On-board PM measurements: Status of regulatory developments and instrumentation technology

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Abstract

Field testing with Portable Emissions Measurement Systems (PEMS) is becoming an important regulatory tool to monitor the in-use compliance of large sources like heavy-duty vehicles, construction and agriculture equipment. Legislative research programmes in Europe, United States and Japan are introducing PEMS in the regulations. The current development status of instrumentation and test procedures is mature for gaseous emissions. The most critical issue remains the development of portable PM instruments and the associated protocol. The main objectives of the paper are:

To provide an overview of the on-going regulatory efforts regarding on-board PM measurements both in the European Union and the United States;

To review the available portable measurement techniques;

To discuss the technical issues related to the development of an official "on-board test procedure".

The discussion and the conclusions will be supported by some findings from the EU-PEMS project and in particular the evaluation of portable instruments under controlled laboratory conditions (i.e. on reference test cycles) and against reference instruments. PM mass measurements were carried out from a Euro III heavy-duty engine. For the filter gravimetric method, the Control Sistem micro-PSS (portable proportional diluter) was compared to the standard gravimetric methods using full dilution within the CVS dilution tunnel and two laboratory proportional flow sampling systems such as the AVL Smart Sampler (SPC 472) and the Control Sistem PSS-20. For real-time measurement, the AVL 483 micro soot sensor was also tested in parallel with the gravimetric methods using both full flow and partial flow dilution. The measurements were found to be highly repeatable over the regulatory cycles. Bio-fuel was also used to characterise the instruments in different ranges and its effect upon the black carbon concentration observed. Regarding the development of on-board test procedures, the first findings from tests conducted on city buses will be presented. The main issues related to a less controlled on-board environment (with vibrations, temperature changes) compared to more controlled laboratory conditions will be highlighted.

Introduction

Field testing with Portable Emission Measurement Systems (PEMS) has become an important tool to monitor the in-use conformity of large sources like heavy-duty vehicles, construction and agriculture equipment. Although laboratory testing is still the base of knowledge for homologation and development of engines and vehicles, homologation cycles cannot simulate the wide range of real world-conditions and field-testing within PEMS offers an important counterpart to check the effectiveness of the official laboratory test procedures.

The scope of the presentation is to provide an overview – in a non exhaustive way – about the on-going regulatory efforts conducted both in EU and US and their associated research programs. Particular attention is given to the EU-PEMS program. The EU-PEMS program, launched in mid -2004 is an on-going co-operative research program involving the European Commission, the heavy duty manufactures and the instrument providers. As no portable PM instrumentation was available when the program started, the activities focused on the development of a test protocol to measure gaseous emissions. PM instruments were introduced mid-2005 and the first vehicle application took place in March 2006. Partial flow sampling (PFS) and PM measurements by mass were selected as the most suitable principle as the current rules for type approval are still based on PM mass.

In the present work, an inter-laboratory comparison of different commercial instruments based on different measuring principles was carried out to compare PEMS instruments against reference laboratory instruments under controlled conditions. Preliminary on board PM measurements from a city bus test campaign are presented.

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PM Instruments and test conditions

Laboratory tests

For the laboratory tests a Euro III heavy-duty engine (Iveco Cursor, 10.6 litre) with no after-treatment was used running on different fuels. Different fuels, including low Sulfur fuel and bio-fuel were used to check the instruments performances at different ranges. Tests were carried out on both the European Transient Cycle (ETC) and the European Steady-state Cycle (ESC). For the standard gravimetric method (PTS) PM was collected on a Teflon coated glass fiber filter (PallflexEMFABTX40HI20 and weighted on a microbalance according to the standards in force for filter conditioning and handling. The standard gravimetric method using the conventional Constant Volume Sampling (CVS) for dilution was compared to portable instruments such as the Particulate Sampling System (PSS-20) and micro-PSS from Control Sistem using the partial flow sampling (PFS) principle [1].

A picture of micro-PSS is shown in Figure 1. This is a prototype portable instrument working according the PFS principle; it uses a 47 mm filter and collects PM with a filter face velocity of 43 cm/s at a filter temperature of 44 ± 1ºC and a dilution factor of 14.8 (average). In its standard configuration (PSS-20), it uses filters of same type but with 70 mm diameter of as for the PTS method.

The AVL Smart Sampler (SPC 472) was also used as reference instrument for the PFS principle; it is a partial-flow tunnel for gravimetric measurement of diluted particulates. From the total engine exhaust flow only a small partial flow is sampled into the mini dilution tunnel and diluted with air which the system conditions internally. The dilution ratio is adjusted and the partial flow rate set by the mass flow controllers for the dilution air and the total tunnel flow; this principle allows not only the simulation of a CVS full-flow dilution tunnel but also the adjustment of constant dilution ratios at constant total tunnel flow.

Alternative methods for PM measurements were also considered. The AVL 483 Micro Soot Sensor (MSS), based on a photo-acoustic measurement principles [2, 3], was used as it is possible to do transient measurement of soot concentration with high sensitivity (detection limit ≤ 10 µg/m³, typically ~5 µg/m³). The instrument picture and its working principle is shown in Figure 2; the exhaust gas is directed through a measuring chamber and thermally animated by a modulated laser beam; Modulated heating produces periodic pressure pulsation, which will be detected by a microphone as acoustic wave. The signal is then amplified in a pre-amplifier and filtered in a „Lock-In“- amplifier. The micro soot sensor may be used to measure directly from the CVS dilution tunnel (full dilution) or directly at the tailpipe by using a conditioning unit that allows a range of dilution ratio up to 10 (partial dilution). The instrument was used in both modes full dilution and partial dilution with a fixed dilution ratio of 10.

In order to consider alternatives to the gravimetric method for PM mass, chemical analysis for the PM collected with the m-PSS was conducted with the Horiba MEXA 1370PM. The MEXA-1370PM is designed to vaporize the particulate matter (PM) collected on its filter by heating it up to 980°C, so that the mass of soot, SOF (Soluble Organic Fraction) and sulfate, which are main components of PM, can be separately measured from the gas generated by oxidation and reduction [4,5].

Vehicle tests

Preliminary on board PM measurements from Euro III HDD city-buses were conducted on two main city routes (line17 and 74) in downtown Barcelona. PM mass measurements on board were conducted using the PFS principle with the micro-PSS and soot measurements with the AVL 483 MSS using settings similar to the laboratory PM tests; gaseous emissions were carried out in parallel using the Horiba OBS2200 and the AVL-Sensors Semtech-D. Regarding the test procedure, the connection of the exhaust flow meter (EFM) using a Pitot for the direct measurement of the exhaust flow to the vehicle tailpipe was essential.

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Testing was carried out with Diesel as well as CNG buses; in this context, data are reported for the Diesel engine case (IVECO Cursor 8) running on standard diesel fuel. Line 17 and line 74 were chosen as city test routes as the former starts in a hilly region of Barcelona, crosses the city center and ends at the sea, while the latter crosses the city from one end to the other one.
In order to simulate the real life conditions, the bus was loaded with additional weight up to ~14.4 tons which corresponds to about full load. Furthermore, a real bus service was simulated including stops along the line.

Results

Laboratory tests
PM mass measurements using the AVL SPC 472, the Control Sistem PSS-20, the m-PSS and the standard gravimetric method with full dilution (PTS) are reported in Figure 3 over the ESC and ETC cycle; data are average over 18 PTS tests, 14 PSS-20, 8 m-PSS and 5 SPC 472 tests for the ETC cycle while over 6 PTS tests, 4 PSS-20, 4 m-PSS and 5 SPC 472 tests for the ESC cycle.
Good agreement is observed among the different instruments and in particular for the prototype m-PSS vs. the standard method using full dilution (PTS).
The AVL 483 MSS was used with two different set-ups: sampling from the CVS (full dilution) and sampling directly at the exhaust pipe (partial dilution) by using a conditioning unit. Good repeatability was found with the AVL 483 over the ETC cycle.
For the case of full dilution (CVS), PM measurements are reported in Figure 4 as concentration vs. test time over 5 consecutive tests (ETC cycle); average CO emissions (ppm) cycle is plotted as well. Figure 5 shows total soot emissions (g/kWh) for 7 consecutive tests over the ETC cycle using full dilution (CVS). PM mass measurement with the standard gravimetric method (PTS) is reported as well for comparison; data are very repeatable.
The effect of different fuels on black carbon concentration, measured with the AVL 483 MSS over the ETC cycle, has been also investigated. Standard Diesel fuel with 50 ppm S content, low S fuel (Tamoil), a blend (70/30) and 100% bio-fuel were used for testing. No difference is observed using a standard or low S fuel while the effect of a bio-fuel both at 30% in the mixture and at 100% is very effective in reducing soot emissions (Figure 6). The same trend with the use of bio-fuel was also observed on CO engine emissions.
Total PM mass measurements with the MEXA1370-PM are reported in Figure 6 for each fuel case. The use of standard diesel and tamoil gives a similar amount of black carbon, representing around 50% of the total PM mass collected on the filter while for the bio-fuel case the percentage is much less. MEXA 1370-PM data for both total PM and soot is reported in Figure 7 with AVL 483 MSS data; good agreement was found between soot measured with the AVL 483 MSS and the MEXA 1370-PM.

Vehicle tests
Preliminary on board PM measurements from a Euro III HDD city-bus are shown for an IVECO Cursor 8 on two test routes (line 17 and 74) in downtown Barcelona; line 17 starts in a hilly region of Barcelona, crosses the city center and ends at the sea, while line 74 crosses the city from one end to the other one. The altitude profile for line 17 could be generally characterized as downhill and uphill for the way back. Test trips characteristics in terms of speed, engine work, altitude and distance are shown in Figure 8 and 9. Soot measurements (g/kWh) with the AVL 483 MSS over three consecutive tests are shown in Figure 10 over line 17 and 74. Total PM mass measurements, conducted with the Control Sistem m-PSS, are shown in Figure 11. Good repeatability was found with both AVL 483 MSS and m-PSS.

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Summary and Future work

Laboratory PM mass measurements from a Euro III heavy-duty engine (IVECO Cursor, 10.3 litre) were carried out, prior on board PM measurements, to compare PEMS instruments against reference laboratory instruments under controlled conditions.
The standard gravimetric method (PTS) using full dilution within the Constant Volume Sampling dilution tunnel, alternative gravimetric systems such as the AVL Smart Sampler (SPC 472) and the Control Sistem Particulate Sampling System **(**PSS-20) and micro-PSS using partial flow dilution were used for testing.
The performance of the AVL 483 micro soot sensor was tested in parallel with the gravimetric methods both full dilution and partial dilution in order to make a comparison. The AVL 483 measurements were highly repeatable over both the ETC and ESC cycles. The black carbon concentration measured resulted to be a high percentage of the total PM mass collected on the filter with the standard gravimetric method, around 80%.
The effect of different fuels and fuel blends on PM mass including low S fuel and biofuel was investigated in order to compare instruments performance on PM at different ranges. The use of biofuel was particularly effective on black carbon concentration, with reduction of around 80% from the standard and low Sulfur fuel and on CO engine emissions that showed a trend similar to black carbon. The AVL 483 MSS was particularly suitable to measure low soot concentrations.

Preliminary on board PM measurements on a Euro III HDD city-bus (IVECO, Cursor 8) on two test routes in downtown Barcelona showed good repeatability with both micro-PSS and AVL 483 MSS. Vibrations and temperature changes, associated to a “less controlled” on-board environment, were not of concern for any of the instruments used but filter handling and conditioning was the main issue on board because of dust and temperature changes: they were found to be acceptable for this generation of vehicles but shall be further developed for cleaner vehicles. PM data analysis from Compressed Natural Gas (CNG) buses is on-going and will be presented in a later stage.
A robust and well developed PM test protocol is under development; this is necessary to provide for a reliable portable emission measurement system in view of future emissions requirements and associated after-treatments. The Commission proposes to launch a second phase of the PEMS project starting in 2006, a manufacturer-run pilot test programme, to conduct confirmatory tests on heavy-duty vehicles. Depending on the outcome and timeframe of this pilot programme, the Commission will make the necessary steps in due course to prepare a proposal for use of PEMS for in-use compliance of heavy-duty vehicles.

Acknowledgements

Special thanks to the instrument manufactures (Horiba, AVL, Sensors inc, Control Sistem), engine manufactures (IVECO) and IDIADA and Metropolitan Transports of Barcelona (TMB) and all colleagues in the Vehicle Emission Laboratory (VELA) at JRC for their contribution.

References

[1] Control Sistem PSS-20 and micro-PSS manual- http://www.controlsistem.it/
[2] Haisch C., Beck H.A., Niessner R., Jacob E. and Rothe D. A ‘Photoacustic Sensor System for Time Resolved Quantification of Diesel Soot Emissions’ SAE paper No. 2004-01-0968.
[3] AVL 483 Micro Soot Sensor manual - htpp// www.avl.com
[4] M.L. Akard, K.E. Oestergaard, R.E. Chase, J.F. Richert, M. Adachi, H. Fukushima “Comparison of An Alternative Particulate Mass Measurement With Advanced Microbalance Analysis” SAE Paper No. 2004-01-0589.
[5] H. Fukushima, H. Uchihara, I. Asano et al., “An Alternative Technique for Low Particulate Measurement” SAE Paper No. 2001-01-0218.

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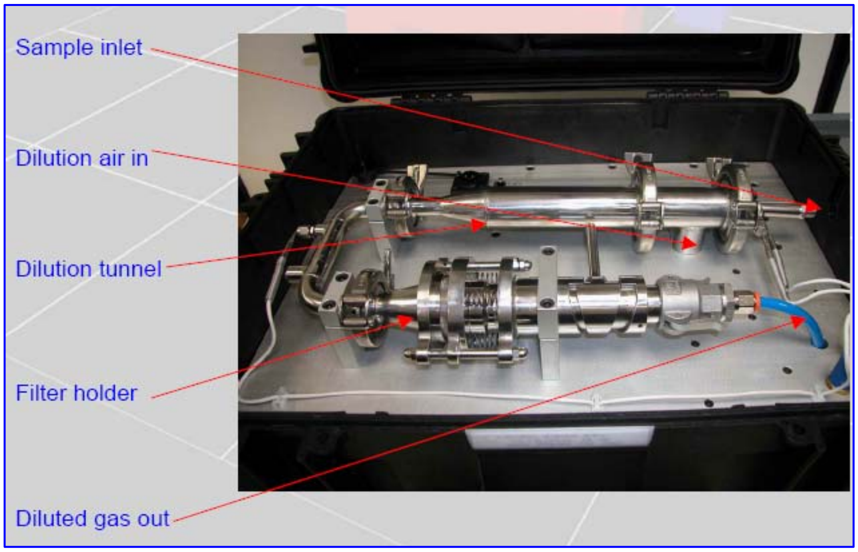
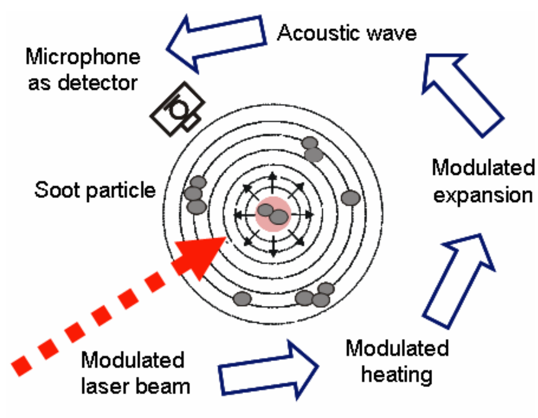


Figure 1: Control Sistem m-PSS [1].

(a)



(b)

Figure 2: AVL 483 micro soot sensor (a) and a schematic of its principle of operation (b) [2].

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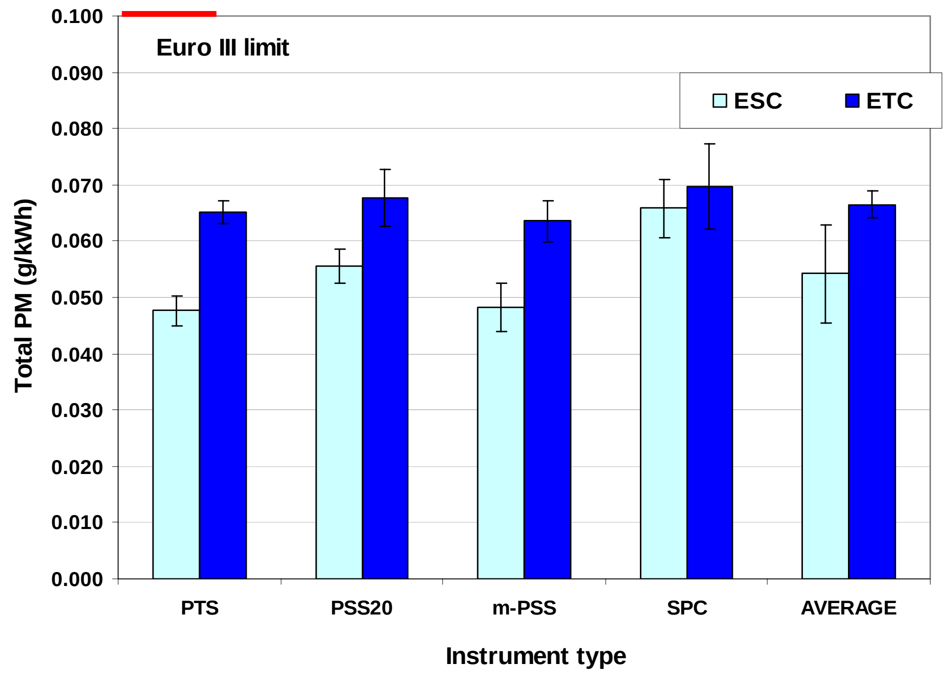

Figure 3: Comparison of PM mass laboratory measurements among different PM instruments over both ETC and ESC cycle.

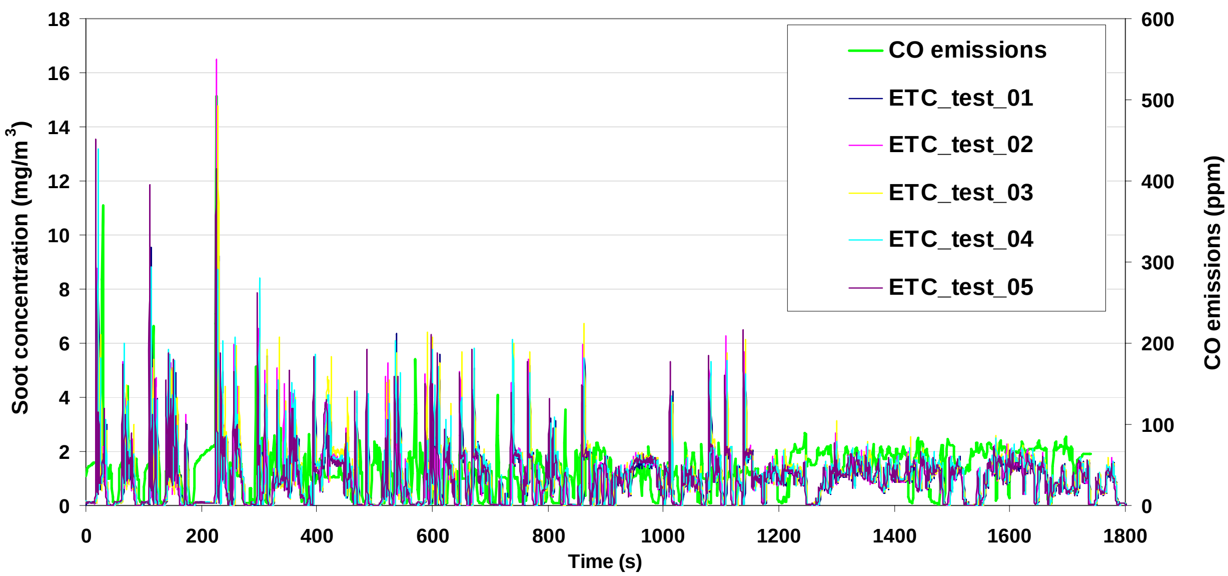

Figure 4: AVL 483 MSS data vs. test time for 5 consecutive ETC tests; CO emissions on the right-hand axis.

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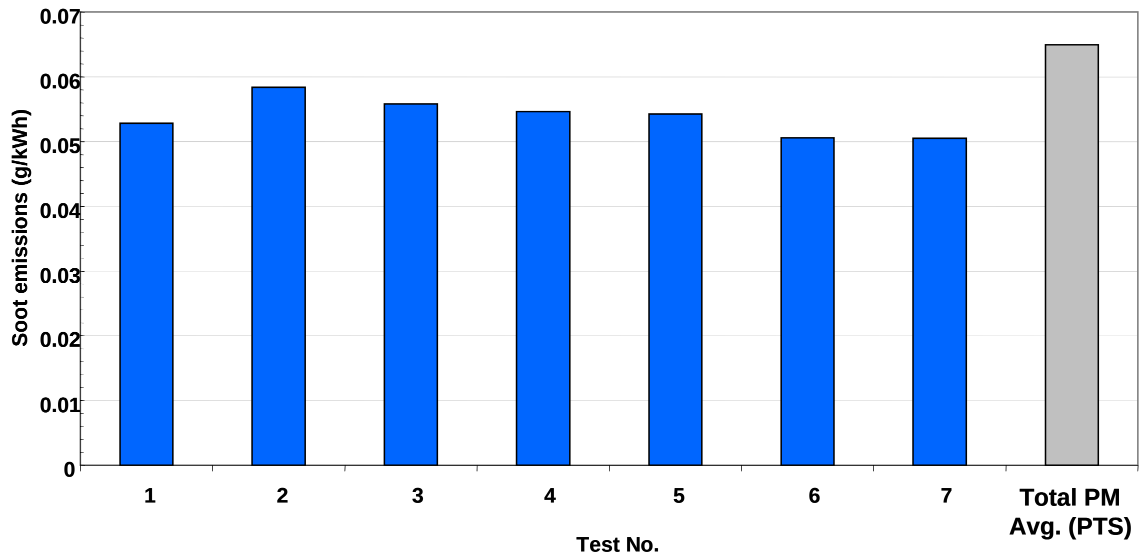

Figure 5: AVL 483 MSS total soot measurements (g/kWh) over 7 consecutive ETC tests; the average PM mass collected on the filter with the standard method is reported for comparison (full dilution).

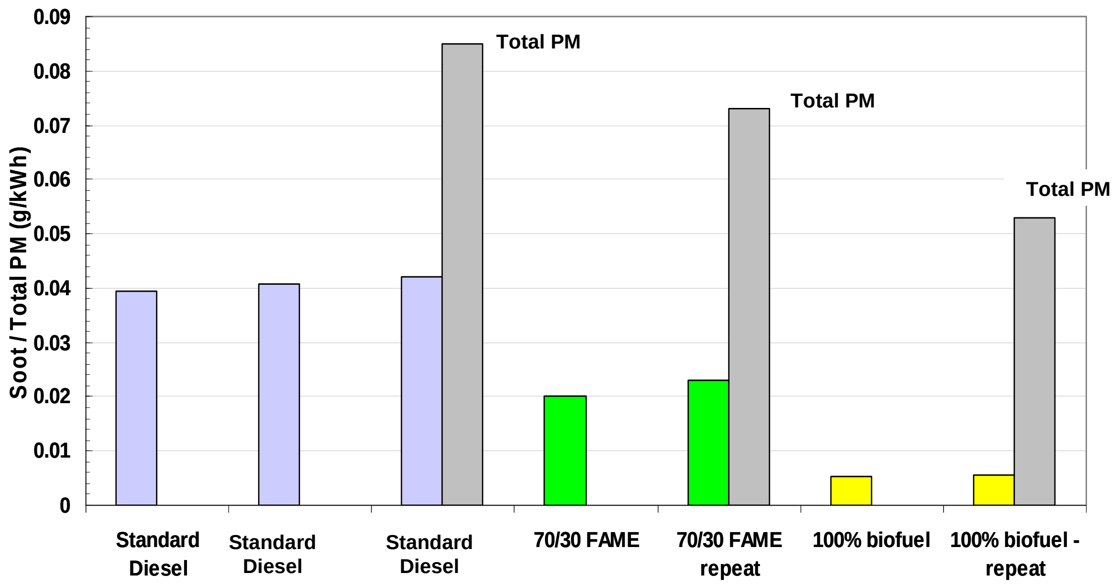

Figure 6: Total PM mass measured with the Horiba MEXA 1370-PM vs. soot measured with the AVL 483 for standard diesel fuel, a blend of bio-fuel at 30% and 100% bio-fuel.

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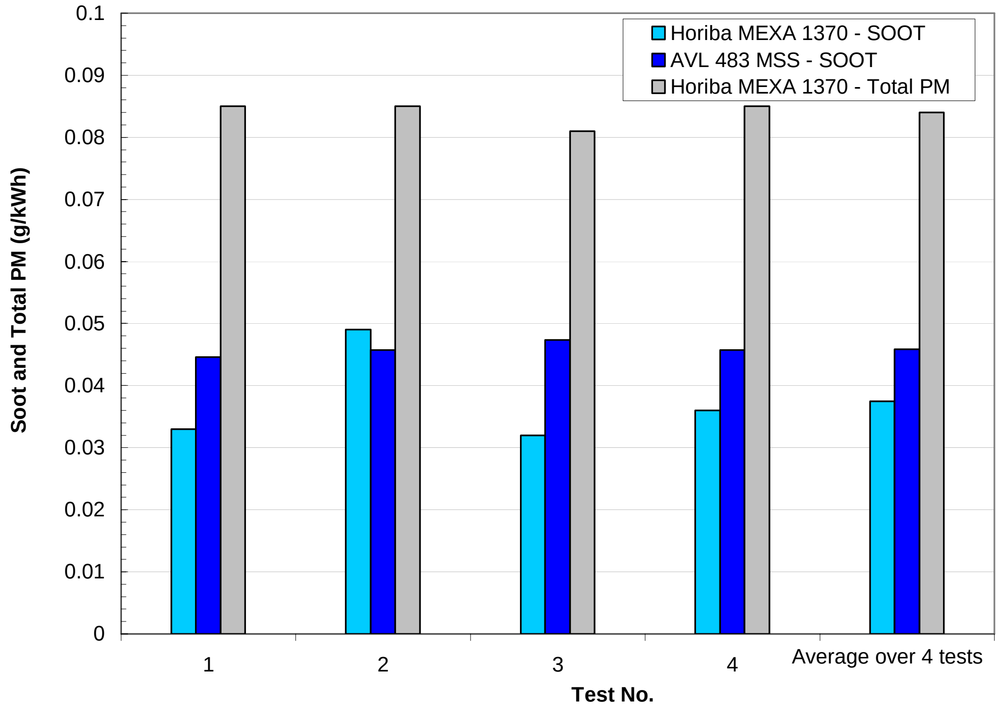

Figure 7: Total PM and soot measured with the MEXA1370-PM and the AVL 483 MSS respectively over the ETC cycle, standard diesel fuel.

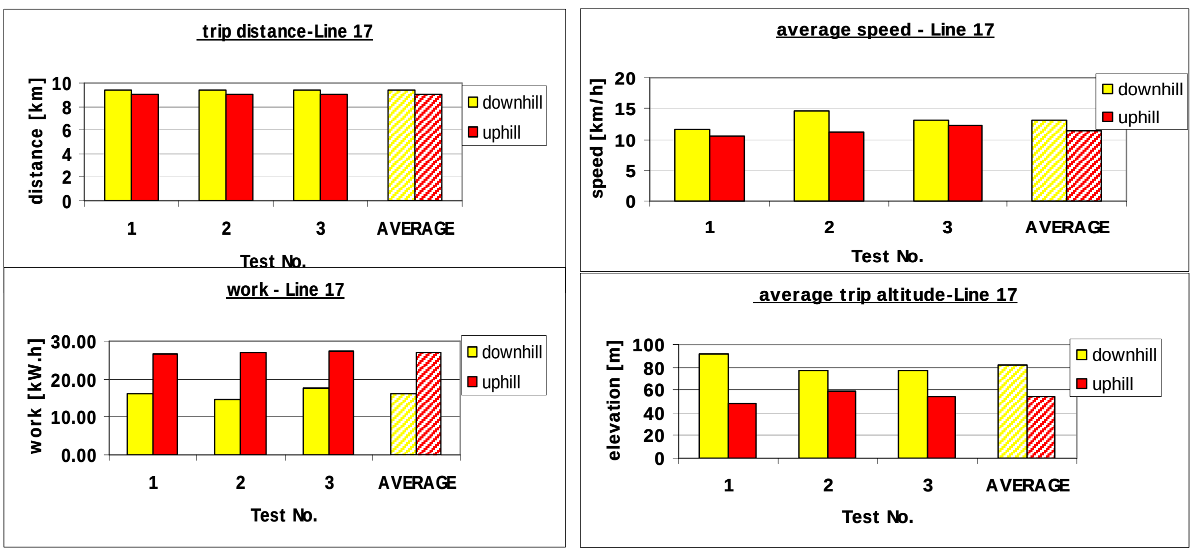

Figure 8: City bus test trip characteristics: trip distance, average engine speed, average engine work, average altitude for line 17.

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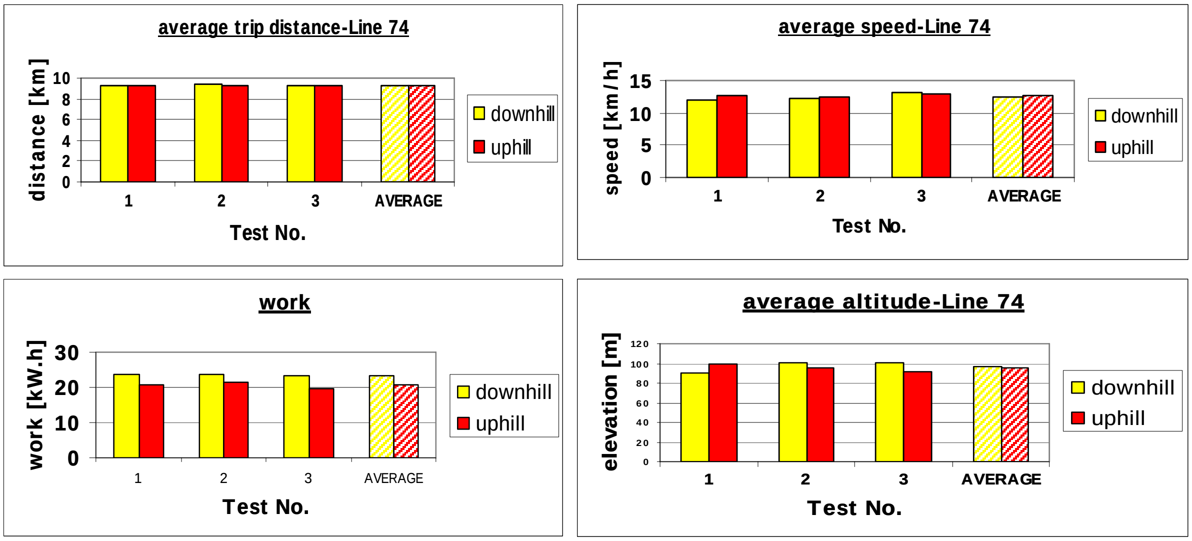

Figure 9: City bus test trip characteristics: trip distance, average engine speed, average engine work, average altitude for line 74.

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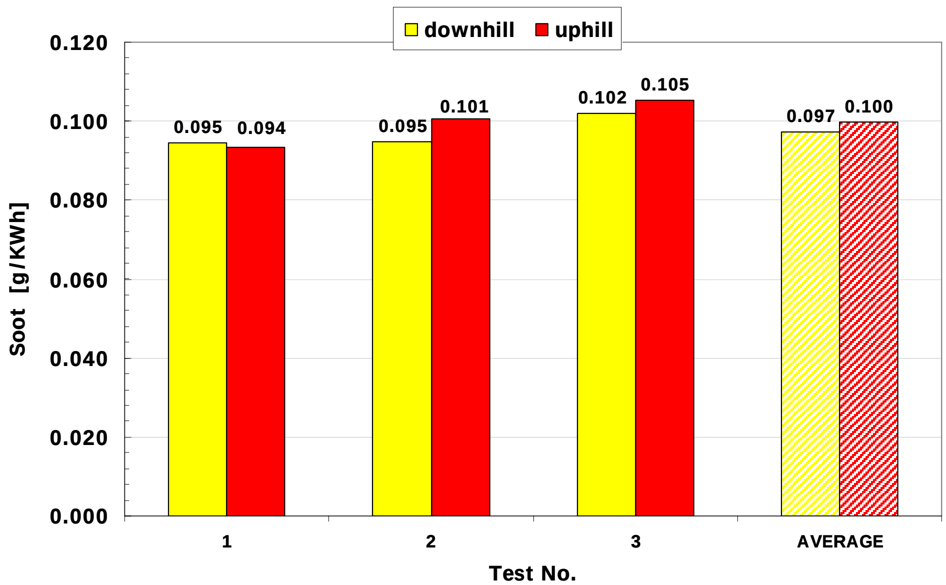
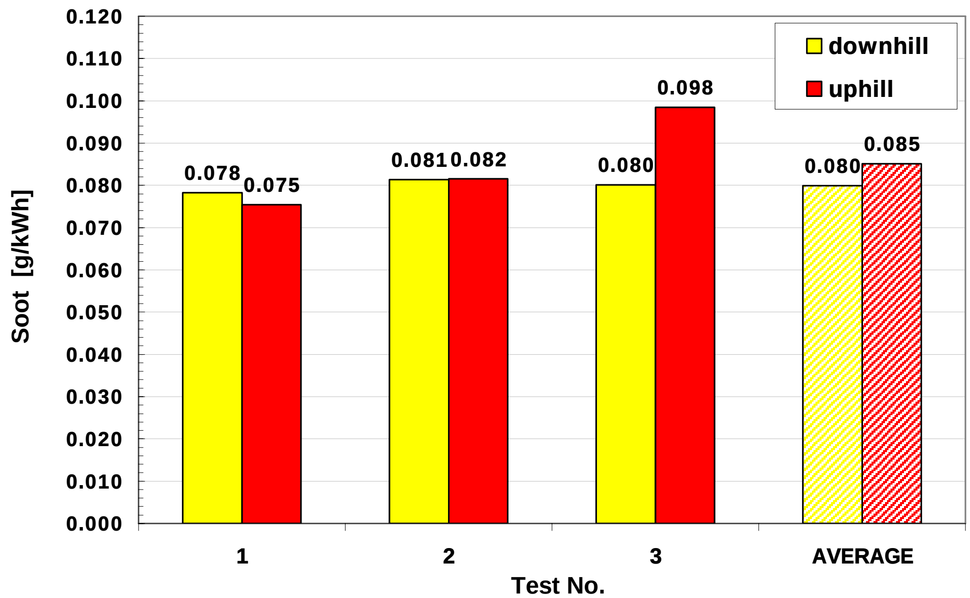


Line 17



Line 74

Figure 10: City bus PM data: total soot measurements (g/kWh) using AVL 483 MSS over three consecutive tests over line 17 and 74 distinguishing between one-way (downhill) and return (uphill); average values are reported as well.

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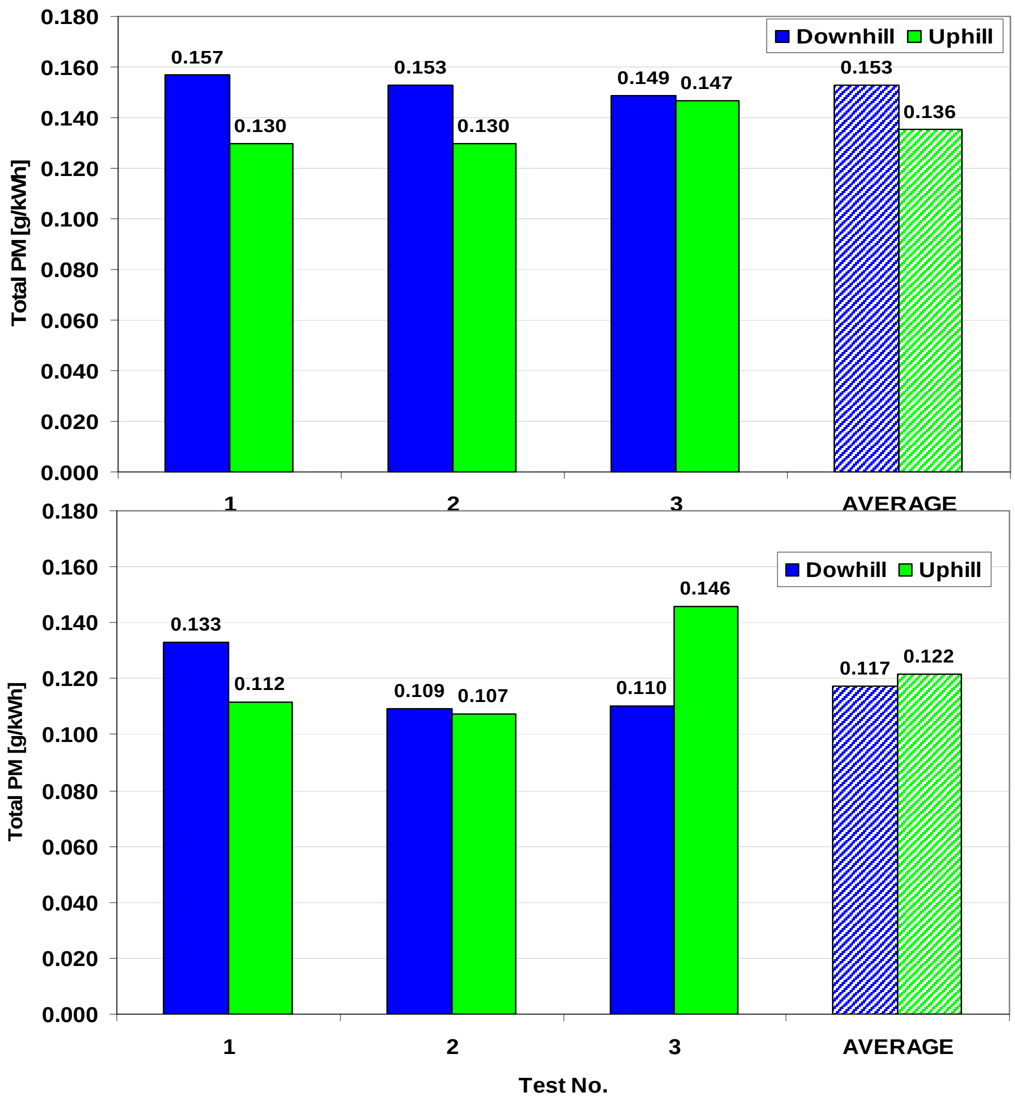

Line 17

Line 74

Figure 11: City bus PM data: Total PM mass (g/kWh) collected on filters using the Control Sistem m-PSS over three consecutive tests over line 17 and 74 distinguishing between one-way (downhill) and return (uphill); average values are reported as well.

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On-board PM measurements: Status of regulatory developments and instrumentation technology

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10th ETH-Conference on Combustion Generated Nanoparticles
Zurich, August 21st 2006

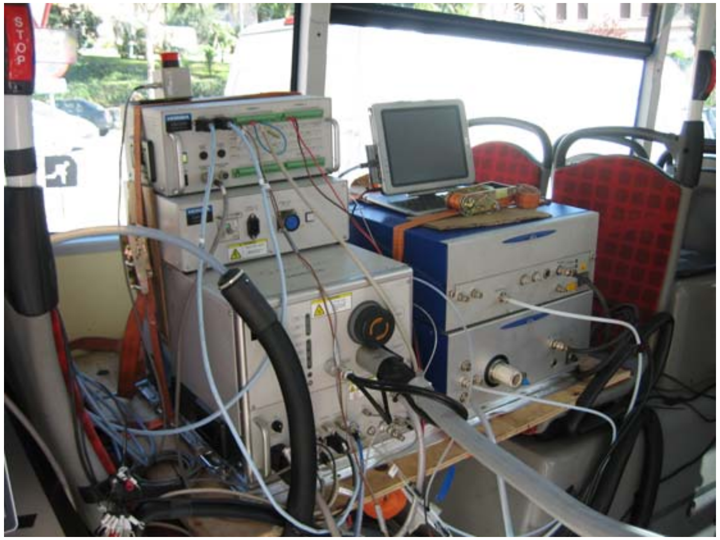
Institute for Environment and Sustainability

Contents

- Background on “PEMS”
  - Why are PEMS being introduced in the regulations?
- Status of EU and US regulations / on-going legislative programs
- On board PM
- Results
- Summary

Portable Emissions Measurement Systems (PEMS)

- PEMS includes:
  - exhaust gas analyzers / exhaust flow meters
  - heated sampling line + filtering unit
  - vehicle activity monitoring systems (GPS, ECU)
  - computer for test management and data logging



Why are PEMS being introduced in the regulations?

- Laboratory testing still the base of knowledge, homologation and development of engines and vehicles
- But… Homologation cycles cannot simulate the wide range of real world-conditions, field-testing offers an important counterpart to check the effectiveness of the official laboratory test procedures
- Testing with PEMS has become - amongst other things - the important tool to monitor the in-use conformity of large sources like heavy-duty vehicles, construction and agriculture equipment

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EU and US regulations

- EU Directive 2005/55/EC, published in October 2005, also includes amendments that allow flexibility in preparing a proposal for the introduction of in-use conformity checking of heavy-duty vehicles based on PEMS

- Development of the technical elements on-going

- US “Final Rule In-Use Testing for Heavy-Duty Engines and Vehicles” introduced in June 2005

- Part 1065 - Subpart (J, "Field Testing") specifies the instruments performance - verifications and the test protocol required to carry out on-board real world emissions measurements using PEMS

On-going legislative research programs

- EU-PEMS project [from 2004]

- EU Pilot Program for Heavy-Duty Diesel Vehicles - Currently in preparatory phase, execution from Fall 2006

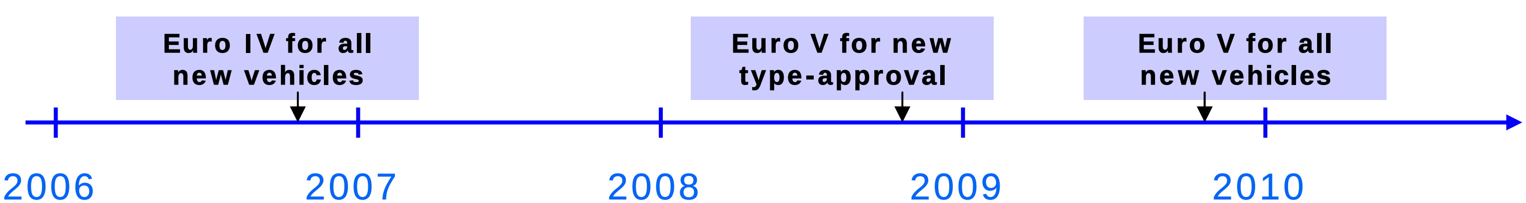
- US Pilot Program for Heavy-Duty Diesel Engines and Vehicles [from 2006]

- US Measurement Allowance Program: explores environmental conditions effects on PEMS: ambient temperature and pressure, shock and vibration, electromagnetic radiation, and ambient hydrocarbons

EU timing and milestones

Milestones of the EU-PEMS Research Program:

- **Target**: In Use Conformity Measure for **Heavy-Duty** mandatory from EURO V
  - Joint Authorities / Industry research program started in February 2004 (EU-PEMS project)
  - Conclusion of the road test campaigns for gaseous emissions in July 2005 (8 vehicles) / Reporting and first proposal finalized at the end of 2005 (for gaseous emissions)
- **EU Industry to run Pilot Program** to validate the test protocol from end of 2006 with EURO4 vehicles and engines



Issues to develop an official test protocol

- Field testing seems.....easy as ...
  - It requires rather short installation times;
  - No controlled environment is needed, you may just select a vehicle and drive once the PEMS equipment is installed.
- but also..... difficult as
  - Rough environments;
  - Calibration and data verification procedures must be adapted…. Analyzers, Exhaust Flow Meters, GPS

Development of robust test protocols

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PEMS instrumentation technology (Gaseous)

- CO2, CO > NDIR
- THC > FID
- NOx > CLD or NDUV
- Exhaust flow > Averaging Pitot
- Engine / vehicle parameters from vehicle Engine Control Unit (ECU) and/or Global Positioning System (GPS)
- Compactness: Size and weight, 40x40x30 cm and 25 - 30 kg
- Robustness
- Easiness of use

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Principles considered for on-board PM

- Optical Methods
  - Opacity
  - Laser Scattering
- Particulate Mass Collection on Filter
  - Portable diluter and filter system

    (however not continuous PM concentration)
- Real Time Particulate Mass Measurement
  - Micro-dilution and TEOM[1] / QCM[2] / ETaPS[3]
- Other: Low Concentration Soot Measurement, Diffusion Charger, etc.

(1) = Tapered Element Oscillating Microscope
(2) = Quartz Cristal Microbalance
(3) = Electrical Tailpipe PM Sensor

On-board PM

Selection criteria:

- Simple, lightweight, robust, compact / Low power consumption
- Good sensitivity for low PM concentrations
- Simple calibration and Quality Control (masses and flows)
- To match the homologation gravimetric principle (PM Mass)
- Cost Factor: low to medium

Methods selected…

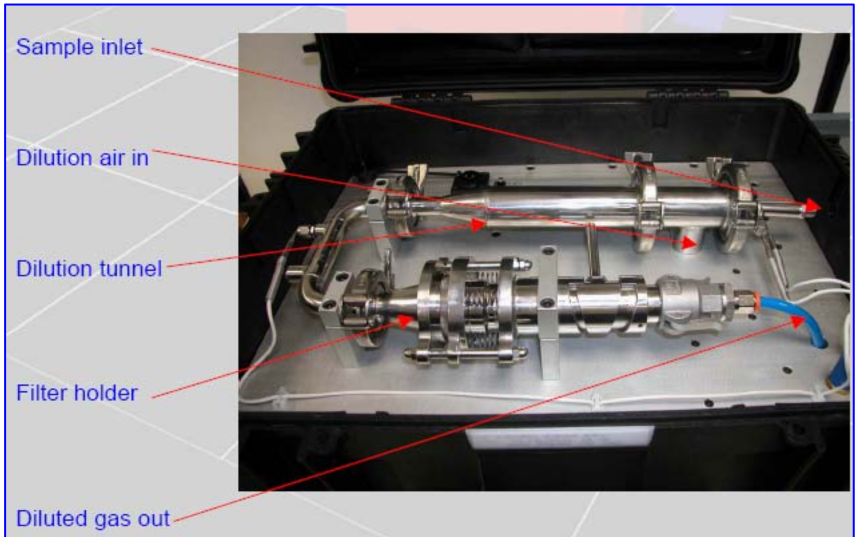
- Sampling & dilution: Proportional Partial Flow Sampling (PFS) (ISO 16183, EU HD Directive)
- PM Mass measurement
  - (1) Cumulative mass (Filter)
  - (2) "Real-time" (sec/sec) Total PM (QCM, TEOM, ETaPS)
  - (3) "Real-time" (sec/sec) Partial PM (i.e. Soot)

PM Laboratory Tests

- **Objective**: comparison between portable and "reference" laboratory instruments
- Test conditions:
  - Engine: IVECO cursor, 10.3 litre, 6 cylinder, Euro III type - No after-treatment
  - Fuels: Standard Diesel (50 ppm S), Tamoil (10 ppm S) and Bio-fuel (RME)
  - Constant Volume Sampling (CVS) - flow set to 100 m^3 with a particulate flow rate of 60 l/min
  - ETC and ESC cycles
- Instruments used:
  - PTS method (Directive, 2001), Control Sistem PSS-20 and m-PSS, AVL Smart Sampler (SPC472), Horiba MEXA 1370PM and AVL 483 Micro Soot Sensor (MSS)

Proportional Partial Flow Sampling: Micro-PSS

(a)



- PM is collected with a filter face velocity of 43 cm/s at a filter temperature of 44 ± 1ºC and a dilution factor of 14.8 (average)
- Filter holder with a filter diameter of 47mm

Real Time Soot Mass Measurement: Micro Soot Sensor (MSS)

Micro Soot Sensor AVL 483

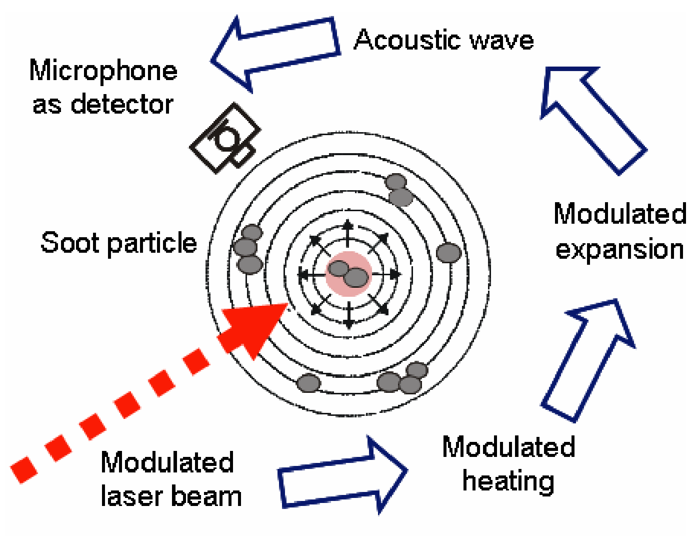


Photo-acoustic principle of operation

- Transient measurement of soot concentration with high sensitivity (detection limit ≤ 10 µg/m³, typically ~ 5 µg/m³)
- Sensor signal is directly sensitive to soot concentration
- Standard interfaces

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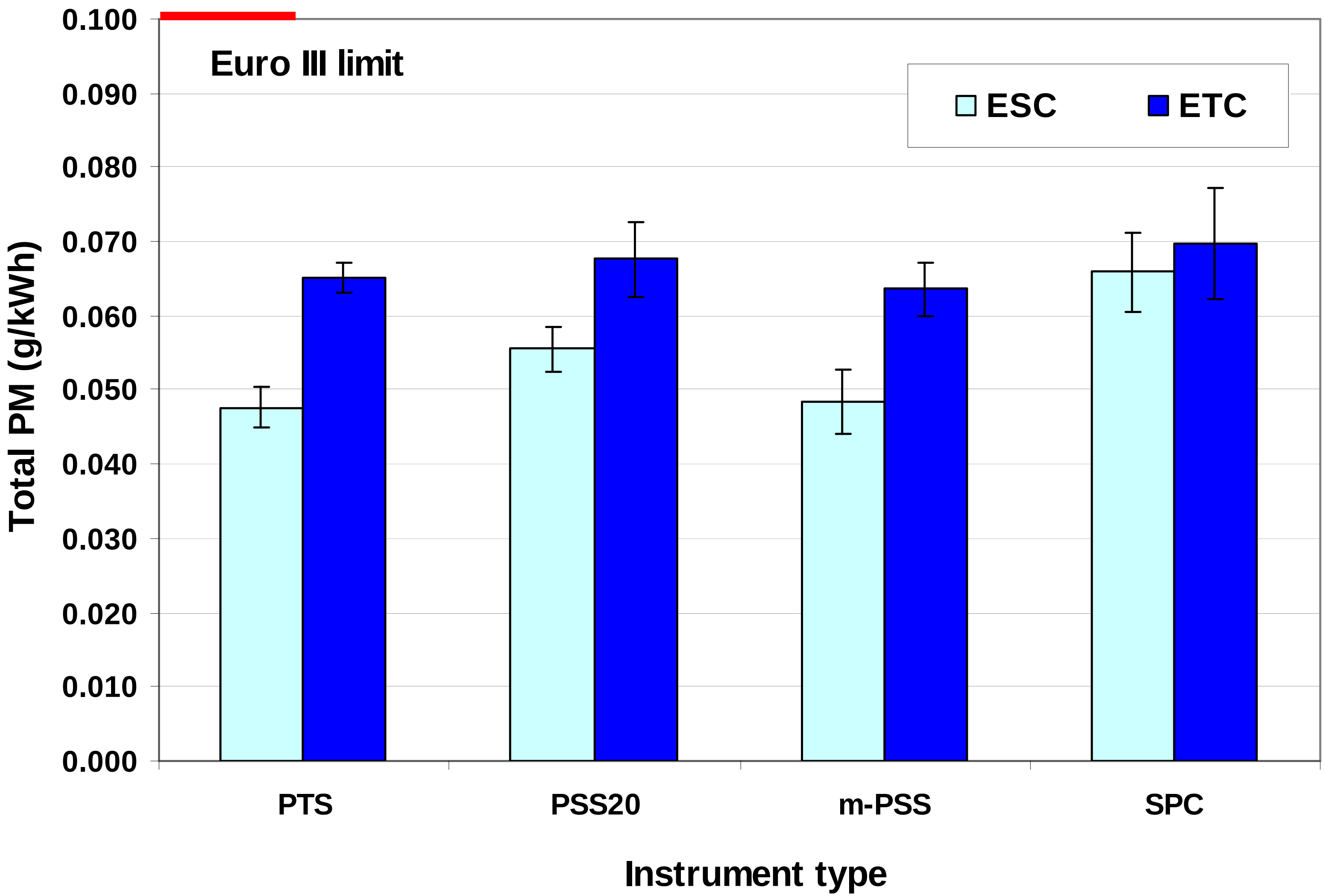
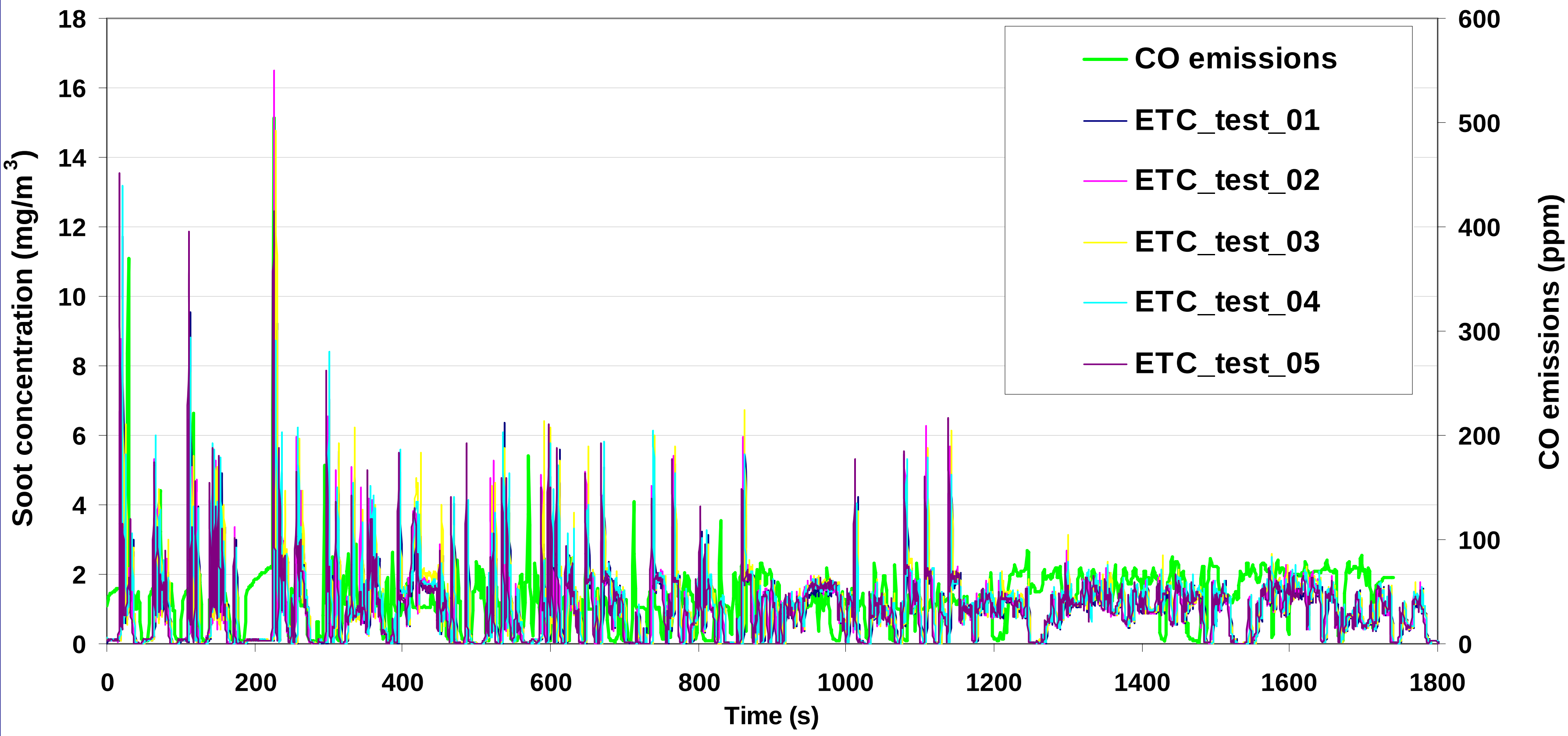
Laboratory Results: Instrument Comparison

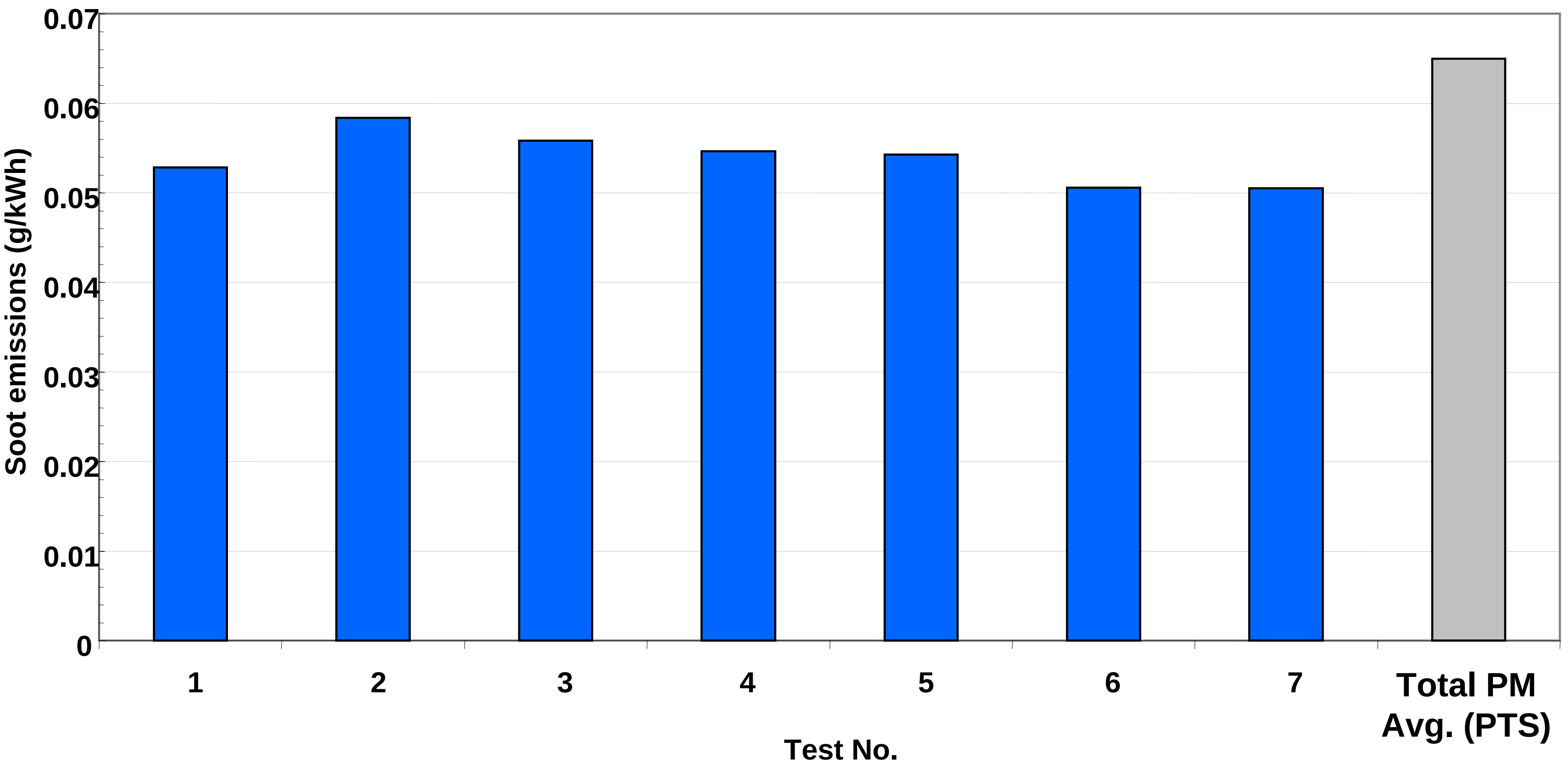


Laboratory Results: AVL 483 MSS



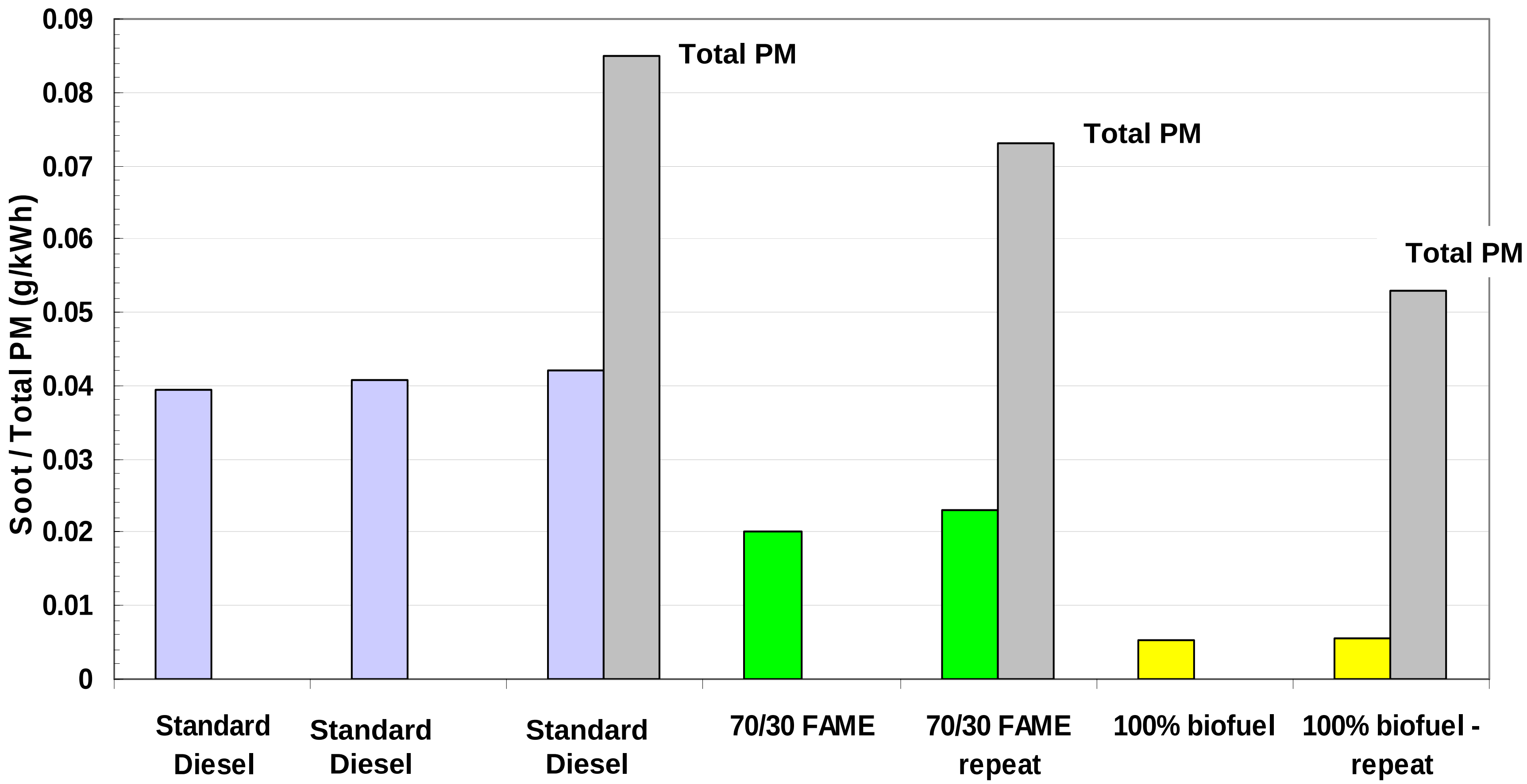
Sampling from CVS – Full dilution - ETC cycle

Laboratory Results: AVL 483 MSS



Sampling from CVS - Full dilution - ETC cycle

Laboratory Results: Fuel effect – AVL 483 MSS



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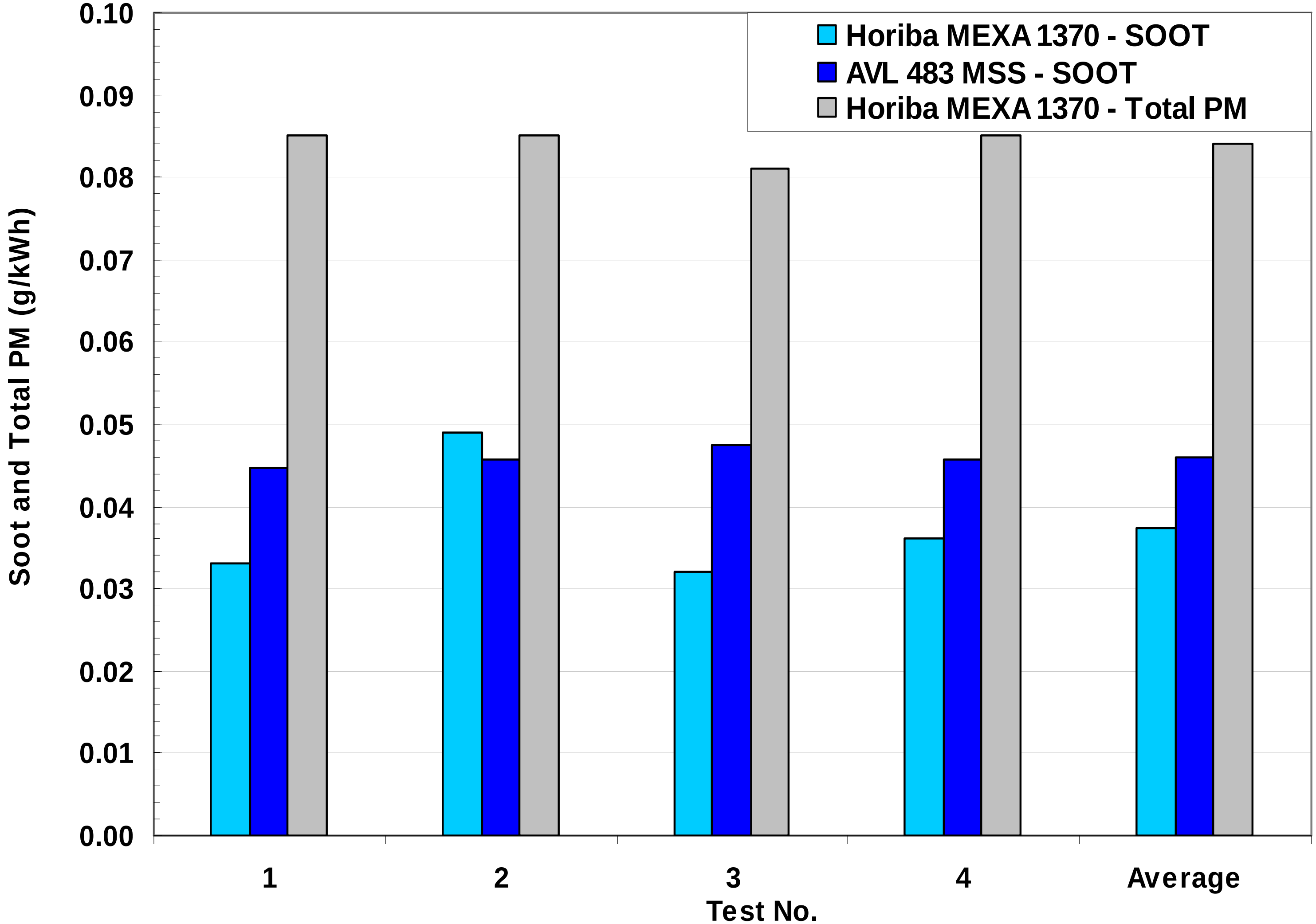
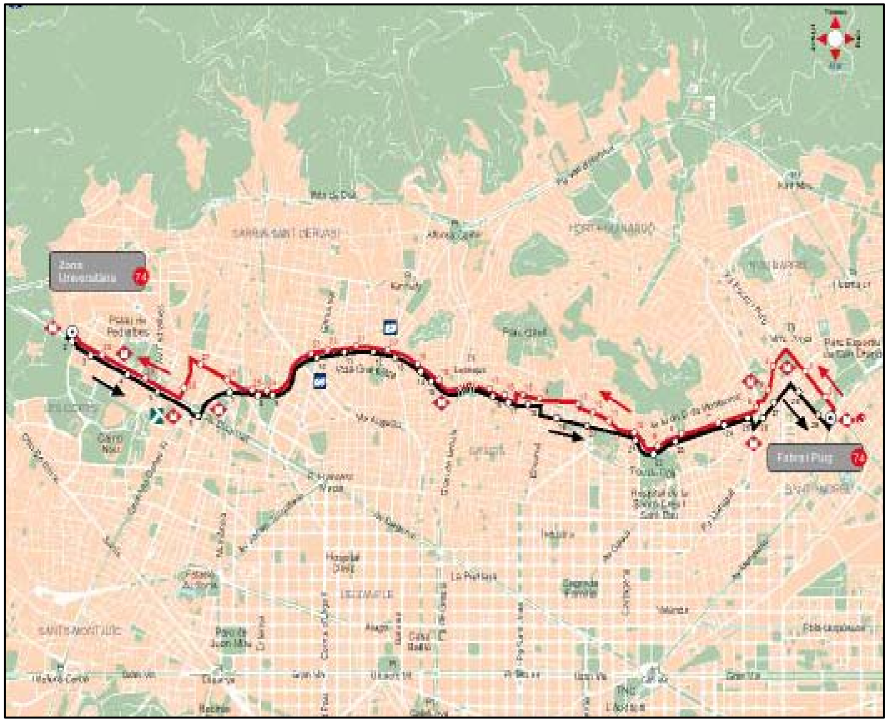
Laboratory Results: MEXA 1370PM vs. AVL 483 MSS



PM measurements on board
City Bus – Barcelona campaign

- **Co-operative and voluntary research effort from all participants**
(DG JRC, IDIADA, MAN, IVECO, TMB, AVL, Sensors, Horiba, Control Sistem)

Line 17
Fabra i Puig – Av. Diagonal



Line 74
Av. Jordà – Barceloneta

On board PM Measurement

- Averaging Pitot, directly measuring exhaust mass flow (EFM) on the vehicles / Interface with the Proportional Flow Sampling System
- Instruments: Control Sistem m-PSS & AVL 483 MSS

EFM

Micro-PSS

AVL 483 MSS

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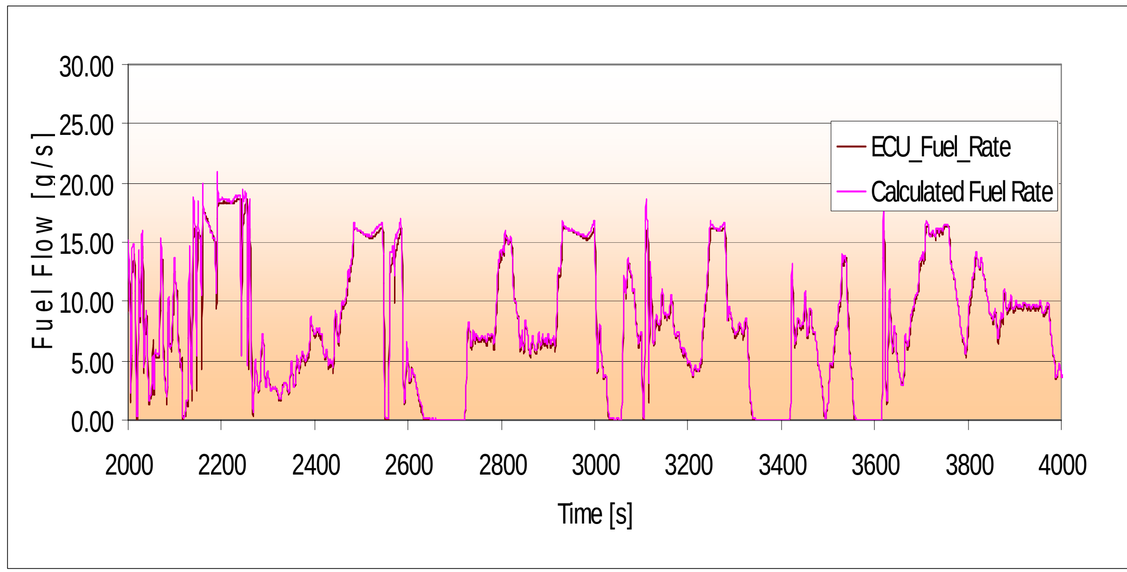
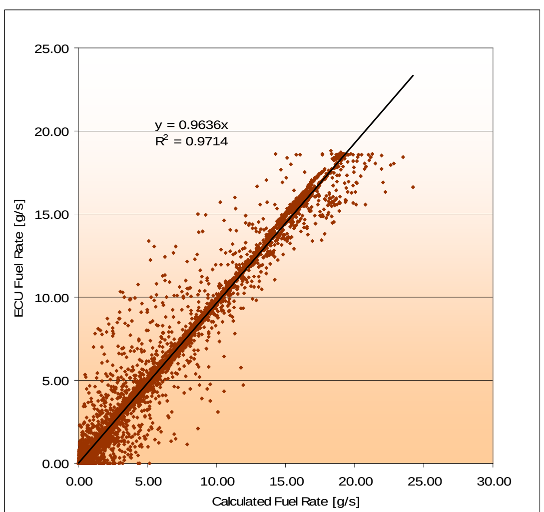
On board Exhaust Flow Measurement

- Averaging Pitot, directly measuring exhaust mass flow
- Interface with the Proportional Flow Sampling System (i.e. exhaust flow signal used as input for the control of the PFS)





- **Quality** of exhaust flow measurement is essential / **Verification** of the directly measured exhaust mass flow vs. calculated.

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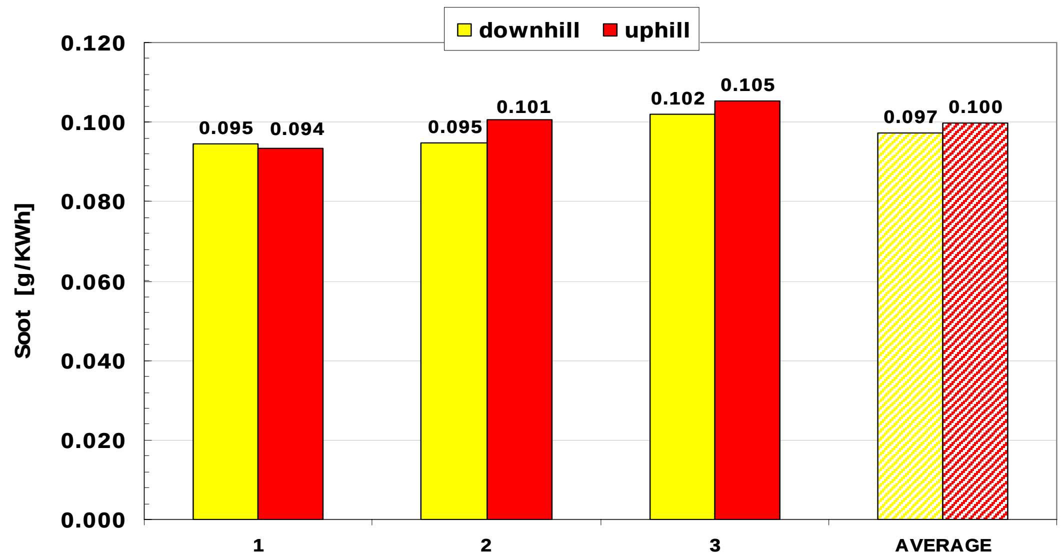
Soot measurements on board - City Bus – AVL 483 MSS



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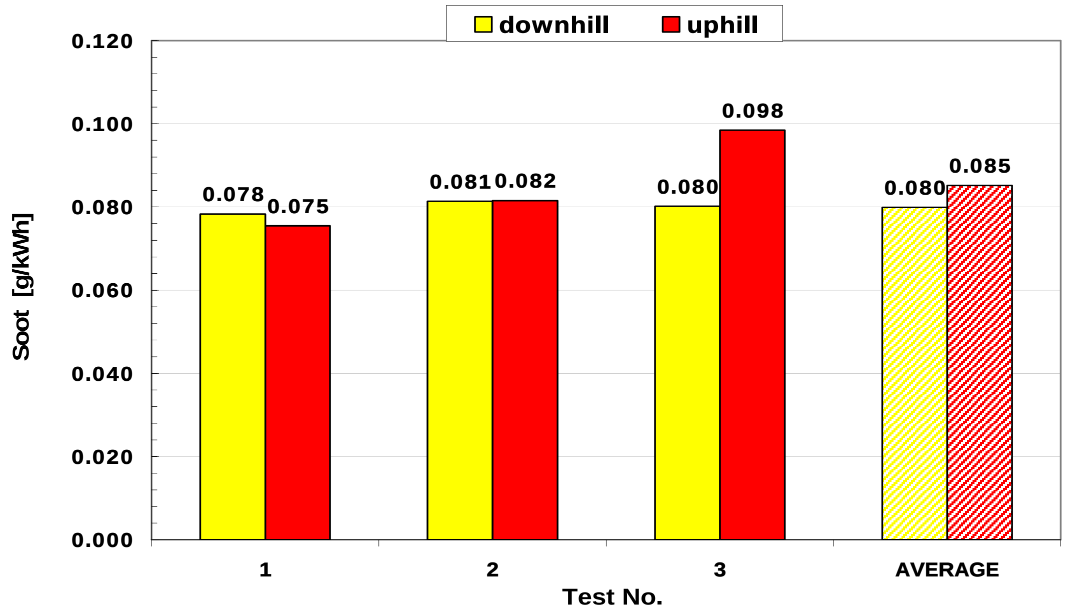

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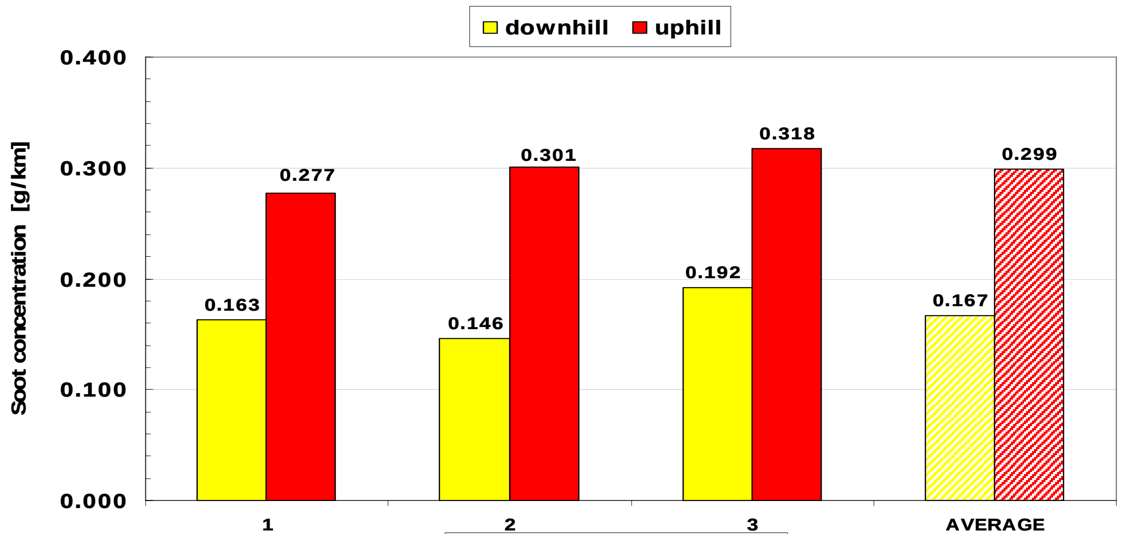
Soot measurements on board - City Bus – AVL 483 MSS



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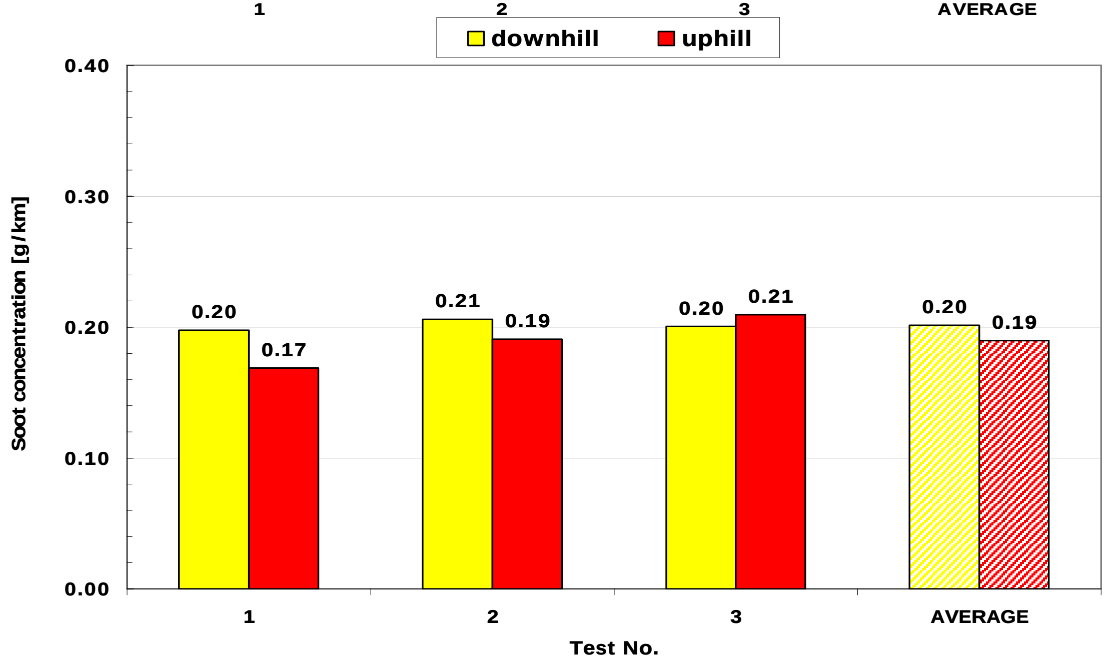

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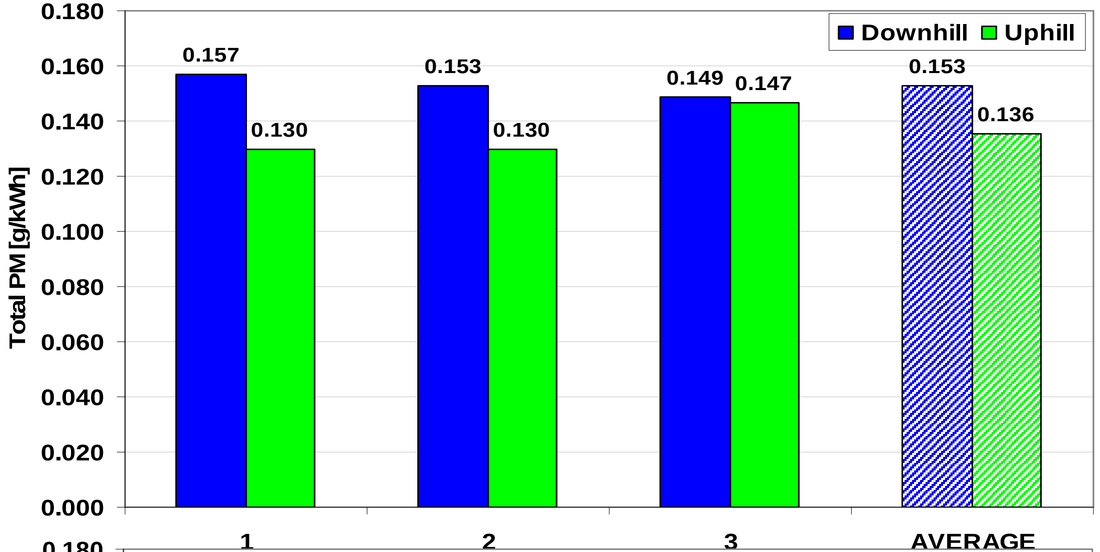
PM measurements on board - City Bus - micro-PSS



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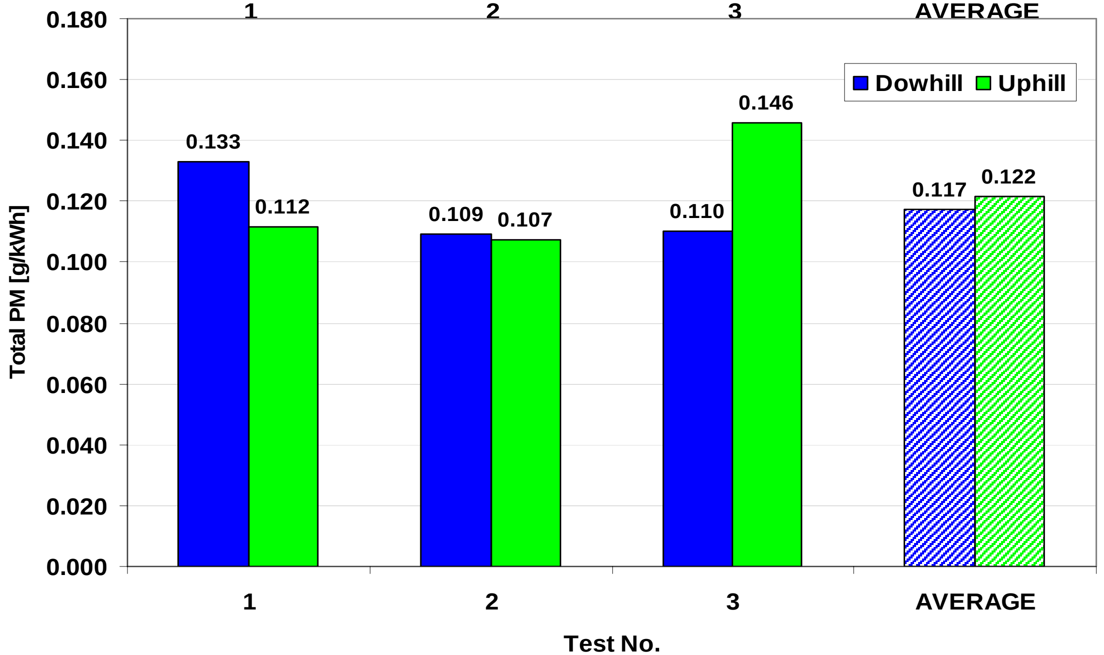

Line 74

Summary (I)

- **Laboratory PM mass measurements** from a Euro III heavy-duty engine (IVECO Cursor, 10.3 litre) were carried out over both ETC and ESC cycles with different fuels
- Gravimetric and non gravimetric methods were used for PM mass measurements using full dilution within the CVS and partial flow sampling (PFS)
- Control Sistem PSS-20 and micro-PSS, AVL Smart Sampler (SPC 472), AVL 483 MSS and Horiba MEXA1370 were used for PM mass measurements
- Good agreement was found between gravimetric and non-gravimetric PM mass measurements
- The AVL 483 MSS was particularly suitable for measuring low soot concentrations
- The use of bio-fuel showed good reduction on soot - CO emissions showed a trend similar to soot

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Summary (II)

- **Preliminary on board PM measurements** on Euro III HDD City-buses (IVECO) on two test routes in downtown Barcelona showed good repeatability using both AVL 483 MSS and Control Sistem m-PSS

- A robust and well developed test protocol is under development

- Further PM testing and data analysis is on-going both in the laboratory and "on board" to better address issues related to PM measurements at low concentrations and over transients

- Euro IV HDD trucks testing from November 2006

- Manufacturer-run PEMS pilot test programme from Fall 2006

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Acknowledgements

Many Thanks…:

- VELA "Heavy-Duty" team, in particular, Pierre Bonnel, Massimo Carriero, Francois Montigny, Ivano Fumagalli

- PEMS instrument manufactures (Sensors inc., AVL, Control Sistem, Horiba) and engine manufactures (IVECO)

- IDIADA and Metropolitan Transports of Barcelona (TMB)

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Thank you for your attention!

- More details on the **EU-PEMS project** can be found at:

http://ies.jrc.cec.eu.int/eu-pems.html
http://ec.europa.eu/enterprise/automotive/pems_meetings/index.htm

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