THE JM LOW-NO_2 CRT® SYSTEM

12 OCTOBER 2006

Johnson Matthey Catalysts

Progress in the Development of a low-NO_2 CRT® System Suitable for Underground Mining

Presentation to the MDEC Conference 2006

Alex Beavan, Claus Görsmann, Richard O'Sullivan, Joe Stevenson & Peter Werth

THE ADVANTAGES OF THE CRT® SYSTEM

The CRT® system reduces PM emissions by >90% and

- requires no extra energy from electrical heaters or fuel burners,
- requires no alterations to or integration with the engine,
- requires no fuel additives,
- regenerates itself continuously giving a low, constant exhaust back pressure.

Regenerates at lower exhaust gas temperatures than any other passive system.

c. 120,000 systems supplied for retrofit applications around the world.

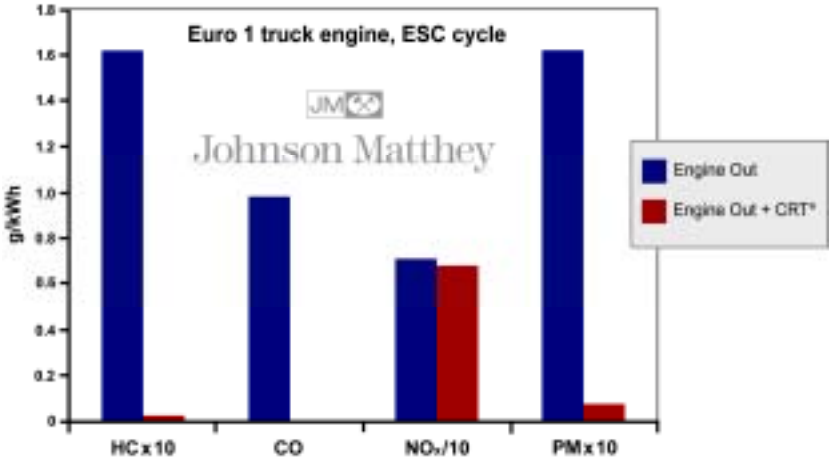
THE CRT® SYSTEM
OPERATING REQUIREMENTS

EPA certifications:

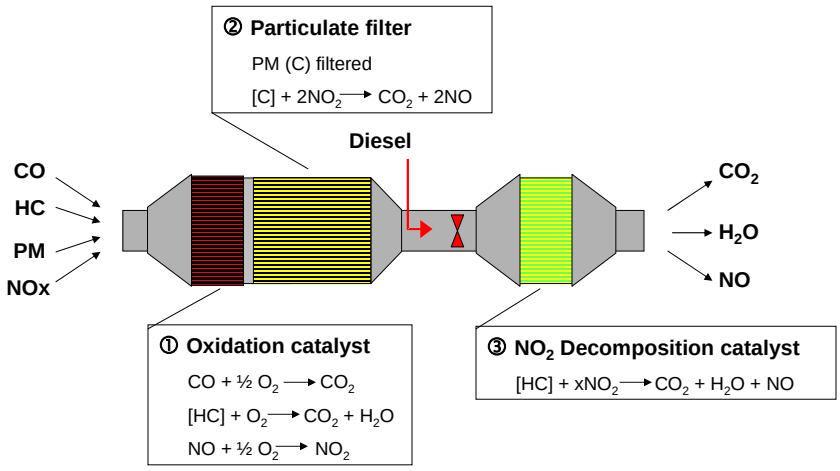
- for CRT® system, T >240°C for 40% operating time
- for CCRT® system, T >200°C for 40% operating time

- This certification based on <30ppm S fuel and sufficient (preferably >20) NOx:PM ratio

THE CRT® SYSTEM
PERFORMANCE



THE LOW-NO_2 CRT® SYSTEM



DEVELOPING THE SYSTEM

System supplied to UMN for NIOSH test programme in April 2005

- Calibration based on ISO8178 C1 emissions data using engine speed and exhaust temperature

Continued development and testing of decomposition catalyst

- Effect of formulation and volume on NO_2 decomposition, hydrocarbon slip, etc..

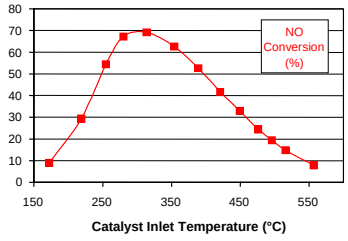
Continued development and testing of control systems on bench engines and on machines above ground

- Improved HC distribution in system
- More sophisticated system calibration – optimisation of HC injection strategy
- Introduction of real time feedback control

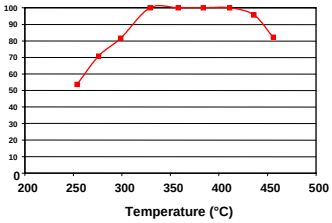
Mine testing

"TEMPERATURE GAP"

POTENTIAL PROBLEM IDENTIFIED AROUND 300°C



NO to NO_2 over CRT® catalyst



NO_2 to NO over decomp catalyst

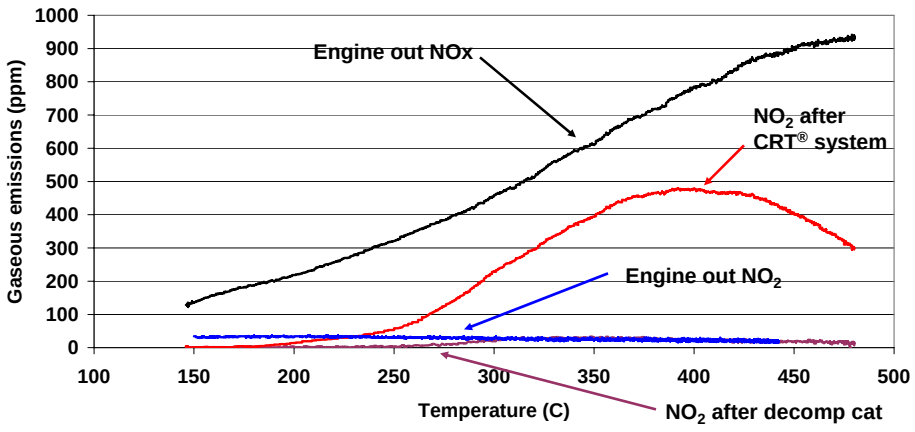
Answers:

- Matching catalyst temperature windows
- More aggressive HC injection strategy: more HC at lower temperatures
- More sophisticated control systems give better response in transient operation
- Retaining heat in decomposition catalyst

BENCH ENGINE TESTING

VOLVO 10 LITRE EURO 2 ENGINE

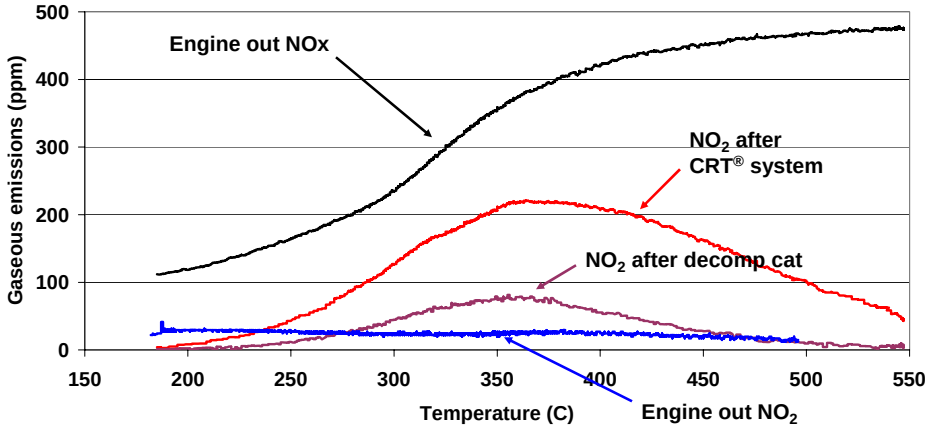
Torque ramp at 1200rpm



BENCH ENGINE TESTING

VOLVO 10 LITRE EURO 2 ENGINE

Torque ramp at 1800rpm



SYSTEM TRIALS UNDERGROUND

KALI UND SALZ, GERMANY

GHH LF-12 LHD

Deutz 19L V12 F12L413FW normally aspirated air-cooled engine, 204kW

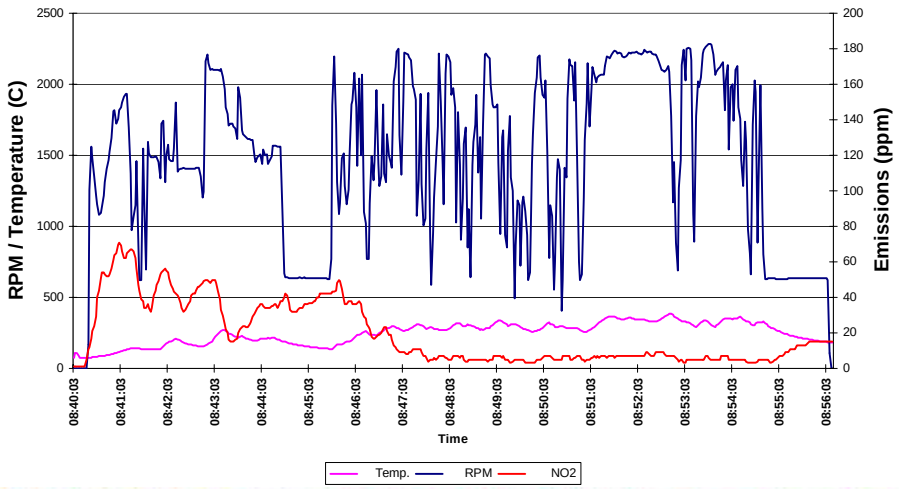
SYSTEM TRIALS UNDERGROUND

INSTALLED SYSTEM

Two systems installed, one for each bank of cylinders

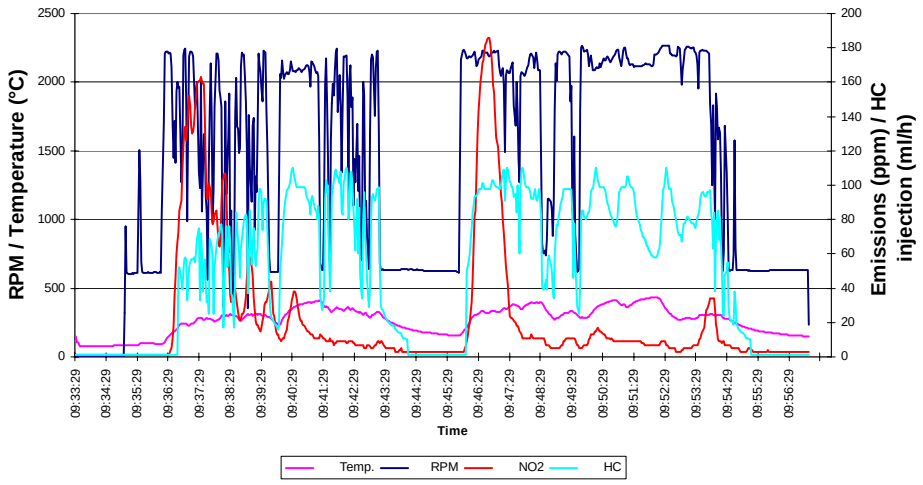
SYSTEM TRIALS UNDERGROUND

MACHINE IN OPERATION WITHOUT SYSTEM



SYSTEM TRIALS UNDERGROUND

MACHINE IN OPERATION WITH SYSTEM



THE NEXT STEPS

- Demonstrate durable performance in a mine environment:
  - PM conversion
  - Regeneration performance
  - Low NO_2 emissions
- Further development of control and monitoring systems and calibration