

## Paper/Poster-Abstract Form

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Title: Monitoring and Managing of PM Emissions

Abstract: (min. 300 – max. 500 words)

The economic and societal costs of PM emissions around the world have been well documented and the cost/benefit analysis strongly supports action. PM is produced by both diesel and petrol engines and action needs to be taken to reduce both sources. The emission regulators around the world have appropriately tightened the emissions laws but verification testing has not caught up. The challenge is to remove the high PM emitters from the population of diesel and petrol engines and use our public and private funds for PM-reduction technologies and devices in the most effective way possible. Currently PM is not tested in petrol engines and when diesel engines are tested in current I/M programs the opacity type measurement device is not sensitive enough measure at the new low level (down to 0.01 mg/m<sup>3</sup>) of PM emissions reliably. The test and the tester must be capable of producing valuable data at low total cost per test to build a useful and statistically significant database for this purpose. In all types of engines the inspection & maintenance (I/M) type testing is the way to build the necessary database. The benefits of an I/M program is early detection of problems with OEM installed and retrofit technologies and devices, the identification of high polluters that cause most of the PM emissions and a side benefit is improved maintenance that reduces fuel consumption. An example of a successful program is the report in October 2007 of several PM traps failing to perform in testing by the German UBA (EPA). The result of this testing was swift and effective, the defective units or even entire product lines were replaced.

There are several tests that are simple, fast and with a long history of success to support using them for I/M testing. If a testing program exists and is using loaded dynamometer testing such as ASM, IM240 or truck "Lug down" then these will work very well for this purpose. As in many areas that do not have a loaded-mode program running then the two-speed (free acceleration) test also works well.

There are devices now available in the market that meets all of the necessary criteria to measure PM: a high enough sensitivity to distinguish a properly functioning motor with DPF (Diesel Particulate Filter), easy to use and low cost.

Pilot projects are now in-process in California, Australia and Germany to get gain experience before the instruments are in widespread use.

# Monitoring and Managing of PM Emissions

Presenters: Antonio Multari and Elmar Tschinkel Authors: Antonio Multari, Elmar Tschinkel and Mark Olson  
13<sup>th</sup> ETH Conference on Combustion Generated Nanoparticles, June 22-24 2009



MAHA Maschinenbau Haldenwang

## Background:

The economic and societal costs of harmful fine particulate (PM) emissions around the world has been well documented and the cost/benefit analysis strongly supports regulatory action. Fine particulates are produced by both diesel and petrol engines and significant action is needed to reduce both sources. Emission regulations around the world have appropriately tightened PM emissions laws but in-use verification testing has lagged behind.

## What is missing?

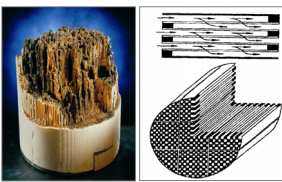
- An in-use HGV and LDV PM-concentration database that is statistically significant
- Testing petrol engines for PM, to fix or replace the worst and create a useable database
- Changes to the diesel I/M program test methods and limits that reflect the current emissions regulations and technologies.
- Appropriate testing beyond the manufactures guarantee period which is most of the functional life of the engine

## Finding the Mobil Sources of PM Pollution

### Early detection of Problems

DPF (Diesel Particle Filter) should deliver a reduction in particle emissions of:  
> 30% to 50% (unregulated/retrofits)  
> 99% (regulated/integrated with EMS)

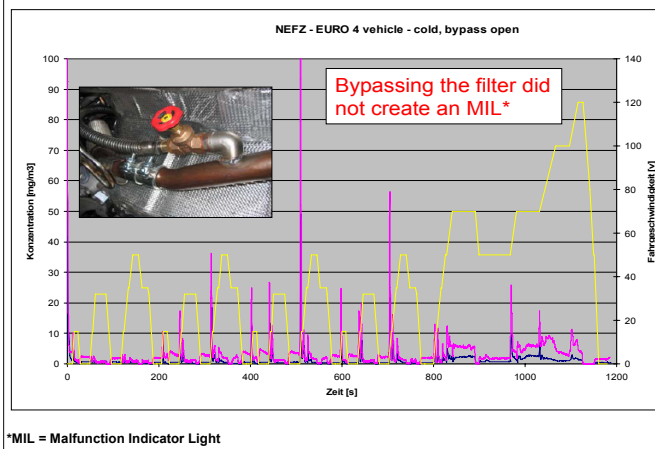
The condition and function of filters must be monitored.  
Excessive heat or shock can damage the ceramic core



Source: A. Mayer, TTM, Switzerland

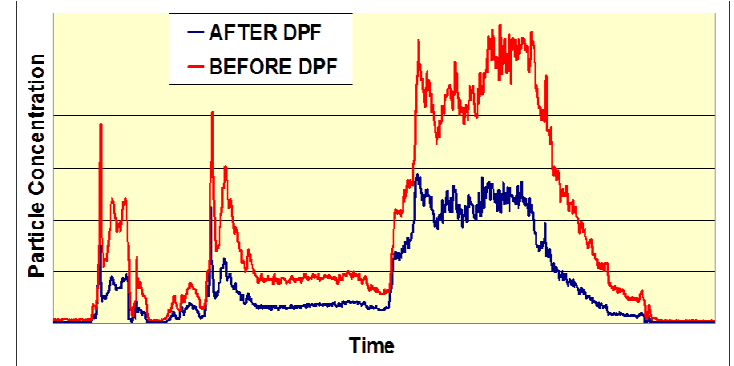
An example of a successful program is the report in October 2007 of several PM traps failing to perform in testing by the German UBA (EPA). The result of this testing was swift and effective, the defective units or even entire product lines were replaced.

### Test Simulating a Failed PM-Filter System



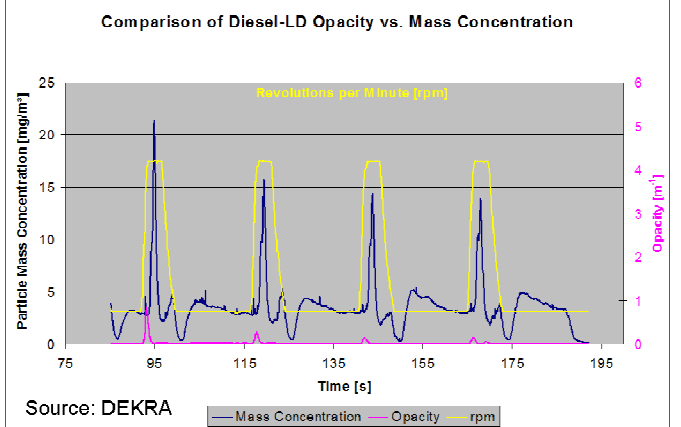
### Testing Sample: "Retrofit filter system"

Results BEFORE and AFTER Diesel Particle Filter (DPF)



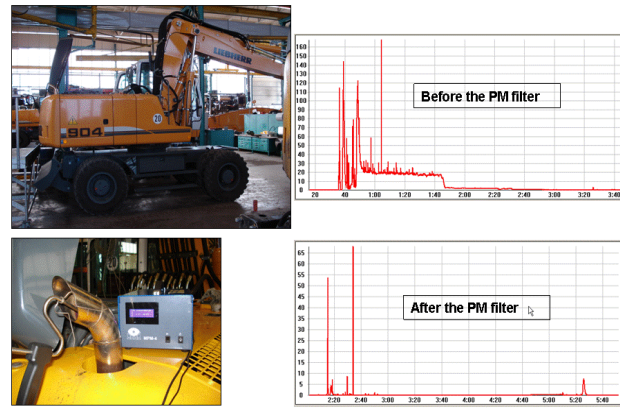
## Beyond Opacity Meters

### Opacity meters lack the sensitivity for measuring clean diesels



## Off-Road Opportunities

PM measurement with off-road HDD from LIEBHERR Model: Bagger A 904 C, MY 2008, with PM filter



## Petrol Vehicles

### Petrol Powered Vehicles

are currently **not measured** for PM emissions. But in many areas they are the source for a large amount of the urban source PM which effects a large number people in our increasingly urbanize societies.

MAHA is currently involved in a pilot program to test petrol powered vehicles.

### Pilot Program in California (SCAQMD, CARB, FCCC and MAHA) since 07/2008

- One MAHA 4WD ASM
- Three MAHA Particle Measurement Units MPM 4 at Referee Stations (LDV) and one at CARB
- Evaluation of feasibility for inclusion in California's Smog Check Program
- Correlation testing between FTP and MAHA Particle Measurement/ MAHA 5 Gas Analyzer performed by CARB



## CARB-Comparisons of Real-Time Instruments and Gravimetric Measurement on Light Duty Gasoline Vehicles

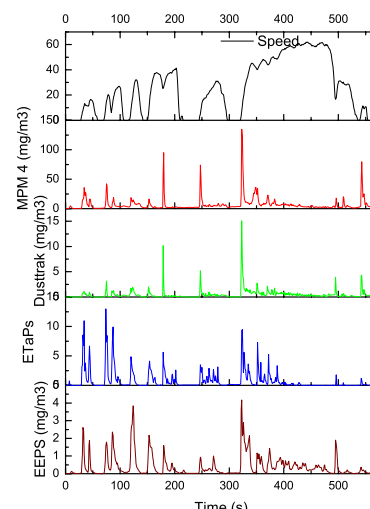
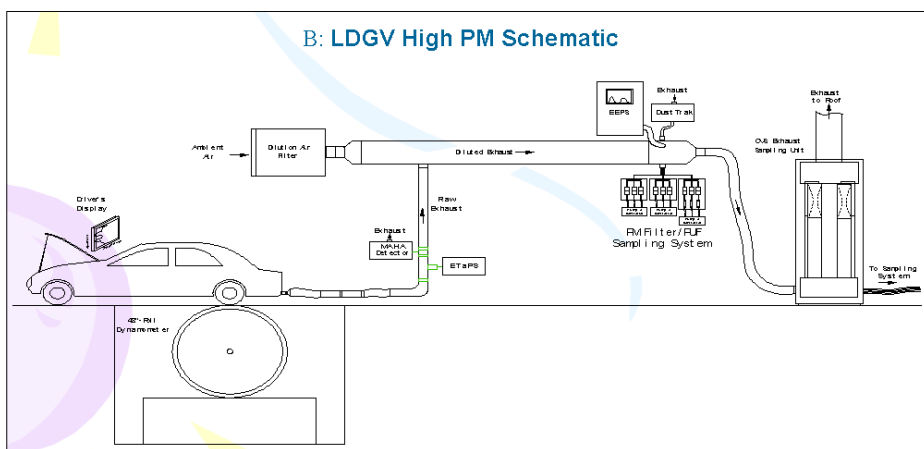


Figure 1. Real-time PM instrument response in a UC test (Vehicle 3, UC, Test # 3, first 550 seconds)

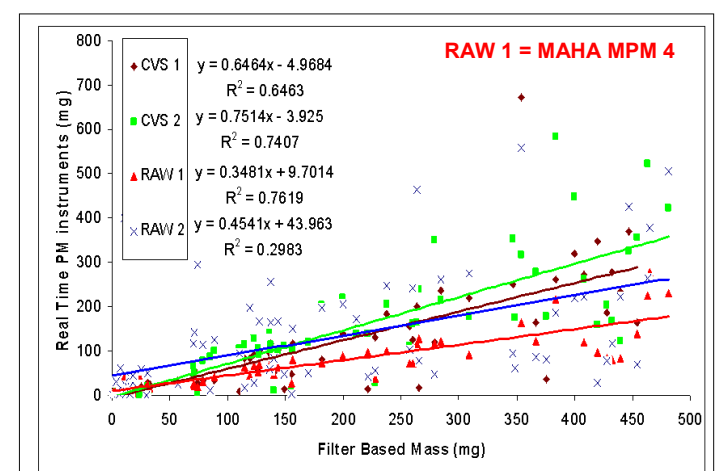
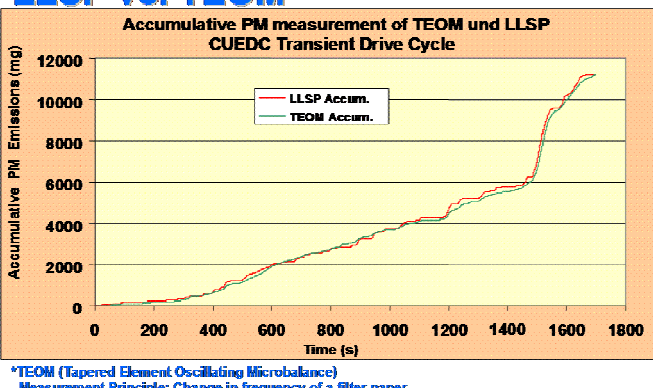


Figure 5. Correlation between real-time instruments measured PM mass vs filter based PM mass.

## Multiple Correlation Sources

### Laboratory Instrument Correlation

#### LLSP vs. TEOM\*

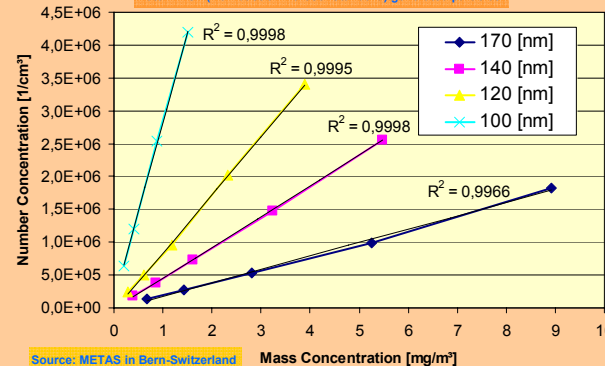


\*TEOM (Tapered Element Oscillating Microbalance) Measurement Principle: Change in frequency of a filter paper

### Size Characteristic

Correlation number concentration vs. Mass concentration

Note: CAST (Combustion Aerosol Standard) generated particles

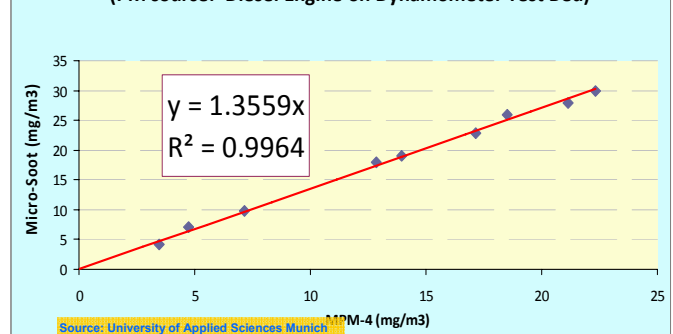


Source: METAS in Bern-Switzerland

### Correlation: AVL Micro-Soot vs

MAHA MPM-4 PM Concentration

(PM source: Diesel Engine on Dynamometer Test Bed)



Source: University of Applied Sciences Munich