The Effect of Diesel Oxidation Catalysts on NO$_2$ Emission from Mining Vehicles

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Background

- Vale employs about 800 diesel-powered units with diesel oxidation catalysts in Sudbury mines.
- In the past, DOCs were used in mines mainly to reduce CO and hydrocarbons, the main pollutants of concern at that time.
- Now, the pollutants of most concern are DPM and NO₂.
- From an occupational exposure point of view NO₂ (TLV 3 ppm) is more toxic than NO (TLV 25 ppm).
- In 2012 ACGIH reduced the TWA value of NO₂ from 3 ppm to 0.2 ppm, a reduction of over 90%.
- Many occupational exposure limits are derived from ACGIH TLVs.
- The recent studies indicate that most of the old DOCs increase NO₂.
Objectives

- Objectives From Laboratory Studies:
  - Determine the effect of DOCs on NO$_2$ emissions
  - Analyze representative DOCs selected from Vale mines
  - Test DOCs using progressive load cycle
  - Quantify any change in NO$_2$ emissions due to the DOC

Note: Ultra-low-sulphur fuel (<15 ppm sulphur) was used for all testing
Selection of DOCs & Laboratory Test Details

- 4 Vale DOCs were selected based on:
  - Engine type
  - Equipment type
  - DOCs type and model
  - Duration in mine service

- **Laboratory test details:**
  - All DOCs were tested on a DDEC 6063-WK32, series 60 engine, rated at 242 kW @ 2100 rpm
  - Mine diesel fuel conforming to CGSB 3.16 standard was used, ultra-low sulphur fuel (15 ppm)
  - Basic engine parameters (speed, torque, fuel rate etc.) and exhaust gas concentrations (CO, CO2, NO, NOx, THC) were measured before and after the DOC
Progressive Load Test Cycle

- Is suitable to generate a performance curve for the DOC over its operating range

- Is useful in determining DOC conversion efficiency for exhaust emissions at a given temperature

- Was performed at intermediate engine speed of 1260 rpm, varying load from 10% to 100% at interval of 10% each

- Measured gaseous emissions at 10 modes, before and after the DOC
## Details of DOCs for Testing

<table>
<thead>
<tr>
<th>Lab ID</th>
<th>Equipment</th>
<th>Engine, kW</th>
<th>Hours in Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOC 4</td>
<td>Boom truck</td>
<td>151</td>
<td>730</td>
</tr>
<tr>
<td>DOC 5</td>
<td>Scissor truck</td>
<td>112</td>
<td>2700</td>
</tr>
<tr>
<td>DOC 6</td>
<td>Jeep</td>
<td>100</td>
<td>3400</td>
</tr>
<tr>
<td>DOC 7</td>
<td>LHD</td>
<td>100</td>
<td>254</td>
</tr>
</tbody>
</table>
## Test Engine

<table>
<thead>
<tr>
<th>Make</th>
<th>Detroit Diesel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>6063-WK32, Series 60</td>
</tr>
<tr>
<td>Rated power, kW</td>
<td>242</td>
</tr>
<tr>
<td>Displacement, L</td>
<td>11.1</td>
</tr>
<tr>
<td>Rated speed, rpm</td>
<td>2100</td>
</tr>
<tr>
<td>Intermediate speed, rpm</td>
<td>1260</td>
</tr>
<tr>
<td>Peak torque speed, rpm</td>
<td>1200</td>
</tr>
<tr>
<td>Peak torque, Nm</td>
<td>1539</td>
</tr>
<tr>
<td>Fuel rate, kg/h</td>
<td>53.4</td>
</tr>
<tr>
<td>Fuel system</td>
<td>Electronic fuel injection</td>
</tr>
</tbody>
</table>
DOC Test System in Test Cell
Percent Reduction in CO VS exhaust temperature

\[\text{CO Reduction, } \%\]

\[\text{Temperature, } ^{\circ}\text{C}\]

- DOC 4
- DOC 5
- DOC 6
- DOC 7

Effects of DOCs_MDEC 2014, Toronto
Percent Reduction in HC VS Exhaust Temperature
NO$_2$ emission before and after the DOCs
DOC-Out NO₂ Values

<table>
<thead>
<tr>
<th>DOC</th>
<th>NO₂ decreases below °C</th>
<th>Maximum NO₂ ppm</th>
<th>Maximum NO₂ at °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOC 4</td>
<td>235</td>
<td>141</td>
<td>409</td>
</tr>
<tr>
<td>DOC 5</td>
<td>225</td>
<td>225</td>
<td>410</td>
</tr>
<tr>
<td>DOC 6</td>
<td>265</td>
<td>115</td>
<td>415</td>
</tr>
<tr>
<td>DOC 7</td>
<td>250</td>
<td>116</td>
<td>416</td>
</tr>
<tr>
<td>Average</td>
<td>244</td>
<td>149</td>
<td>412</td>
</tr>
</tbody>
</table>

Engine-Out NO₂ = 13 ppm at 412 °C
Concluding Remarks

- The impact of in-mine use of DOCs with regard to exhaust emissions were evaluated in the laboratory using a controlled engine dynamometer.

- The testing utilized progressive load test cycle.

- All DOCs reduced CO and HC emissions.

- At low temperatures all DOCs decreased NO₂, and then after reaching a certain temperature (~ 244 °C) started increasing NO₂.

- The maximum DOC-out NO₂ value varied from 115 ppm (DOC 6) to 225 ppm (DOC 5), compared to an engine-out value of 13 ppm.

- The maximum NO₂ increase was observed at a temperature of 412°C, where NO₂ significantly increased (up to 17 times) from its baseline value of 13 ppm.

- More extensive DOC evaluation is planned with additional units from other underground mines to confirm emission trends witnessed from the Vale DOCs.
Acknowledgements

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- David Young, Brent Rubeli, Eric Leung, and Vince Feres, NRCan/CanmetMINING for laboratory testing of DOCs
Questions?