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Transport, Energy and Communications DETEC

Federal Office for the Environment FOEN
Air Pollution Control and Chemicals Division
Traffic Section

Periodical Technical Inspection based on Particle Number (PN) for NRMM

47th PMP IWG Meeting – Ispra, 16.-17.05.2018
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Regulation in Switzerland

The Swiss Ordinance on Air Pollution Control (OAPC) defines since 2009 a particle number (PN) limit from construction machinery of 10^{12} Particles/kWh – same PN-limit as in upcoming Stage V for NRMM!

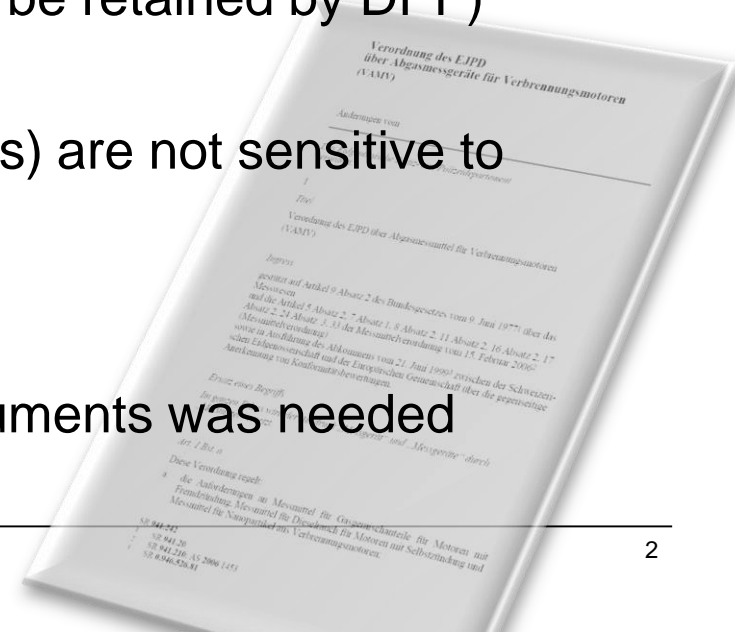


Efficient diesel particle filters (DPF) are necessary (97% of all particles between 20 und 300 nm must be retained by DPF)

Current testing instrument (Opacimeters) are not sensitive to nanoparticles

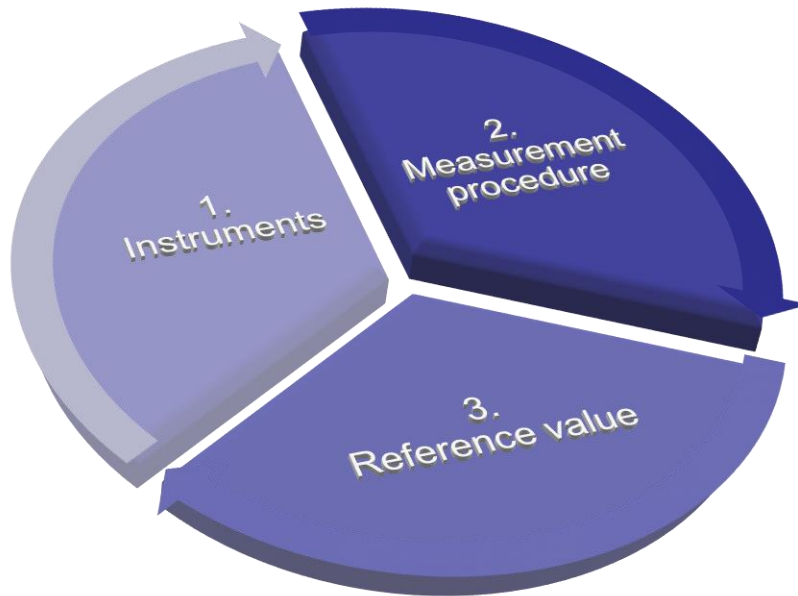


Development of a «new» class of instruments was needed





PN Measurement for Construction Machinery: a well-defined system



NPET 3795 from TSI

1. Requirements for PN-measuring instruments: [VAMV](#)
2. Measurement procedure: [construction guideline air](#)
3. Reference value: [construction guideline air](#)



VAMV: Specific requirements for nanoparticle measuring instruments from combustion engines

A. Definitions and explanations

Mobility diameter

Diameter of a spherical particle which exhibits the same electrical mobility as a spherical particle of known diameter when measured with a mobility analyser in accordance with ISO 15900:2009.

(Refers to geometric mean diameter of a particle size distribution with $\sigma_g < 1.6$)

Nanoparticle

Solid, carbonic components of the hot exhaust gas in the exhaust pipe of combustion engines.

The particles have a mobility diameter in the range from 20 nm to 300 nm. The volatile portions are not considered as nanoparticles.

Particle number concentration

Number of nanoparticles per unit volume, specified per cubic centimetre (cm⁻³).

Efficiency E

Quotient of the displayed particle number concentration and the particle number concentration entering into the measuring instrument.



VAMV: Specific requirements for nanoparticle measuring instruments from combustion engines

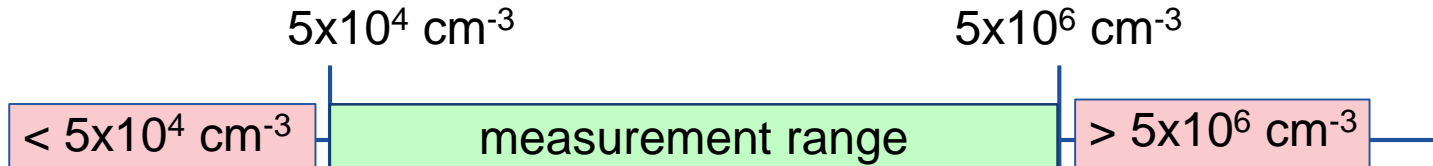
B. Measurement requirements

1. Measurement range

1.1) The measurement range for the nanoparticle number concentration is at least between $5 \times 10^4 \text{ cm}^{-3}$ and $5 \times 10^6 \text{ cm}^{-3}$.

1.2) In case of measured values outside the measurement range, the measuring instrument must indicate whether the measured value lies below or above the measurement range. If no categorisation is possible, then no value should be displayed.

1.3) The particle number concentration of each measurement must be indicated at the ambient conditions.





VAMV: Specific requirements for nanoparticle measuring instruments from combustion engines

2. Nominal operating conditions

The following nominal operating conditions must be fulfilled:

2.1 Climatic, mechanical and electromagnetic ambient conditions:

- ~~– Range for ambient temperature from 10 °C to 40 °C;~~
- Range for ambient pressure from 860 hPa to 1060 hPa;
- Mechanical environment class M2;
- Electromagnetic environment class E2.

Messmittelverordnung (Ordinance on measuring instruments SR 941.210)

	Temperature limits			
Upper temperature limit	+30 °C	+40 °C	+55 °C	+70 °C
Lower temperature limit	+5 °C	-10 °C	-25 °C	-40 °C
	Indoor	Outdoor measurement		



VAMV: Specific requirements for nanoparticle measuring instruments from combustion engines

Error limits

The following error limits apply:

Depending on the particle size and particle composition, the measuring instrument must exhibit an efficiency E over the entire measurement range within the limits specified in the table below.

Suggestion for revision (suggestion will be discussed with instrument manufacturers)

PN-PEMS (type approval of motor vehicles)

d_p [nm]	Sub-23	23	30	50	70	100	200
$E(d_p)$ PN analyser	To be determined	0,2 – 0,6	0,3 – 1,2	0,6 – 1,3	0,7 – 1,3	0,7 – 1,3	0,5 – 2,0
Filter test at exhaust of construction machines			Revision VAMV			Revision VAMV	
d_p (nm)	≤ 23		41			≥ 200	
E	< 0.5		> 0.5			0.7 - 1.3	
						< 2.0 ≤ 3.0	

(EU) 2017/1154

(CH) VAMV

Liquid droplets: $E < 5\%$ for 30 nm droplets of tetracontane (up to 10^5 cm^{-3})



VAMV: Specific requirements for nanoparticle measuring instruments from combustion engines

Other following metrological requirements tested during pattern approval:

1. disturbances

results have to stay within error limits

or no results has to be indicated

no official measurement shall be allowed

2. other requirements

individual effects have to be minimized

response time after steep increase or decrease ≤ 5 s

delay time ≤ 10 s

readable 10 Hz signal for pattern approval

portable use outside



Nanoparticle measurement instruments procedures to put on the market

- Ordinance of exhaust gas analyzers demands the following conformity evaluation procedure:
 - 1) **pattern approval:**
Module B (type examination)
 - 2) **product examination:**
Module F (declaration of conformity to type by product verification)
- only conformity assessment body is METAS-Cert.

CH **M 18** **CH01**





Nanoparticle measurement instruments procedures to maintain measurement stability

VAMV requires the following procedures to maintain measurement stability:

1. Yearly maintenance by an experienced person (e.g. manufacturer)
 2. Yearly verification by METAS or an authorized verification office (at the moment only METAS will verify instruments)
- **The instrument user is responsible to follow the procedures to maintain the measurement stability (Art. 21 Ordinance on measurement instruments)**
 - **For official controls only verified instruments are allowed.**





Measurement procedure

- The engine must be warmed up.
- The engine coolant and lube oil must be at operating temperature.
- PN must be measured at high idle (engine cut-off speed)
- Overall duration of the measurement: 40 s



waiting time

measurement time 1

measurement time 2

measurement time 3

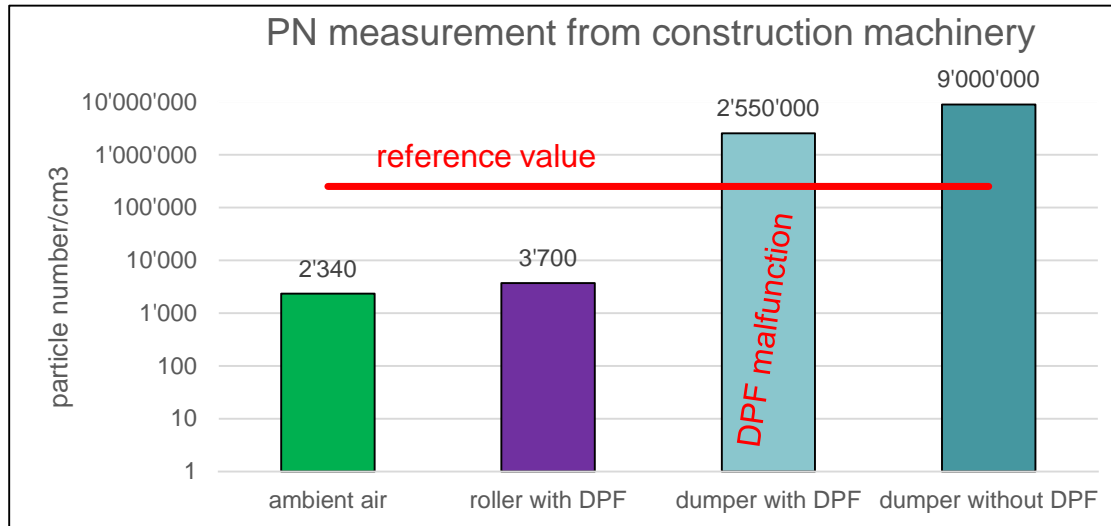
- The testing value to be compared with the reference value is the arithmetical mean value.



PN reference value in the exhaust

Type approval value: 1×10^{12} particles/kWh

→ **reference value: $2,5 \times 10^5$ particles/cm³**



Opacity is still the decisive measurement method. Since 2016 it is possible, to measure PN instead of opacity during periodic control of Swiss construction machinery.



Thank you for your attention