Effect of Intake Air with Methane on Diesel Engine Emissions with Control Technologies

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Gassy Mine Environment

- Characterized by explosive atmosphere
- May contain methane gas and combustible dust
- Diesel equipment conforms to flameproof, electrical, fuel, safety shutdown etc. requirements
- Equipment surface temperature below 150ºC
- Monitoring of gas levels
- Ventilation requirement
Ventilation Air Requirement (National Standard of Canada)

- Non-Gassy U/G Mines (CAN/CSA-M424.2-M90)
  - Sample engine testing on a dynamometer
  - Fuel conforms to CGSB standard 3.16
  - CO<2500 ppm, NO_x<1500 ppm, PM<150 mg/m^3
  - Exhaust treatment devices allowed
  - Suitable procedures to maintain devices
  - Vent rate pertains to worst operating conditions
  - Local conditions may change the vent rates

- Gassy U/G Coal Mines (CAN/CSA-M424.1-88)
  - As in for non-gassy underground mines
  - Flameproof requirements
  - Testing with intake air mixture of 1.25% methane
  - Engine shutdown at 1.25% methane
  - Maximum surface temperature of 150ºC
Equipment Tested

- Diesel Engine
  - Isuzu 6BG1-MAP
- Flameproof package (DST®)
  - Water cooled exhaust manifold
  - Flame arresters
  - Heat exchanger
- Emission control devices (DST®)
  - Catalyst
  - Low temperature particulate filter

Schematic Diagram of DST® Exhaust System
Engine Dynamometer Testing

- Test Lab: NRCan, CANMET-MMSL, Ottawa
- Test method: ISO 8178-1
- Test data: 8-modes of ISO 8178-C1
- Baseline test: With clean engine intake air
- Methane test: With intake air mixture of 1.25% methane
- Fuel: Mining diesel CGSB-3.16, 310 ppm sulphur
ISO 8178-C, 8 Mode Test Cycle With Weighing Factors

<table>
<thead>
<tr>
<th>Mode Number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
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</thead>
<tbody>
<tr>
<td>Speed, rpm</td>
<td>2500</td>
<td>1500</td>
<td>735</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Torque, %</td>
<td>100</td>
<td>75</td>
<td>50</td>
<td>10</td>
<td>100</td>
<td>75</td>
<td>50</td>
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<tr>
<td>Weighing factor</td>
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<td>0.15</td>
<td>0.15</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.15</td>
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</table>

Test Measurements

- Engine parameters
  - Speed, torque, power, fuel rate
- Exhaust gases
  - CO, CO₂, NO, NOₓ, O₂, THC
  - Particulates (DPM)
- Calculations
  - Emission rate in g/h
- Measurements were taken after the DST® exhaust treatment
Effect of Methane on Engine Power

![Bar chart showing the effect of methane on engine power. The chart compares baseline and methane modes, with an increase of 15% hp due to methane.]

Effect of Methane on Fuel Rate

![Bar chart showing the effect of methane on fuel rate. The chart compares baseline and methane modes, with a decrease of 4% due to methane.]

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Effect of Methane on Exhaust Temperature

- Baseline
- Methane

Effect of Methane on CO₂

- Baseline
- Methane

+ 12% due to Methane
Effect of Methane on CO

Effect of Methane on NO₂
Effect of Methane on NO

![Bar chart showing the effect of methane on NO.]

- Baseline
- Methane

+15% due to Methane

Effect of Methane on NOx

![Bar chart showing the effect of methane on NOx.]

- Baseline
- Methane

+8% due to Methane
Effect of Methane on DPM

**Effect of Methane on Power & Emissions (8-Mode Integrated Value)**

<table>
<thead>
<tr>
<th></th>
<th>Baseline g/h</th>
<th>With Methane g/h</th>
<th>Change %</th>
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<tbody>
<tr>
<td>HP</td>
<td>55</td>
<td>63</td>
<td>15</td>
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<tr>
<td>CO₂</td>
<td>30812</td>
<td>34599</td>
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<tr>
<td>CO</td>
<td>48</td>
<td>108</td>
<td>124</td>
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<tr>
<td>NO₂</td>
<td>37</td>
<td>32</td>
<td>-13</td>
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<tr>
<td>NO</td>
<td>103</td>
<td>119</td>
<td>15</td>
</tr>
<tr>
<td>NOₓ</td>
<td>140</td>
<td>151</td>
<td>8</td>
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<tr>
<td>DPM</td>
<td>2.8</td>
<td>2.7</td>
<td>-4</td>
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</tbody>
</table>

-4% due to Methane
Comments

• 1.25% of methane mixture in engine intake air
  • increased power, CO\textsubscript{2}, and CO at all modes, by an average value of 15%, 12%, and 124% respectively.
  • reduced NO\textsubscript{2} by 13%, and increased NO by 15%.
  • reduced fuel consumption and DPM by an average value of 4% each.
  • decreased DPM at all 4 modes at rated speed, but increased DPM at other modes.

Comments

• The tested DST® power package system incorporating a low temperature particulate filter with exhaust gas cooling and catalyst could also be applied in non gassy hardrock mines.
  • Application of DST® low exhaust temperature filtration would be beneficial where DPF regeneration is difficult to obtain.