


**New NH₃-SCR Catalyst for DeNO_x Reduction
Applicable to Mining Diesel Engines**

G. Caravaggio, M. Stanciulescu, R. Burich, L. Nossova
CanmetENERGY

David Young, Brent Rubeli, Vince Feres, Mahe Gangal
CanmetMINING

CanmetENERGY
Leadership in ecoInnovation


 **Natural Resources Canada** **Ressources naturelles Canada**

Canada

Outline

- Background
- Bench scale development of NOx-SCR catalysts
- Catalyst testing unit
- Large scale preparation of catalysts
- Manufacture prototype catalytic converter (PCC)
 - DCL International Inc
- Preparation for engine test
- Results
- Conclusions
- Future Work

CanmetENERGY
Leadership in ecoInnovation

 **Natural Resources Canada** **Ressources naturelles Canada**

Canada

Background

- Objective
 - Development of new materials for the catalytic reduction of NO_x from diesel vehicle exhaust
- Testing of catalyst
 - Bench scale
 - Prototype catalytic converter (PCC)
 - Engines (light, medium and heavy duty)
- Applications
 - On- and off-road diesel vehicles

CanmetENERGY
Leadership in ecoinnovation



Canada

Bench Scale Development of Catalysts

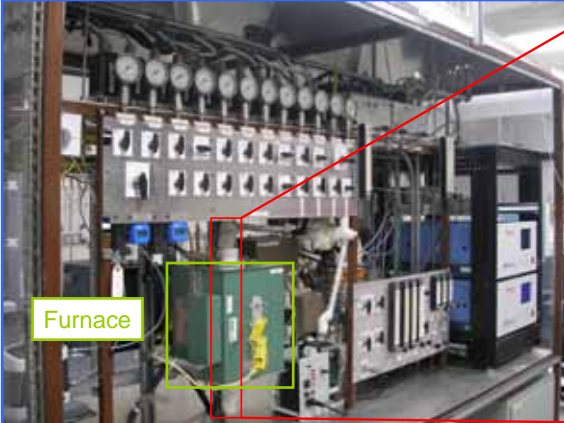
- Materials for supports
 - New supports developed in our lab
 - Commercial zeolites
 - Other commercial supports
- Prepare catalyst using various methods
 - Wet impregnation technique
 - Ion exchange
 - Selection of transition metals for active phase
- Characterization
 - BET (surface area measurements)
 - SEM/EDX (metal content measurements and surface imaging)
 - XRD (for structure confirmation)
 - Temperature Programmed Desorption (TPD) (surface analysis for indication of catalytic activity)
 - Particle size analysis (by X-ray sedimentation)
 - Optical microscope (imaging of mini-cores)
 - XPS (X-ray Photoelectron Spectroscopy for oxidation state of active metal)

CanmetENERGY
Leadership in ecoinnovation

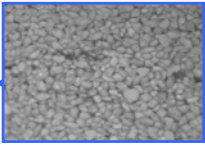


Canada


Catalyst Testing Unit (CTU)



Sieved catalyst particles
(80-120 mesh, 20X mag.)




Cordierite mini-core 400cps



Reactor

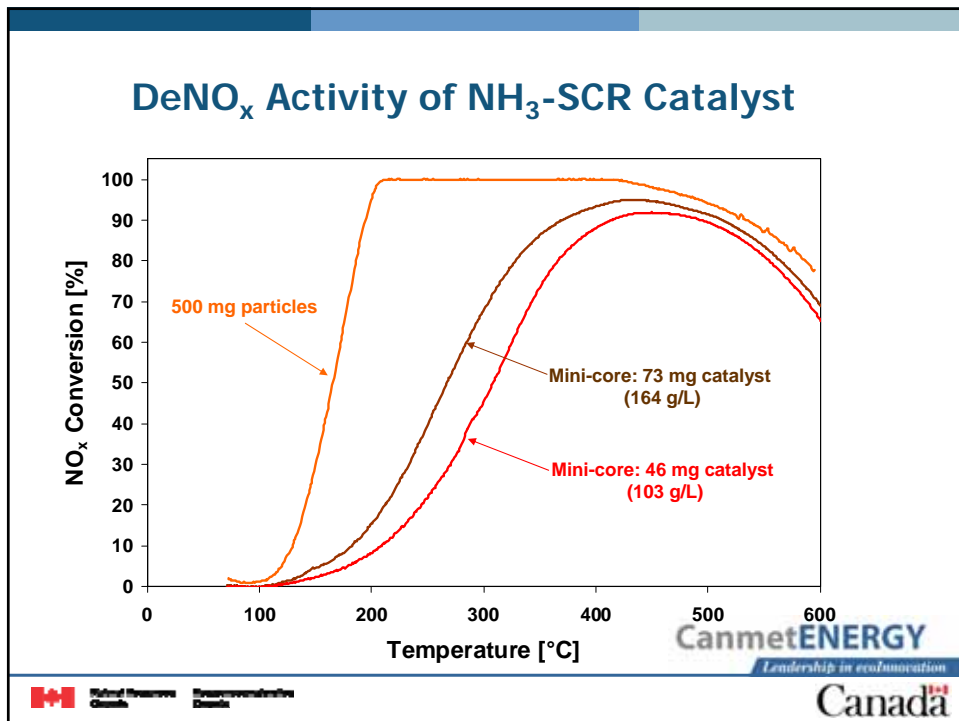
Furnace

- Variable simulated diesel exhaust compositions
- GHSV: 90k-100k h⁻¹
- Feed composition: 5-10% H₂O, 500-800 ppmv NO_x, 5-17% O₂
- Reductant: 500-800 ppmv NH₃



CanmetENERGY
Leadership in ecoinnovation

Canada



Preparation of Large Scale Catalyst Batch

- Bench scale preparation: ~ 10 g catalyst
- Parameters considered for large scale preparation
 - Reduce solvent usage (waste reduction) to prepare supports/catalysts
 - Ensure activity of large and small batch were equal or similar
- Catalyst prepared
 - Batch ranges: 250 to 800 g/batch
 - Final amount: ~5 kg/catalyst

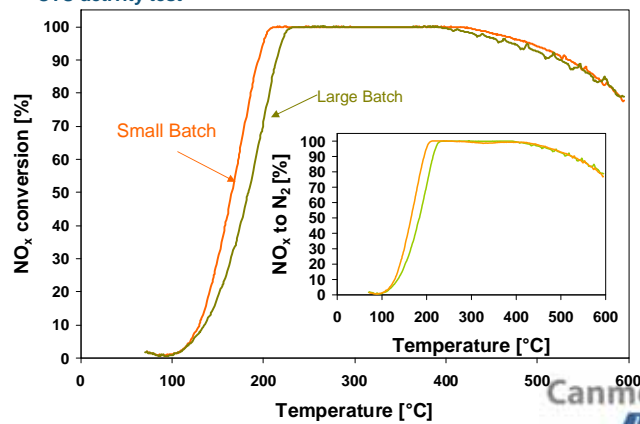
CanmetENERGY
Leadership in ecoinnovation



Canada

Quality Control/DeNO_x Activity of Large Batch

- Quality Control
 - BET surface area
 - SEM metal content
 - CTU activity test



CanmetENERGY
Leadership in ecoinnovation

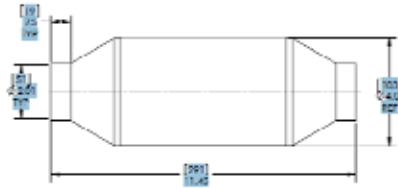


Canada

Manufacturing of PCC (by DCL International Inc)

- Cordierite core (400 cpsi)
- Stainless steel can

1.0 L, loading: 206 g/L_{sub}



CanmetENERGY
Leadership in ecoinnovation



Canada

Engine Tests of PCC

- 1 L PCC (at CanmetMINING)
 - ISO 8178(C1) test
 - Progressive load increase test, at fixed RPM
 - Catalyzed Diesel Particulate Filter (CDPF)
 - Split flow
 - Reductant: NH₃ (g)

CanmetENERGY
Leadership in ecoinnovation



Canada

Engine Specifications and Test Parameters

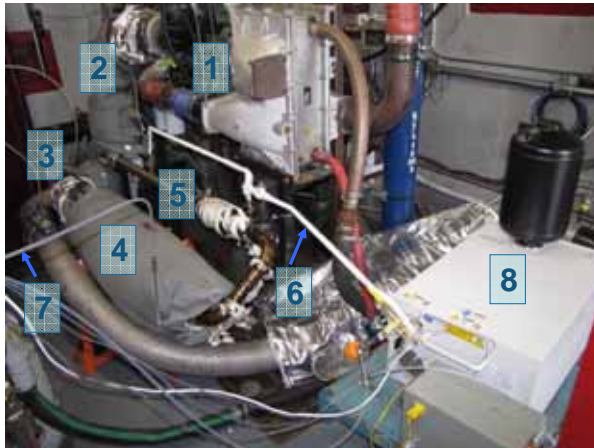
Test Facility	CanmetMINING	
Engine type/size	DDEC series 60, 11.1L	
Cylinders	6	
Maximum power	325 bhp @ 2100 rpm	
Test	ISO8178 (C1)	Progressive load
GHSV (k, h ⁻¹)	~6-98	~45-60
Engine speed (rpm)	600-2100	1260
Torque (lb.ft)	0-1075	26-1074
Power (bhp)	0-312	26-258

CanmetENERGY
Leadership in ecoinnovation



Canada

Engine Test PCC Setup at CanmetMINING



1. Engine
2. Engine exhaust pipe
3. Flow Splitter
4. CDPF
5. 1 L NH₃-SCR PCC
6. Heated sampling line
7. Reductant delivery line
8. FTIR

CanmetENERGY
Leadership in ecoinnovation



Canada

Reductant Delivery System



- Reductant delivery system built at CanmetENERGY labs
 - Mass flow controllers and flow meter to adjust reductant delivery
- NH₃ needed: calculated from exhaust flow and NO_x amount measured at upstream of the PCC
- NH₃:NO_x ratio adjusted to 1:1

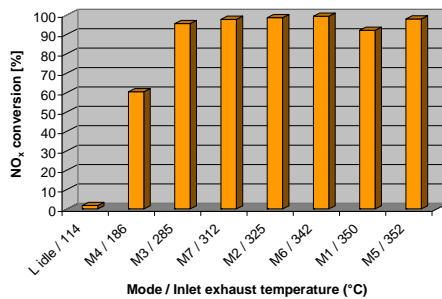
CanmetENERGY
Leadership in ecoinnovation



Canada

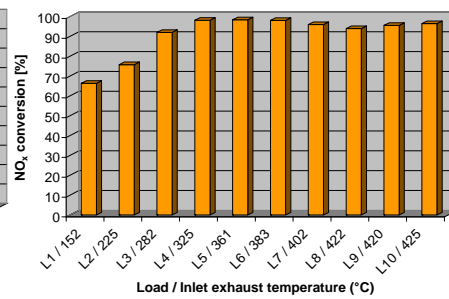
Engine Test Results DDEC Series 60, 11.1L Engine

ISO8178(1)



NO_x range (ppmv): ~30-1020

Progressive load

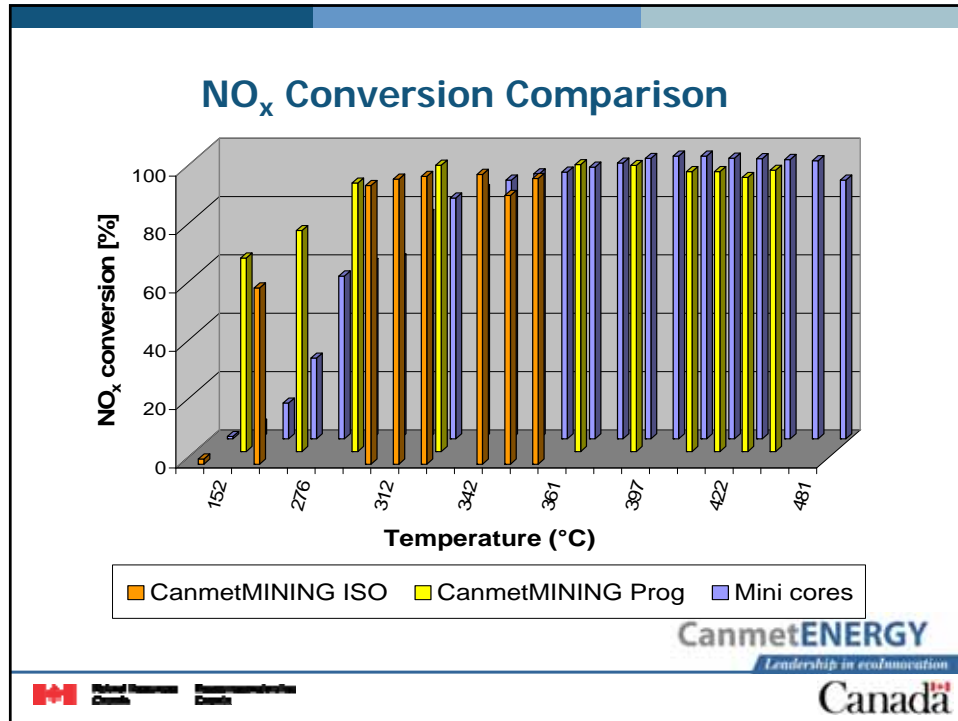


NO_x range (ppmv): ~300-1000

CanmetENERGY
Leadership in ecoinnovation



Canada



Conclusion

- **New DeNO_x catalytic materials were developed**
 - Active phase: common transition metals
 - Supports with high surface area: commercially available
- **Excellent NO_x reduction at low and high temperatures under mining engine conditions (up to a max of 99% NO_x conversion)**
- **Potential to be used in different diesel engines**
 - 5 L PCC was tested on a CAT 3045C, 4.4 L engine

CanmetENERGY
Leadership in ecoinnovation
Canada

Future Work

- Improve low temperature activity of catalyst by adding and/or replacing the active metals
- Accelerated aging test of catalyst
- Test PCC on other diesel engines (locomotive diesel engines)
- Long term aging study of PCC on board vehicle

CanmetENERGY
Leadership in ecoInnovation



Canada

Acknowledgment

Funding for this project was provided by the Government of Canada Program on Energy Research and Development (PERD), through the Advanced Fuels and Transportation Emissions Reduction (AFTER) and eco-EI1 programs.

CanmetENERGY
Leadership in ecoInnovation



Canada

- Thank you!
- Questions?

CanmetENERGY
Leadership in ecotechnology



Canada