Testing a Low NO_2 CRT® DPF System

Presentation to the

Mining Diesel Emissions Conference

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Center for Diesel Research

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Testing a Low NO_2 CRT® DPF System

We gratefully acknowledge our project sponsors and supporters:

NIOSH
INCO
Johnson Matthey

& Others

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Outline

- Objectives
- Background
- Apparatus & Measurement Systems
- Methods
- Results
- Conclusions

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Objective

To evaluate the performance of a Johnson Matthey low NO_2 CRT® in a test cell under steady state and transient operation.

To determine the performance on particulate matter and gaseous emissions.

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Background

The continuously regenerating trap (CRT®) is a Johnson Matthey patented invention.

CRT's may produce elevated levels of NO_2 in the exhaust.

Inco sponsored literature surveys

- *Evaluation of CRT™ NO_2 Production (2003)*
- *Influence of Fuel Sulfur Content and Diesel Oxidation Catalysts on Nitrogen Dioxide Concentrations in Diesel Exhaust (2004)*

JM presented this device last year at MDEC as a method to control the CRT's enhanced NO_2 emissions

NIOSH sponsored project to evaluate emission control devices with potential for in-mine application.

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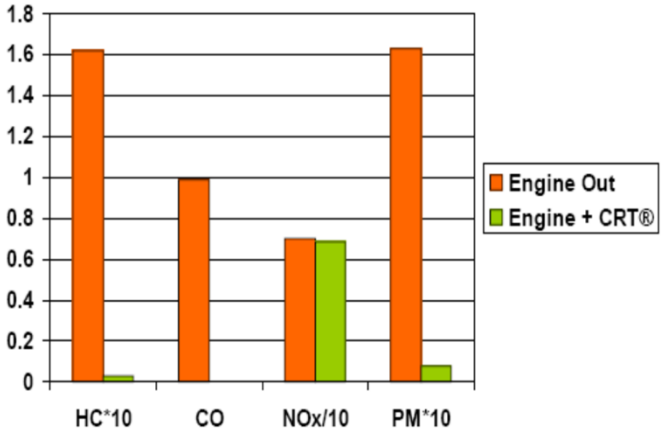
CRT® System Performance

Euro 1 truck engine, ESC Cycle, units: g/kWh



Courtesy Johnson Matthey

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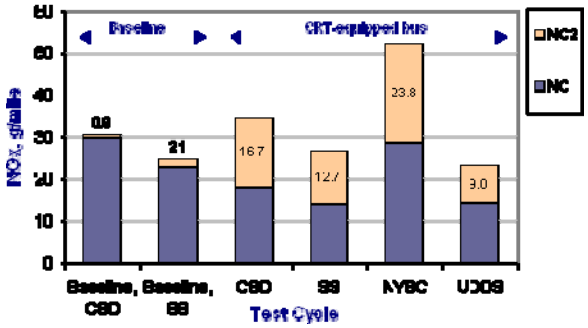
CRT® Issues

Enhanced emissions of NO_2 or NO_2 slip.



Ayala, A., Kado, N., Okamoto, R., 2001. "ARB Study of Emissions from Late-model Diesel and CNG Heavy-duty Transit Buses", California Air Resources Board

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Experimental Apparatus

- 1999 Cummins ISM Engine
- 370 HP
- ULSD Fuel <15 ppm S
- Sierra BG-2 used for PM mass sampling
- TSI 3007 CPC, TSI 3070A EAD, DC and PAS for real-time particulate sampling.
- Pierburg emissions rack used for gaseous emissions sampling.
- ECOM KL used for direct NO and NO_2 measurements.

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Fuel Analysis

SUMMARY OF TEST DATA

Consumers' Co-operative Refineries Ltd.

Federated Co-operatives Limited (FCL)

Test Parameter	Test Method	NIOSH ULSD Fuel Canada 06-22-05
Density at 15 °C, g/ml	ASTM D 4052	0.8440
Flash Point, °F	ASTM D 93	142
Cloud Point, °C	ASTM D2500	-48
Sulfur, mass %	ASTM D 2622	<0.001
Distillation, °F	ASTM D 86	
IBP		325.7
5%		362.9
10%		372.8
15%		385.0
20%		396.9
30%		415.4
40%		431.3
50%		445.7
60%		460.8
70%		476.9
80%		497.0
90%		525.7
95%		550.6
FBP		576.8
Recovery		98.1
Loss, vol%		0.9
Residue, vol%		1.0
Hydrocarbon Types	ASTM D1319	
Aromatics		25.3
Olefins		3.4
Saturates		71.3
Cetane Number	ASTM D613	47.7
Gross Heat of Combustion, Btu/lb	ASTM D 240	19555.0

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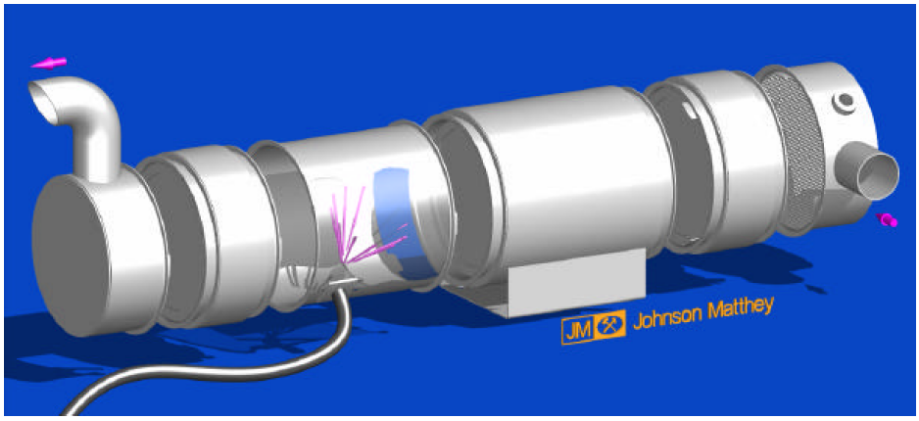
Low NO_2 CRT® System



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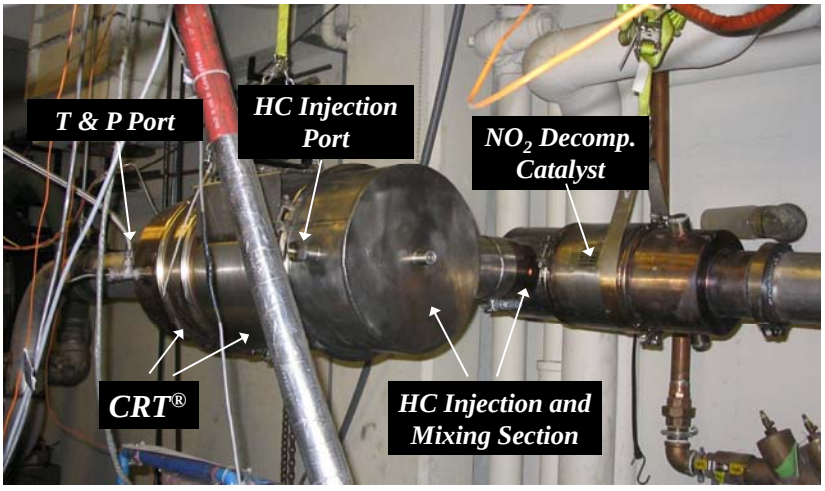
Low NO_2 CRT® System



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HC Injection Controller

Basic Contents

- Fuel Pump
- Air Compressor (2 bar)
- Controller

Inputs

- Engine Speed
- Exhaust Pressure
- Exhaust Temperature
- Computer Interface

Output

- HC (Fuel) Injection Rate

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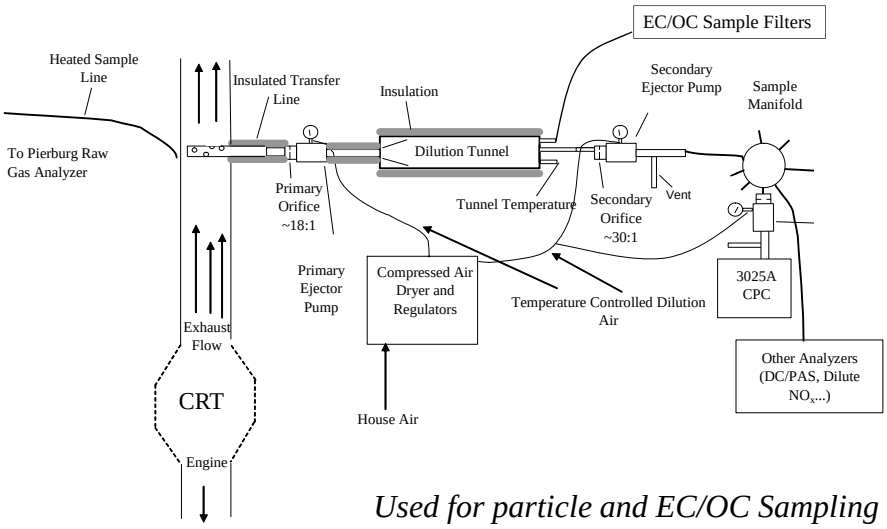
Particulate Sampling Setup



Used for particle and EC/OC Sampling

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Test Modes

ISO 8178 8-Mode Steady State Test

Mode	Speed (rpm)	Load (%)	Torque (N-m)	Power (kW)	T Exhaust (C)
1	1800	100	1451	273	480
2	1800	75	1118	211	439
3	1800	50	725	137	377
4	1800	10	149	28	195
5	1200	100	1897	238	581
6	1200	75	1424	179	532
7	1200	50	948	119	462
8	725	0	0	0	85

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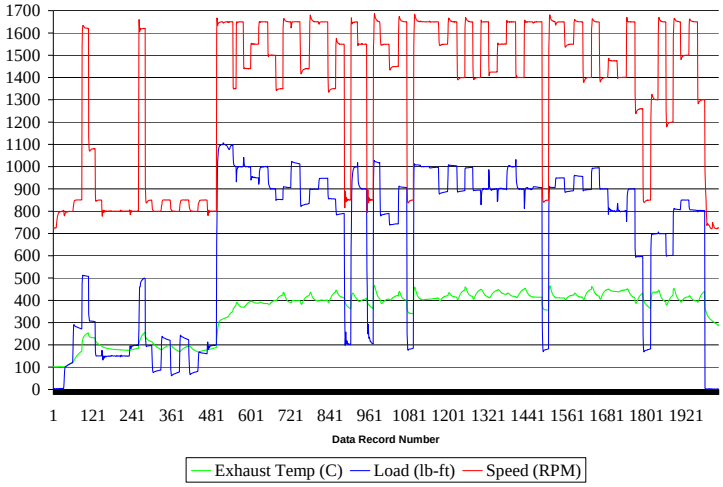
Test Cycle

"INCO" Transient Cycle

Based on logged exhaust temperature date

Similar Temperature Frequency Distribution



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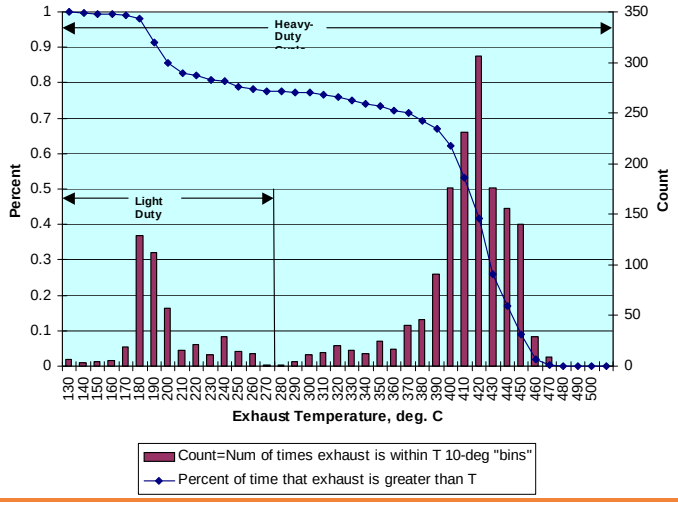
Test Cycle

"INCO" Transient Cycle – Exhaust Temperature Frequency Distribution



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Procedures

- System Installed and De-greened
- System run to collect "characterization" data for JM
  - CRT without HC injection
  - Gaseous emissions, flows, temperature data, etc
- Baseline Data Collected
  - No CRT installed
  - Steady State and Transient Testing
- Collect Data w/Low NO_2 CRT System Installed
  - Steady State and Transient Testing
  - *Issues Arose*

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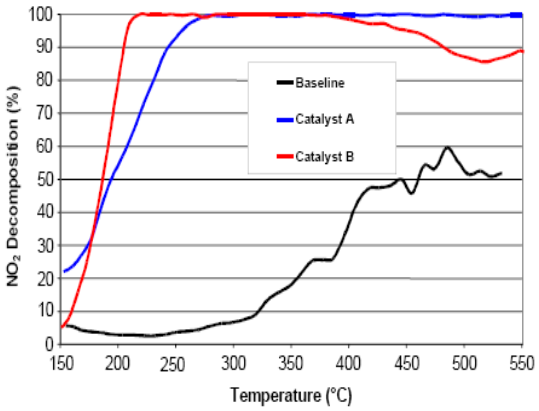
Experiments with a Synthetic Gas

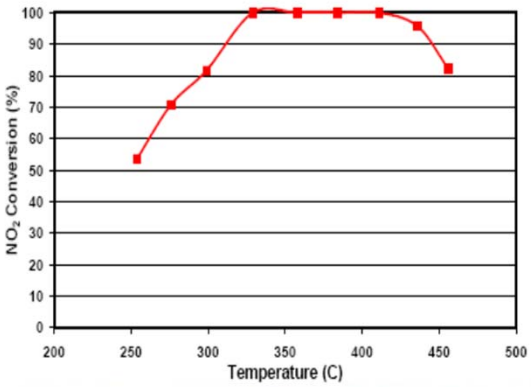
Figure 1: NO_2 decomposition over two catalyst types across a temperature range



Courtesy Johnson Matthey

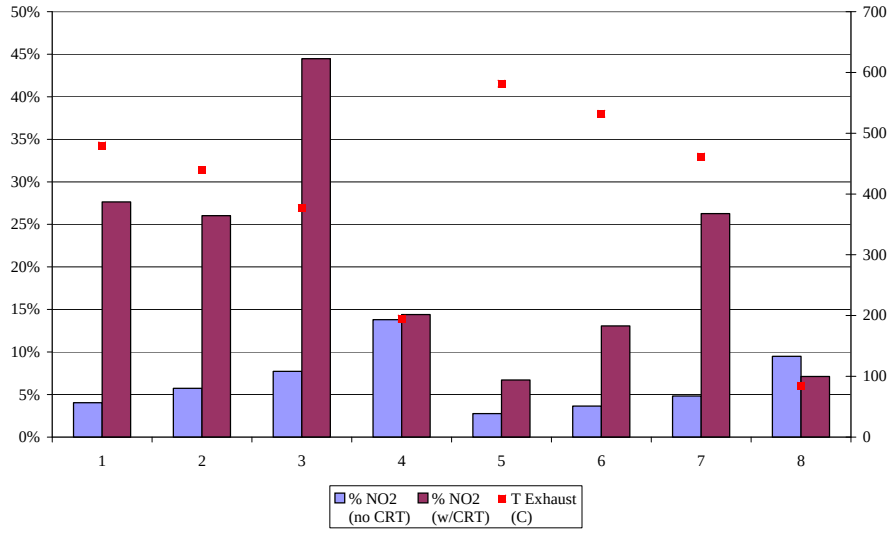
JM Published Results

Initial engine bench results for NO_2 decomposition to NO using diesel fuel reductant



JM - MDEC 2004

NO_2 Percent Vs Mode, w and w/o CRT



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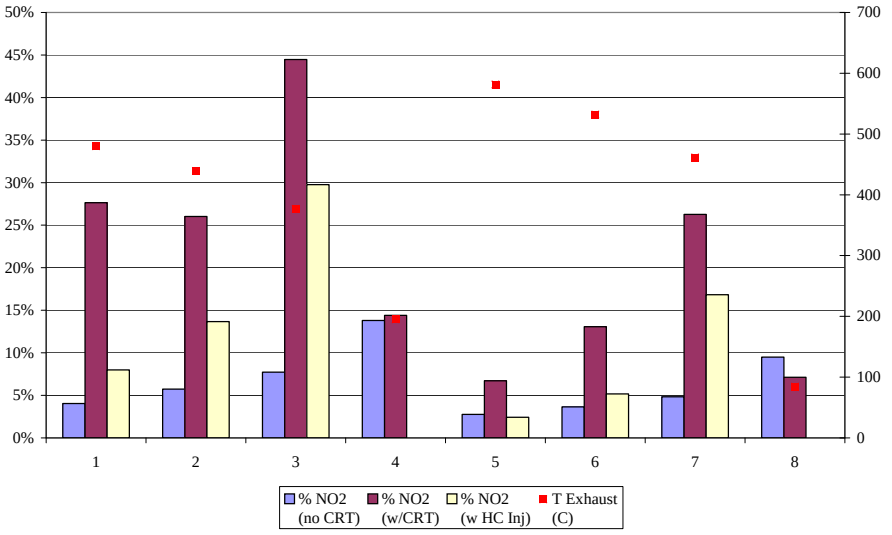
NO_2 Percent Vs Mode, w and w/o CRT



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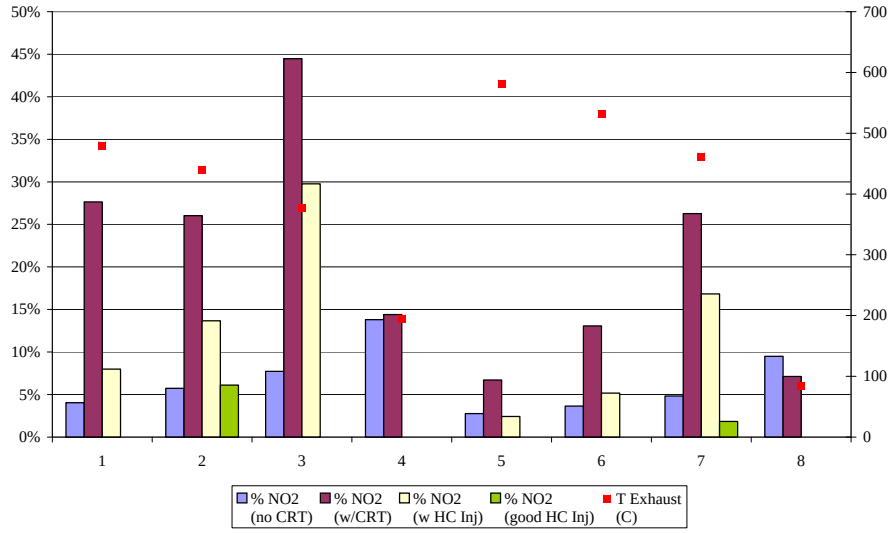
NO_2 Percent Vs Mode, w and w/o CRT



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NO_2 Catalyst Inlet

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NO_2 Control Concerns

Mode		% NO_2 (no HC Inj)	T Exhaust (C)
1800	25%	50%	341
1200	25%	61%	312

Turbo Outlet Temperatures

Cooler within system.

JM data indicates ~80% efficient at 300 C

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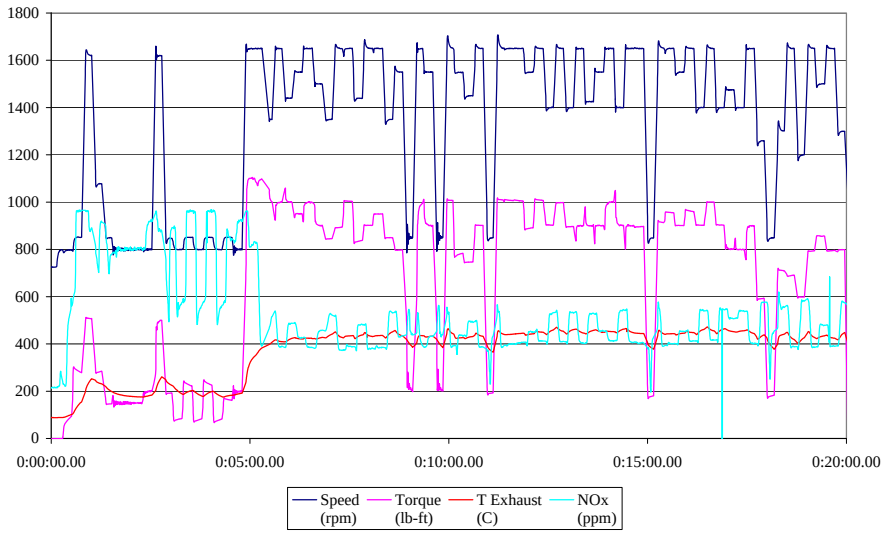
Transient Cycle Example NO_x Data



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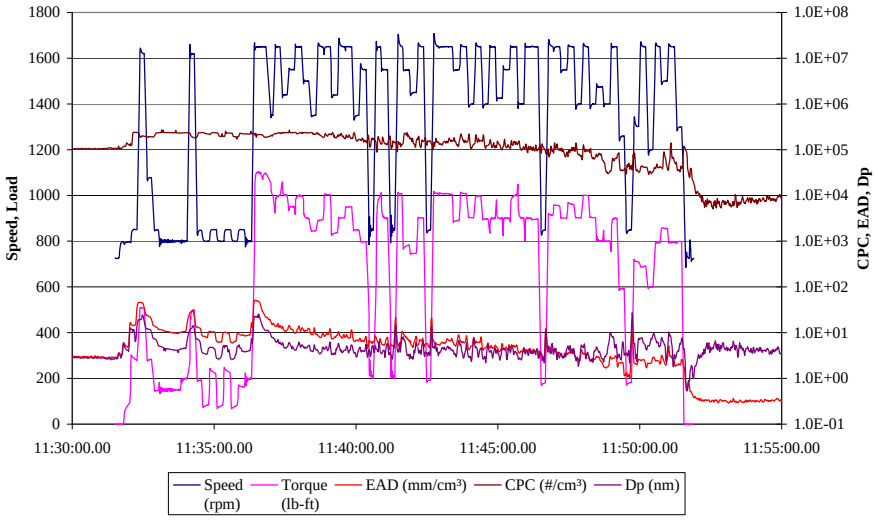
Example Real-Time Particulate Data



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Status

- *Final Version of the system, including an improved NO_2 Decomposition Catalyst, In-house.*
- *Complete 8-mode and transient data set to be collected.*
- *Look towards getting the device field tested.*

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Conclusions

- *System performance has been primarily a function of HC mixing prior to the catalyst.*
- *Injection air pressure appeared to have no effect on system performance.*
- *Performance at exhaust temperature below 300 C may be an issue.*
- *Control system may need repackaging for in-mine use.*
- *Results look very promising.*

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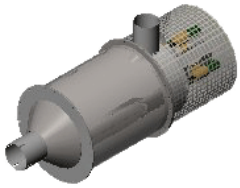
Other Current Testing

- *RYPOS DPF*
- *Viscon Fuel Additive*

Rypos DPF Testing



Rypos DPF Testing

- *Rypos has supplied a passive DPF for system "characterization".*
- *"Characterization" is in process.*
- *Active system to be designed based on passive system performance.*
- *Active system to be tested in the same manner as the JM Low NO_2 CRT®.*
- *Active system to be designed to operate on mobile applications.*

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Viscon Fuel Additive

- *New Deutz 2011 Engine*
- *Additive claims PM reduction*

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- *Questions?*
- *Comments?*

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