International comparisons of national standards for particle counting and sizing

13th ETH-Conference on Combustion Generated Nanoparticles, June 22nd to 14th 2009
Outline

- **Introduction**
  Motivation – range of concentrations and sizes

- **National metrology Institutes (NMI)**
  role – traceability

- **Project EURAMET 1027**
  scope – procedure – participants – instrumentation

- **EURAMET 1027 – Comparison**
  aerosols – procedure – results number – results size

- **Summary and Outlook**
Motivation for Metrology

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ambient measurements

emission measurements

clean-room monitoring

human protection / security
Number concentration and size range

Examples of number concentrations:

- Diesel exhaust fumes: $1\times10^9$ cm$^{-3}$
- Urban air: $1\times10^6$ cm$^{-3}$
- Rural air: 10 000 cm$^{-3}$
- Mountain air (Jungfraujoch): 100 cm$^{-3}$
- Clean room class 9 (> 0.5 μm): 35 cm$^{-3}$
- Clean room class 6 (> 0.1 μm): 1 cm$^{-3}$

Examples of particle sizes:

- Water molecule: 0.1 nm
- Viruses: 1 nm – 5 nm
- Tobacco and Engine smoke: 10 nm – 1000 nm
- Bacteria: 0.5 μm – 50 μm
- Coal dust: 1 μm – 100 μm
Role of a metrology institute (NMI)

NMI must cover the need for correct measurements:

• Trading units:
  Mass, electrical current, volume, length …

• Public health of human, animals (production and wild):
  contamination of food, air pollution, soil pollution, noise …

• Public security:
  radioactivity, speed of cars, …

• Administrative measures:
  Homologation of vehicles, exhaust measurements, …

NMI may delegate the responsibility to a designated body.
Traceability on level of NMIs

e.g. for gas analytics CCQM from CIPM is responsible
www.bipm.org

www.bipm.org

www.euramet.org

Process is necessary for declaration in BIPM-database:
Calibration and measurement capabilities (CMC)
http://kcdb.bipm.org/

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Project EURAMET 1027 – framework

Goal:
• Degree of equivalence for particle number concentration of national standards
• Degree of equivalence for particle sizing (equivalent mobility diameter) of national standards
• Exchange of knowhow between NMIs
• Assessment of measurand (especially size distribution parameters) for future comparisons

Method:
• Experimental work
• Comparison with combustion aerosol (CAST): unimodal and quasi monodisperse particles
• Measurement at same moment the same aerosol
Participants

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<td>AIST (JP)</td>
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<td>DFM (DK)</td>
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Instrument types

- **Number:** Condensation Particle Counter (CPC)
- **Size:** Scanning Mobility Particle Sizer (SMPS)
- **Structure:** Electrical Low Pressure Impactor (ELPI)
- **Structure:** Atomic Force Microscope
EURAMET 1027 – aerosol generation

Particle generation:

"natural" size distribution

monodisperse size distribution

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EURAMET 1027 – comparison routine

Particle number and concentrations

„natural“ size distribution $\sigma_g \approx 1.6$

$d_i$: 70 ... 170 nm at $c_i$: $10^3$ cm$^{-3}$ ... $10^6$ cm$^{-3}$

„monodisperse“ size distribution: $\sigma_g < 1.1$

$d_i$: 50 ... 180 nm at $c_i$: $10^3$ cm$^{-3}$ and $10^4$ cm$^{-3}$

**Cycle per particle size:**

<table>
<thead>
<tr>
<th>Stabilisation $d$ and $c_1$</th>
<th>Measurement $c_1$</th>
<th>fresh air</th>
<th>Stabilisation $c_2$</th>
<th>Measurement $c_2$</th>
<th>fresh air</th>
<th>Stabilisation $c_3$</th>
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Number concentration – “natural” size distribution

Nominal particle concentration for d = 100 nm and GSD = 1.6

The bars indicate the uncertainties with $k = 2$
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Nominal particle concentration for \( d = 50; 70; 180 \) nm and \( \text{GSD} = 1.1 \)

The bars indicate the uncertainties with \( k = 2 \)
Material erosion of a particle under an AFM scan sequence

AFM pictures from DFM

(image rotated 180°)

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Mode and geometric mean – “natural” size distribution

Diameter = Electrical Mobility ≠ Aerodynamic diameter

The bars indicate the uncertainties with \( k = 2 \)

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Mode and geometric mean – “monodisperse” size distribution

Nominal particle concentration for d = 50; 70; 180 nm and GSD = 1.1

Diameter = Electrical Mobility ≠ Aerodynamic diameter

The bars indicate the uncertainties with $k = 2$
National standards for particle number concentration and particle size measurement have been established in NMIs.

**Particle number concentrations:**
- Equivalence of particle counters within stated uncertainties
- Equivalence of particle counters normally within ± 5 %
- Equivalence of particle sizers much better
- Lack of uncertainty statement for sizers

**Particle size distributions (electrical Mobility):**
- Equivalence of particle counters within stated uncertainties
- Equivalence for Mode and Geo. Mean within ± 5 %
- Equivalence of particle sizers much better
- Lack of uncertainty statement for sizers
Outlook

- Particle number concentration and particle size become important quantities in environmental protection and occupational safety.

- With EURAMET 1027 collaboration of NMIs has started; project supports future national initiatives.

- Equivalence is proved for “well-behaved” particles; NMI are willing to take over the responsibility to establish the reference for particle measurements.

- Further discussion is needed on: cropped size distributions, distribution parameters, size distributions curve fitting, uncertainty.

- Further work needed to enlarge size range.
Thank you

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