

**MDEC 2008 - ROUND TABLE FORUM  
ENGINES & VEHICLES**



**Facilitator: John Vergunst - Ontario Ministry of Labour**

**CONCERNS**



- 1. Potential effect of emissions with depth**
- 2. Problems with NO<sub>2</sub> production**
- 3. Problems with Tier 4 & 3 engines**

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## Emissions & Depth

- Very little information on the impact of emissions with depth
- Discussion: Steve Forbush's presentation, "Chassis Dynamometer Results from 2008 On-Highway Pickups", MDEC 2008
- Pickup trucks built to meet US EPA on-highway transition tests & not off-highway steady state tests



## Emissions & Depth

- MSHA 8-mode tests on a 1-ton truck (220 bhp) required vent rates as high 31,000 cfm to dilute NO<sub>2</sub>
- The vent rate was based on NO<sub>2</sub> in 5 of 6 tests (with catalyzed filters the levels may even be higher)
- NIOSH is warns of potential high NO<sub>2</sub> concentrations with catalyzed filters

S. Forbush, "Chassis Dynamometer Results from 2008 On-Highway Pickups", MDEC 2008



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## Emissions & Depth

Altitude		Fuel Rate Factor
Feet	Metres	
sea level	Sea level	1.00
+ 2,000	+ 610	0.94
+ 4,000	+1220	0.89

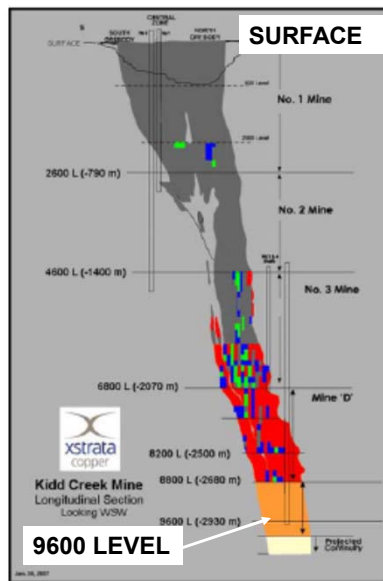
Afterwards Brent Rubeli provided a paper presented at the SAE.

Altitude work done by MSHA

Engine mfg specifies amount of de-rating to ensure fuel doesn't exceed the maximum air / fuel ratio

SAE 2007-01-4144, "The Effects of Depth on Diesel Engine Emissions in an Underground Mine", Brent Rubeli, Mahe Gangal of CANMET-MMSL and David Counter of Xstrata Copper

## Emissions & Depth




- study from surface – 8,000 ft
- MSHA studies for altitude similar
- effect on CO & NOx same for similar engines

**Conclusion:**

- emissions did not follow a trend
- rapid acceleration and loading have a greater effect

SAE 2007-01-4144, "The Effects of Depth on Diesel Engine Emissions in an Underground Mine", Brent Rubeli, Mahe Gangal of CANMET-MMSL and David Counter of Xstrata Copper



## Emissions & Depth

- Engines compensate for altitude using turbocharge boost pressure or wastegate. Some loss of engine performance can be expected
- behavior of turbocharger at depth is unknown & may negatively affect emissions.
- electronic control modules (ECM) can become confused at depth due to pressure sensors falling out of the programmed range.

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## NO<sub>2</sub> Production

Large room & pillar operations have long air residence times (days) & operate close to the occupational exposure limit (OEL) for NO<sub>2</sub> = 3 ppm

To meet NO<sub>x</sub> emissions for Tier 3, engines reduce NO<sub>x</sub> but increase DPM and NO<sub>2</sub> concentrations.

Report of in mine tailpipe testing – using ECOM  
CO OEL = 25 ppm, tailpipe 50 – 60 ppm  
NO<sub>2</sub> OEL = 3 ppm, tailpipe as high as 60 ppm

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# Tier 3 & 4 Engines

- NOx drives Tier 3 engines
- Tier 2 engines will be made as long as there is demand
- Unlikely that the mining industry alone can support the demand



Example: DDEC series 50 are no longer made

DDEC series 60 will be replaced by 1600 series

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# Tiers 1 - 4 Nonroad Emission Standards

kW (HP)	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
kW < 8 (HP < 11)					(10.5) / 8.0 / 1.0					(7.5) / 8.0 / 0.80							(7.5) / 8.0 / 0.40 <sup>1</sup>					
8 ≤ kW < 19 (11 ≤ HP < 25)						(9.5) / 6.6 / 0.80				(7.5) / 6.6 / 0.80							(7.5) / 6.6 / 0.40					
19 ≤ kW < 37 (25 ≤ HP < 50)							(9.5) / 5.5 / 0.80			(7.5) / 5.5 / 0.60							(7.5) / 5.5 / 0.30	(4.7) / 5.5 / 0.03				
37 ≤ kW < 56 (50 ≤ HP < 75)										(7.5) / 5.0 / 0.40							(4.7) / 5.0 / 0.30 <sup>2</sup>	(4.7) / 5.0 / 0.03				
56 ≤ kW < 75 (75 ≤ HP < 100)																						
75 ≤ kW < 130 (100 ≤ HP < 175)																						
130 ≤ kW < 225 (175 ≤ HP < 300)																						
225 ≤ kW < 450 (300 ≤ HP < 600)																						
450 ≤ kW ≤ 560 (600 ≤ HP ≤ 750)																						
> 560 kW (>750 HP)																						

Standard Reference: NOx / HC / CO / PM (NOx+NMHC) / CO / PM  
All standards are indicated in g/kW-hr

Tier 1 Tier 2 Tier 3 Tier 4 Tier 4

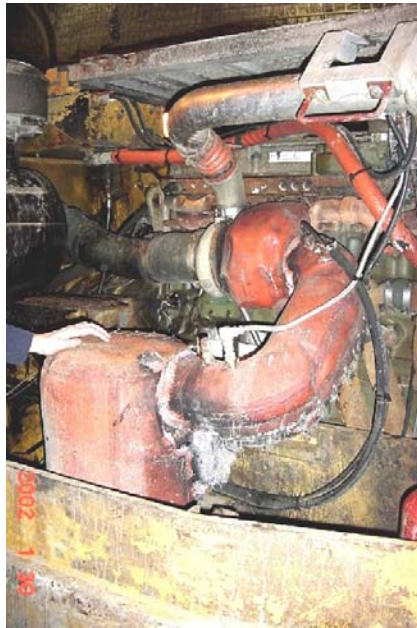
<sup>1</sup> May certify until 2010 under special provisions and then must meet 0.60 g/kW-hr without AB&T  
<sup>2</sup> Optionally may certify to 0.03 g/kW-hr PM starting in 2012 (Tier 3 prior which has a 0.04 PM in 2008)  
<sup>3</sup> If manufacturer complies without using credits, can continue thru 2015  
<sup>4</sup> Alternate Nox available with FEL caps OR split family certification (certify to Nox halfway in between old and new standards)  
<sup>5</sup> Applies to portable power generation > 1200 hp  
<sup>6</sup> Applies to portable power generation > 751hp

2010

Courtesy of Detroit Diesel

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## Tier 3 & 4 Engines

Tier 4 requires after-treatment technology as part of the engine package, such as

- cooled exhaust gas recirculation (EGR)
- staged turbo-charging
- diesel particulate filters (DPF) for DPM and / or
- selective catalytic reduction (SCR) for NOx / NO2
- EPA will have anti-tampering that shuts down the engine

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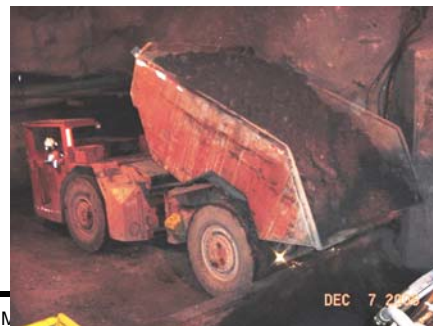
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## Tier 3 & 4 Engines

Mining companies apprehensive about using Tier 3 & 4 engines

One Solution: look at the scrapped equipment and rebuild Tier 2 engines



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## Tier 3 & 4 Engines

**Mining industry only finds out about problems with new Tier engines after they've been purchased and underground**

**Other Solution: Work with manufacturers. Engine mfg stated that if all the multi-national mining companies got together they could attract attention**



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## ROUND TABLE RECOMMENDATIONS

1. More OEMs should attend forums & listen to industry concerns.
2. OEMs should present custom solutions for underground equipment at MDEC

**MDEC organizers informed the OEMs of this conference**

3. Diesel emissions with depth needs to better defined.
4. That a depth simulator be used for testing engines under controlled conditions. Depth at many mines are near 8 - 10 000-feet..
  - **CANMET Paper presented to SAE in 2007 and CANMET will approach the DMRC (Deep Mining Research Consortium) for further work.**
  - **CANMET determined that a depth pressure simulator for engine testing does not exist anywhere in the world.**

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