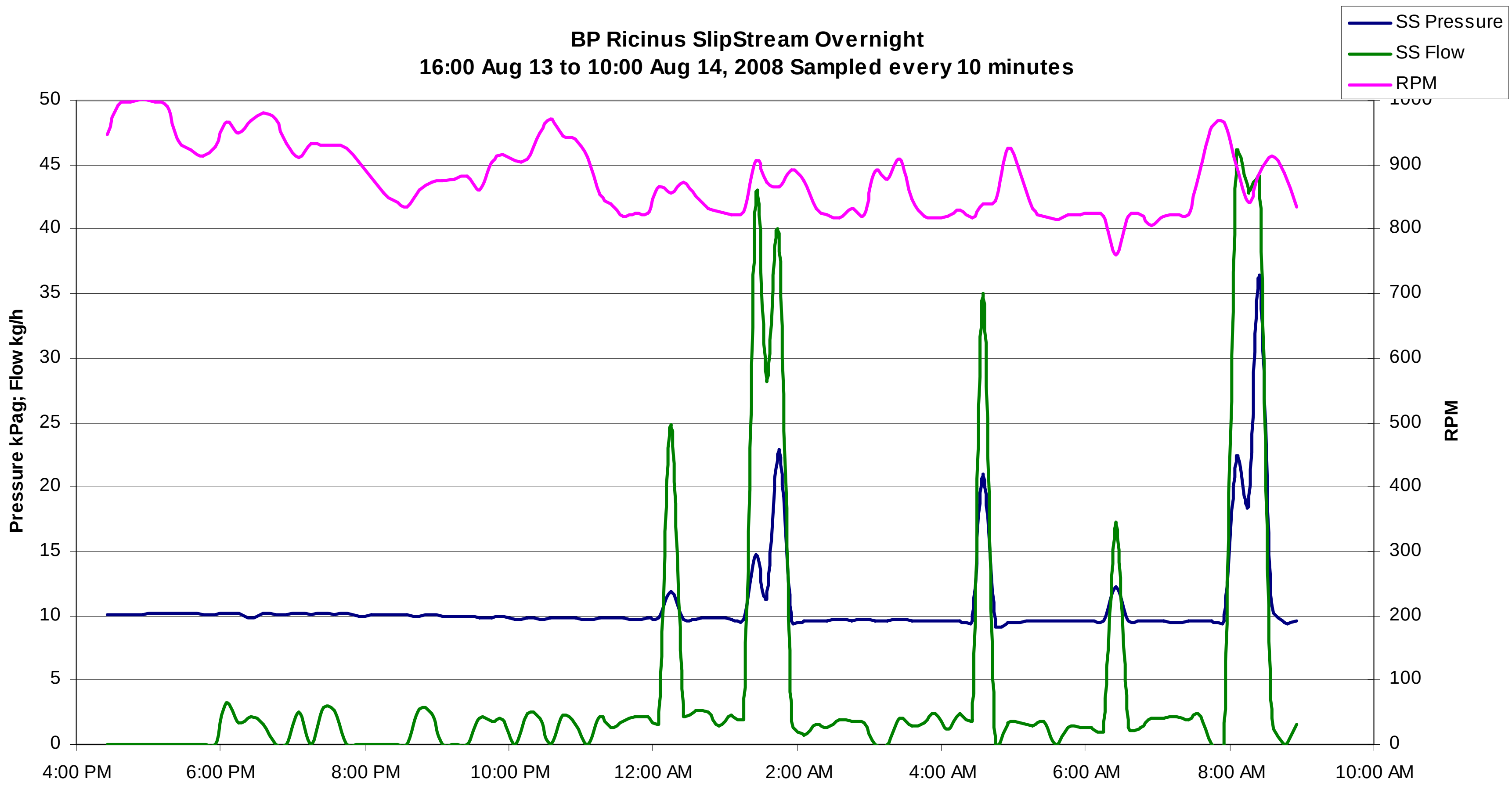
Engine Fuel Flows



RPM Under Capacity Control



VRU Excess Gas Capture



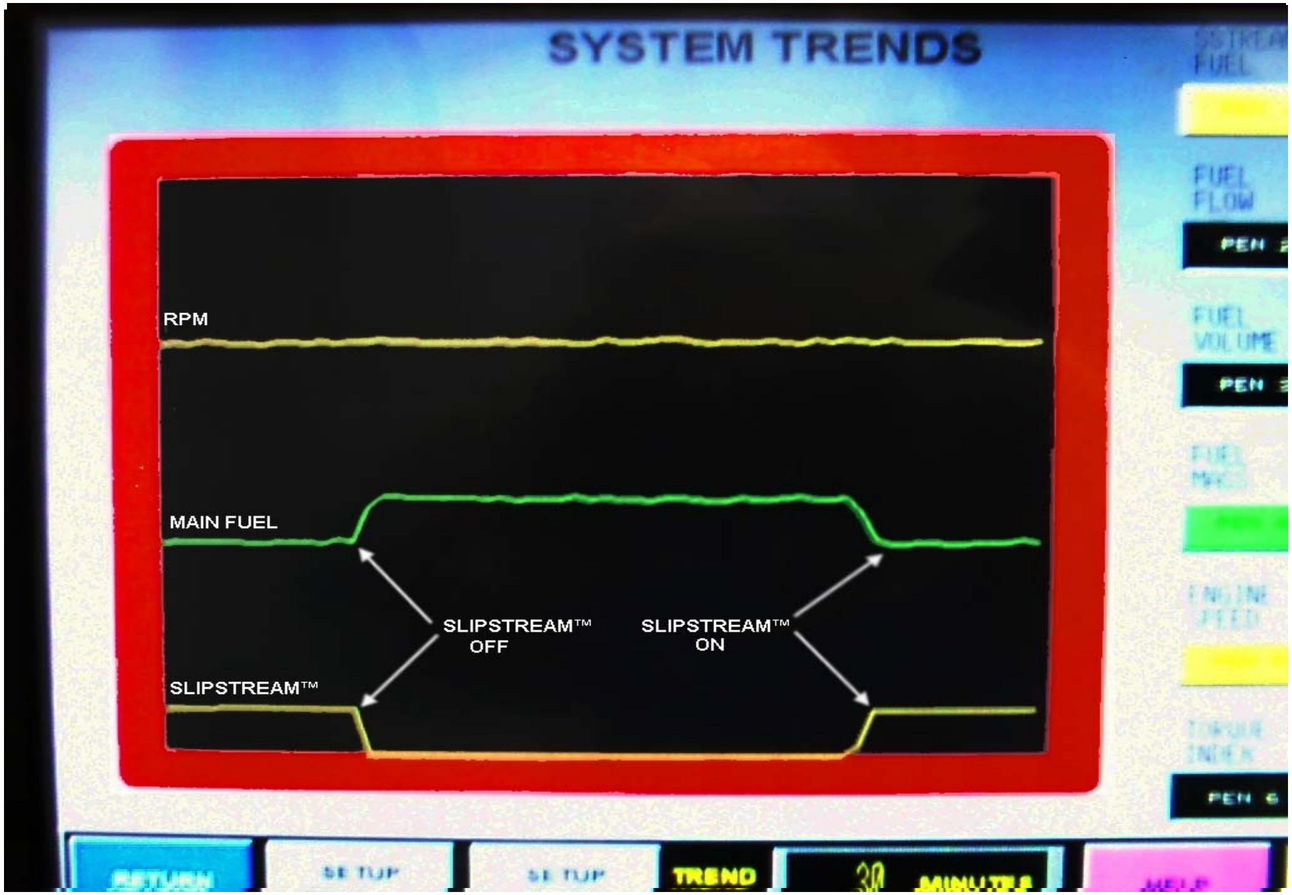
Overnight run shown above for the VRU overflow (anything causing the suction pressure before the VRU to exceed 12 kPa). The make-up gas regulator opens to supply the VRU at 10 kPa

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.

SlipStream™ Results



- 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

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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