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Mining Diesel Emissions Conference - 2010

***Evaluation of SCR Technology
Retrofit for NO_x Reduction in
Diesel Mining Vehicles***


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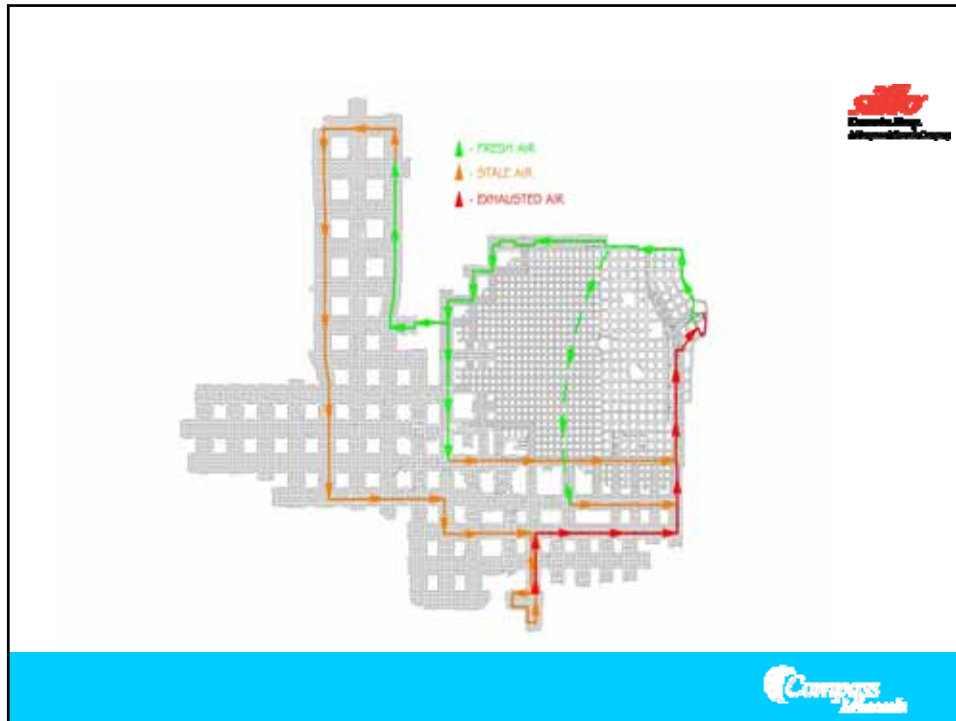
NO₂ Generation at Goderich Mine



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





NO₂ 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

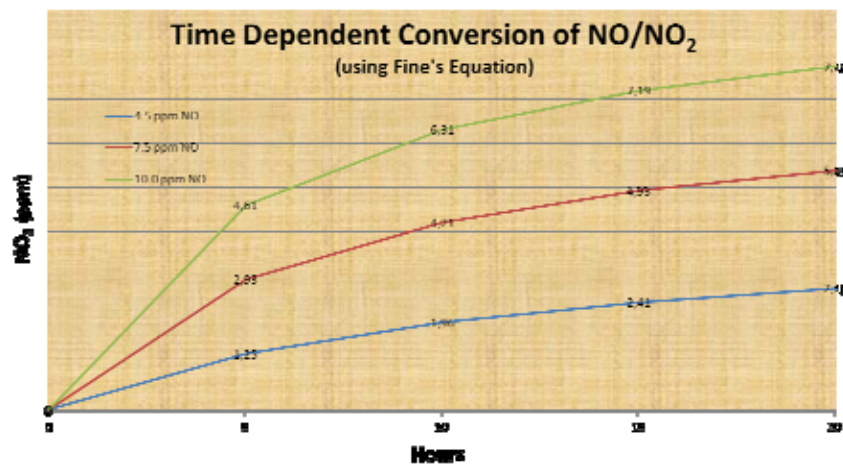



NO₂ Generation at the Goderich Mine



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 NO₂
- Typical NO:NO₂ ratios in multi-level mines are 10 : 1. Goderich mine ratio is 1 : 1








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Introduction

- Oxides of nitrogen (NO_x) are significant pollutants in the underground mine environment.
- Health hazards include:
 - Central nervous system effects (NO)
 - Lung irritation (NO₂)
- Provincial regulations limit the level of NO and NO₂ in ambient air quality.
- Significant efforts are being made to reduce the levels of NO_x emissions at the source.

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Diesel Engines and NO_x

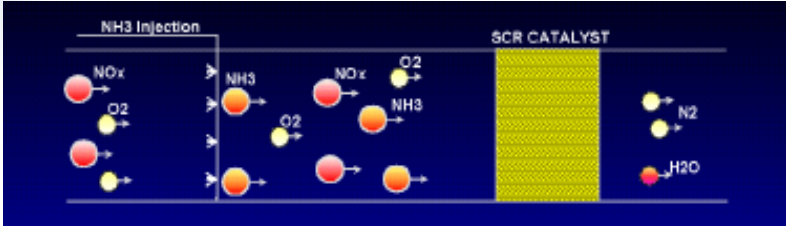
- Diesel exhaust is an oxidizing environment (lean fuel/air ratio means O₂ is left over).
- Not possible to reduce NO_x without an additional reductant.
- Selective catalytic reduction (SCR) uses urea-based agent to permit control of NO_x emissions in diesel exhaust.
- SCR provides 60%-80% NO_x reduction.

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SCR for NO_x Control

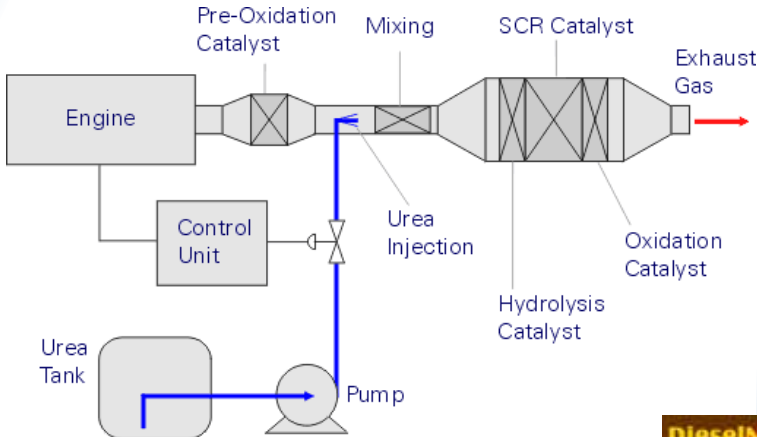



- Urea liquid is hydrolyzed to ammonia upon injection into the exhaust.
 - $6\text{NO} + 4\text{NH}_3 \rightarrow 5\text{N}_2 + 6\text{H}_2\text{O}$
 - $4\text{NO} + 4\text{NH}_3 + \text{O}_2 \rightarrow 4\text{N}_2 + 6\text{H}_2\text{O}$
 - $6\text{NO}_2 + 8\text{NH}_3 \rightarrow 7\text{N}_2 + 12\text{H}_2\text{O}$
 - $2\text{NO}_2 + 4\text{NH}_3 + \text{O}_2 \rightarrow 3\text{N}_2 + 6\text{H}_2\text{O}$



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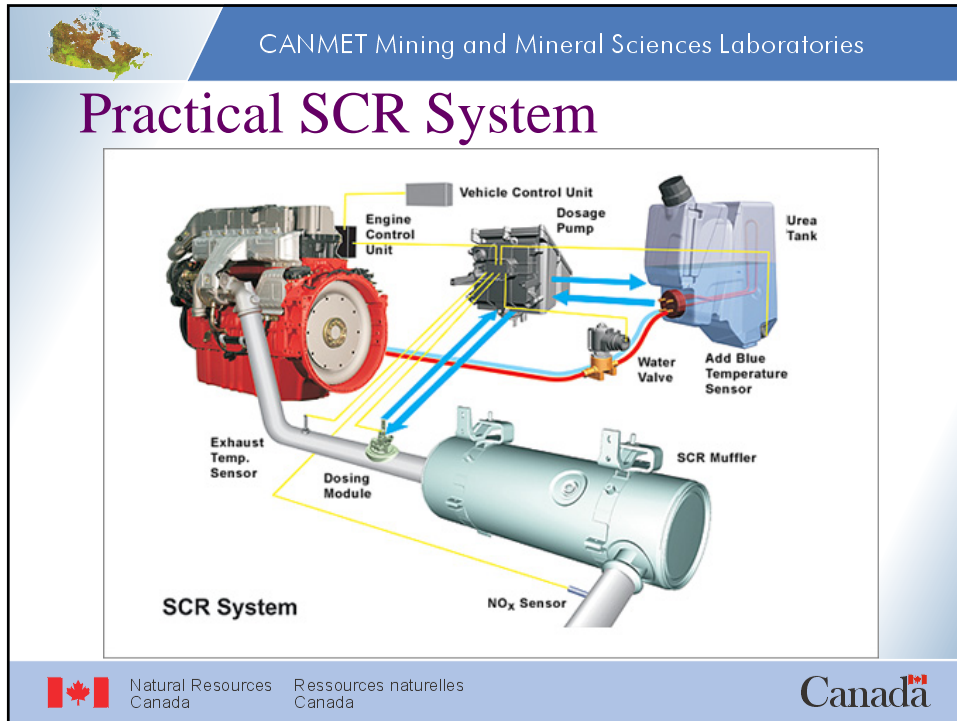
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SCR System Concept





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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 NO_x 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).
- World's 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%	0.1%	± 0.1% or ± 3% of rdg
CO	0 – 8%	10 ppm	± 50ppm or ± 3% of rdg ± 3% or ± 0.02% of rdg
	0 – 8%	0.01%	
THC	0 – 100 ppm	0.1 ppm	2 ppm or ± 1% of rdg ± 5 ppm or ± 1% of rdg ± 10 ppm or ± 1% of rdg
	0 – 1,000 ppm	1 ppm	
	0 – 10,000 ppm	1 ppm	
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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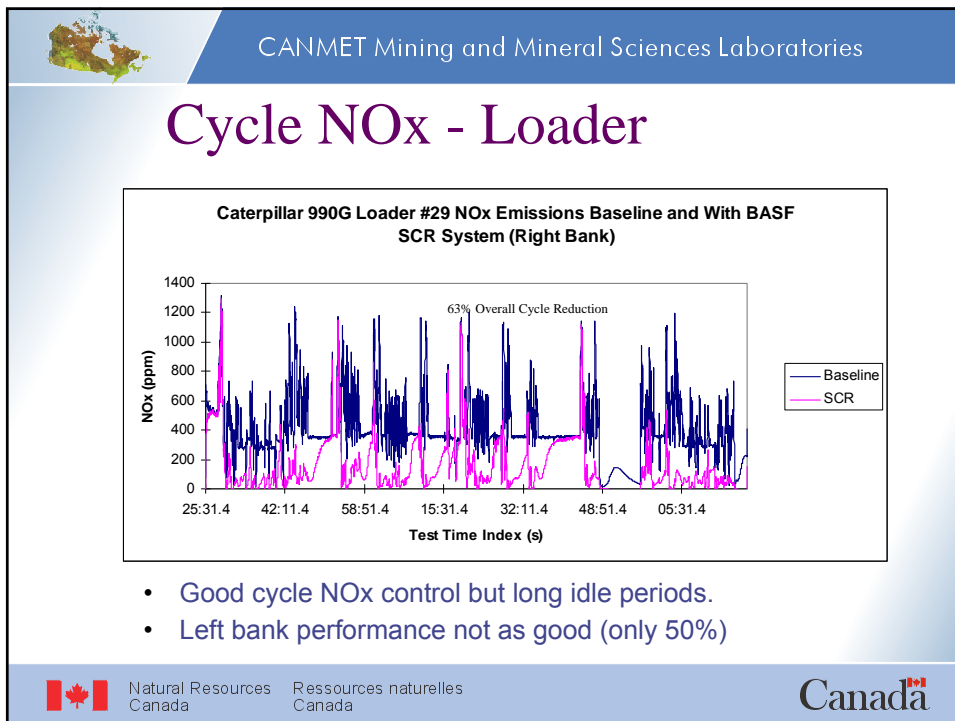
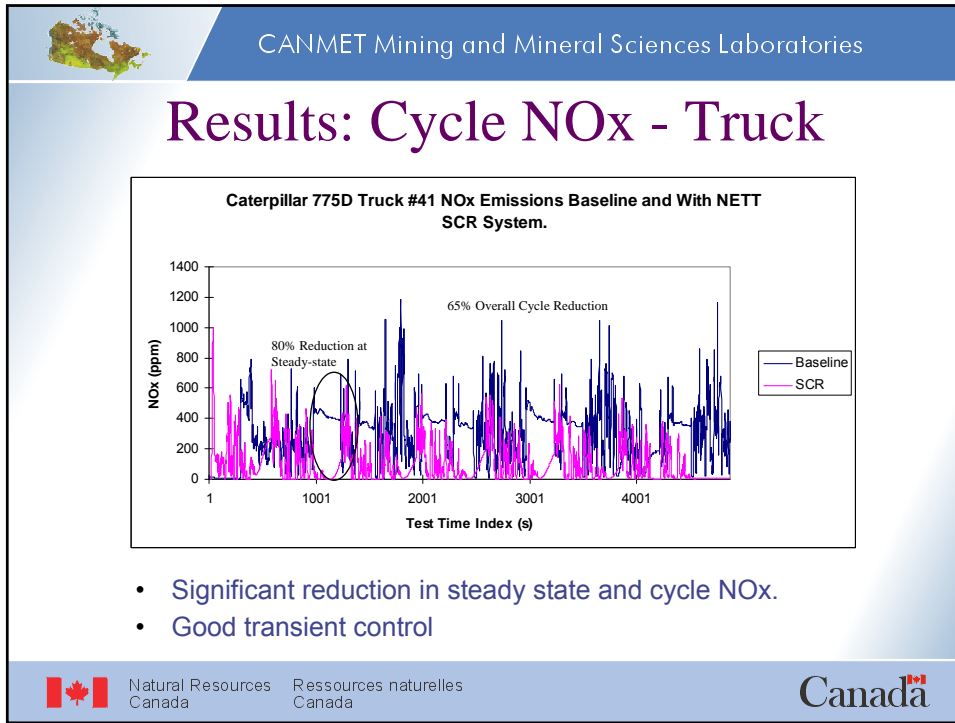
Truck / Loader Cycle



- Loaded at face and tram to pile.

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Idle Emissions and NO₂

- 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 NO₂ for a favourable SCR reaction and may be active at low temperatures.
- There is a risk of NO₂ passing through the system unaffected at idle.

$$\text{NO} + \text{NO}_2 + 2\text{NH}_3 \rightarrow 2\text{N}_2 + 3\text{H}_2\text{O}$$

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NO₂ 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.


Caterpillar 990G Loader #29 NO₂ Emissions Baseline and With BASF SCR System (Right Bank)

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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.




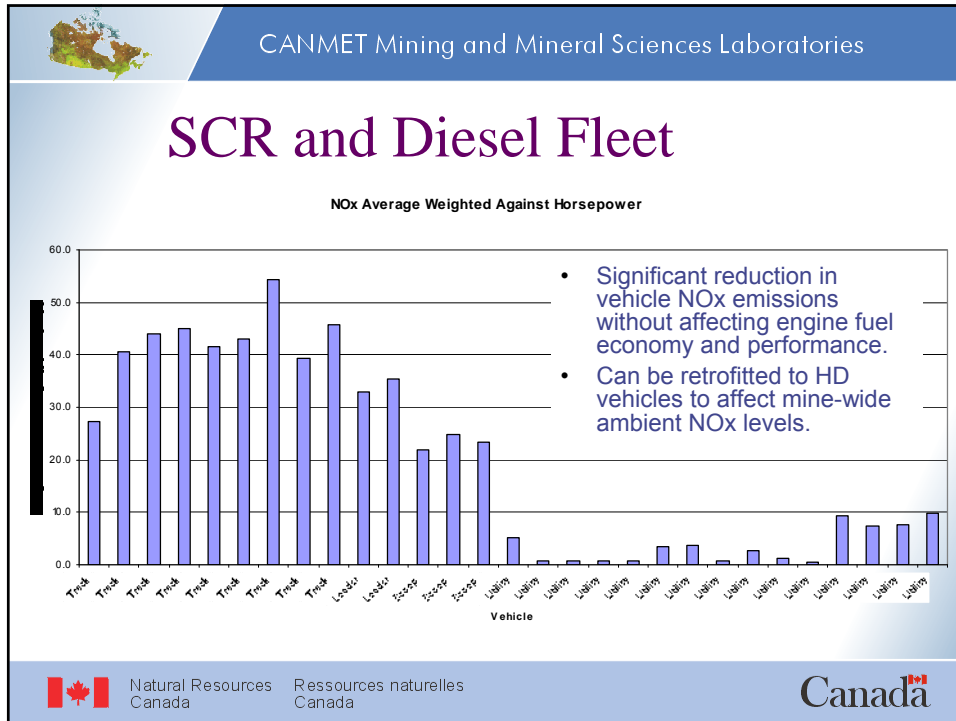




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Conclusions


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

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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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Questions?



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