New York City Transit
Department of Buses

NYCT EXPERIENCE WITH CLEAN DIESEL TECHNOLOGIES

Diesel Day 2 at the World Bank
January 17, 2003

NYCT Bus Fleet

	2001	2006
40' 2-stroke Diesel Transit	1,349	0
40' 4-stroke Diesel Transit	2,085	2,370
45' 4-stroke Diesel Coach	450	450
60' 4-stroke Diesel Articulated	370	630
40' CNG Transit	221	646
40' Hybrid Transit	11	390
Total	**4,486**	**4,486**

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NYCT "Clean Fuel" Bus Commitment

- Program is technology neutral, and combines several different approaches
  - → CNG Buses
  - → Hybrid Buses
  - → Clean Diesel Technologies
- Designed to give cost-effective emissions reductions as quickly as possible
- MTA 2000 - 2004 Capital Plan includes $304 million for Clean Fuel Programs

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Clean Diesel Technologies

- Retire all 2-stroke engines NLT 12/03
  - → Will require "re-powering" up to 800 buses with 4-stroke EGR engines; 581 completed to date
- Convert entire fleet to reduced sulfur fuel
  - → completed September 2000
  - → Similar to #1 Diesel; sulfur level of 30 ppm; lubricity enhancement
- Install particulate filters on all diesel buses
  - → Oxidation catalyst and wall-flow ceramic filter; packaged to replicate OEM muffler dimensions
  - → 1,550 installed to date (300 OE on new buses)

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Diesel "Technology Ladder"

EPA Certified Emission levels (gm/bhp-hr)

		HC	CO	NOx	PM
Old Tech	Pre-1993 2-Stroke (6V92)	0.66	3.10	10.20	0.31
	1993 2-Stroke (6V92)	0.23	0.81	4.30	0.17
Current US	1998 4-Stroke (Series 50)	0.10	0.90	3.80	0.04
	2000 4-Stroke (Series 50) w/ EGR	0.02	0.16	3.47	0.03
Future	1998 4-Stroke (Series 50) + Catalyzed Filter	*0.01**	*0.09**	3.80	*0.004**
	2002 4-Stroke (Series 50) w/ EGR + Catalyzed Filter	*0.002**	*0.016**	2.40**	*0.003**

* Assumed levels based on chassis testing. Numbers represent a 90% reduction

** Certified level in accordance with new EPA standards in effect October 2002

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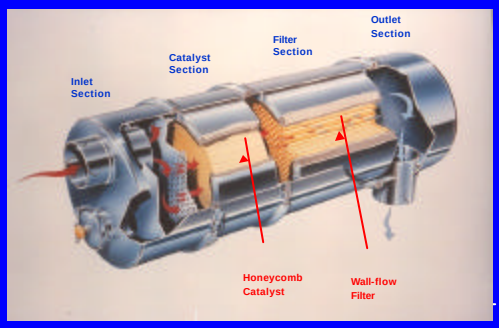
Johnson Matthey CRT ™



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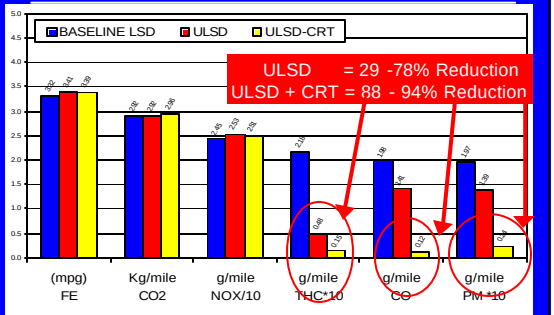
REGULATED EMISSIONS
Series 50 Bus on CBD Cycle



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CRT FILTER AFTER 9 MONTHS

CRT Inlet Section

CRT Outlet Section

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Clean Diesel Costs

- Advanced After-Treatment
  - ➔ Ultra Low Sulfur Diesel Fuel: $0.12/gallon incremental cost ($0.04/mile)
  - ➔ Catalyzed Filter Installation: $5,000 - $7,000/bus with back-pressure monitoring
  - ➔ Annual Maintenance: $300 - $600 /year / bus to remove filter, clean, and replace (2 - 4 hour job)
- Complete Repower
  - ➔ Replace engine & Transmission & associated equipment: $84,000 (new bus cost ~$300,000)
  - ➔ Annual maintenance: similar to existing

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Challenges with Particulate Filters

- Every bus model is different - requires multiple prototyping of filter installation
- Filter introduces increased back-pressure - integrity of exhaust system is more important (increased leaks)
- Filter masks underlying engine problems - increased “smoke” not seen and can plug filter; turbo and other engine failures can damage filter
- Exhaust temperature is very important - some duty cycles and some installations may not be viable
- New replacement filters are expensive - $2,500 to $5,000

Challenges with EGR Engines

- EGR technologies are immature - first generation has had serious problems with durability of EGR control valve and turbo-chargers
  - → component re-design has improved reliability, but EGR engines still require more maintenance
- EGR engine includes additional equipment that is hard to fit into tight bus engine compartment
- EGR engine introduces additional heat load to already marginal engine cooling system

EGR + Particulate Filters

- Reduced NOx from EGR engines affects catalysis in the particulate filter - there is less margin in any particular duty cycle for effective regeneration
- Engine programming presents challenge to balance smoke control and power/acceleration
- Initial EGR system failures caused a high incidence of catastrophic particulate filter failures
- The incidence of plugged filters remain much higher on new EGR engines than on pre-EGR engines

Engine Diagnosis and Troubleshooting

- Filters mask underlying engine problems - increased "smoke" not seen and can plug filter; turbo and other engine failures can damage filter
- Plugged filters must be removed (1 to 4 hours) to diagnose engine problems, adding cost and increasing downtime
- Failure to diagnose correctly results in repeat problems - more cost and downtime
- Engine troubleshooting procedures need to be revised to test EGR systems more thoroughly
- Engine preventive maintenance and diagnostics needs to be able to detect less obvious engine problems that cause smoking and clog filters

Conclusions

- Stepping down the "technology ladder" by application of "clean diesel" technologies can significantly reduce in-use diesel emissions
- Some "clean diesel" technologies are quite mature and present little challenge (4-stroke engine, catalyst mufflers, reduced sulfur fuel)
- More aggressive technologies provide much higher benefits but are less mature, more costly, and more complex (catalyzed filters, EGR, hybrid)
- There is no "free lunch" - all emissions reduction technologies increase engine/system complexity, resulting in increased maintenance costs. The trick is to balance costs/benefits with available resources

Further Information

- Speaker Contact:

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- Clean Diesel Emissions Report:

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