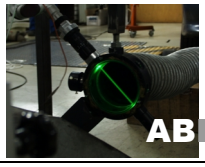
L.-E. Schulte
RWTÜV
Essen
Germany

4

ABEME-PM measurement system for the evaluation of extremely low emission vehicles



5. ETH Conference on
Nanoparticle Measurement

6th August 2001, Zürich

Dipl.-Ing. Leif-Erik Schulte
RWTÜV Fahrzeug GmbH
D-45032 Essen

ABEME

Abgaspartikelmeßverfahren zur Bewertung von Fahrzeugen mit Minimalemission

PM measurement system for the evaluation of extremely low-emission vehicles

1. Introduction

The worldwide importance of (ultrafine) particulate emissions has been the subject of increasing attention over the last few years and the discussion of which parameters are important for a health-effect-based PM characterization is still ongoing worldwide. Methods of both potential and actual use in the sampling, analysis and characterization of particulates are being examined in a large number of projects.

New generations of diesel and direct injection petrol engines mean that there is a need for appropriate measuring techniques for particulates. The current medical knowledge with regard to the health effects of particulates and air quality criteria studies shows that the PM measurement methodologies used for the today's type approval process are no longer capable of meeting the requirements of tomorrow.

Government agencies / authorities, regulators, technical services and whole industries are being forced to move new measurement technologies away from laboratory status into the type approval procedure.

It has to be ensured that future very low, strict and certainly supplemented emission limits can be monitored in an appropriate way, acknowledging the potential health hazards of such emissions.

For all these reasons **ABEME** was established in 2000 with the support of the *German Ministry of Education and Research bmb+f (Project No. 19 U 0053)* and the *German Engineering Federation VDMA* as an interdisciplinary consortium of vehicle / engine manufacturers, measurement system manufacturers and OEM's, research institutes and NGO's in order to investigate on the possibilities of alternative particulate characterization methods.

At the moment the following project members are involved in **ABEME**:

• BMW • DaimlerChrysler • Deutz • Ford • MAN Nutzfahrzeuge
• Opel (General Motors) • Volkswagen

• AVL List • Bosch • Kolbenschmidt Pierburg (Pierburg Instruments) • Sensors Europe

• Fraunhofer Gesellschaft – Institut für Toxikologie und Aerosolforschung (FhG – ITA)
• Lehrstuhl für Technische Thermodynamik (LTT),
Friedrich-Alexander-Universität Erlangen-Nürnberg

• VDMA – Gesellschaft für Forschung und Innovation (VFI)
• RWTÜV Fahrzeug GmbH, Institut für Fahrzeugtechnik (IFT)
} **ABEME** Administration

2. Intention / Timetable

2.1 Pre-Project Study

The intention of **ABEME** in the first project stage (pre-project study) was to gather extensive knowledge of all existing measurement systems and to conduct an assessment / verification of these systems for both the R&D and the type approval process combined with a description of the parameters needed for future particulate limits in the light of current air criteria knowledge. The goal of the **pre-project study** was intended to define the performance specifications for new methodologies as well as put forward a proposal for a candidate system / sensor.

The pre-project study was performed by the Fraunhofer Gesellschaft – Institut für Toxikologie und Aerosolforschung (FhG – ITA) / *Fraunhofer Gesellschaft – Institute of toxicology and aerosol research* in conjunction with the project administration (*RWTÜV*).

The pre-project study was started in October 2000. The pre-project-study report is expected to be published shortly.

2.2 System and procedure development

In a second step the candidate system(s) will be evaluated and developed in the **system and procedure development phase**. Using the findings and conclusions of the pre-project study the aim of this project part is:

• to develop a new particulate matter assessment with special regard to health effects / hazards and air quality criteria

• to develop an ultra-sensitive, high-resolution sensor tailored to future extremely low emission standards

• to realise an advanced particulate matter characterization without influencing PM formation / without artefacts

• to introduce an on-line measurement system for particulates which could be used in both the R&D and the type approval process

• to ensure a reliable and practicable calibration on the candidate system

• to obtain a sensor system at a reasonable price

In order to shorten the development time for a new sensor the consortium decided at the start of **ABEME** that a candidate system with good prospect of success should be developed in parallel to the pre-project study.

The methodology considered as possible in advance is Laser-Induced Incandescence (LII) developed and supported by the Lehrstuhl für Technische Thermodynamik (LTT), Friedrich-Alexander-Universität Erlangen-Nürnberg / *Institute of Technical Thermodynamics (LTT), University of Erlangen-Nürnberg*.

The development is progressing well and is based on the premise that a change-over to every other sensor principle or to an additional sensor will be possible as a result of the findings of the pre-project study.

The basic principle of time-resolved laser-induced incandescence (TIRE-LII) is the heating up of the soot particles by means of a highly energetic laser pulse to temperatures of about 4000-4500 K and detection of the enhanced thermal radiation with particular high temporal resolution. From the shape of the signal curve two different parameters can be determined simultaneously. The peak height can be used to determine the local soot mass concentration without the measurement volume and from the temporal decay during particle cooling the specific surface of the soot particles, mainly determined by the primary particle size, can be evaluated. For this purpose, light absorption, heating and cooling of the particles have to be modelled in order to obtain an unambiguous correlation between the signal decay time and the primary particle size.

The **system and procedure development phase** was started with preliminary work in parallel to the pre-project study and is scheduled for completion at the end of October 2002.

2.3 Testing and validation program

The third stage of **ABEME** is planned as **testing and validation program.** The schedule for this part consists of engine and chassis dynamometer testing and examinations at the laboratories of *RWTÜV* and *LTT*. The final step is a round-robin test in which the consortium partners will give more detailed information about the applicability of the candidate system. The testing and validation program is scheduled for the period April 2002 to April 2003.

During the ABEME project interim reports will be published at frequent intervals according to the project stages. The final report is expected to be published in October 2003.

3. Current project status

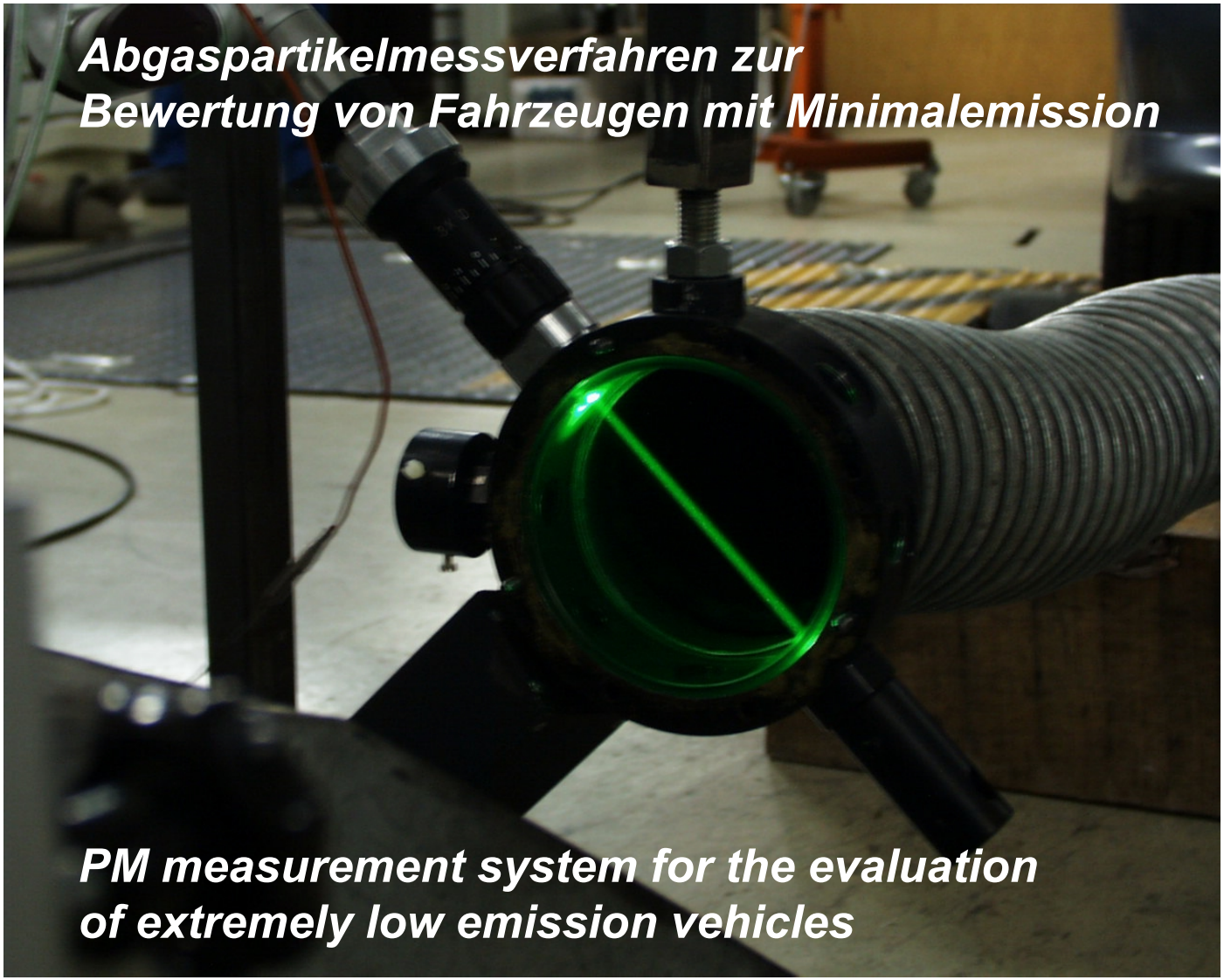
The current project status reveals good process, the pre-project study was finished on schedule. The findings and conclusions finalized are expected to be published in August 2001. The (pre-) LII-sensor principle development was performed in parallel to the pre-project-study. The existing sensor has reached a very good working laboratory / prtototype state and is to be improved and optimised. At the moment the lowest measurable concentration range is << **100µg/m³** with a time resolution **< 1sec**.

Other development activities include the improvement of the calibration procedure (against existing metric mass based systems traceable to international standards, available aerosol generators etc.) as well as the optimisation of the sensors' sensitivity/accuracy, repeatability and reliability. Furthermore the recent consortium research is orientated towards combination of the LII principle with other optical methodologies to extend the list of the available measurement parameters.

For further information about **ABEME** contact:

RWTÜV Fahrzeug GmbH, Institut für Fahrzeugtechnik, P.O. Box. 10 32 61, D-45032 Essen
Tel.: ++49 / (0) 201 / 825 / 4129, Fax: ++49 / (0) 201 / 825 / 4109
e-mail: L.Schulte@rwtuev-fz.de

RWTÜV



ABEME

5th Conference on Nanoparticle Measurement

6th August 2001
ETH Zürich

Study Group

ABEME is an interdisciplinary consortium of:

VEHICLE AND ENGINE MANUFACTURER

BMW / DaimlerChrysler / Deutz / Ford / MAN Nutzfahrzeuge / Opel (General Motors) / Volkswagen

MEASUREMENT SYSTEM MANUFACTURER / OEM´s

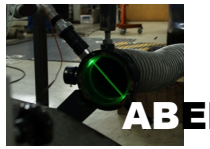
AVL List / Bosch / Kolbenschmidt Pierburg (Pierburg Instruments) / Sensors Europe

RESEARCH INSTITUTES

Fraunhofer – Institut für Toxikologie und Aerosolforschung (FhG-ITA)
Lehrstuhl für Technische Thermodynamik, Erlangen (LTT)

NGO´s

VDMA - Gesellschaft für Forschung und Innovation (VFI)
RWTÜV Fahrzeug GmbH, Institut für Fahrzeugtechnik (IFT)



Aim / Intention (1)

Pre-Project-Study

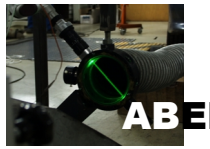
- to gather extensive knowledge of all existing measurement systems for particulates and to conduct a verification of these instruments

- to define the performance specifications needed for new methodologies incl.
  - measurement parameters
  - definition of „particulates“

(soluble?, volatile?, solids?, <52°C?, etc.)

- to propose a candidate sensor / system

(potential analysis)



Aim / Intention (2)

System and Procedure Development

- to develop a new particulate matter assessment with special regard to health effects and air quality criteria

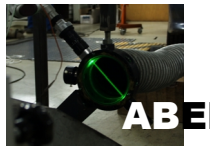
- to develop an ultra sensitive system tailored to future extremly low emissions standards

- to realise an advanced particulate matter characterization without influencing PM-formation / without artefacts

- to introduce an on-line measurement system für particulates which could be used in both R&D and type approval

-to ensure a reliable and practicable calibration on the new system

-to obtain an easy handling sensor system at a reasonable price



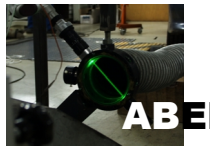
Aim / Intention (3)

Testing and Validation Programme

Sensor verification through

chassis dyno / engine dyno measurement programme

- on passenger cars / HD engines
- on otto-cycle / diesel-cycle engines
- on advanced vehicles / engines with and without aftertreatment systems

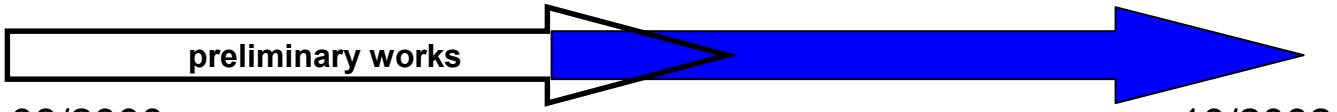


Schedule

1. Pre-Project-Study

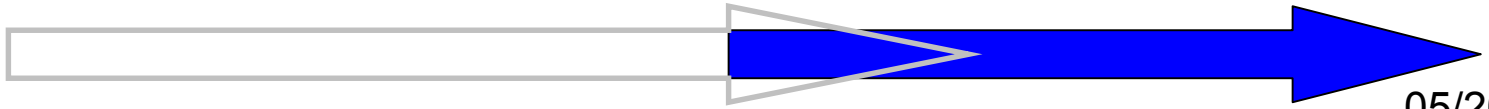
10/2000 08/2001

2. System and Procedure Development

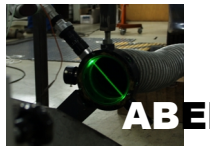


08/2000 07/2001 10/2002

3. Testing and Validation Programme



04/2002 05/2003



LII - Sensor

-Laser-induced incandescence (LII) is based on the analysis of the enhanced thermal radiation of the PM-material after heating with an intense laser pulse.

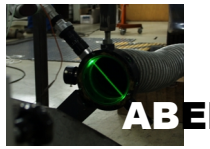
-Beside carbon mass concentration, also the primary particle size/surface and primary particle number concentration is accessible by this technique

- applicable in the raw and diluted exhaust gas (in-situ measurement)

- high temporal resolution for transient / dynamic cycles (on-line measurement)

- high sensitive on carbonaceous components

- simultaneously monitoring of different parameters possible



Current Project Status

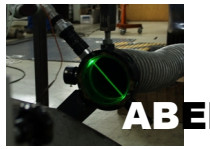
- Pre-Project-Study is due to be on schedule; conclusions / findings expected to be published at the end of July 2001

Fraunhofer ITA Institut Toxikologie und Aerosolforschung Pharmaforschung und Klinische Inhalation

- LII-Sensor development runs parallel to the Pre-Project-Study since the funding of ABEME System and Procedure Development to be started shortly

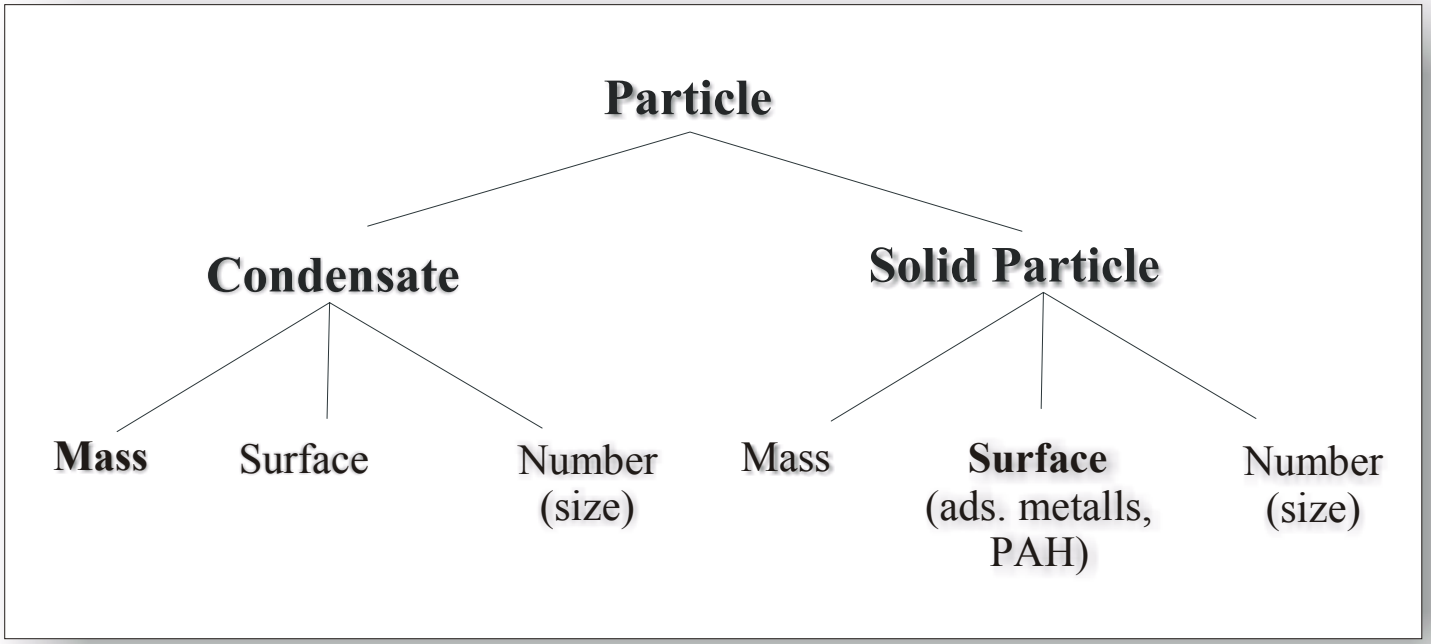
preliminary works

- system development (test bench prototype sensor available)
- measurement programms (correlation programs to existing systems)
- correlation / calibration against existing mass metric related systems



Pre-Project Report / first extracts (1)

Inferences from the health effects discussion



Fraunhofer ITA Institut Toxikologie und Aerosolforschung
Pharmaforschung und Klinische Inhalation

Pre-Project Report / first extracts (2)

Specific basic requirements: Health effects point of view

- It should be distinguished between soluble and insoluble fraction. Mixing both makes no sense.
- If the soluble material is considered too, this should be done on a mass basis. This fraction has to be judged material specific (e.g. to distinguish between water and organics).

Fraunhofer Institut Toxikologie und Aerosolforschung
Pharmaforschung und Klinische Inhalation

Pre-Project Report / first extracts (3)

Specific basic requirements: Practical point of view

- The solid fraction should be assessed on a mass and surface basis (link to historical data, conservation of quantity, health effects).
- The chosen metric should have an unequivocal relation to parameters measured (and regulated) in urban atmosphere (conservation of quantity).
- For practical reasons and because it is not necessary: No size resolved results, only one value (no size distribution!) should be given.
  - Relevant size range for solid particles from burning processes is normally in the range of 50 to approx. 300 nm.
  - From health perspective there is no reason to exactly determine size.

Fraunhofer ITA Institut Toxikologie und Aerosolforschung
Pharmaforschung und Klinische Inhalation

Future Activities

- Further development of the LII / candidate system depending on the findings of the pre-project-study
  - sensor improvement / optimisation (performance specifications)
  - measurement / comparision / correlation -programms
  - progress on the extension of available LII-sensor signals

    current stage:
    - mass of elementary carbonaceous material
    - primary particle size
    - primary particle number concentration

    recent activities:
    - *consideration of sensor extension through combination with other optical methodologies (extension of LII-sensor / combination of sensors)*

  - investigations on sensor calibration procedures
    - against existing mass metric related systems traceable to intern. Standards

      (coulometry, gravimetry etc. ⇒ Reference ?)
    - against available aerosol generators etc.