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Effect of In-Use DOCs on NO_2 Emission in the Underground Operation

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Background

- DOCs have been used in mines mainly to reduce CO and hydrocarbons, the main pollutants of concern at early times.
- The pollutants of most concern now are DPM and NO_2.
- Occupational exposure point of view NO_2 (TLV 3 ppm) is more toxic than NO (TLV 25 ppm).
- In 2012, ACGIH reduced TWA-TLV of NO_2 from 3 ppm to 0.2 ppm, a reduction of over 90%.
- Many occupational exposure limits are based on ACGIH TLVs.
- The recent studies indicate that DOCs may increase NO_2 .

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Objectives

- Laboratory Studies (results presented here)
  - To study the impact of in-mine used DOCs on exhaust NO_2 in a controlled engine dynamometer environment.
  - To test DOCs using steady state and simulated transient mine duty cycles
- Field Studies
  - To study the impact of DOCs on exhaust NO_2 from mine vehicles under actual mine operating conditions
- Comparison of laboratory and field test results

2

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Selection of DOCs & Laboratory Test Details

- 10 DOCs were selected for this study, 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

3

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Test Cycles

- Test cycles used for laboratory engine dynamometer testing are:
  - ISO-8178-C1 8-mode steady state test cycle (most commonly used worldwide for off-road applications).
  - LHD transient test cycle developed by CanmetMINING from an underground operating mine vehicle duty cycle.
  - Progressive increasing load test cycle, 10 steady state test modes

4

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Presented Results

- Because of large amount of test data results, only results from two DOCs tested for ISO 8178-C2 8-mode steady state test cycle and transient test cycles are presented here.
- DOC #3, taken from a heavy duty LHD vehicle, and had 3014 hours of operation
- DOC #7, taken from a light duty LHD vehicle, and had 134 hours of operation
- Test results from steady state and transient test cycles are compared

5

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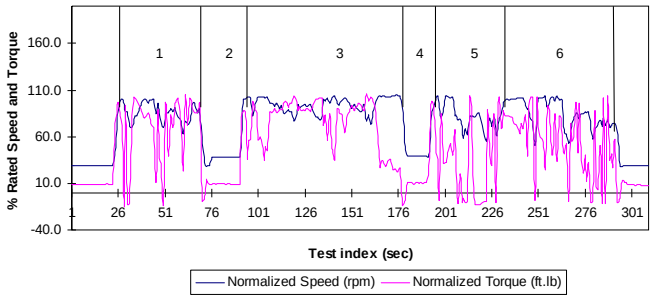
Test Cycles – 8 Mode and LHD Transient

Mode	1	2	3	4	5	6	7	8
Speed, rpm	2100				1260			600
Torque, %	100	75	50	10	100	75	50	0
Weighting factor	0.15	0.15	0.15	0.1	0.1	0.1	0.1	0.15



1- Loading, 2 – Idle. 3- haul loaded, 4- Idle, 5- Dumping, 6 –Return empty

6

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DOC Test System in Test Cell

7

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Percent Emission Reduction for 8-Mode Steady State & LHD Transient Test Cycles

Exhaust Gas	DOC 3		DOC 7	
	Steady state test cycle (53% engine load)	Transient test cycle (44% engine load)	Steady state test cycle (53% engine load)	Transient test cycle (44% engine load)
CO	77	57	80	64
CO_2	1	3	1	5
NO	3	4	11	9
NO_2	-46	-17	-315	-119
THC	45	57	49	59

8

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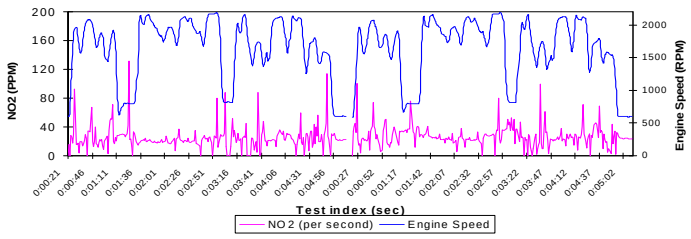
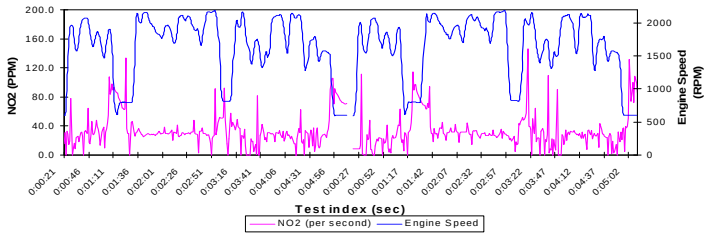
Transient Cycles-Engine Baseline & DOC 3





9

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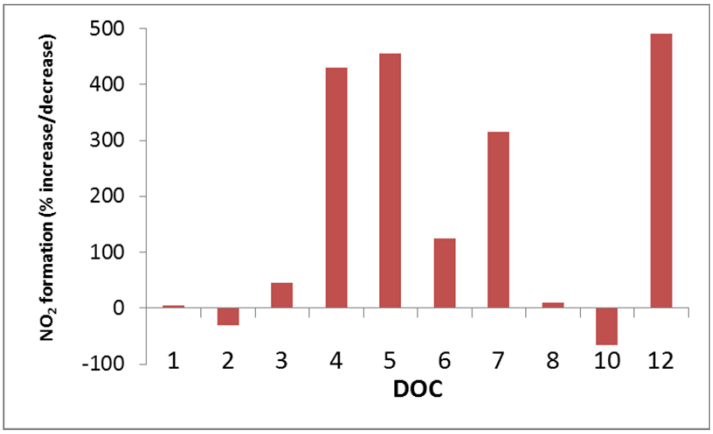
Test Results – NO_2 Formation from 10 DOCs



10

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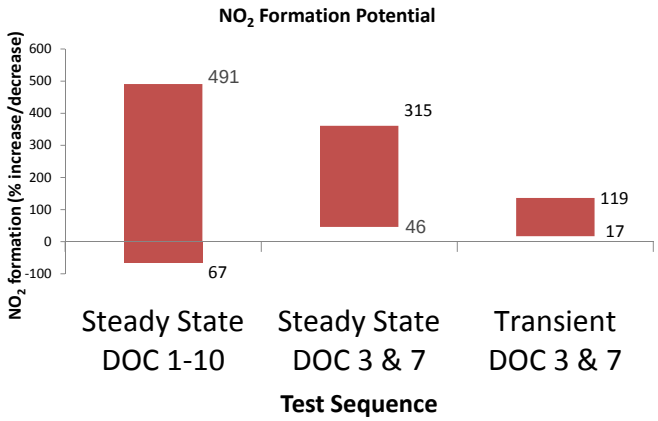
Test Results – NO_2 Formation Steady State VS Transient Test Cycle



11

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Test Results Summary

- 8-mode results on 10 DOCs (over all study)
  - CO reduction, 16% to 99%
  - NO_2 reduction, - 491% to 67%
- 8-mode results on DOC 3 and 7 (this presentation)
  - CO reduction, 77% and 80%
  - NO_2 reduction, -46% and -315%
- LHD transient results on DOC 3 and 7 (this presentation)
  - CO reduction, 57% and 64%
  - NO_2 reduction, -17% and -119%
- 8-mode test cycle had higher engine load (53%) compared to the LHD transient test cycle (44%)

12

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Concluding Remarks

- The impact of in-mine use DOCs on exhaust emissions were evaluated in a controlled engine dynamometer laboratory
- The testing was done for (1) ISO-8178-C1, 8-mode steady state, and (2) Canmet MINING LHD transient test cycles
- Most of the DOCs increased NO_2 emission
- Comparison of both test cycles showed the same pattern in emission reduction although the magnitude of reduction was less for the LHD transient test cycle
- DOCs should also be tested in field to determine the level of reductions
- All DOCs do not have the same effects on emissions, and therefore only properly tested DOCs should be used on mine equipment

13

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