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Fine PM CEMS Evaluation Study
Status of a Current Joint European Project

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ABSTRACT

Particulate matter (PM) is one of the most significant pollutants due to its harmful effects to human beings and the environment. The EC accordingly established a Framework Directive in 1996 and the First Daughter Directive for Fine Particles PM 10/PM 2,5 in 1999 /1,2/. These initial requirements must form part of the national concepts of all EU member states by July 2001. In case of non compliance with air standards, measures and action plans for the emission sources must be implemented. Reliable data can be provided only by continuous monitoring systems. Approved monitors are in operation for ambient air, but not for fine PM emissions from industrial sources.

This intermediate report of a joint EU project is focused on the introduction of individual PM monitors, the results obtained from the executed wind tunnel tests and the efforts to separate fine PM. Finally an overview will be given for further activities and workplans.

1. Introduction

For the emissions determination and monitoring of PM 10 mass concentrations from industrial sources no approved and validated measurement methods exist. Random samples with multi-stage cascade impactors are used to determine the size distribution of particles in flue gas.

In general reliable and time representative data can only be provided by automated monitoring systems. Today real-time as well as long term based information for PM 10 cannot be provided for industrial emission sources. The actual available CEMS can simply measure total suspended matter (TSP) but not differentiate fine particle fractions.

2. Competence of Partnership and Resources

The consortium of the proposed CRAFT project consists of

- 6 SME proposers, specialised in automated dust measuring and monitoring equipment,
- 2 SME proposers specialised in mass and particle size measurement systems,
- 1 RTD performer experienced in determination of PM emissions of industrial sources, the appraisal and qualification of emission measurement equipment.

The competence and resources of the EU partners can be briefly described as follows:

SINTROL / Finland:	In-stack PM monitors for dry gases based on tribolelectric principle
SIGRIST / Switzerland:	PM monitors for dry and wet gases with extractive sampling and dual-beam scattered light photometer

FOEDISCH / Germany:	In-stack and out-stack PM monitors for dry and wet gases based on triboelectric principle
ETS / Belgium:	Real-time in-stack PM method for mass concen tration using TEOM (Tapered Element Oscillating Method)
LAND / United Kingdom:	In-stack monitor based on light scatter
MIP / Finland:	Laser based in-stack PM transmissiometer with dual-path design
DEKATI / Finland:	Real-time monitors for particle size distribution and particle number based on electrical low pressure impactor ELPI
HUND / Germany:	Fine PM monitors based on impactor and scattering light esp. for work hygiene conditions.

3. Test Programme and Equipment

TUV is conducting the laboratory, wind tunnel and field experiments for verifying the monitors main functions. The necessary optimisations must be agreed on. Manual CEN resp. VDI reference methods for PM concentration and particle size will be applied simultaneously. Real flue gas matrices of varying composition pose a strong challenge for the PM monitors, given (e.g.) the interference by high-level water and acidic gas constituents. Maintenance and functional checks must be examined. Last but not least the ability of calibration for fine PM must be validated and the performance characteristics set up.

A step by step procedure in work packages has been scheduled as follows:

- **Selection of Sites**
  - Compiling the emission sources and boundary conditions,
  - Selection of the plants and preparations for the field tests.

- **Specification and Selection of Monitors**
  - Provision of hardware devices and software tools,
  - Status of equipment and application ranges,
  - Potentials for measurement of fine PM.

- **Laboratory Pretests**
  - Ascertaining of the performance characteristics (analysis function, detection limit, cross interferences, output signals),
  - Alignment of optical systems and test of the installation parts,
  - Necessary further developments and optimisations for measurement of fine PM.

- **Wind Tunnel Tests**
  - Definition of process conditions (dust concentration, velocity)
  - Selection of dust types and particle size distribution
  - QA/QS methods for tunnel operations.

- **Calibration tools and methods**
  - CEN reference method and calibration of PM monitors /3,4/,
  - Determination of particle size distribution by multi stage impactors /5,7/,
  - Simultaneous determination of particle size distribution of used dust types.

- **Field Application**
  - Adaptation of the measuring devices to field conditions,
  - Field test of the devices,
  - Availability and maintenance requirements,
  - Check of correctness and calibrating ability.

- **Evaluation and Final Report**
  - Documentation and evaluation of the instruments,
  - Transferability onto other plants and further branches.

4. Performance of Wind Tunnel

The main operational parameters for the wind tunnel are as follows:

- air flow: 4.000 – 20.000 m^3/h
- air velocity: 5 – 25 m/s
- load of particulates: 1 – 60 mg/m^3.

Figure 1 : Dosage system (dust feeder)

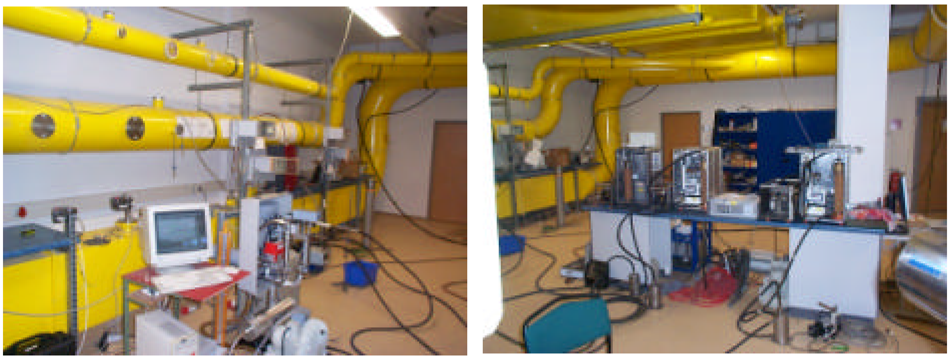

Figure 2 : Wind tunnel site

5. Intermediate results

This chapter contains briefly a selection of the techniques used and the results obtained at wind tunnel investigations. The information is summarized in statistical form as correlations due to CEN reference methods /3,4/ and also for plausibility purposes.

- **Three types of Quartz dust and one Calcium-Carbonate dust are used at wind tunnel test**

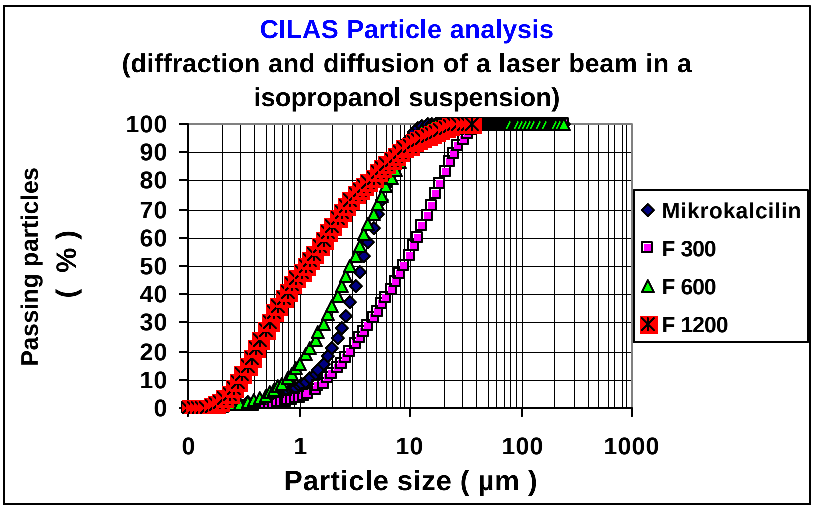

Figure 3: Comparison of particle size distributions

- **Standard reference methods for PM in total and PM 10 resp. 2.5 are as follows:**

  - **Plane filter as in-stack method according EN 13 284-1 /3/**
  - **Johnas 3stage impactor according VDI /5/ and /6,7/**

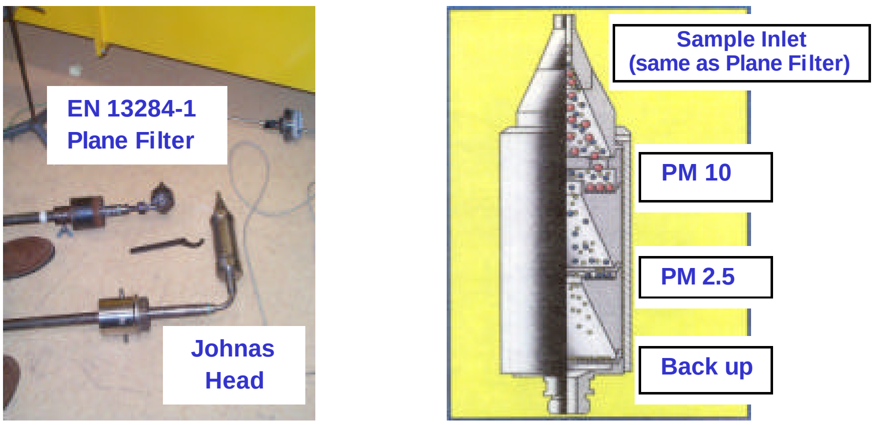

Figure 4: Sampling Heads for reference methods and fine PM sampling with Johnas impactor

- For QA/QS measures several checks are done to compare the CEN reference method vs. Johnas for total dust concentration (TDC).

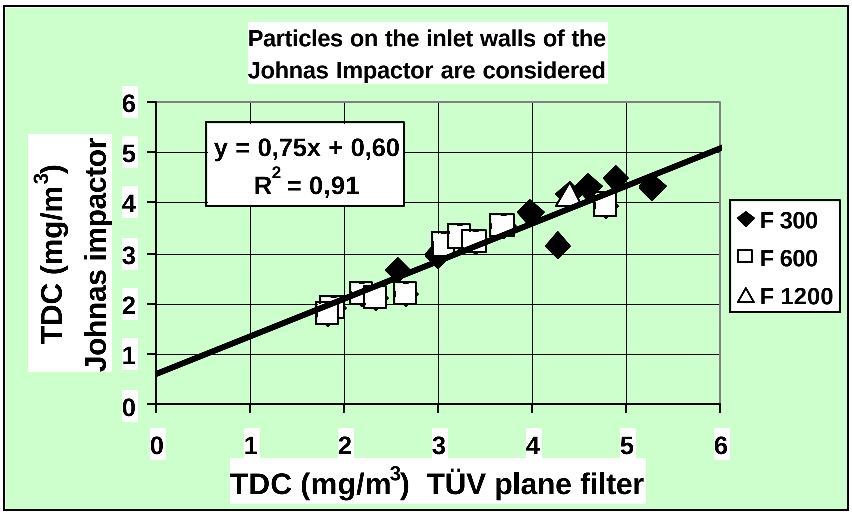

Figure 5: Comparison of CEN reference method vs. Johnas impactor

- In parallel to the reference methods for TDC a real-time in-stack PM method for mass concentration using Tapered Element Oscillating Method (TEOM) has been operated.

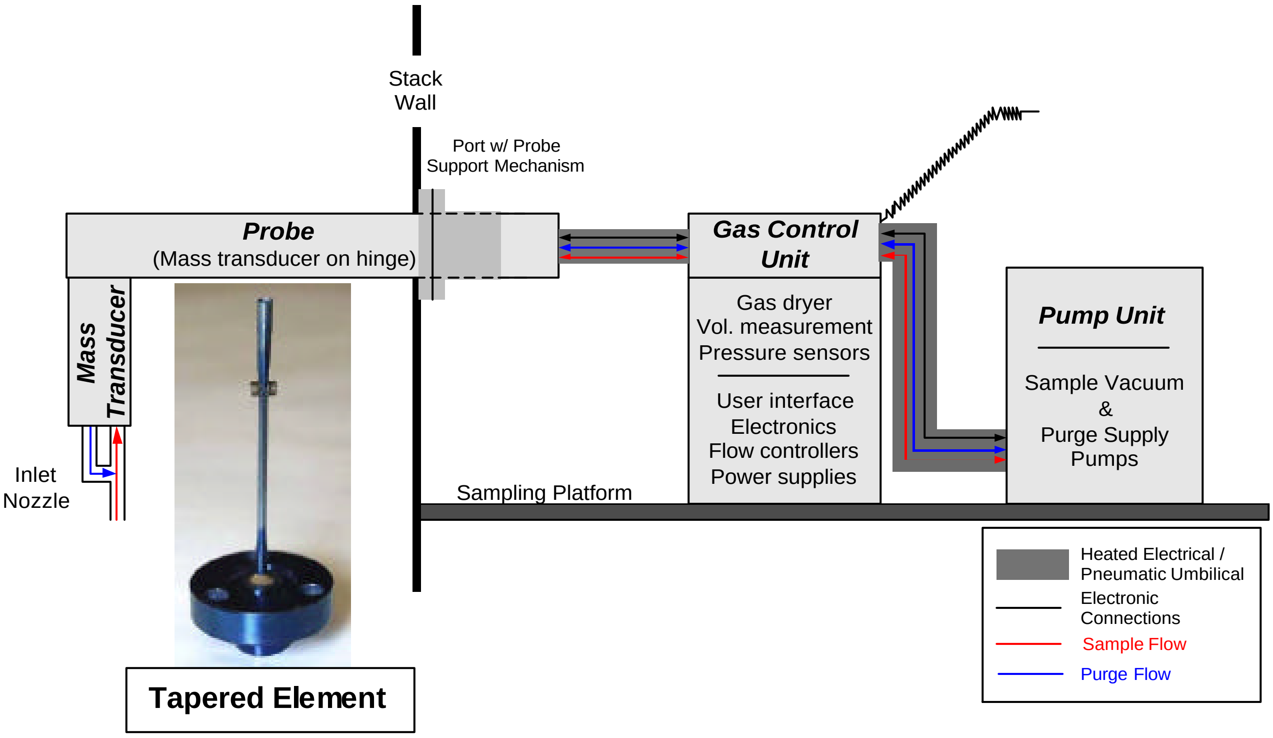

Figure 6: Scheme of TEOM 7000 real-time PM monitor

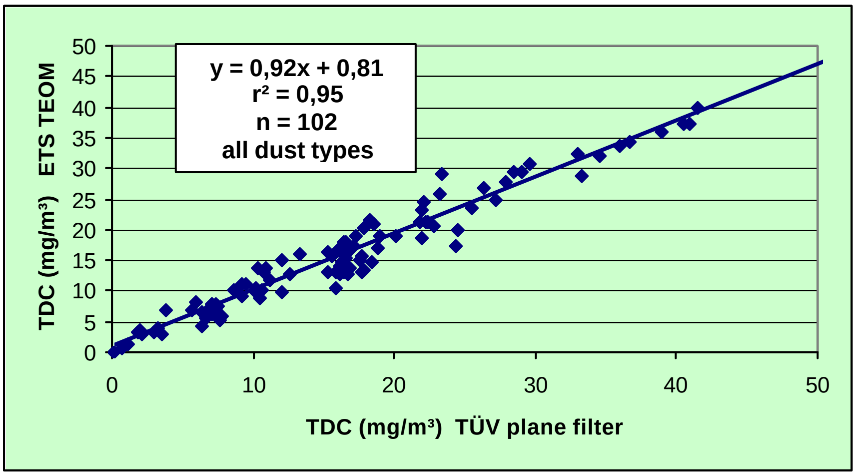

Figure 7: Comparison of TEOM 7000 vs. reference method

- **At wind tunnel there is a permanent installation of an approved SIGRIST KTN monitor. The new SIGRISTmodel has got some changes in the optical design.**

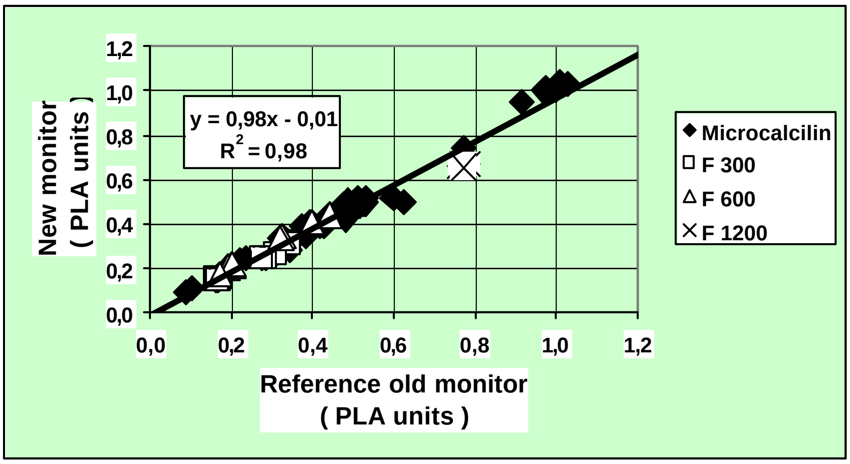

Figure 8: Comparison between old and new SIGRIST photometer

- **During the test campaign two different triboelctric in-stack systems has been permanently operated:**
  - **Monitor of Dr. Foedisch**
  - **Monitor of SINTROL.**

Due to very similar signals and identical calibration curves (see Figure 9) both monitors have reached high significance vs. reference method.

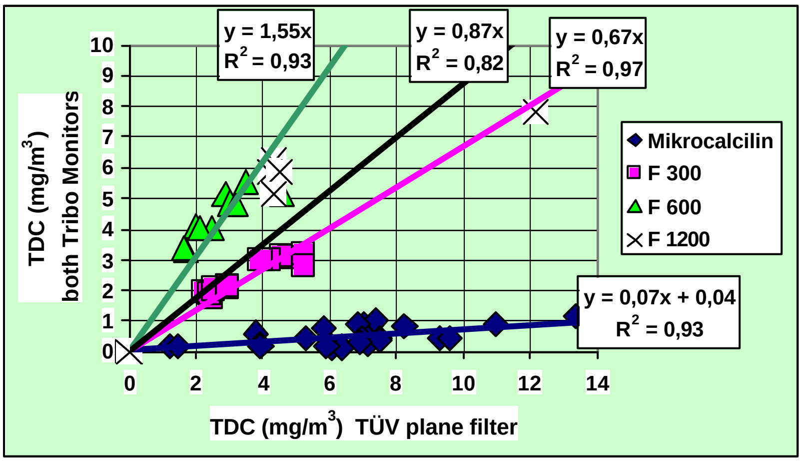

Figure 9: Comparison of signals of two triboelectric monitors vs. reference method

- **For the test campaign LAND has provided a prototype of an in-stack monitor based on light scatter**

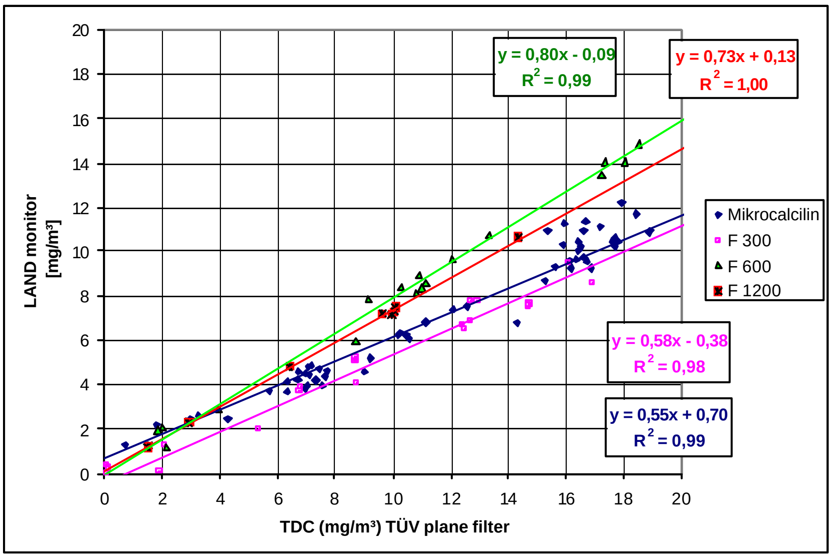

Figure 10: Comparison of LAND light scatter monitor vs. reference method

- **The transmissiometer of MIP has been installed for cross-duct monitoring**

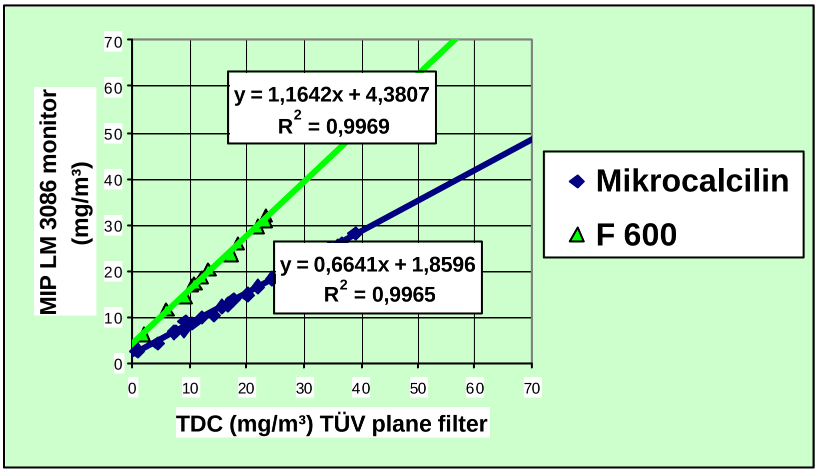

Figure 11: Comparison of MIP transmissiometer vs. reference method

6. Provisional Summary

The main conclusions from the first campaigns are as follows:

- o Functionality and ability of calibration of all provided monitors could be shown
- o Calibration curves of PM vary between 0...40 and 0...10 mg/m³ and are highly significant for different fine dust types and gas velocities between 8..15 m/s
- o Triboelectric Monitors are influenced by changes of velocity
- o Quality control measures for reference methods are in accordance with standards.

7. Further Activities

The focus of the next campaigns at wind tunnel and field sites will be given to

- o Application of further improved and modified systems and
- o PM 10 and fine PM determination.

Some new equipment will be made available e.g.:

- o TEOM 7000 with PM10 Head
- o Out- stack triboelectric monitor with pre-cyclone of Dr. Foedisch
- o Scattering light monitor of LAND (particle fraction – software)
- o ELPI on-line impactor (12 stage fractions) of DEKATI
- o Optical Impactor (three stages for fine PM) of Hund AG.

8. References

/1/ Council Directive 96/62/EC on Ambient Air Quality Assessment and Management (FRAMEWORK Directive)

/2/ Council Directive 1999/30/EC on Ambient Air for SO_2 , NO_x, Particulate Matter PM and Lead (FIRST DAUGHTER Directive)

/3/ EN 13284-1 Determination of low range mass concentration of dust. Part 1: Manual gravimetric method, March 2000

/4/ EN 13284-2: Part 2: Validation of automated measurement systems, 2003

/5/ VDI 2066 Part 10: Measurement of PM 10 and PM 2.5 emissions at stationary sources by impaction method, July 2003 (Draft)

/6/ John, A.C. et al,: Entwicklung eines PM 10 / PM 2.5-Kaskadenimpaktors zur Messung der Emissionen von Feinstäuben. Gefahrstoffe-Reinhaltung der Luft 59 (1999), pp. 449-454

/7/ Geueke, K.-J. et al.: Emission measurements of PM 10 and PM 2.5 at industrial sources. CEM 2001 Conference, Arnhem NL

Acknowledgement

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