

RETROFIT EMISSION CONTROL TECHNOLOGIES FOR HEAVY DUTY DIESEL ENGINES - THE STATE OF THE ART

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Johnson Matthey Catalysts
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ENVIRONMENTAL CATALYSTS AND TECHNOLOGIES

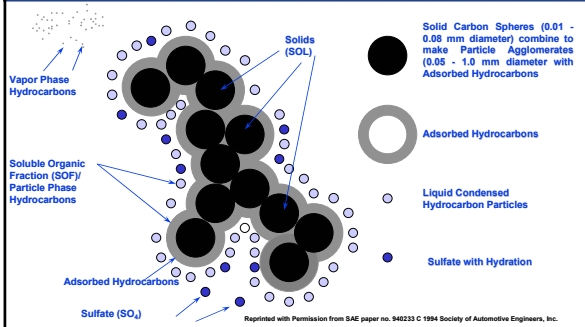
Outline

- Diesel Engine Emissions
- PM Control Technologies
- NOx Control Technologies
- Conclusions

Diesel Engine Emission Control

- Diesel engine emissions:
 - PM (Particle Matter)
 - NOx (Nitrogen Oxides)
 - CO (Carbon Monoxide)
 - HC (Hydrocarbons)
- New engine emissions are being significantly reduced with increasingly tighter emission standards
- However, some of the existing, high-emitting diesel engines will be in use for the next 10 to 25 years
- Using emission control technologies to produce extremely clean new engines as well as to retrofit existing engines is the way to reduce emissions

Schematic of Diesel Particles and Vapor Phase Compounds



Outline



- Diesel Engine Emissions
- PM Control Technologies
 - DOC technology
 - DPF technology
 - Fuel Sulfur Effect
 - Advanced DPF technology
 - Active Regeneration Filter Technology
 - Partial Filter technology
- NOx Control Technologies

Diesel Oxidation Catalyst



Diesel Oxidation Catalysts (DOC)



- Oxidizes CO and HC to CO₂ and H₂O (desired)
- Oxidizes toxics such as aldehydes
- Oxidizes SO₂ to SO₃ (undesired)
- Oxidizes Soluble organic fraction (SOF, HCs) adsorbed on Particulates to reduce PM
- CO, HC reduction up to 90%.
- PM reduction up to 50% depending on SOF content of PM; Typically 25% on new engines

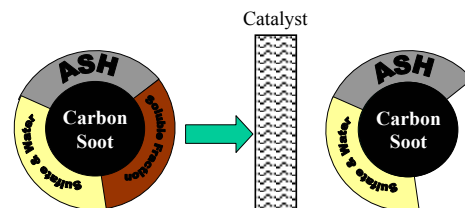


Ceramic Catalyst



DOC in a muffler

Particulate Matter Oxidation



Note: Soluble Fraction, Sulfates and Water are in Vapor form.

DOC - Applications



- Can work with high sulfur fuel (up to 500 ppm)
- Benefits from low S fuel (low sulfate make)
- Can activate at lower temperature for CO & HC reductions
- Proven low-cost technology
- Combined catalyst and muffler to provide sound attenuation and emission benefit
- Easy to retrofit on existing vehicles
 - 2 stroke & 4 stroke
- No required maintenance
- Variety of sizes and shapes for different applications

DOC Performance

500 PPM S Fuel

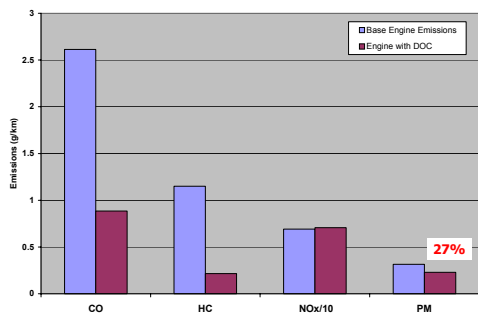


	PM (g/bhp-hr)	Reduction	CO (g/bhp-hr)	Reduction	HC (g/bhp-hr)	Reduction
2-Stroke						
Baseline	0.44		1.0		0.7	
W/ CEM	0.22	50%	0.6	40%	0.4	43%
4-Stroke						
Baseline	0.073		1.11		0.115	
W/ CEM	0.055	25%	0.35	68%	0.014	88%

Tested at Southwest Research Institute
under
EPA approved FTP transient test cycle

DOC Performance on BEST EURO II Bus

500 ppm S Fuel



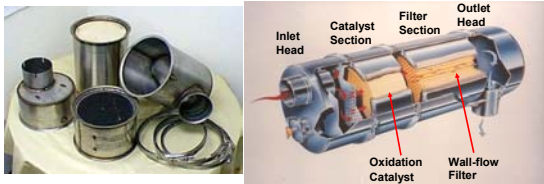
Diesel Particulate Filter



Diesel Particulate Filter



- Johnson Matthey Continuously Regenerating Technology (CRT®) Diesel Particulate Filter

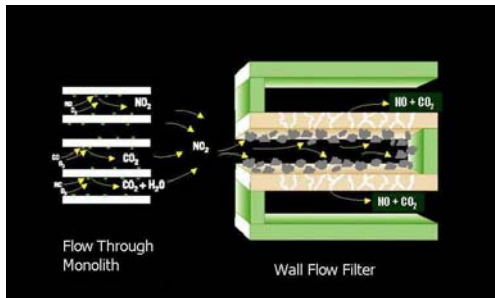


CRT® Particulate Filter for >90% PM Removal



- Patented CO/HC/PM Emission Control System combining Oxidation Catalyst & Filter
- Engineered as a totally passive emission control system which requires no supplemental heat
- Uses NO_2 produced by a specially formulated catalyst to burn soot collected by the filter at typical operating temperatures of diesel engine exhaust
- Requires the use of Ultra Low Sulfur fuel (< 50 ppm S) for maximum emission reduction and filter regeneration

CRT® Particulate Filter – Operating Principle



Examples of CRT Installations in the US

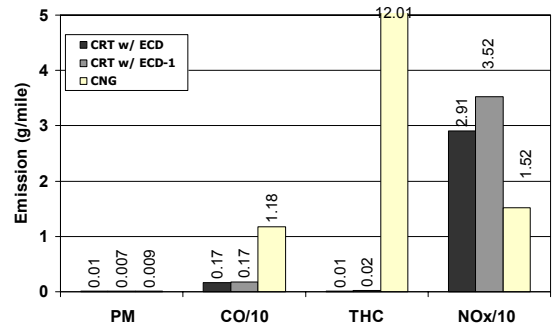


Mumbai Transit (BEST) Hino Engine Euro II Bus with CRT

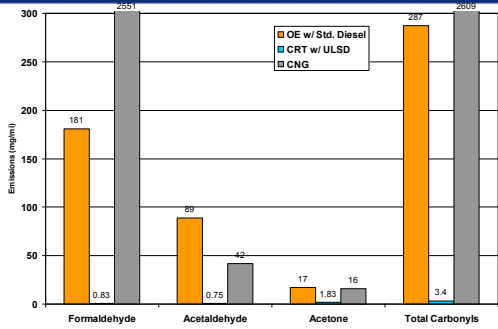


Avg. Emissions Test Results- CRT vs. CNG

LA MTA Data – Ser 50 Engines - CBD Cycle



Carbonyl Destruction with CRT on Ser 50 under NY Bus Cycle



Fuel Sulfur Effect on Diesel Particulate Filter

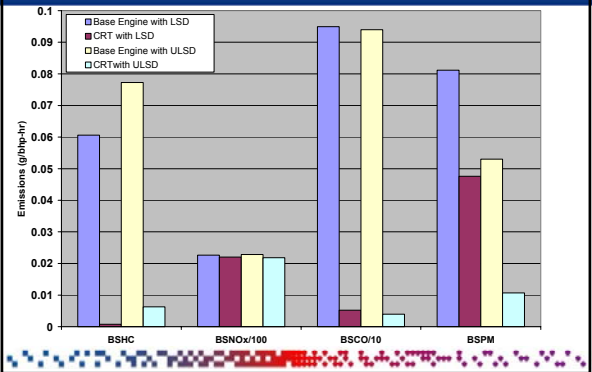
Impact of Fuel Sulfur



- **Impact of Fuel Sulfur on CRT Regeneration**
 - Catalyst can be poisoned by high sulfur in fuel
 - Lower NO₂ generation; Problem in filter regeneration
- **Impact of Fuel Sulfur on CRT Particulate Emissions**
 - High SO₂ oxidation, so sulfate can increase measured PM
 - Low PM reduction (40 – 50%) due to high sulfate make

Impact of Fuel S on Emissions

350 ppm vs. 15 ppm fuel with CRT under FTP



CCRT™ - Advanced Passive Filter System

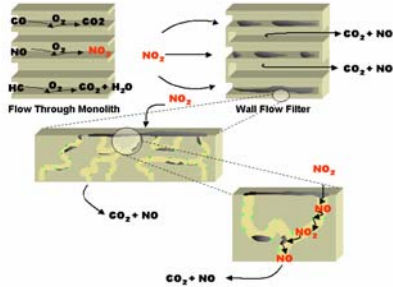


CCRT™ – An Advanced CRT for Challenging Applications



- CCRT = DOC + Catalyzed Filter
- Advantages of CCRT:
 - Higher soot burn rate than CRT or CSF
- Install in Challenging Applications
 - Low temperature applications (200 – 250°C)
 - Low NO_x/PM applications (NO_x/PM > 15)
- Even at low CSF loadings, we see improved performance with the CCRT
- Successfully demonstrated in field trials in the US, Europe and Asia

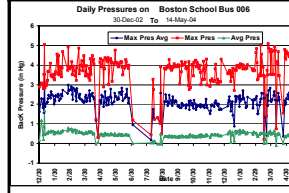
Use of NOx Within CCRT System



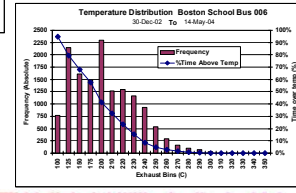
CCRT Experience on low temperature School Bus



Boston School Bus with 175 hp 2000 MY CAT 3126 Engine



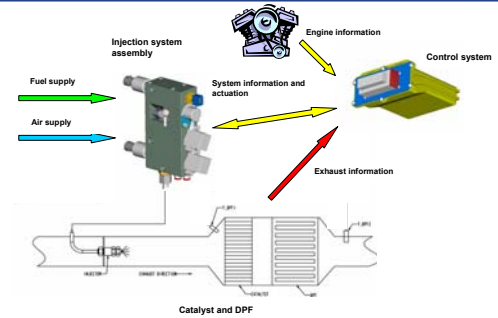
- Cold Exhaust Temperature Profile
- Only 8% of time Temp > 260 C;
- 40% time @ 200 C
- CCRT operating with stable back pressure for over 17 months



Active Regeneration: Low NOx/PM applications

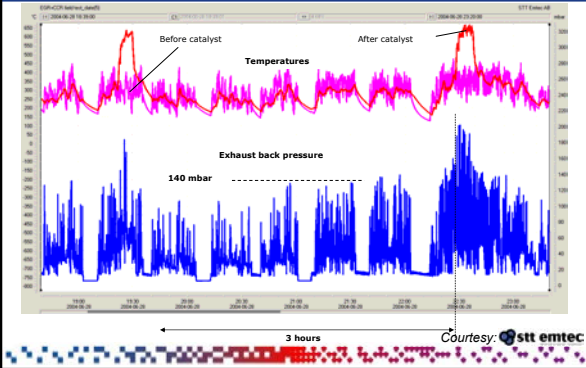


Active Regeneration with Fuel Injection



Courtesy: stt emtec

Active Regeneration of CRT with Fuel Injection System



Partial Filter Systems



Partial Filter Product Development



- Partial filtration = moderate (>50%) PM reduction, but minimize filter plugging
 - Some PM is trapped, rest goes through
- Use variety of substrates:
 - Flow through with notches
 - Wire mesh
 - Ceramic foam
- Can use in CRT or CCRT configuration for effective soot burn
- Ideally suited for old, dirty engine retrofit
 - America, Asia
- Work with ULSD proven; Tests in progress with LSD fuel

Partial Filter Product Development



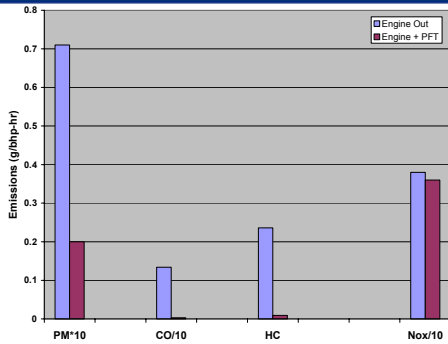
Step to filtration activity:

porous layer made of sintered metal fiber fleece

Trash Truck in CA with Partial Filter

Clean outlet head on partial filter after operation

Emissions Results for Partial Filter System Caterpillar 3126 MY 1998, under US FTP Transient cycle



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- NOx Control Technologies
 - EGRT
 - SCRT
- Conclusions

EGRT Development & Applications

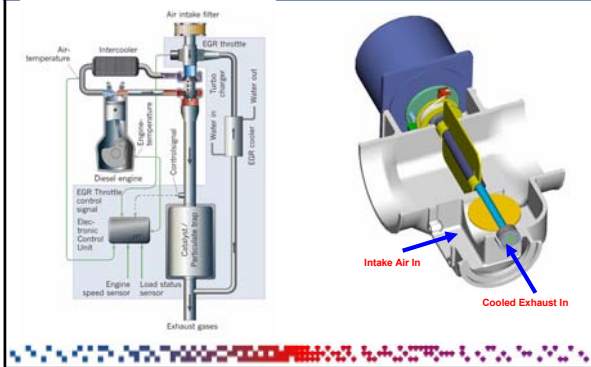


EGRT™ System

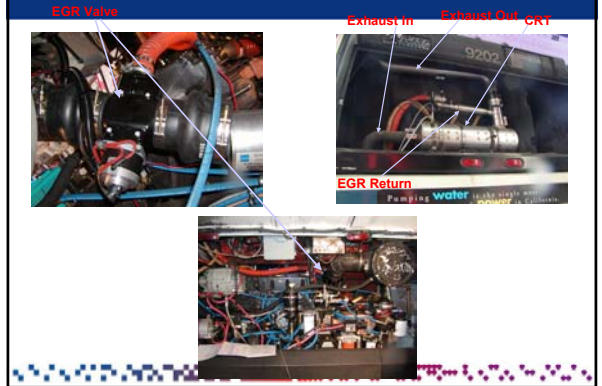


- EGRT™ = EGR + CRT®
- CRT = Continuously Regenerating Technology Diesel Particulate Filter
- EGR = Re-circulation of part of the exhaust gas to engine intake air
- Uses STT patented EGR technology in combination with the CRT particulate filter
- ULSD (< 50 ppm) fuel is required

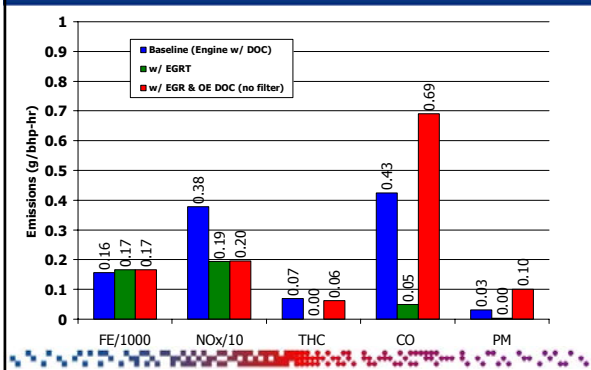
EGRT System and Throttle Valve



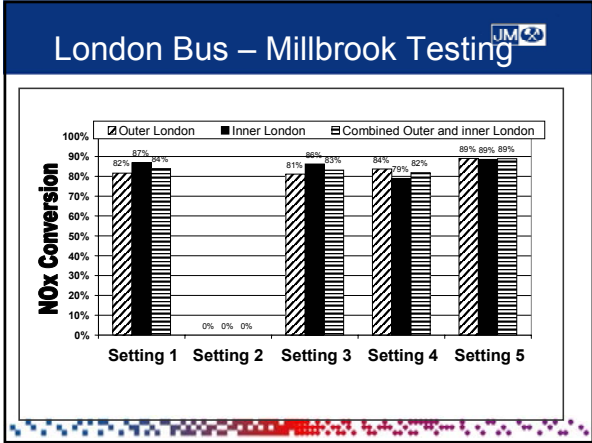
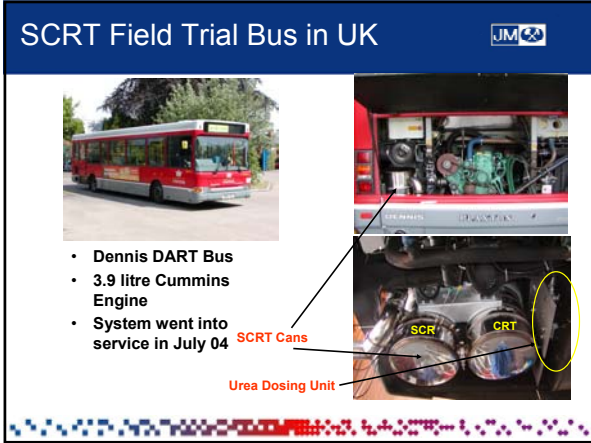
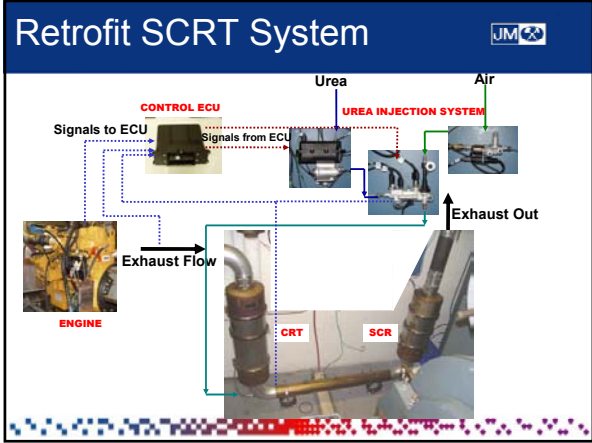
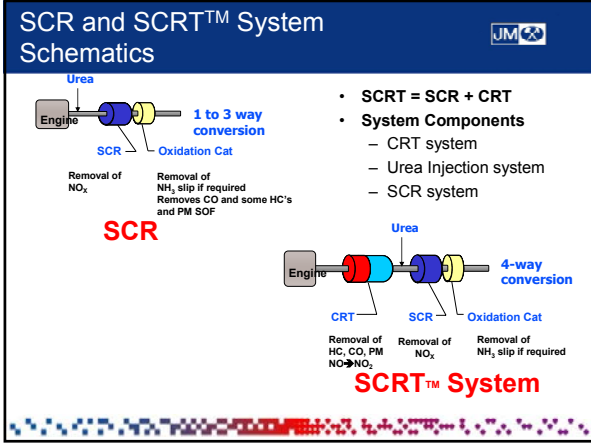
EGRT Retrofit on VTA Transit Bus



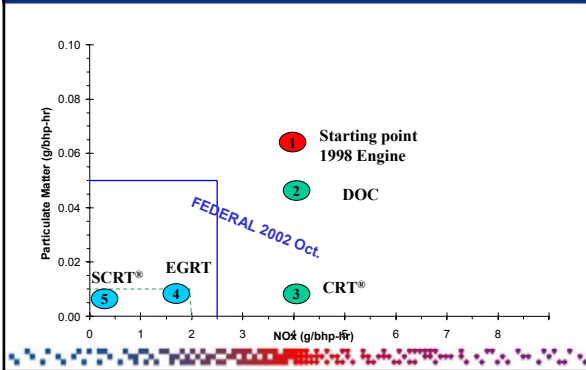
Emissions Results for EGRT System Cummins ISL 330 Engine, FTP Cycle on Engine Dyno



Selective Catalytic Reduction (SCR)



Effect of Emission Control Retrofit on Current Engines



Conclusions



- A multiplicity of catalytic emission control technologies now exists to aid the emissions engineer in achieving virtually zero emission levels from diesel engines
- Johnson Matthey provides a variety of PM and NOx control technologies for retrofit and OE applications
 - PM Control: DOC, CRT, CCRT, PF
 - NOx Control: EGR, SCR and LNT
- DOC is a cost effective solution for use with 500 ppm S fuel
- Improved fuel quality especially ultra low sulfur fuel (< 50 ppm) enables the most advanced control strategies (CRT)
- Some engineering challenges remain for advanced system development, and overcoming infrastructure issues

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