Johnson Matthey
Catalysts

Low NO_2 CRT® Particulate Filter Systems for Diesel Engine Exhaust in Mining Applications

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ENVIRONMENTAL CATALYSTS AND TECHNOLOGIES

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- The SCRT® system: complete 4-way emissions control for diesel exhaust
- A new low NO_2 CRT® system
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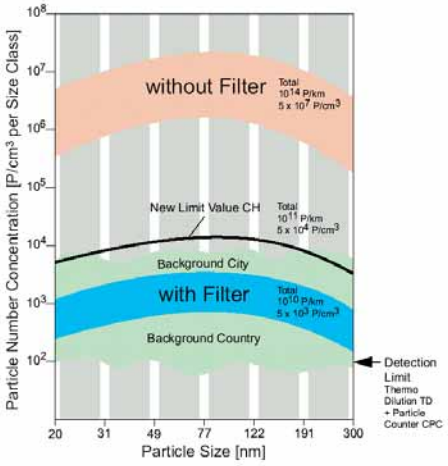
DPF Impact on Particles



Source: A Mayer, TTM

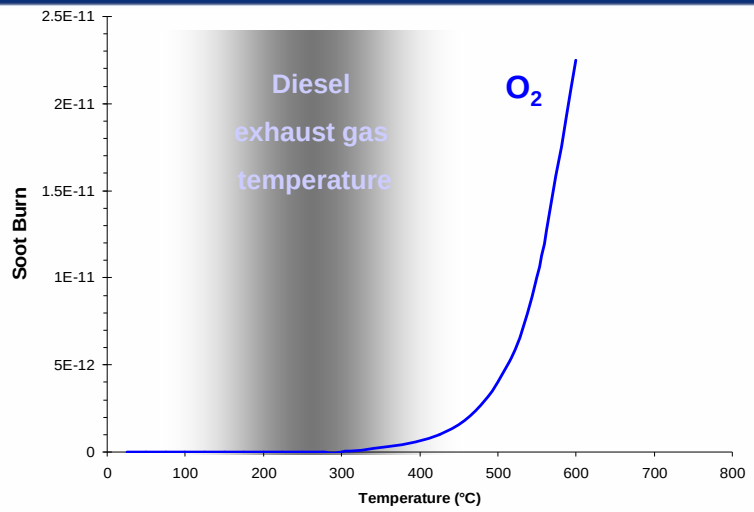
The CRT® System

- The continuously regenerating trap (CRT®) is a Johnson Matthey patented invention.
- 100,000 CRT® systems have been retrofitted to trucks and buses around the world and it is the class leading system.

ROYAL ACADEMY OF ENGINEERING
MacRobert Award 2000

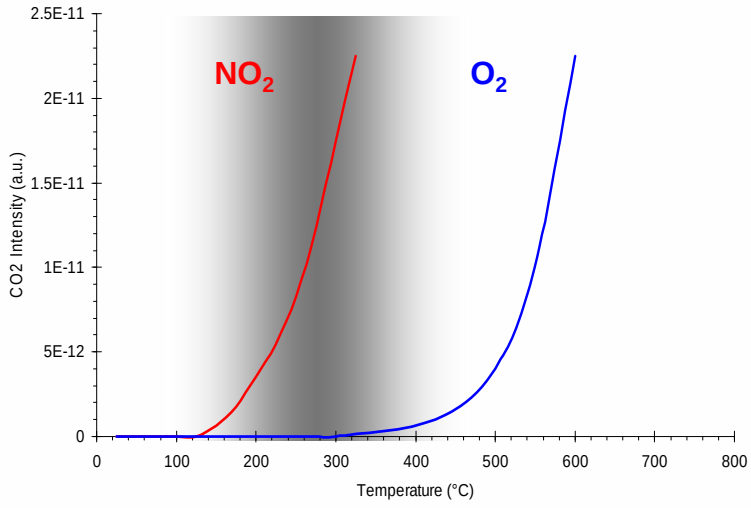
- However, concerns about increased levels of NO_2 have prevented widespread use of the CRT® underground.

The Regeneration Challenge



Soot burns in air at c. 600ºC but Diesel exhaust is cooler

Using NO_2, soot can be burned at typical exhaust gas temperatures

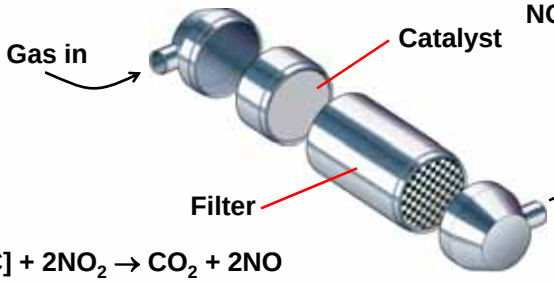


The CRT® principle

$CO + ½O_2 \rightarrow CO_2$

$[HC] + O_2 \rightarrow CO_2 + H_2O$

$NO + ½O_2 \rightarrow NO_2$

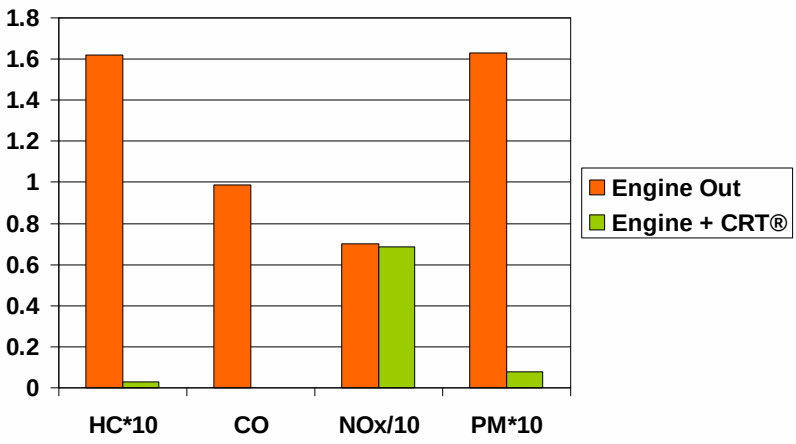


$[C] + 2NO_2 \rightarrow CO_2 + 2NO$

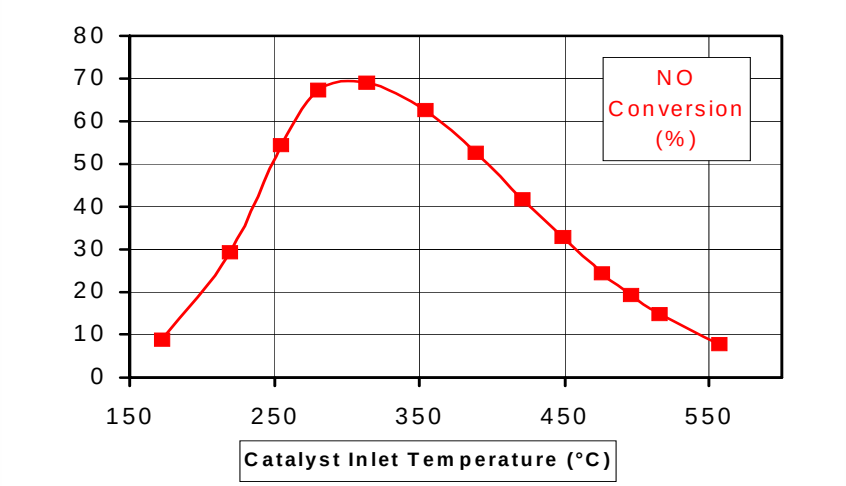
CRT® System is NO_2 dependent, therefore NO_2 slip is to be expected

CRT® system performance

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



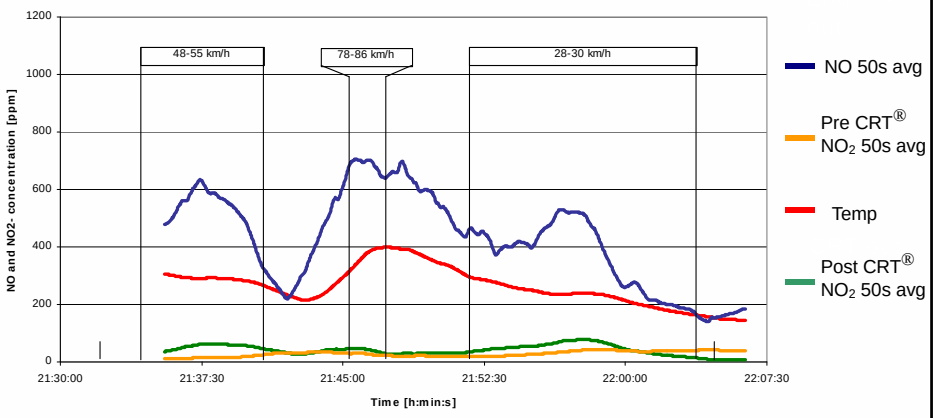
NO oxidation activity



Factors Influencing NO_2 Emissions

- **Catalyst age**
  - fresh catalysts may produce artificially high levels of NO_2 until properly degreened, after which they behave as designed
    - catalyst development important
- **Engine-out PM emissions**
  - higher PM emissions will consume more NO_2 in the regeneration process
- **Catalyst formulation**
  - Catalyst systems can be formulated to convert less NO to NO_2 for regeneration purposes
    - but we need to ensure reliable regeneration
- **Catalyst and/or filter size**
  - control technologies can be optimally sized to consume the maximum quantity of NO_2 produced during regeneration

"real-world" bus cycle: CRT®-out NO_2 at circa 15% NOx



The SCRT® system

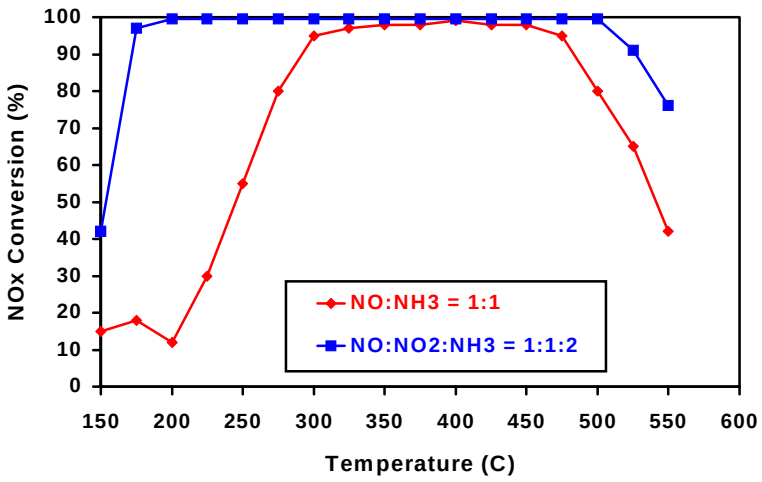
SCR = Selective Catalytic Reduction

CRT® + SCR = SCRT®

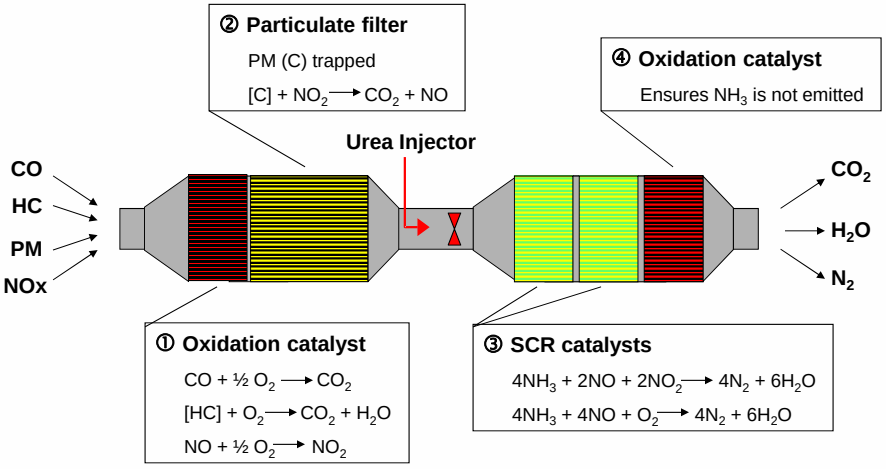
Ammonia-based SCR

- Uses ammonia as a reductant to remove NOx
- Source of ammonia is usually an aqueous solution of urea but other systems are possible.
- Urea to ammonia :
  - $NH_2C(O)NH_2 \rightarrow HNCO + NH_3$ (thermolysis at 120°C)
  - $HNCO + H_2O \rightarrow CO_2 + NH_3$ (hydrolysis at 160°C)
- SCR reactions with ammonia:
  - $4NH_3 + 4NO + O_2 \rightarrow 4N_2 + 6H_2O$ **FAST**
  - $2NH_3 + NO + NO_2 \rightarrow 2N_2 + 3H_2O$ **VERY FAST**
  - $8NH_3 + 6NO_2 \rightarrow 7N_2 + 12H_2O$ **SLOW**

NO_2 Promotes SCR

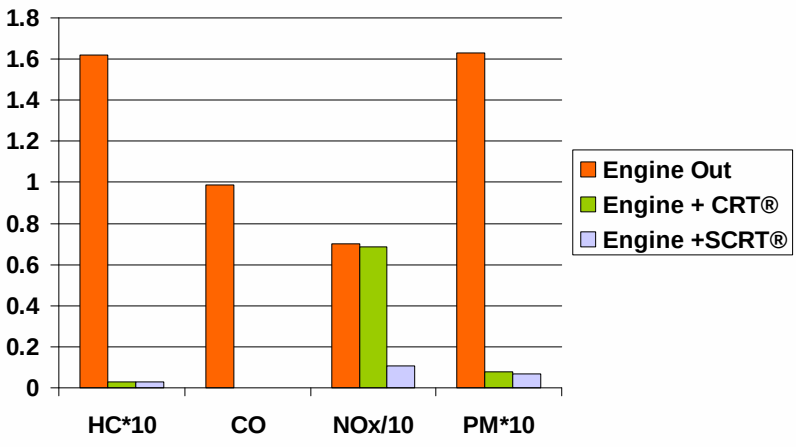


The SCRT® system



SCRT® system performance

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



SCRT® system NO_2 emissions

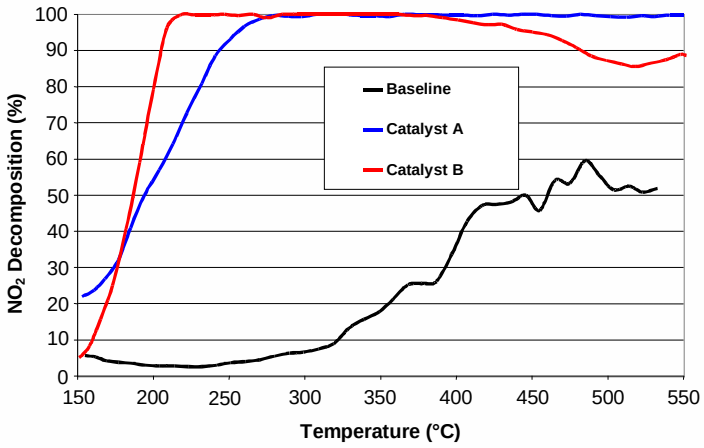
ESC Mode	Speed	Load	Temp. °C	Engine NO_2 (ppm)	Tailpipe NO_2 (ppm)
1	Low idle	0	140	22	3
2	low	100	397	20	8
3	int.	50	325	27	3
4	int.	75	362	30	2
5	low	50	339	21	10
6	low	75	382	34	11
7	low	25	276	22	7
8	int.	100	414	18	0
9	int.	25	287	22	3
10	high	100	478	16	0
11	high	25	295	19	0
12	high	75	363	20	0
13	high	50	323	20	0

SCRT® system installed in test cell

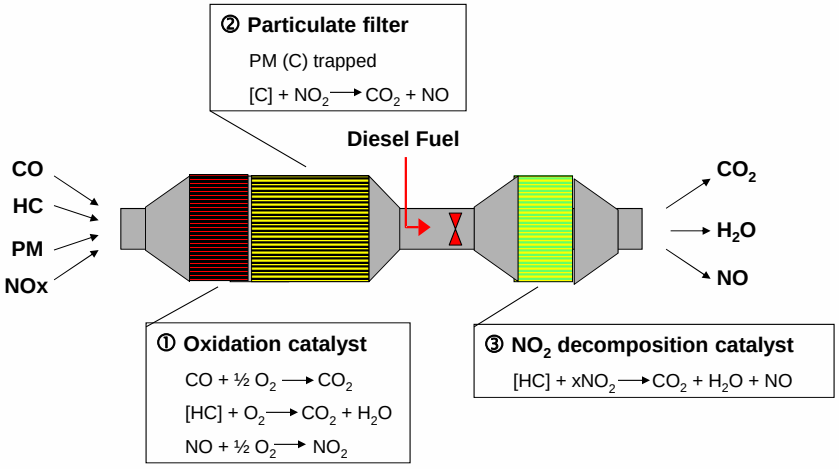
Low NO_2 CRT® System

Experiments using a synthetic gas reactor

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

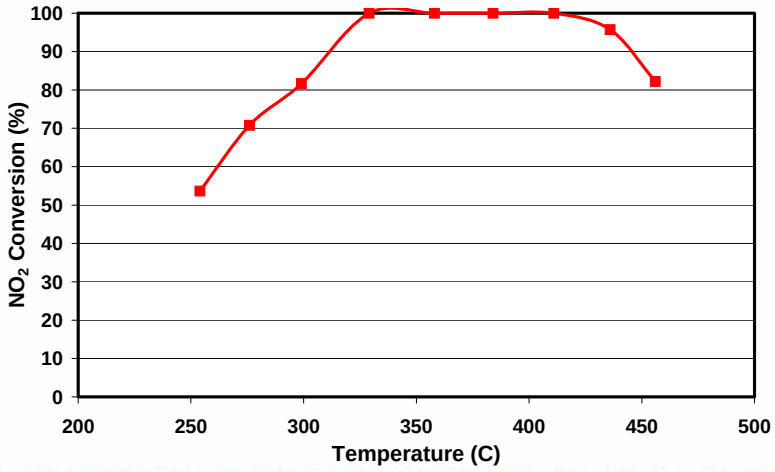


The low NO_2 CRT® system

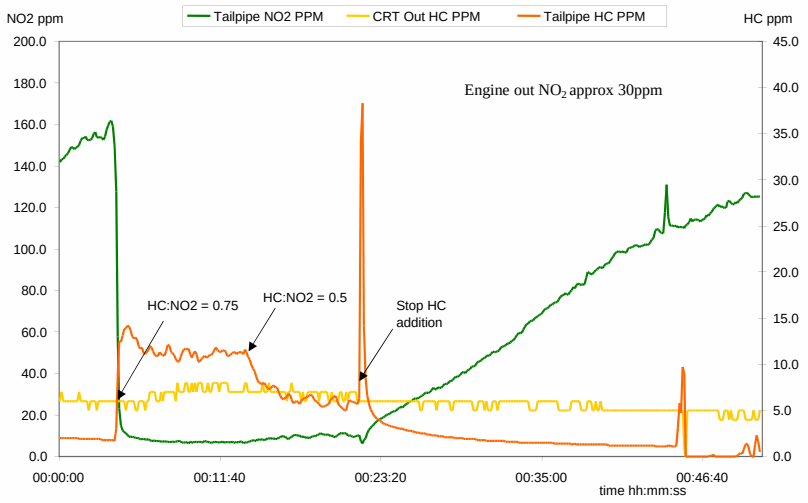


Experiments using diesel engine exhaust

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



Emissions from low NO_2 CRT® System with and after HC injection



Features of the new Low NO_2 CRT® System

- Engine out particulate is removed using a ceramic filter.
- This is regenerated using the CRT® principle.
- Excess NO_2 from the CRT® system is reduced to engine out levels or lower over a proprietory catalyst.
- Tailpipe hydrocarbon is usually reduced compared to engine out levels.
- The system is relatively simple to install and control.

Summary

Reductions in diesel emissions typically achievable from the two systems described.

	Low NO_2 CRT® system	SCRT® system
HC	-	95%
CO	96%	98%
Total NOx	4%	85%
NO_2	30%	80%
PM	95%	95%

Conclusion

It is possible to use the class leading CRT® particulate filter in underground applications by reducing any excess NO_2 with downstream SCR or by using a new NO_2 decomposition system.