



Beijing Pilot Retrofit



Real World Particulate Matter Reduction From Three Retrofit Technologies



Drs. Magdi Khair & Imad Khalek – Southwest Research Institute



Outline



- Introduction
- Buses & Engines
- Retrofit Equipment
- Instrumentation
- Results
- Conclusion





Introduction



PURPOSE

- Promote Clean Air
- Serve as Model for Other Cities
- Demonstrate Retrofit Capabilities
- Demonstrate Importance of ULSD



SCOPE

- 25 Buses
- City of Beijing
- Mix of EURO I & II
- Three Retrofit Technologies
- Two Sulfur Levels

Nov. '05



Dec. '07



Buses & Engines



19 EURO II – Yuchai Engine



6 EURO I – Yuchai Engine

Parameter	Specifications
Type	IL, 4-Str., DI, Wtr.-Cooled
Cylinders	4
Displacement	5.2 L
Compression Ratio	16.8:1
Aspiration	Turbocharged/Intercooled
Rated Output/Speed	132 kW/2300 rpm
Max. Torque/Speed	700 N.m/1550 rpm
Static Timing	14 – 18 BTDC
Exhaust Smoke (FSN)	3.0
Emissions Standards	EURO II – ECE 13

Parameter	Specifications
Type	IL, 4-Str., DI, Wtr.-Cooled
Cylinders	6
Displacement	6.13 L
Compression Ratio	17.5:1
Aspiration	Turbocharged
Rated Output/Speed	107 kW/2800 rpm
Max. Torque/Speed	500 N.m/1500 rpm
Static Timing	9 – 12 BTDC
Exhaust Smoke (FSN)	≤ 3.0
Emissions Standards	EURO I – ECE 13



Condition of Buses



EURO I



EURO II

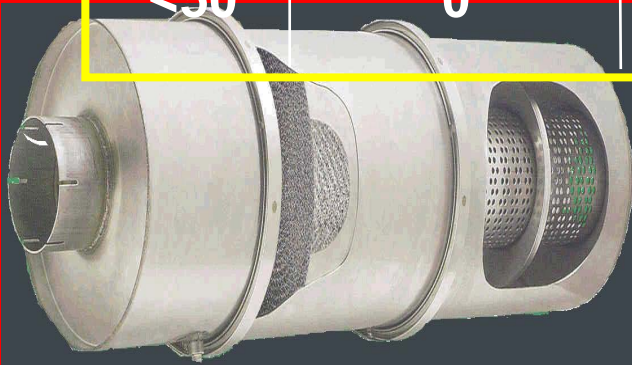
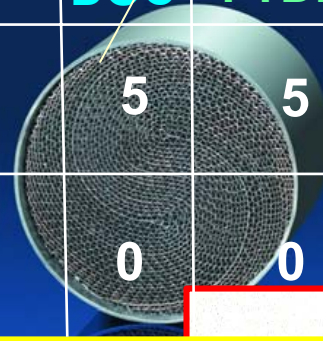
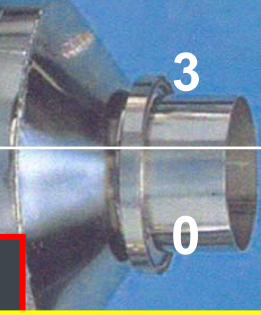
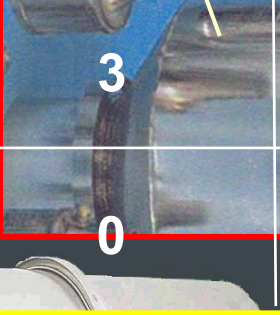


Retrofit Equipment

Catalyzed Continuously Regenerated Foil-Type DPF

DOC

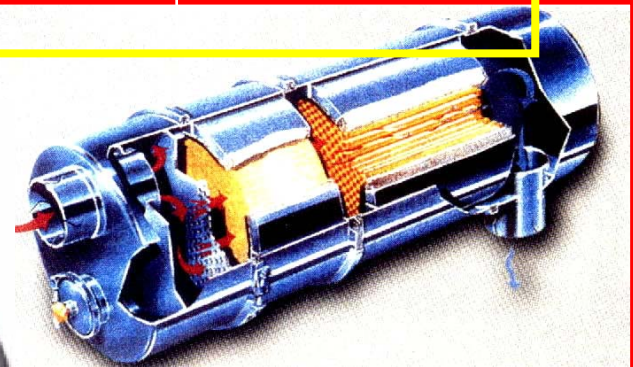
Fuel Sulfur Level, ppm	Engine Technology				
	EURO I		EURO II		
	DOC	FTDPF	DOC	FTDPF	WFDPF
350	3	3	5	5	0
<50	0	0	0	0	9



Compact Wire-Mesh/CRT Concept



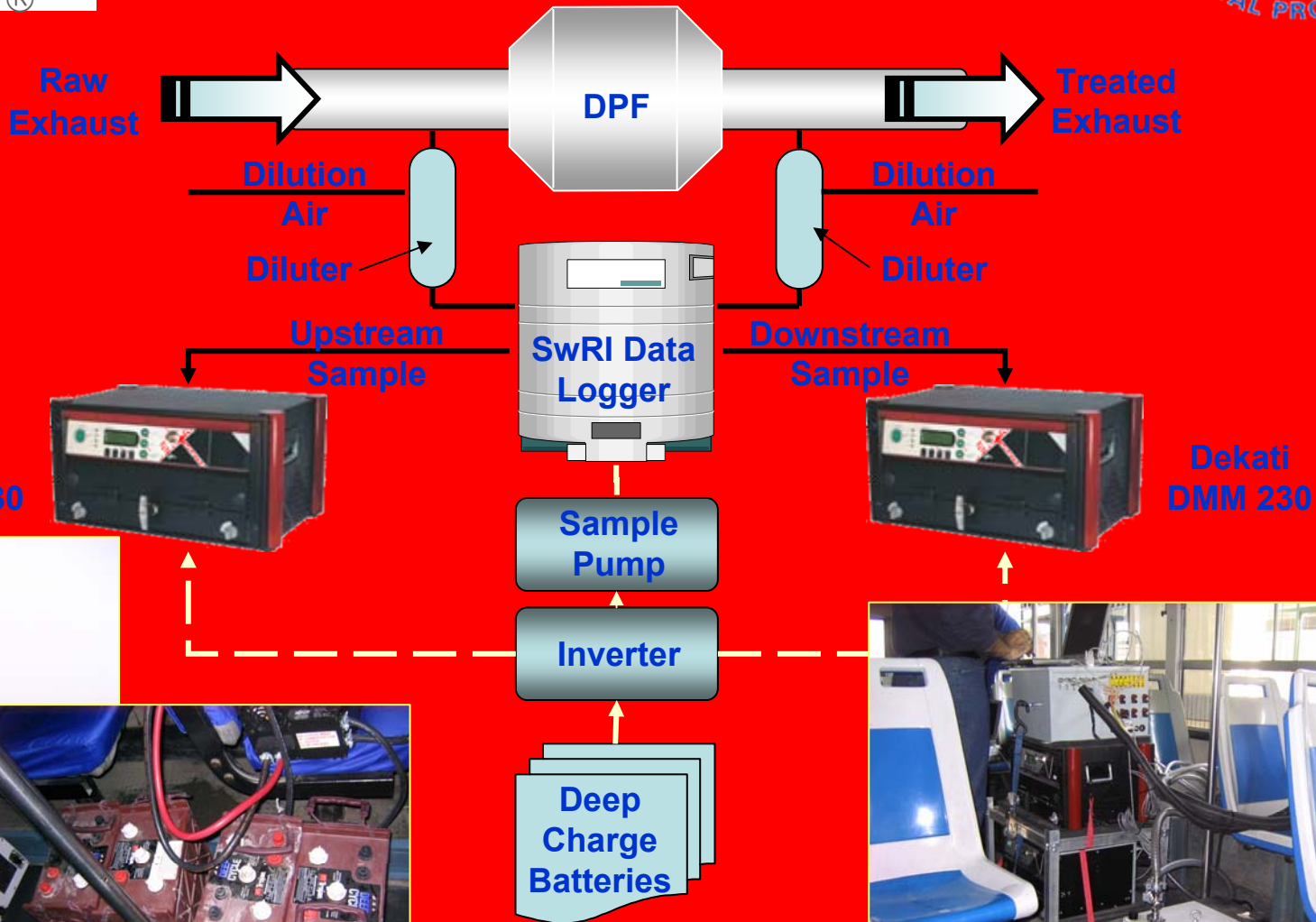
Electrically-Regenerated Non-Catalyzed Wallflow



Catalyzed Continuously Regenerated Trap Concept

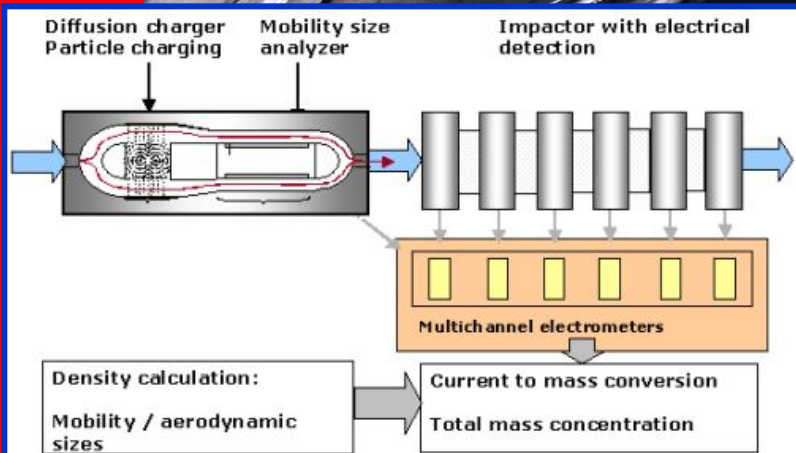
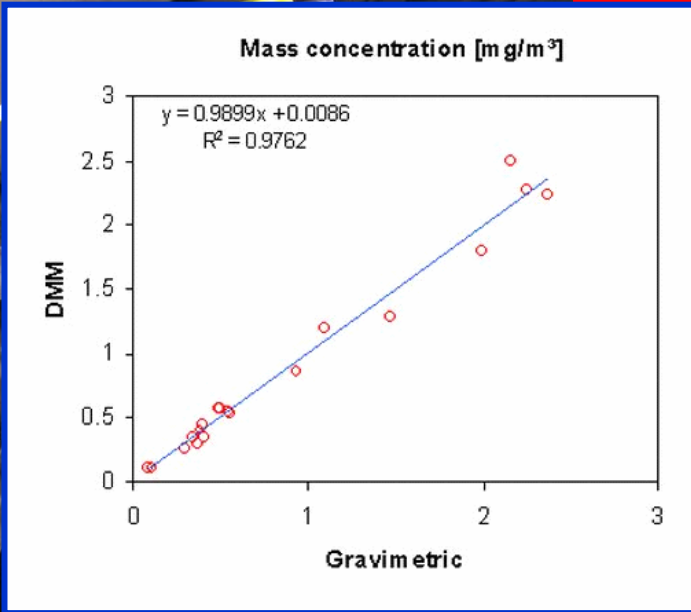
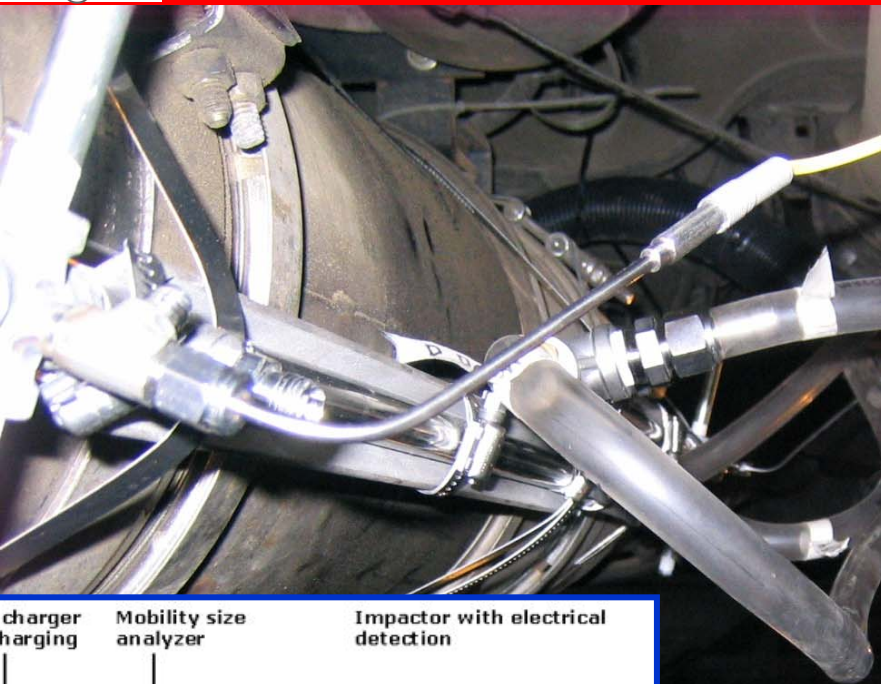


Analytical System





Dekati DMM 230



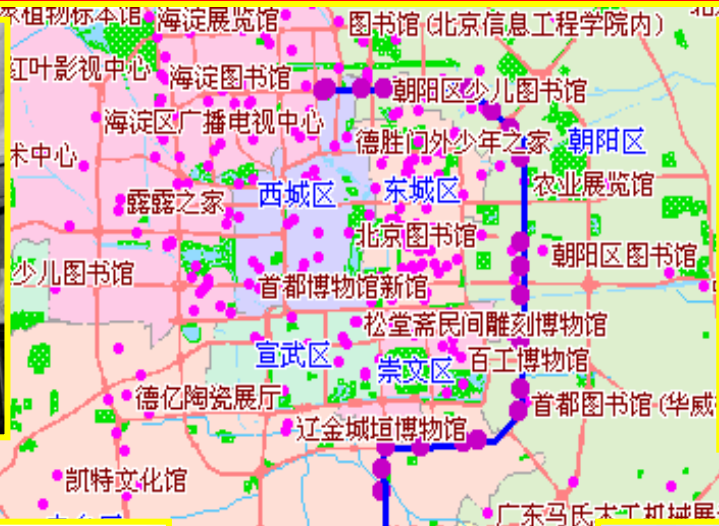


Special Provisions



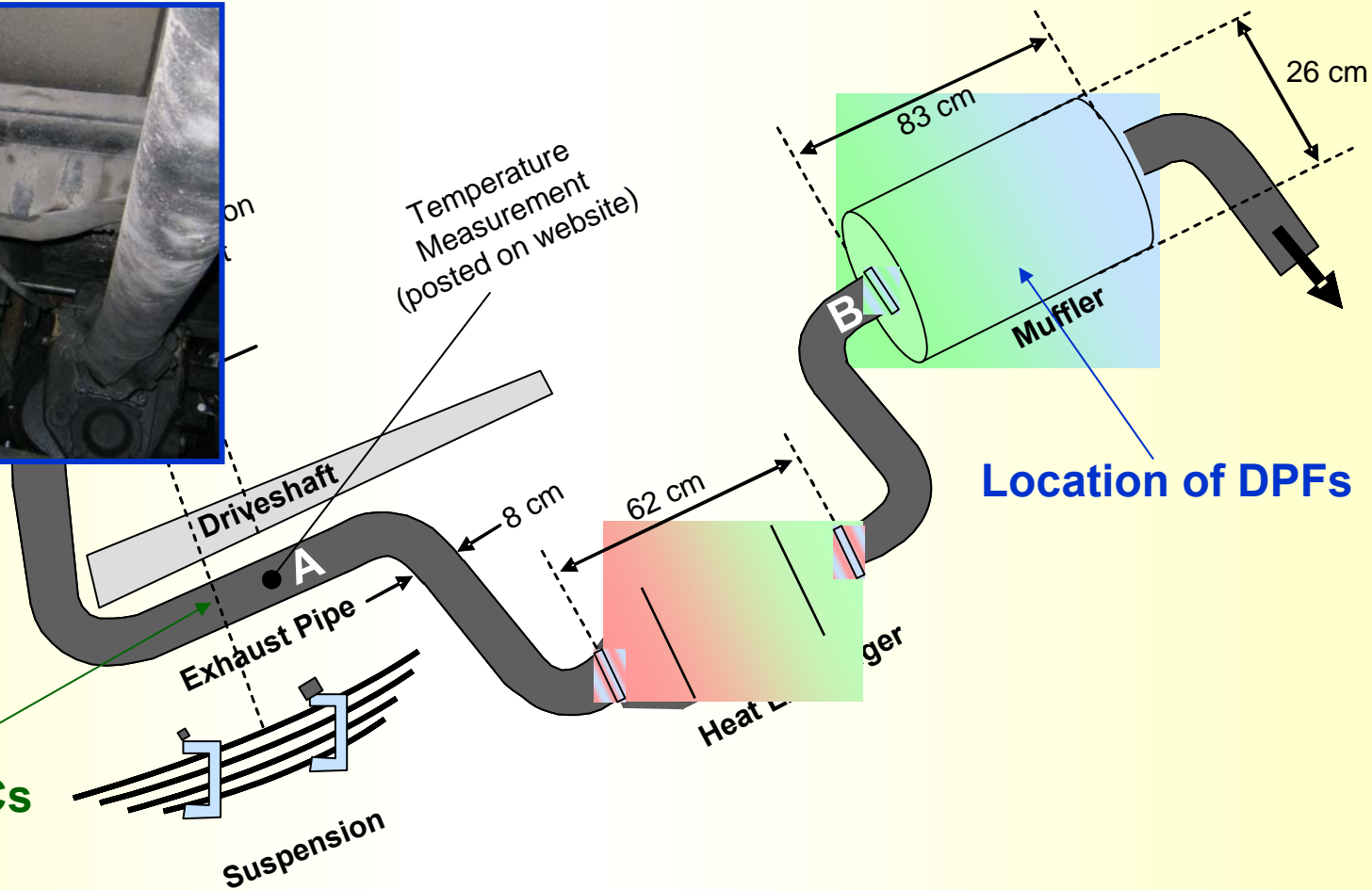


Bus Route & Miscellaneous





Exhaust System Details





Exhaust Temperature - A



MadgeTech - [Summary]

File Edit View Communication Device Graph Window Help

Summary Composite Graph Graph Data

01 - Untitled Dataset

Summary	

Statistics for Untitled Dataset

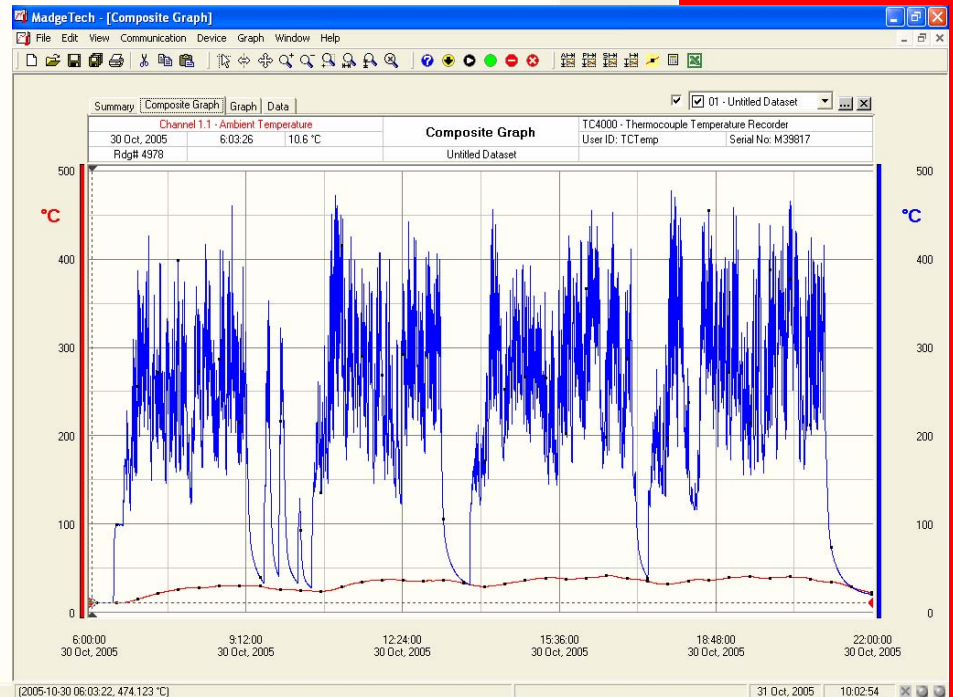
First Reading: 1
 Last Reading: 12737
 Total Readings: 12737
 Start Time: 29 Oct, 2005 9:19:11
 End Time: 31 Oct, 2005 14:23:11
 Duration: 2 days 5 hours 4 minutes

Channel 1: Ambient Temperature

Minimum: 7.6 °C @ 31 Oct, 2005 8:08:56
 Maximum: 42 °C @ 30 Oct, 2005 16:36:41
 Average: 24.2094 °C
 Standard Deviation: 10.9134 °C
 Mean Kinetic Temperature: 29.4911 °C

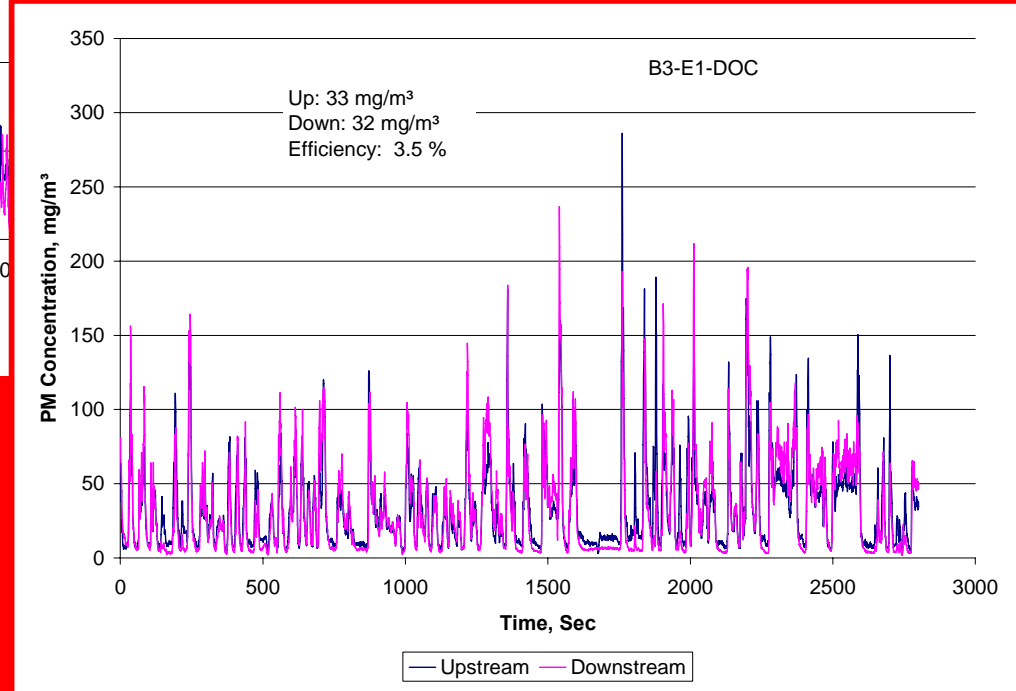
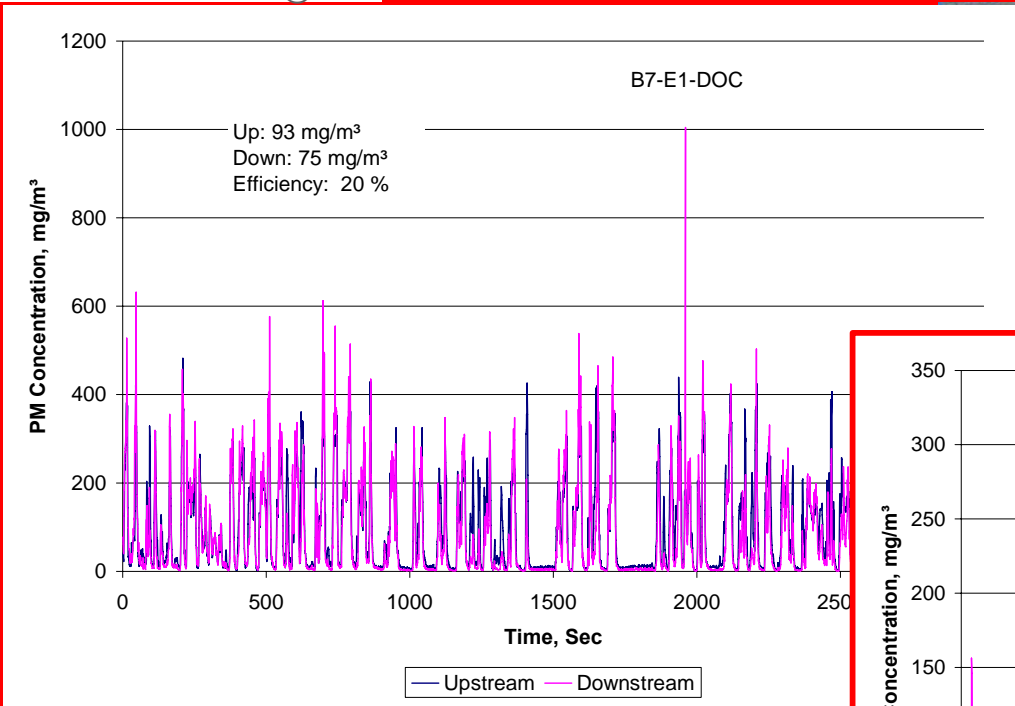
Channel 2: Thermocouple Temperature

Minimum: 8.02 °C @ 31 Oct, 2005 8:11:56
 Maximum: 477.25 °C @ 30 Oct, 2005 17:53:26
 Average: 128.024 °C
 Standard Deviation: 126.636 °C
 Mean Kinetic Temperature: 296.452 °C





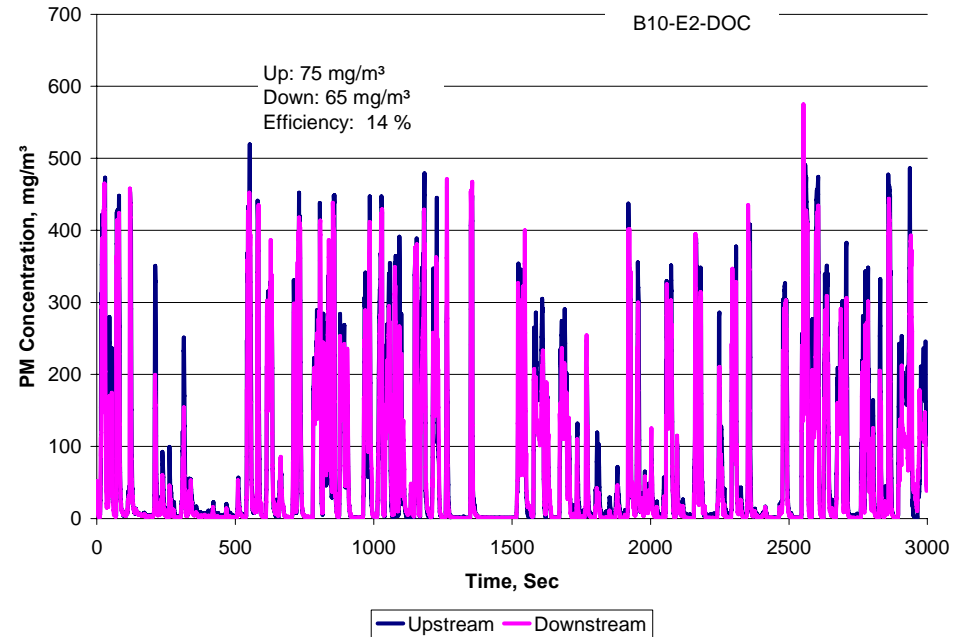
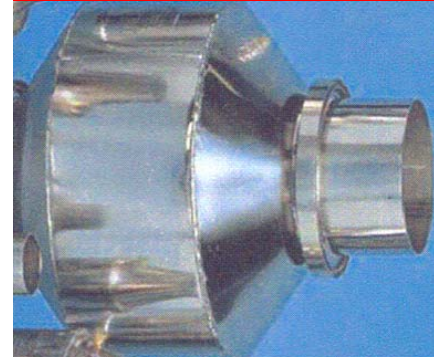
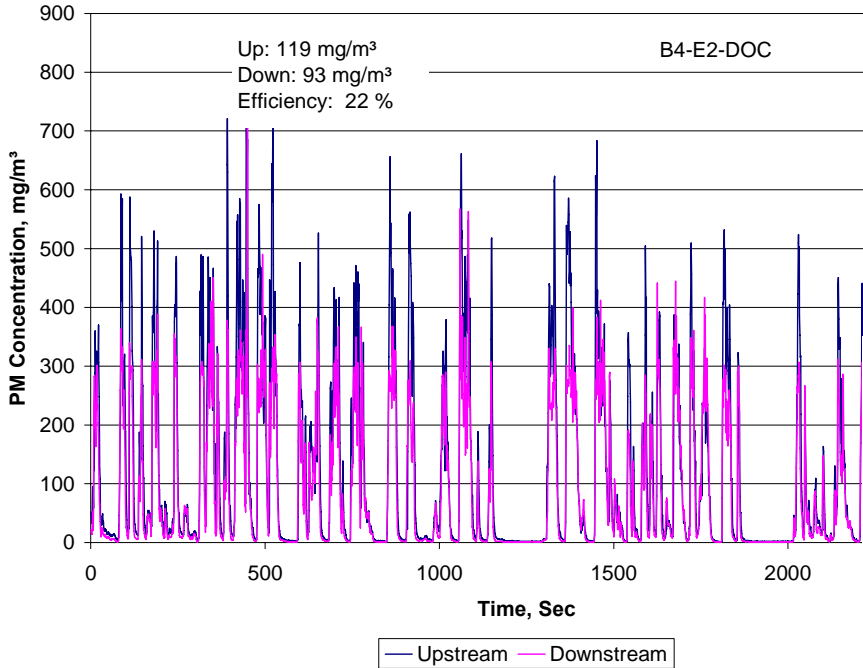
DOC Conversion Efficiency



EURO I



DOC Conversion Efficiency



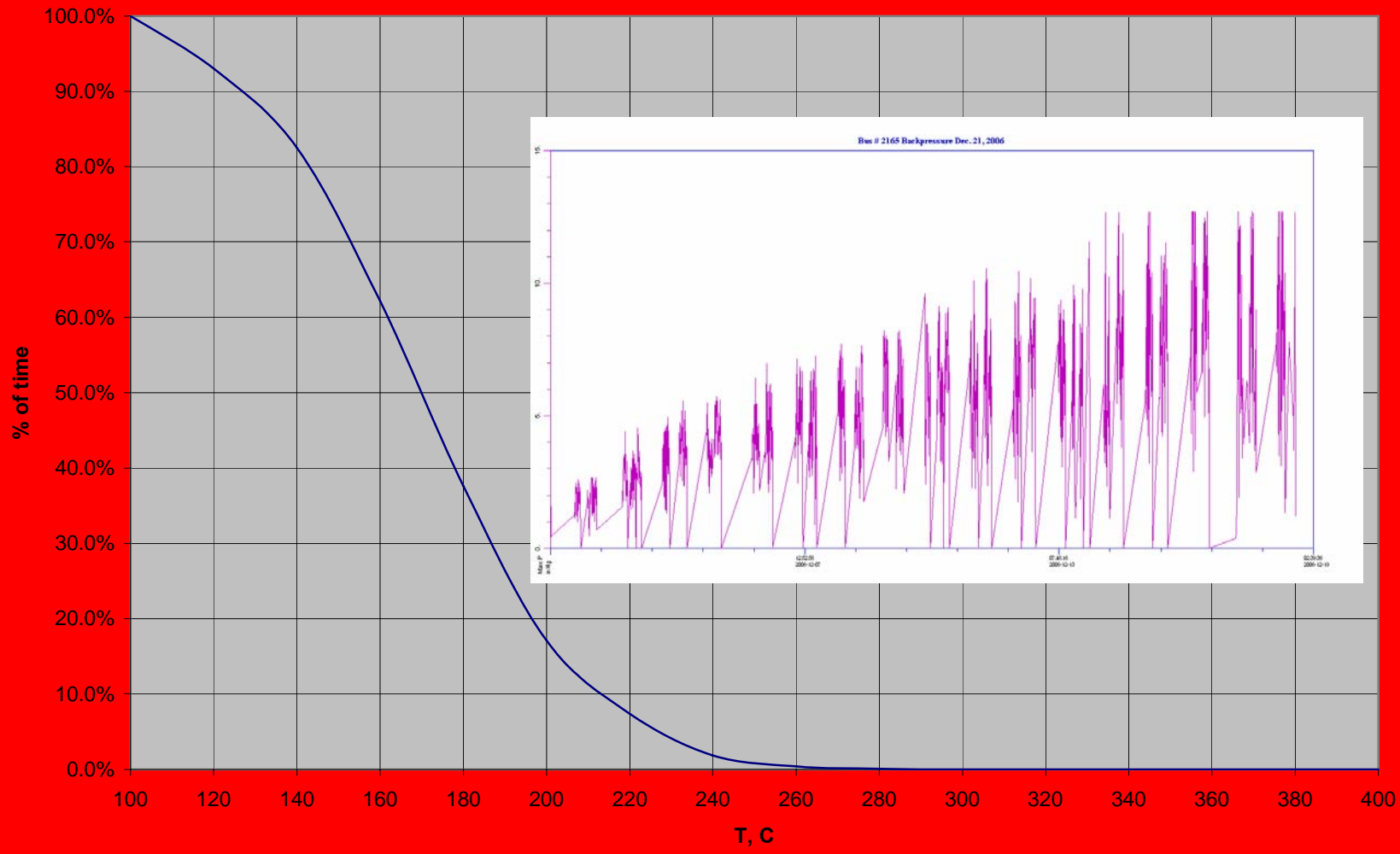
EURO II



Exhaust Temperature - B

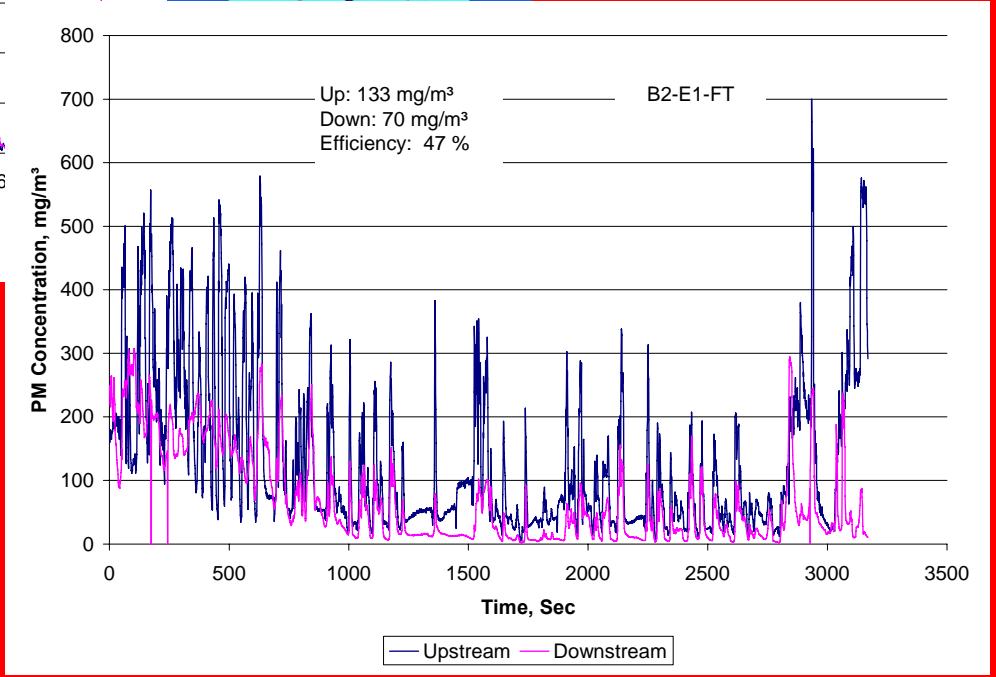
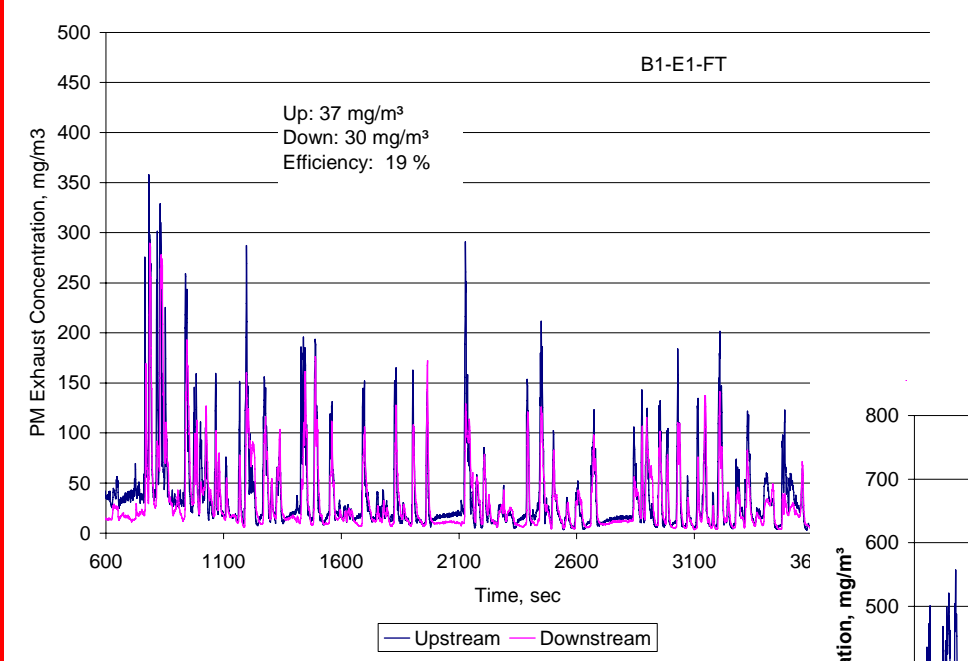
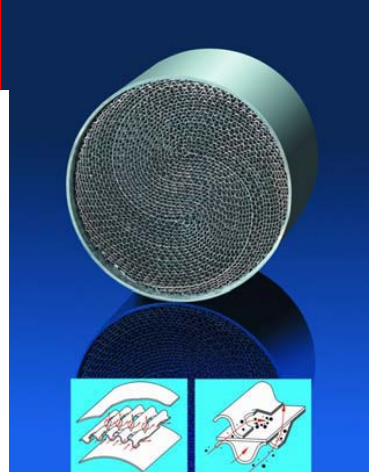


Bus # 2165 Temp. Profile Dec 21, 2006





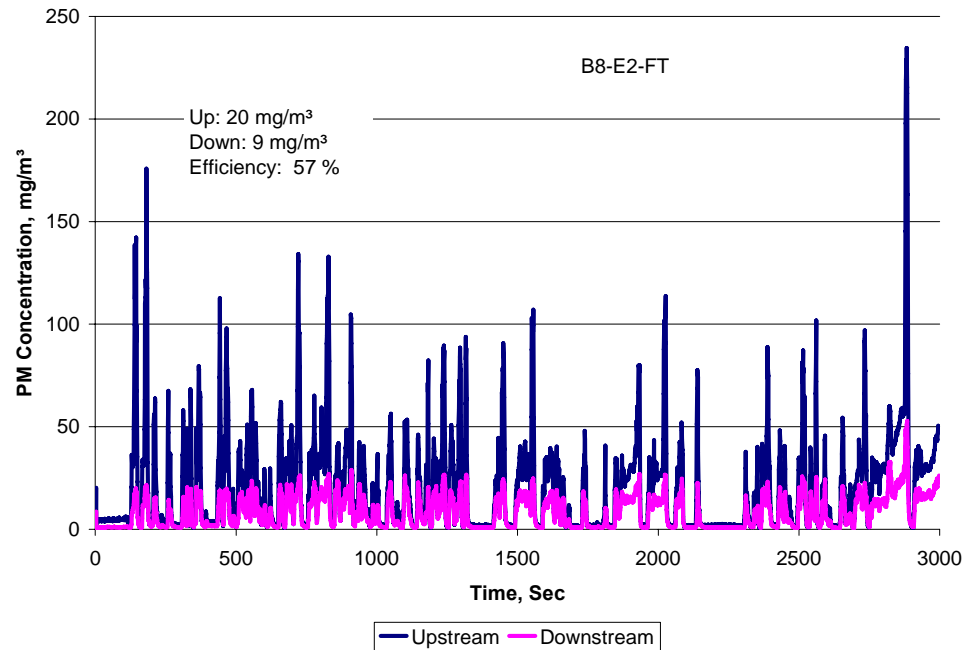
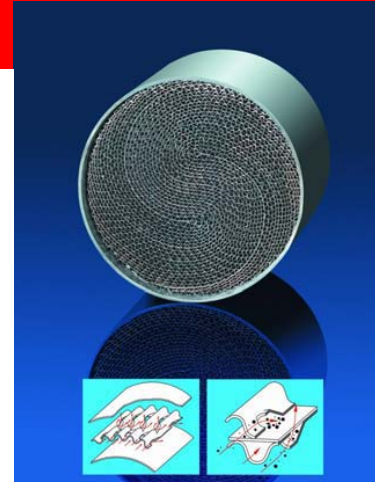
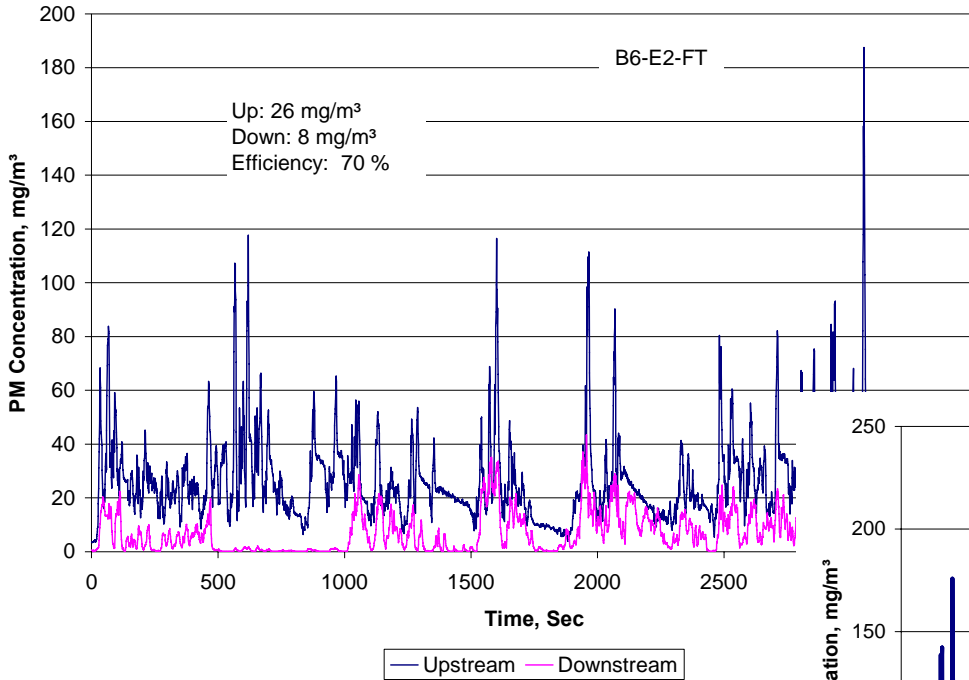
FT-DPF Conversion Efficiency



EURO I



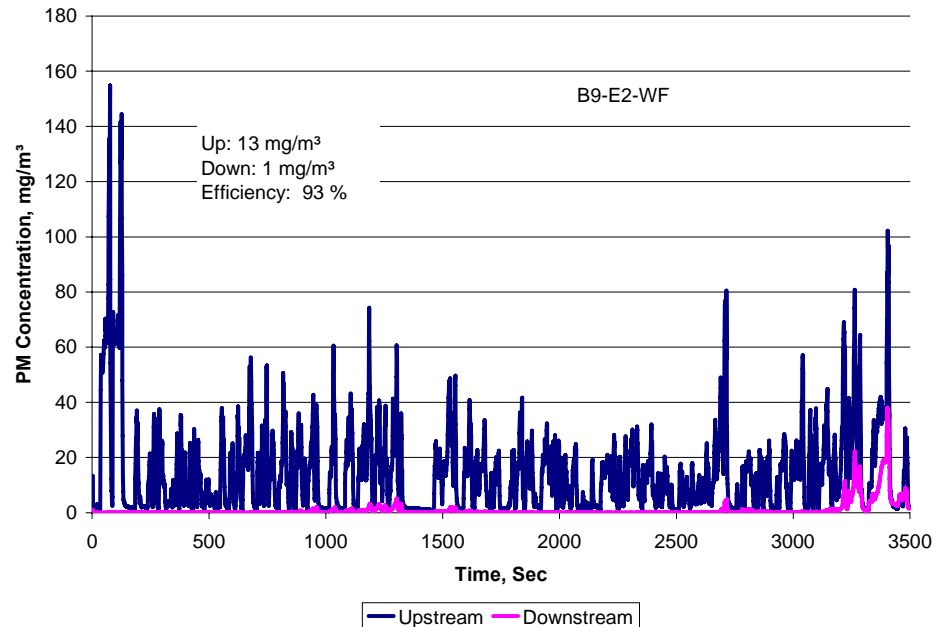
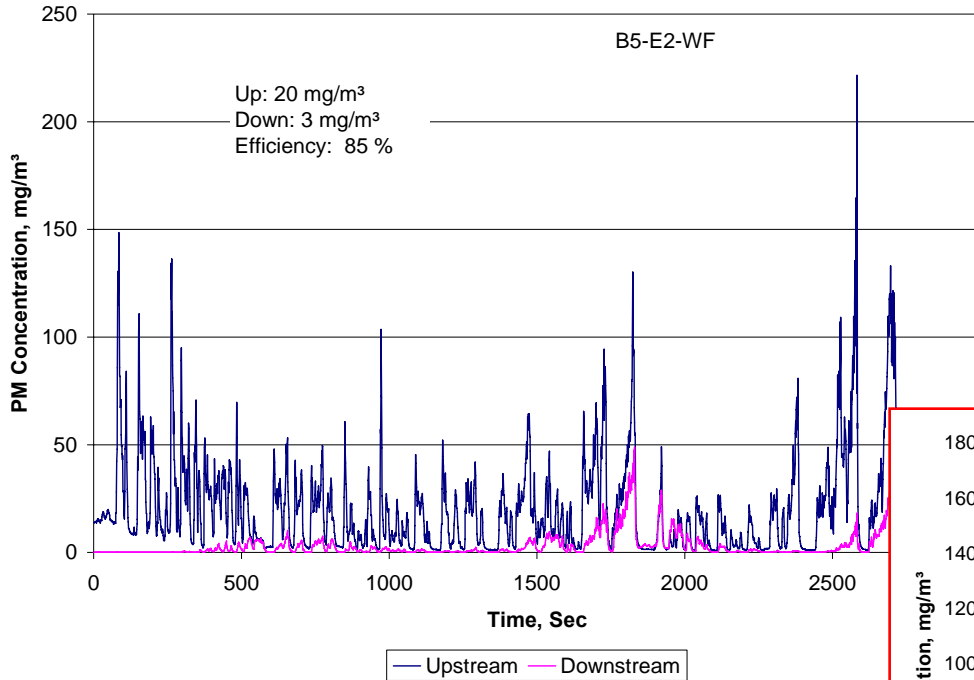
FT-DPF Conversion Efficiency



EURO II



WF-DPF Conversion Efficiency



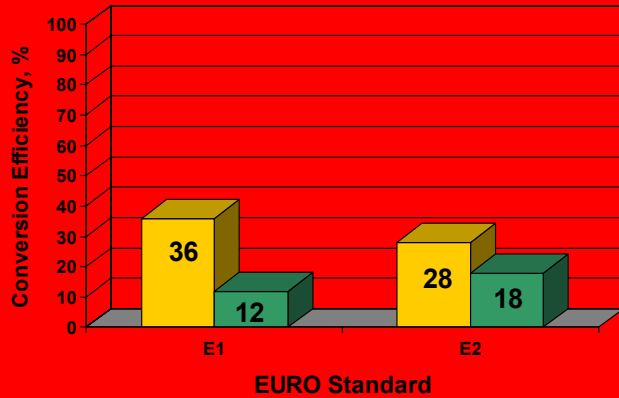
EURO II



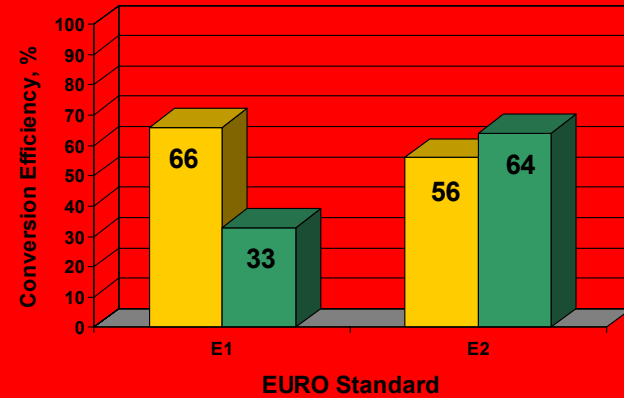
Lab Vs. Onboard PM



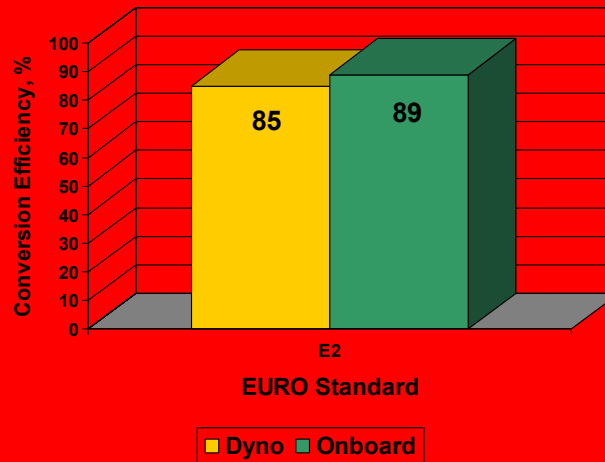
DOC



FT-DPF

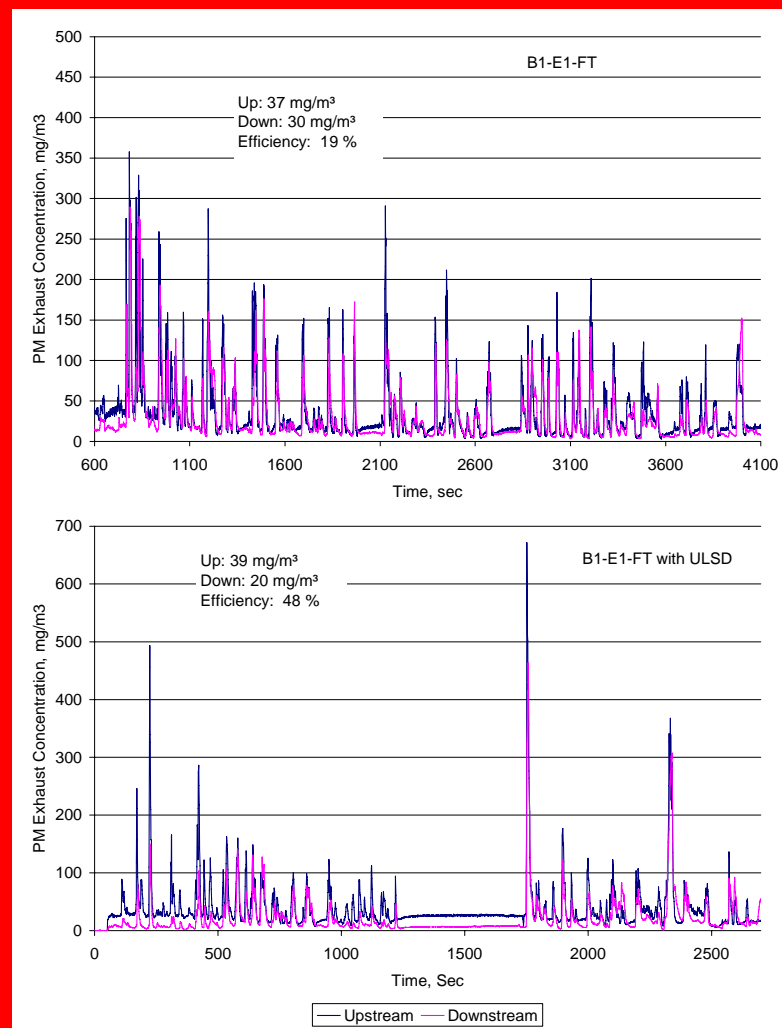
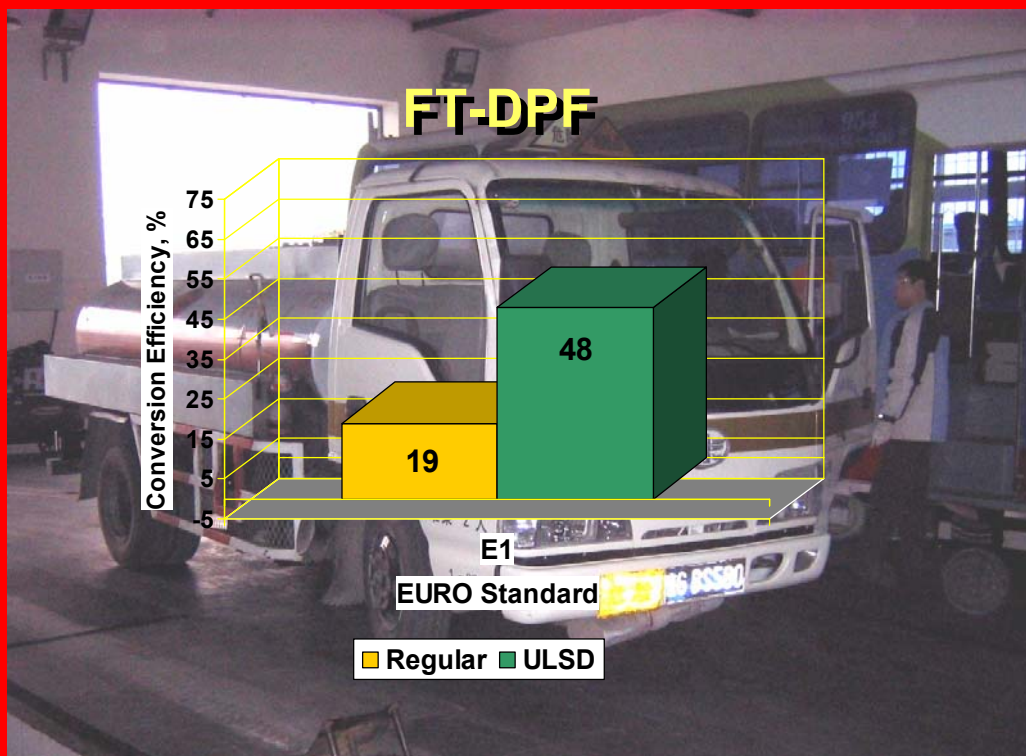


WF-DPF





Effect of ULSD

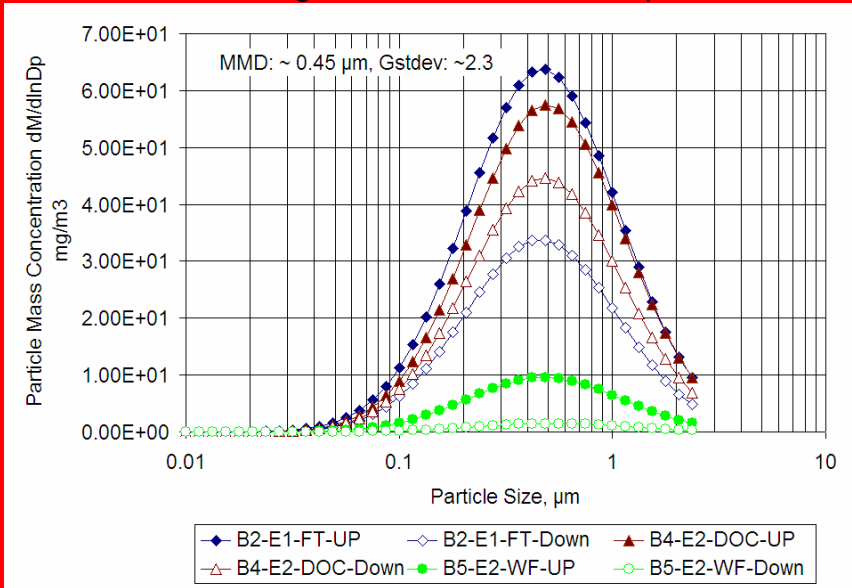




Particle Size Analysis



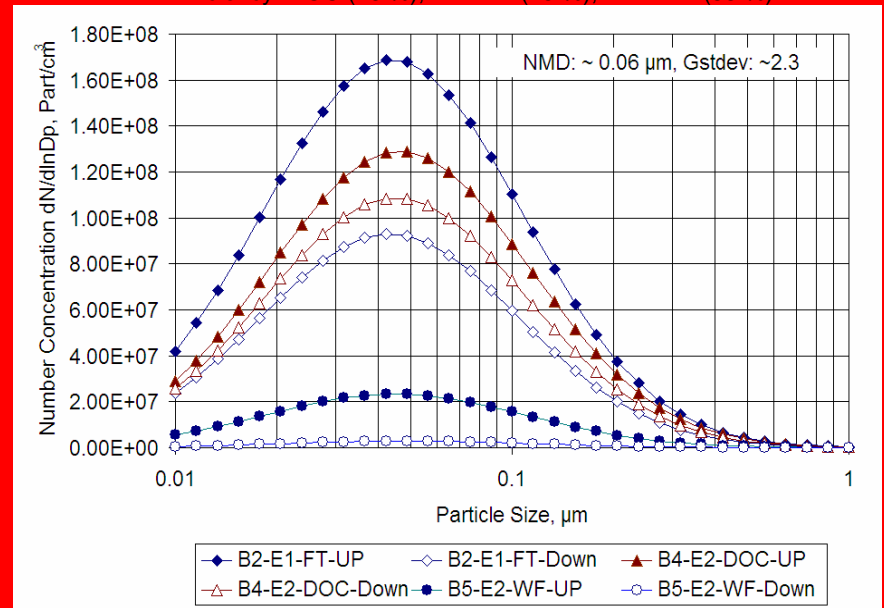
Particle Mass -Weighted Size Distribution Upstream and



Distribution was Derived from the MMD and Gstdev reported by DMM -230

Particle Number Weighted Size Distribution Upstream and Downstream of DOC, FT, and WF

Efficiency: DOC (16 %), FT DPF (45 %), WF DPF (88 %)



Distribution was Derived from the MMD and Gstdev reported by DMM-230



Conclusions



- ◆ **Major Inconsistencies in Engine-Out PM Emissions Even Within Same EURO Standard Buses**
- ◆ **Low Exhaust Temperature Profile Especially at Muffler-In Position**
- ◆ **DOC Conversion Efficiencies Ranged From 3.5 to 22% for E1 & E2 Buses**
- ◆ **FT-DPF Conversion Efficiencies Ranged From 19 to 70% for E1 & E2 Buses**
- ◆ **WF-DPF Conversion Efficiency Was Between 85 and 93% for E2 Buses**
- ◆ **It Appeared That The Volatile Content of PM Led to a Greater Variability in The Results Between The Lab and The Onboard Measurements**
- ◆ **The More Dependent The Device on Chemical Reaction for PM Reduction, The More Variable The Results**
- ◆ **The More Dependent The Device on Physical Filtration for PM Reduction, The Less Variable The Results**