Utilization of Associated Gas to Power Drilling Rigs – A Demonstration in the Bakken

Webinar
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Senior Research Manager
Background

• This was a North Dakota Industrial Commission and U.S. Department of Energy-funded project, with commercial support and cost share from Continental Resources.

• With the continued flaring of nearly 30% of wellhead gas produced in North Dakota, alternatives for gas use are desired.


• Bifuel Rig Demonstration – assess fuel savings and operational impacts of using a mixture of diesel and wellhead gas to power a drilling rig in the Bakken.
A Use for Flared Natural Gas

- Drill rigs are typically powered by three large diesel generators.
- Diesel engines, properly outfitted with bifuel systems can utilize a mixture of diesel and natural gas.
- Significant fuel savings can be achieved because of the price differential between diesel and natural gas.
  - 30%–60% reduced fuel costs
  - Reduced fuel delivery and associated traffic, engine emissions, and fugitive dust
Wellhead Gas Use in Internal Combustion Engines Powering Drilling Rig Operation

Challenges:
Wellhead gas contains hydrocarbons such as propane, butane, pentane, and hexane. The introduction of these gaseous fuels to compression ignition engines can lead to:

– Engine knock at high replacement rates.
– Slight increases in exhaust temperatures.
– Changes in stack emissions.
– Changes in the combustion properties in the engine.

The purpose of this project was to evaluate these impacts with two tasks:

– Evaluate GTI Bi-Fuel® System at the EERC with Simulated Wellhead Gas
– Demonstrate GTI Bi-Fuel® System During Actual Drilling Operations
Evaluate GTI Bi-Fuel® System at the EERC with Simulated Wellhead Gas
Simulated Gas Test Objectives

- Evaluate knock characteristics of constituent gas components of a wellhead gas
- Monitor ignition delay
- Demonstrate performance of the GTI Bi-Fuel® system
- Determine the operational limits of the GTI system using typical Bakken wellhead gas
Caterpillar 3512 Diesel Generator
Supplied by Butler Machinery Co.

<table>
<thead>
<tr>
<th>Engine</th>
<th>Caterpillar 3512 (four-stroke cycle)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinders</td>
<td>12</td>
</tr>
<tr>
<td>Bore, mm (in.)</td>
<td>170 (6.7)</td>
</tr>
<tr>
<td>Stroke, mm (in.)</td>
<td>190 (7.5)</td>
</tr>
<tr>
<td>Aspiration</td>
<td>Turbo-charged-after-cooled</td>
</tr>
<tr>
<td>Compression Ratio</td>
<td>13:1*</td>
</tr>
<tr>
<td>Speed, rpm</td>
<td>1800</td>
</tr>
<tr>
<td>Engine Power, hp (kWe)</td>
<td>1592 (1100)</td>
</tr>
</tbody>
</table>

*Compression ratio of the test engine is lower than referenced in literature.
GTI STEPCON Bi-Fuel® System
Simulated Wellhead Gas Delivery System
## Gas Composition

<table>
<thead>
<tr>
<th></th>
<th>Dry Pipeline Gas</th>
<th>Simulated Bakken Gas</th>
<th>Bi-Fuel System Recommended Gas Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane, CH₄</td>
<td>92.2%</td>
<td>55%</td>
<td>&gt;92%</td>
</tr>
<tr>
<td>Ethane, C₂H₆</td>
<td>5.5%</td>
<td>22%</td>
<td>&lt;8%</td>
</tr>
<tr>
<td>Propane, C₃H₈</td>
<td>0.3%</td>
<td>13%</td>
<td>&lt;8%</td>
</tr>
<tr>
<td>Butane, C₄H₁₀</td>
<td></td>
<td>5%</td>
<td>&lt;2% combined total butane – heptane</td>
</tr>
<tr>
<td>Pentane, C₅H₁₂</td>
<td></td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td>Hexane, C₆H₁₄</td>
<td></td>
<td>0.25%</td>
<td></td>
</tr>
<tr>
<td>Heptane, C₇H₁₆</td>
<td></td>
<td>0.1%</td>
<td></td>
</tr>
<tr>
<td>Nitrogen, N₂</td>
<td>1.6%</td>
<td>3%</td>
<td></td>
</tr>
<tr>
<td>Carbon Dioxide, CO₂</td>
<td>0.4%</td>
<td>0.5%</td>
<td></td>
</tr>
<tr>
<td>Higher Heating Value, Btu/scf</td>
<td>1041</td>
<td>1495</td>
<td></td>
</tr>
</tbody>
</table>
## Parametric Test Matrix

<table>
<thead>
<tr>
<th>Test #</th>
<th>Load, %</th>
<th>Diesel Replacement, %</th>
<th>Methane, mol %</th>
<th>Ethane, mol %</th>
<th>Propane, mol %</th>
<th>Butane, mol %</th>
<th>Pentane, mol %</th>
<th>Hexane, mol %</th>
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<tbody>
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<tr>
<td>8</td>
<td>20</td>
<td>Up to 70</td>
<td>56.1</td>
<td>23.1</td>
<td>13.9</td>
<td>4.9</td>
<td>1.1</td>
<td>0.9</td>
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<tr>
<td>9</td>
<td>40</td>
<td>Up to 70</td>
<td>56.1</td>
<td>23.1</td>
<td>13.9</td>
<td>4.9</td>
<td>1.1</td>
<td>0.9</td>
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<tr>
<td>10</td>
<td>60</td>
<td>Up to 70</td>
<td>56.1</td>
<td>23.1</td>
<td>13.9</td>
<td>4.9</td>
<td>1.1</td>
<td>0.9</td>
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<tr>
<td>11</td>
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<tr>
<td>12</td>
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<td>Balance</td>
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<td>Up to 30</td>
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<tr>
<td>13</td>
<td>60</td>
<td>70</td>
<td>Balance</td>
<td>0</td>
<td>Up to 30</td>
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<td>0</td>
<td>Up to 4%</td>
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</tr>
<tr>
<td>19</td>
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<td>Balance</td>
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<td>Balance</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Up to 4%</td>
</tr>
</tbody>
</table>
Knock at 20% Engine Load

- Safety Limit
- Control Limit

Knock, ips

Time

50% Simulated Bakken Replacement
60% Simulated Bakken Replacement
Knock at 40% Engine Load

Time:
- 13:30
- 13:40
- 13:50
- 14:00
- 14:10

Knock, ips:
- Safety Limit
- Control Limit

50% Simulated Bakken Replacement
60% Simulated Bakken Replacement
70% Simulated Bakken Replacement
Conclusions

• Diesel engines can run on wellhead gas, but the replacement rate is limited because of the potential for engine knock.

• Injection of individual gas components at typical concentrations did not cause knock.

• There was a slight increase in ignition delay and peak cylinder pressure when firing wellhead gas, which is consistent with the knock observed.
Demonstrate GTI Bi-Fuel ® System During Actual Drilling Operations
Field Demonstration Objectives

- Evaluate diesel engine performance using wellhead gas during actual drilling operations
  - Monitor engine knock
  - Measure emissions
  - Calculate fuel savings
# Caterpillar 3512C Diesel Generator

<table>
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<tr>
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<td>12</td>
</tr>
<tr>
<td>Aspiration</td>
<td>Turbo-charged-after-cooled</td>
</tr>
<tr>
<td>Compression Ratio</td>
<td>14.7:1</td>
</tr>
<tr>
<td>Speed, rpm</td>
<td>1200</td>
</tr>
<tr>
<td>Engine Power, hp</td>
<td>1476</td>
</tr>
</tbody>
</table>
Typical Engine Load During Steady-State Drilling Operations
Diesel Consumption Rate During Steady-State Drilling Operations

- GTI system stopped gas supply and diesel fuel rate increased to meet engine demand.
- Gas supply restored to Engine No. 2, decreasing diesel fuel consumption.
Engine Load While Tripping

- Engine No. 1
- Engine No. 2
- Engine No. 3

Engine Load, %

Time

6:00 8:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00 0:00 2:00 4:00 6:00
Engine Knock During Tripping

![Graph showing engine knock during tripping](image)

- Engine No. 1
- Engine No. 2
- Engine No. 3
- Control Level
- Safety Level
Diesel Fuel Savings

Cumulative Diesel Saved, gal

- Engine No. 1
- Engine No. 2
- Engine No. 3
- Total

Date

Load Profile

- % of Time
- % of Diesel Used
- % of Diesel Saved

Percentage

Engine Load Factor, %

- 0-12
- 12-20
- 20-30
- 30-40
- 40-60
- 60-70
- >70

The International Center for Applied Energy Technology®
Comparison of Emissions

The graph compares emissions for different fuel types:

- **Bi-Fuel**
- **Diesel Only**
- **Diesel Only + Flare**

The emissions are measured in g/hr for CO, NOx, and THC.
Summary of Results

- Diesel fuel consumption reduced by 18,000 gallons for two wells. A period of 47 days.

- Fuel-related net cost savings of nearly $60,000.

- Reduced delivery truck traffic.

- Beneficial use of wellhead gas.

- Reduced emissions compared to diesel-only drilling and flaring of gas.

- Seamless engine operation using the GTI Bi-Fuel® system.
Effect of Broad Applications

- Nearly 200 drilling rigs in operation at any given time
- 1,800,000 Mcf of wellhead gas used per year
- 18,000,000 gallons of diesel fuel saved per year
- $72,000,000 diesel fuel cost saved per year
- 3600 fuel deliveries avoided per year
- 68% reduction in overall emissions compared to diesel-only operation plus flaring gas
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