Defined calibration of the particle measuring system according to PMP

Dipl.-Ing. Martin Schmidt
Dr.-Ing. Maximilian Weiß,
Dipl.-Ing. Leander Mölter, Managing Partner

Palas® GmbH, Karlsruhe, Germany

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Which counting measuring methods do exist?

Information content of the measuring results of counting compared to gravimetric measuring methods!

Why must the counting measuring methods be calibrated?

How can they be calibrated?

Calibration and test of function of the PMP measurement chain!

Summary!

PMP – measurement chain

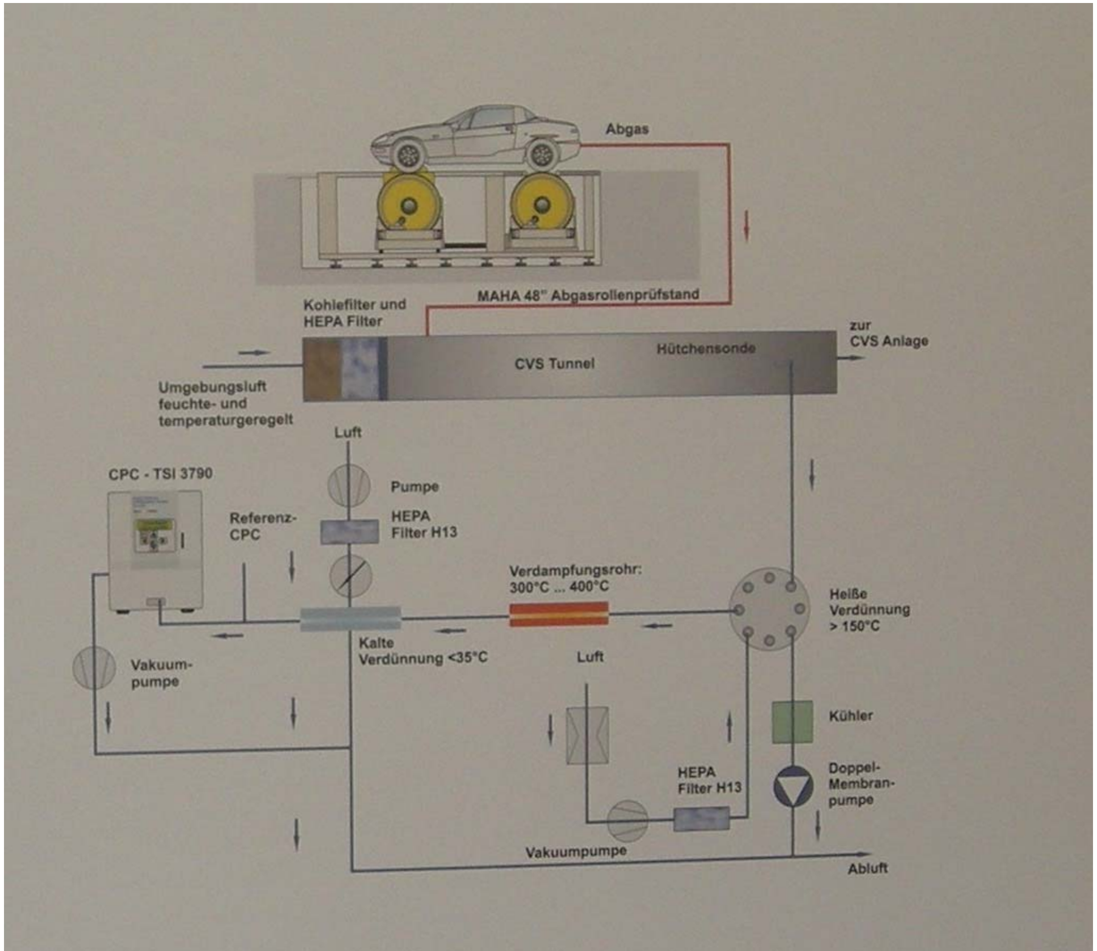


Photo: MAHA Automotiv 08

EURO 5a: **Sept. 2009**

5 mg/km

EURO 5b: **Sept. 2011**

6 x 10^{11} #/km;

5 mg/km

EURO 6: **Sept. 2014**

PMP

Calibration particles:

30, 50 and 100 nm

Counting measuring methods

- Counting methods measure at the single particle.
  - Time resolution of the measurement is possible, i.e. short-term concentration and size variations are analysed.
  - Even slight differences of particle sizes can be seized with certain measuring devices (e. g. welas® system).

- Thus, in research counting methods are combined and used.

Information content

Relation between particle diameter and volume

d_p in µm	**Number/Mass**
0,02	1 000 000 000
0,2	1 000 000
2	1 000
20	1

Particle measurement in PMP

For PMP two different measurment methods are discussed:

- **CPC Condensation particle counter**
  - **in count mode, direct measurement method**
  - **In photometer mode, indirect measurement method**

- **Electrometer**
  - **Indirect measurement method**

Due to time limitation only the CPC is being discussed in this paper!

A CPC works basically in the same way as a optical particle counter.

Due to the condensation process the size information is lost.
The counting procedure is usually the same as used in an optical particle counter.

Influence of device parameters

The device parameters for the CPC as

- Counting efficiency
- Zero counting rate
- Coincidence limit
- Volume flow

have an influence on the particle concentration measured.

Why calibrate?

At all counting measuring devices the device parameters should be clearly verified, i.e. they must be calibrated.

Consider: There are size standards!
There is no counting standard!

So, how is the concentration measurement calibrated?

How calibrate?

Calibration of optical aerosol spectrometers:

see VDI 3867 part 1 and ISO/FDIS 21501-1
(Reference method)

Calibration of condensation particle counters

with Faraday cup aerosol electrometers
see ISO/WD 27891
$d_p < 100$ nm

How calibrate?

Consider:
The test aerosol should resemble the aerosol to be tested in terms of size, structure, material and concentration.

During the measurement, even at temperature and pressure changes, the test aerosol should be stable regarding the size, concentration and charge characteristics. d_p= 30 - 100 nm

The carrier gas should not influence the exhaust gas mixture.

With a NaCl aerosol these demands can not be observed.

Monodisperse VDI:GSD ≤ 1,15 PMP = GSD ≤ 1,2

How calibrate?

PALAS offers the following solutions:

•AGK 2000 for NaCl, KCl and Lactose etc.

•DSP 3010 for soot particles from combustion process

•GFG 1000 for carbon particles, Carrier gas Argon

•DNP 2000 for carbon particles, Carrier gas Nitrogen

Nebulizing of NaCl from a suspension AGK 2000

- **Function principle binary nozzle with integrated cyclon**

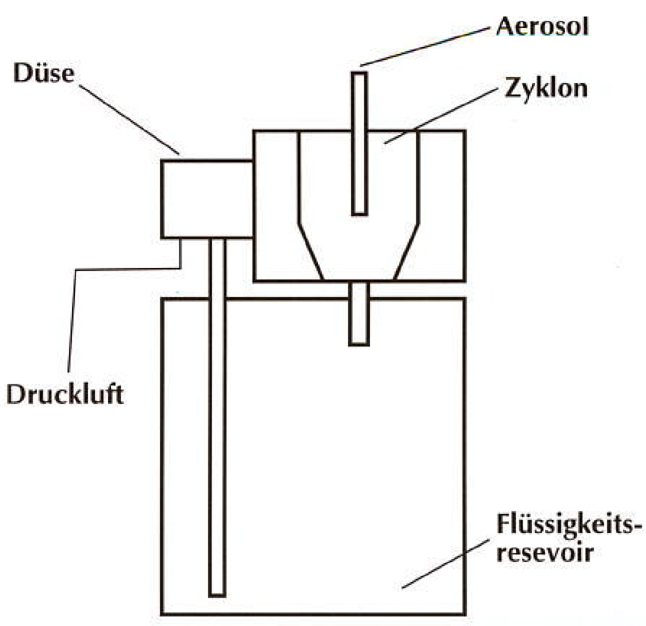


Abb. 1: Schematic function of AGK 2000

A special developped nozzle avoids the clogging of the nozzle with Salt

Large droplets are separated in the cyclon

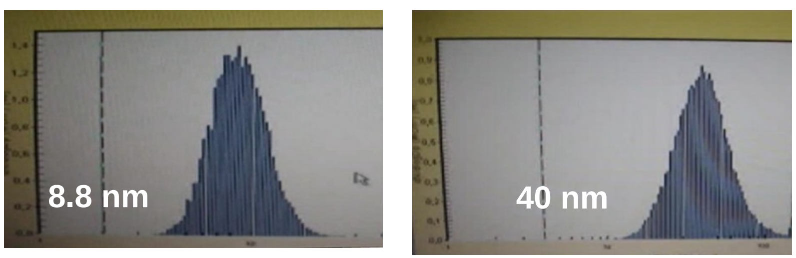
Particle size distribution can be shifted to small particles by using low salt concentrations in the liquid.

Defined Soot Generator DSP 3010

Calibration generator for low mass flows

- Calibration of particle measuring devices
- Test of diesel soot filter media
- Inhalation tests
- Atmospheric research
- Test of fire detectors

Particle size distributions (examples)



- Particularly high stability of concentration and particle size distribution
- Modal values of particle sizes variably adjustable from approx. **10 nm to 150 nm**
- Particle size distribution Log-Normal distributed

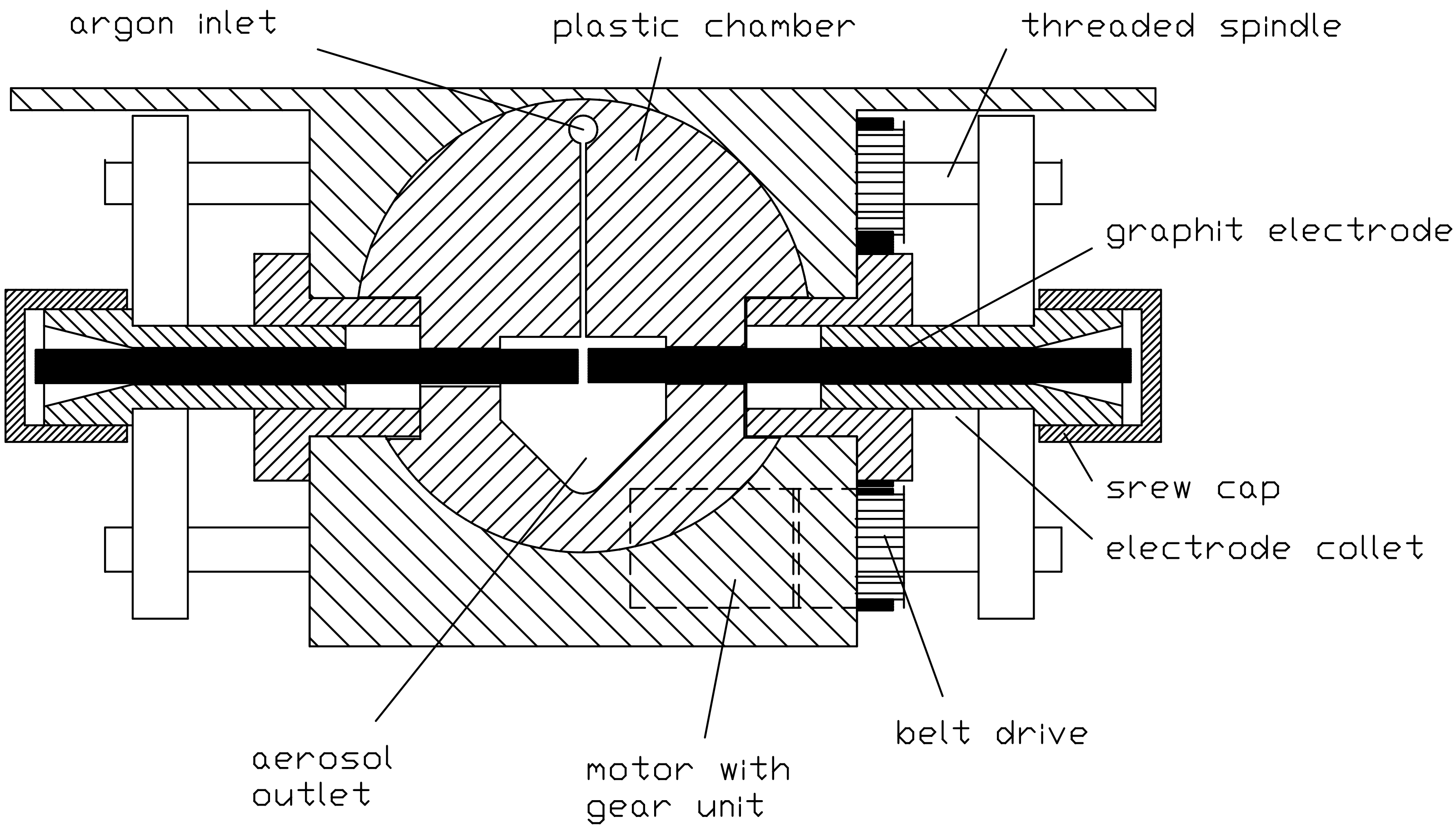
Generation of test aerosols similar to diesel soot

For the generation of particles similar to diesel soot and low mass flows the spark generator DNP 2000.

$$\dot{m} = 0{,}07 - 4\ \mathrm{mg/h}$$

Generation of test aerosols similar to diesel soot

Functional principle of DNP 2000

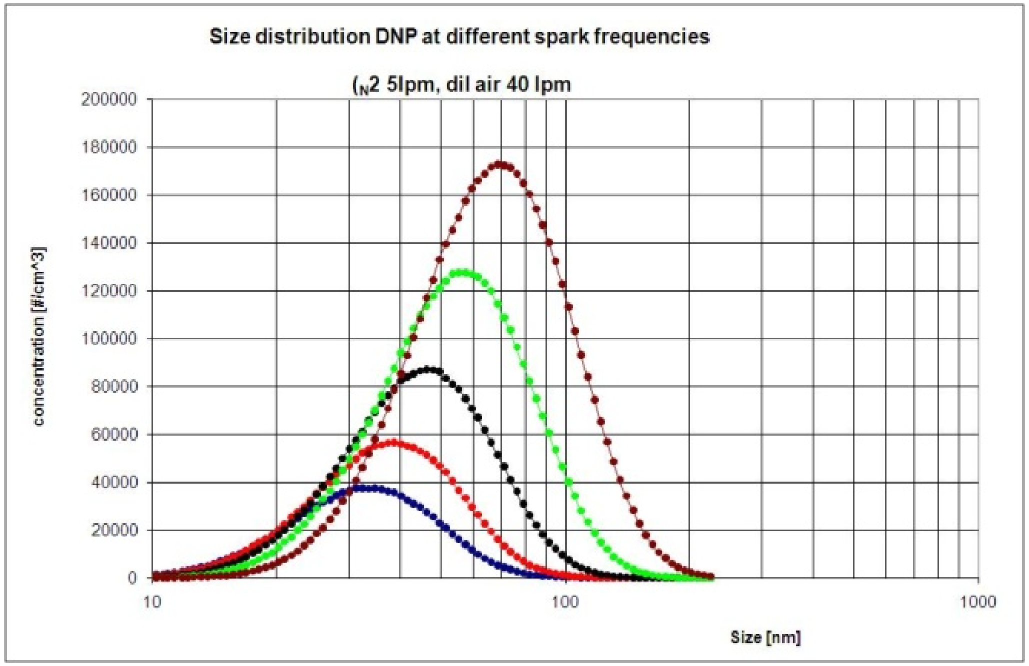


Generation of test aerosols similar to diesel soot

Particle mass flow:

0,07 – 4mg/h

The mass output is linear to the adjusted spark frequency

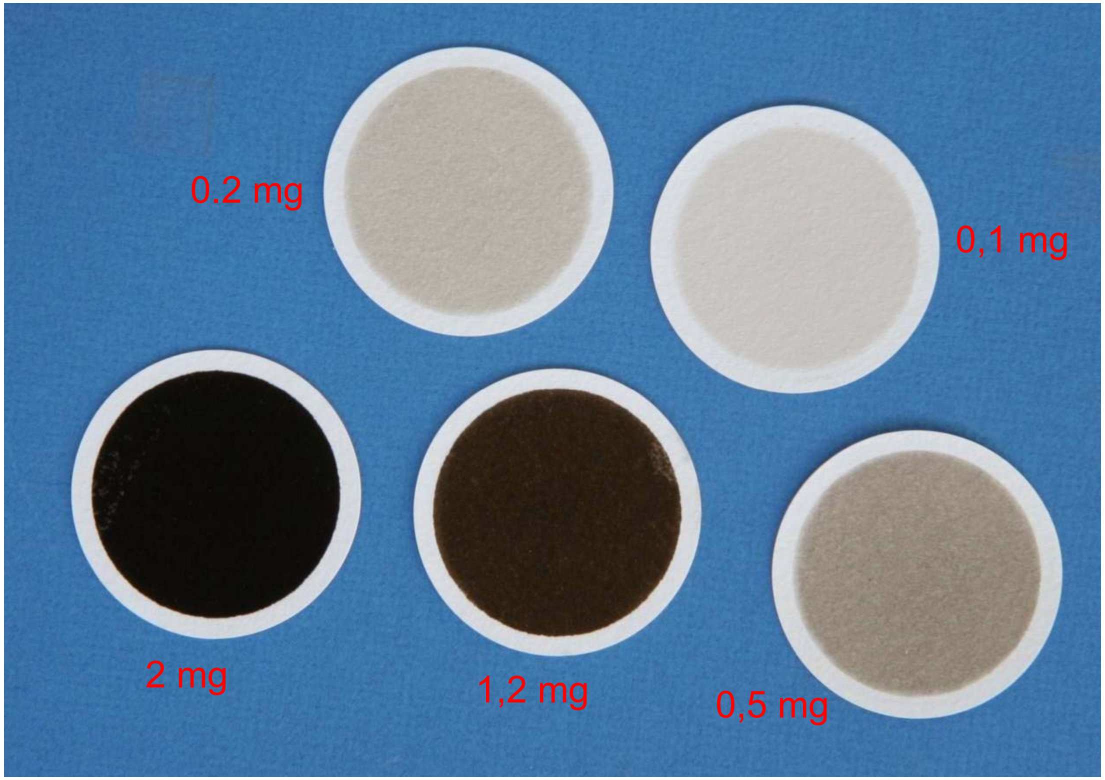


Size distribution of the particle agglomerates at different spark frequencies

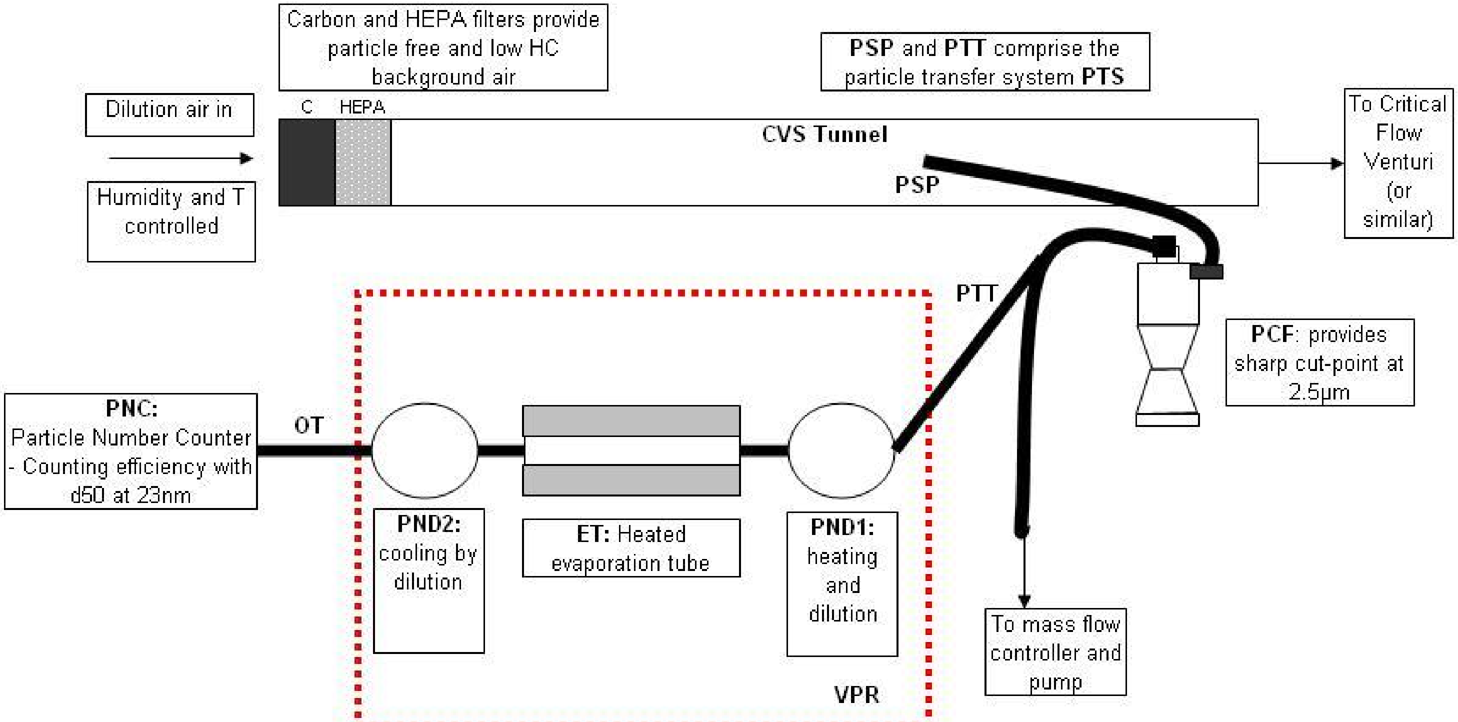
Generation of test aerosols similar to diesel soot

The soot of the DNP 2000 is black!

The white of the filter more or less shines through the soot with appropriate loading.



PMP – measurement chain



Recommended Particle Sampling Systems
A test system should be calibrated with a test Aerosol similar to the Aerosol used in practice VDI 3491Blatt 2

PMP – measurement chain
Critical consideration

1. Sampling with Chinese Hat from CVS tunnel or cyclone as pre-separator after CVS tunnel.
Particle size and quantity in CVS tunnel? d_p < 2,5 µm?

2. First dilution PND1: V_F = 1:10 - 1:200; V_T = 150°- 400°C
Second dilution PND2: V_F = 1:10 - 1:30; V_T < 35°C

Problem: The total dilution factor V_{Ftotal} can be chosen between 100 and 6000.
The first dilution can be chosen with 250°C differently.

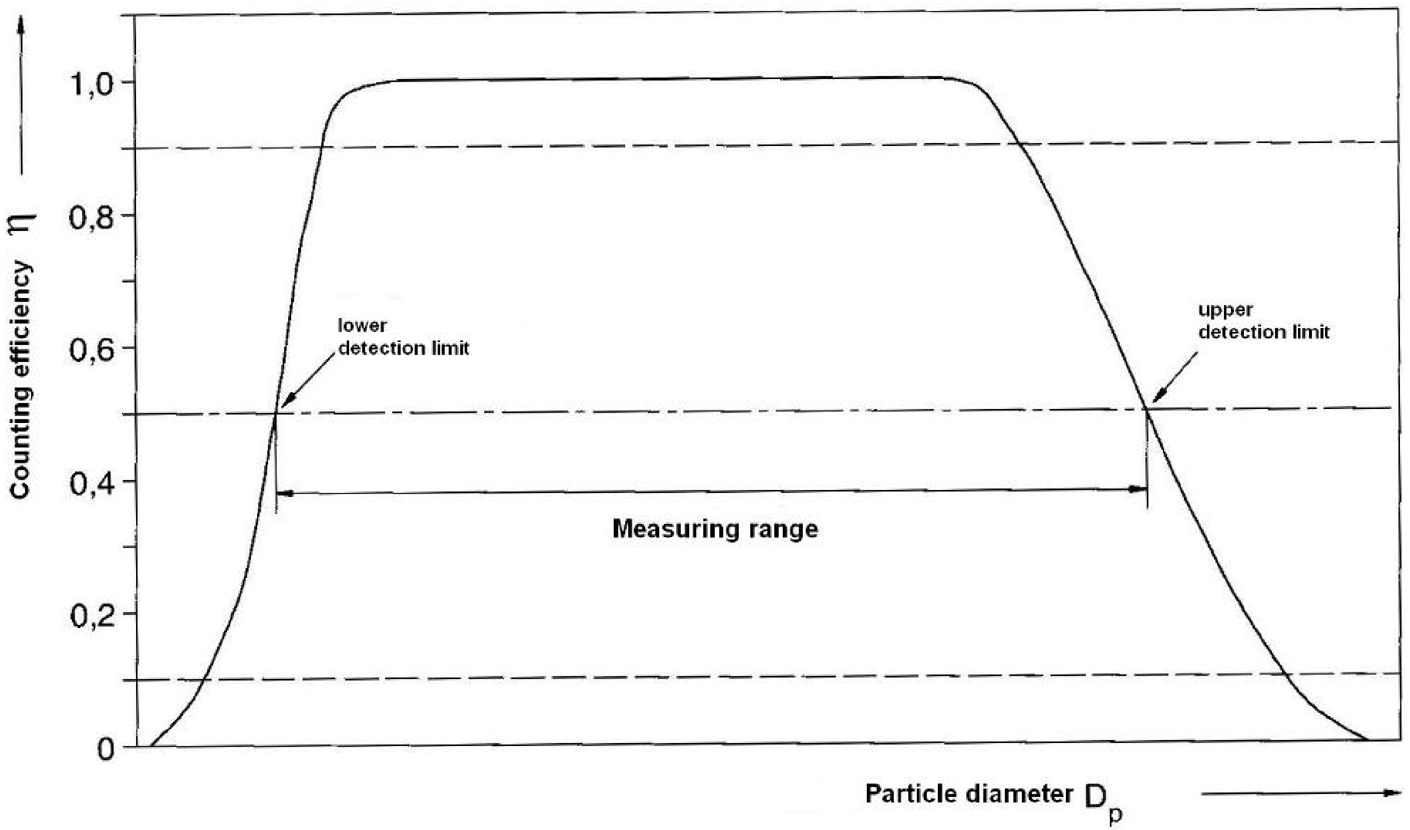
Retention time of the particles in CVS < 5 sec and total residence time < 20 sec. The retention time depends on the sampling volume flow and on the line cross-section.

3. Particle Number Counter PNC:

C_{Nmax}= 10000
50% efficiency at 23 +/-1nm
>90% efficiency at 41 +/-1nm
10% efficiency = ?
Volume flow = ? l/min

Counting measuring methods

Graphical representation of the counting efficiency

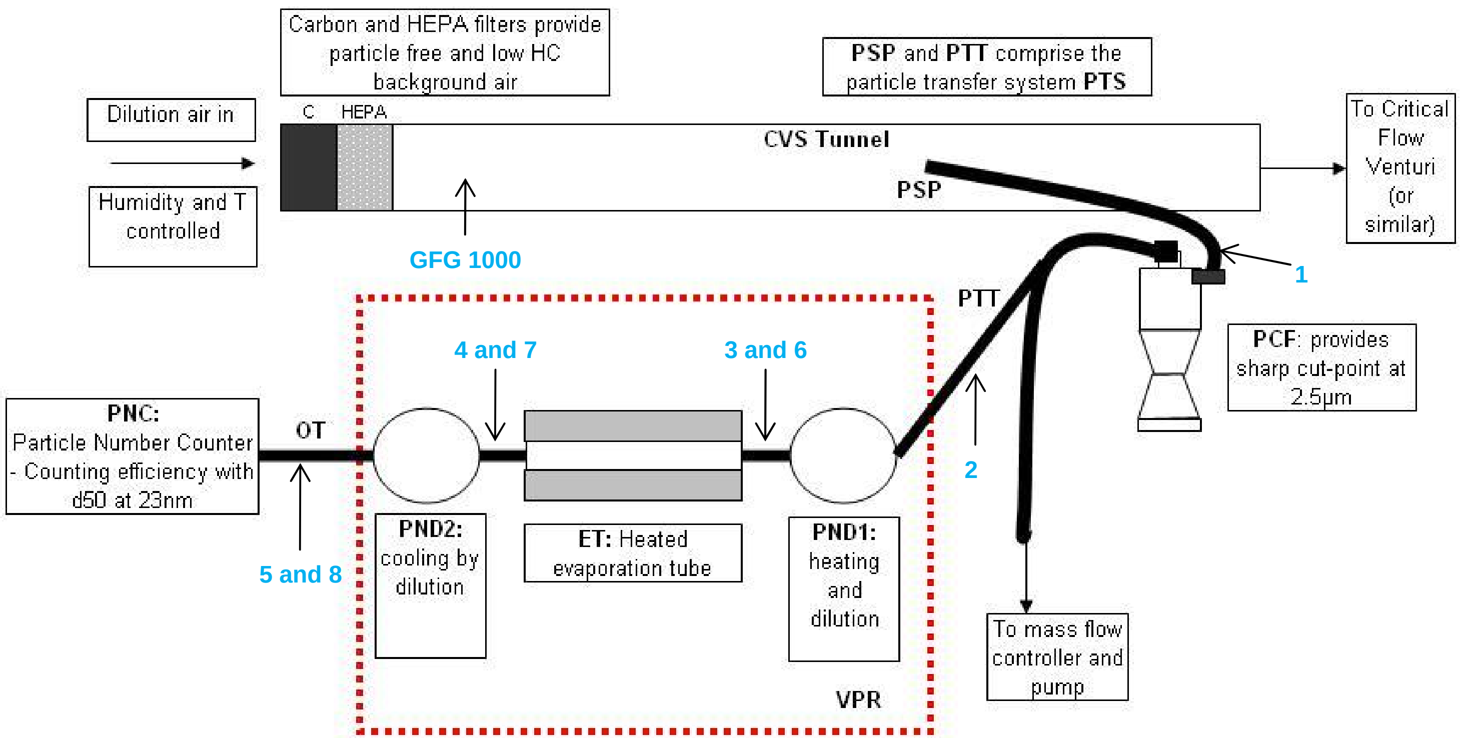


90% line

10% line

PMP – measurement chain

Functional evidence of the single elements of the measurement chain.
Time expenditure for every 5 x 1 min approx. 1 h without heating period.



Test aerosol:
GFG 1000

1 with and without Chinese Hat
2 with pre-separator
3 with PND1
4 with heating tube
5 with PND2
6 PND1 heated
7 heating tube heated
8 complete

Calibration particle size 30nm, 50nm, 100nm

Summary

1. The single components of the PMP – measurement chain, like pre-separators, PND1, PND2, PNC and connection lines, have to be clearly defined and characterised.
2. The calibration of these single components has to be effected clearly. Thus, for example the PND1 must be characterised with the corresponding temperature and with particles.
3. The required checks must lead to reliable results.

Then the PMP – measurement chain supplies reliable results with the particle number measurement.

Thank you for your attention.

I will gladly respond to your questions.