CANMET Mining and Mineral Sciences Laboratories

Mining Diesel Emissions Conference - 2010

Evaluation of SCR Technology Retrofit for NOx Reduction in Diesel Mining Vehicles

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NO_2 Generation at Goderich Mine

Background

- Mining Operation entirely under Lake Huron
- Surface Facilities situated on peninsula totaling about 6 Hectares
- Intake and exhaust shafts less than 100m apart
- Approximately 750,000 CFM enters the mine through two 16’ diameter shafts
- Air exhausts through one 22’ diameter shaft
- Air travels ~17 km from intake to exhaust

NO_2 Generation at the Goderich Mine

Mining Operation

- 3 sizes of headings:
  - Conventional (60’ wide by 43’ High)
  - Development (60’ wide by 12’ High)
  - Bench (60’ wide by 48’ High, ultimate height: 60’)
- Air velocities range from 10’/min. to 700’/min.

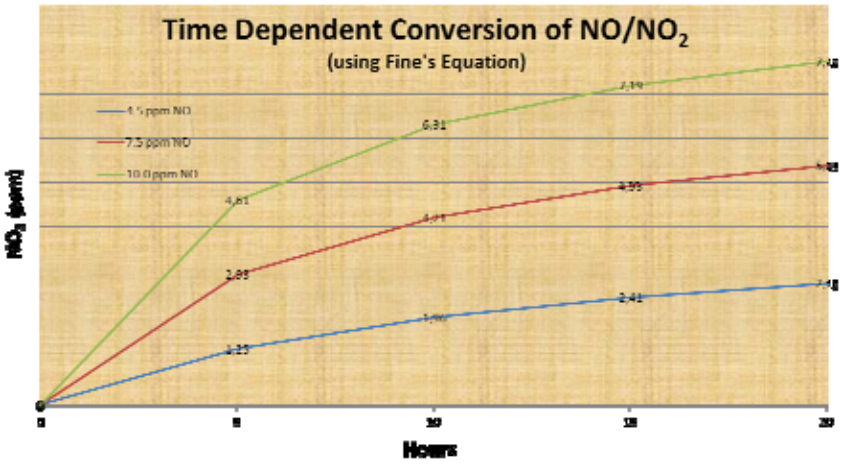
Ventilation Studies

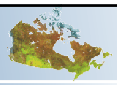
- CANMET – 1997
  - Tracer gas, barometric psychometric to determine maximum capacity of intake and exhaust shafts
- CANMET – 1999
  - Tracer gas to determine retention time and total time air is in the mine

NO_2 Generation at the Goderich Mine

Results of Studies

- Ventilation system capable of supplying up to 800,000 CFM
- Air can be in the mine for over 40 hours
- Using Fine's equation, 61% of original NO generation converts to NO_2
- Typical NO:NO_2 ratios in multi-level mines are 10 : 1. Goderich mine ratio is 1 : 1





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Introduction

- Oxides of nitrogen (NOx) are significant pollutants in the underground mine environment.
- Health hazards include:
  - Central nervous system effects (NO)
  - Lung irritation (NO_2)
- Provincial regulations limit the level of NO and NO_2 in ambient air quality.
- Significant efforts are being made to reduce the levels of NOx emissions at the source.

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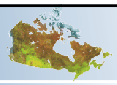

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Diesel Engines and NOx

- Diesel exhaust is an oxidizing environment (lean fuel/air ratio means O_2 is left over).
- Not possible to reduce NOx without an additional reductant.
- Selective catalytic reduction (SCR) uses urea-based agent to permit control of NOx emissions in diesel exhaust.
- SCR provides 60%-80% NOx reduction.

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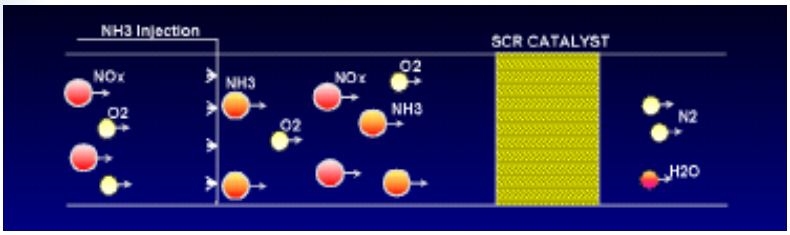
SCR for NOx Control



- Urea liquid is hydrolyzed to ammonia upon injection into the exhaust.
  - $6NO + 4NH_3 \rightarrow 5N2 + 6H_2O$
  - $4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$
  - $6NO_2 + 8NH_3 \rightarrow 7N_2 + 12H_2O$
  - $2NO_2 + 4NH_3 + O_2 \rightarrow 3N_2 + 6H_2O$

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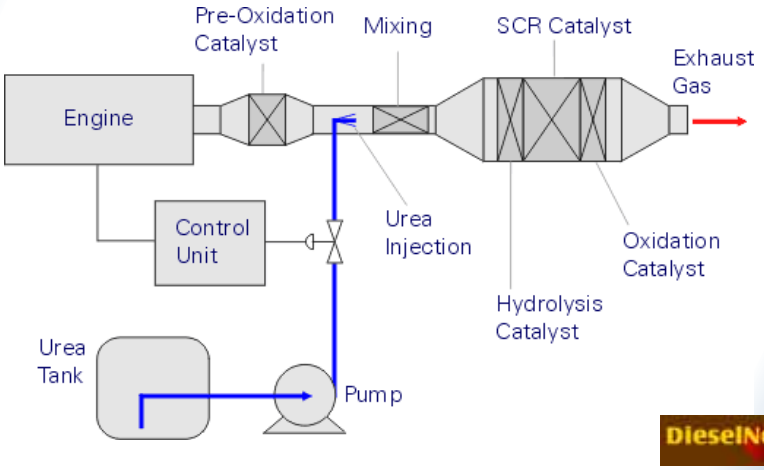
SCR System Concept



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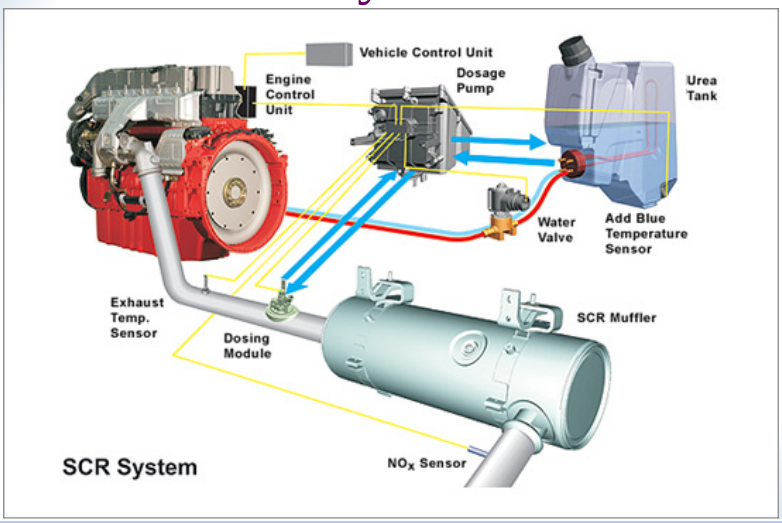
Practical SCR System



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SCR Experience

- Approximately two thirds of all HD highway trucks in Europe are equipped with urea SCR mandated by Euro 4 NOx limits.
- SCR is the technology of choice where fuel economy is the major driving factor, as with heavy-duty diesel.
- Off-highway mobile equipment is a new market for SCR, but trials are promising.
- Industrial stationary power generation has used SCR for decades!
- This project is the first underground mining application for SCR retrofit technology in North America.

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SCR Project Objectives

- Conduct a demonstration project at the Compass Minerals Sifto Salt Mine.
- Help mine plan for effective SCR technology implementation.
- Perform a two vehicle pilot study of SCR technology.
- Real-time underground emissions test.
  - Determine the SCR emission reductions possible.
- Look at system long-term durability.

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Compass Minerals

- Compass Minerals Sifto Salt (Goderich).
- Words largest salt mine.
- Over 22,000hp diesel fleet underground.
- Large single unit vehicles over 600hp.

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Demonstration Project

- In-mine pilot study using two vehicles.
  - Caterpillar 775D truck
  - Caterpillar 990G loader
- SCR systems:
  - NETT Technologies (sensor feedback)
  - BASF Tenneco (engine map-based)
- Portable emissions measurement system.
  - SEMTECH-DS
- Vehicle emissions sampling over actual production duty cycles during regular shift operation.

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Pilot Test Vehicles

- Caterpillar 775D
- Caterpillar 990G

Both use C27 engine at 725hp (truck) and 675hp (loader)

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Portable Emissions Measurement System

- SEMTECH-DS

	Range	Resolution	Accuracy
CO_2	0 – 20%	.01%	± 0.1% or ± 3% of rdg
CO	0 – 8% 0 – 8%	10 ppm .001%	± 50ppm or ± 3% of rdg ± 3% or ± 0.02% of rdg
THC	0 – 100 ppm 0 – 1,000 ppm 0 – 10,000 ppm	0.1 ppm 1 ppm 1 ppm	2 ppm or ± 1% of rdg ±5 ppm or ± 1% of rdg ± 10 ppm or ± 1% of rdg
NO	0 – 2,500 ppm	1 ppm	± 15 ppm or ± 3% of rdg
NO_2	0 – 500 ppm	1 ppm	± 10 ppm or ± 3% of rdg

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SCR Pilot Systems (Truck)

- NETT Technologies
- Sensor Feedback
- Custom fit

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SCR Pilot Systems (Loader)

- BASF Tenneco consortium
- Map-based
- Dual bank

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Truck / Loader Cycle

- Loaded at face and tram to pile.

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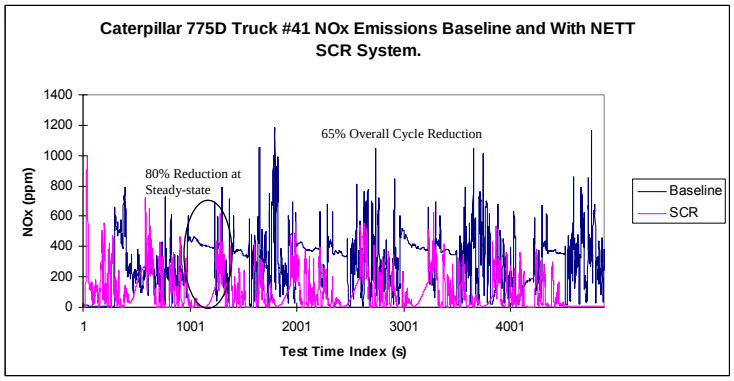
Results: Cycle NOx - Truck



- Significant reduction in steady state and cycle NOx.
- Good transient control

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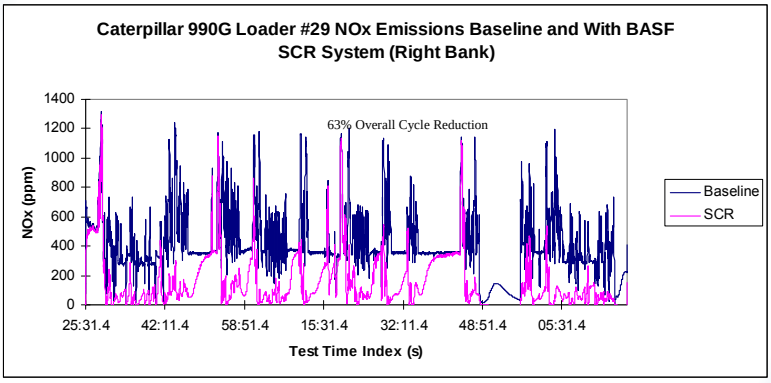
Cycle NOx - Loader



- Good cycle NOx control but long idle periods.
- Left bank performance not as good (only 50%)

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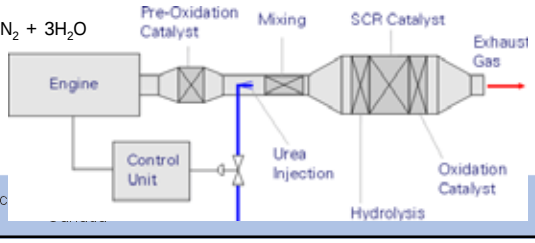
Idle Emissions and NO_2

- SCR systems do not inject urea at idle due to low exhaust temperatures. The SCR catalyst is not active and the urea would pass through the system into the mine.
- Compounding this, the pre-catalyst is designed to make NO_2 for a for favourable SCR reaction and may be active at low temperatures.
- There is a risk of NO_2 passing through the system unaffected at idle.

$NO + NO_2 + 2NH_3 \rightarrow 2N_2 + 3H_2O$



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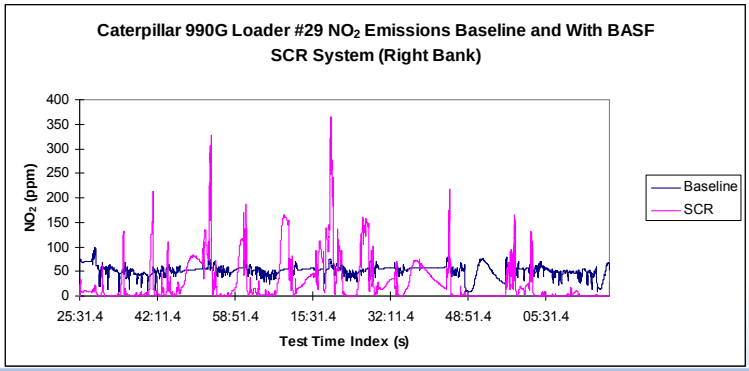
NO_2 Formation and Slip

- This effect was seen with both SCR systems at Sifto and will have to be addressed in the production units.
- Limiting potential NOx reductions for cycles with long idling.
- Minimize cycle idle time for best performance.



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Other issues

- Good acceptance from operators and mechanics.
- Minimal maintenance issues once initial installation problems overcome.
- Recording urea consumption important for diagnostics.
- Electronic control system calibration optimization important for best performance.
  - Especially for map-based system.

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Routine Tailpipe Testing

- SCR systems can be tested by mechanics at the mine using standard portable gas analyzers.
- Loaded (stall) test.

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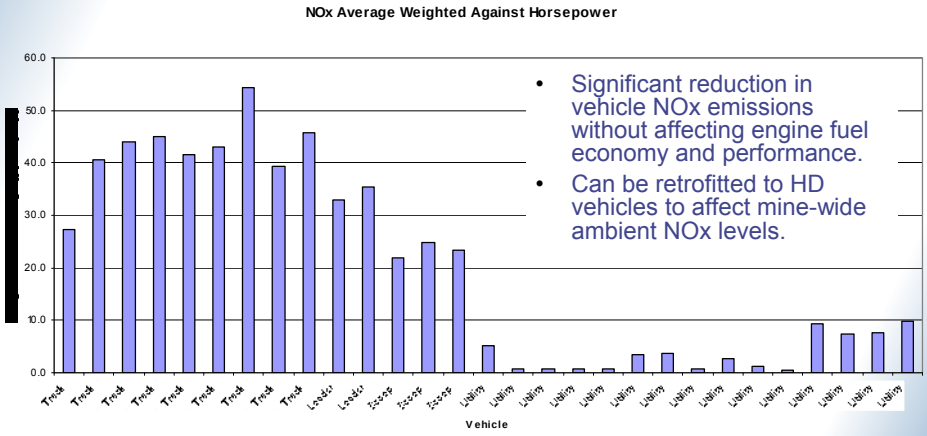
SCR and Diesel Fleet



- Significant reduction in vehicle NOx emissions without affecting engine fuel economy and performance.
- Can be retrofitted to HD vehicles to affect mine-wide ambient NOx levels.

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Conclusions

- Initial SCR system performance very good! 60-65% cycle NOx reduction.
- Potential for significant reductions of NOx emissions. DPM emissions reduction similar to simple DOC catalyst (25%)
- Good acceptance of the technology at the mine.

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Conclusions

- First underground application of SCR technology to mobile equipment.
- SCR specifically targets NOx, which has been an issue for large mines.
- Commonality of 990x and 775x vehicles allows for economies of scale and mine-wide air quality improvement.

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Biodiesel & SCR?

- Potential for biodiesel to increase NOx, or at least be NOx neutral.
- SCR can clean-up any extra NOx generated.
- Biodiesel has inherently low sulphur, which is advantageous for SCR operation.
- Combined to take advantage of GHG / carbon reductions of biodiesel without suffering NOx penalty.

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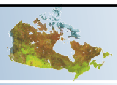

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Next Steps

- Model projected mine-wide effects from implementation on target vehicles.
- Considerations for ventilation reduction and certification air volumes.
- Retrofit of target fleet vehicles with production SCR systems.
- Look at combined SCR and Biodiesel.

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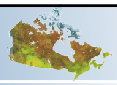

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Questions?

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