# Propriety to use NaCl particles by atomizing on calibration of particle number counting system as reference particles

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Recently, particle number (PN) emission from automotive has been paid much attention from the view point of public health on the ultra fine particles. The Introduction of the PN emission limits is scheduled in the European Union regulation. The PN counting method for the regulation is described in UNECE Regulation No.83. The required PN counting system consists of a Volatile Particle Remover (VPR) and a Condensation Particle Counter (CPC). The VPR is composed of a first diluter (PND1), the Evaporation Tube (ET) and a second diluter (PND2). The regulations require calibrating the Particle Concentration Reduction Factor (PCRF) of VPR periodically and after major maintenance.

The PCRF is used in calculation of PN emission; therefore the improper calibration of the PCRF can cause a large uncertainty of PN emission measurement. This study investigates propriety to use NaCl particles by atomizing (LCU) being compared with soot particles (MiniCast) by combustion and carbon particles (Palas) by electrical spark in PCRF calibration as reference particles from the following points of view: (1) PCRF dependency on the particle species used in the calibration, (2) stability of particle generators, and (3) PCRF reproducibility of different VPR.

To calibrate the VPR according to the UNECE Regulation No. 83 particles of diameter d= 30nm, 50nm and 100nm are used. For each adjustable dilution of the VPR, the PCRF $f_r(d)$ of each particle size is measured. After the generation of the particles, the aerosol sample flows through the neutralizer to establish a natural charge distribution. In the SMPS the needed particle size is cut out of the size distribution provided by the particle generator. The particle number concentration is measured at the VPR inlet and the VPR outlet.
Either successively ( 1-CPC-Method ) or simultaneously (2-CPC-Method). The ratio of the obtained inlet concentration $N_{in}(d)$ to the outlet concentration $N_{out}(d)$ results in the PCRF. The average fr of the three obtained PCRF values is than used in the calculation of the particle number measured during a test (e.g. NEDC).

From the comparison of obtained PCRFs by the different particle generators, it is shown that the PCRF dependency on the particle

species used in calibration process can be minimized by adding thermal treatment for generators. It is also confirmed that the NaCl particles by atomizing shows sufficient stability, being compared with the other methods. The difference in the obtained PCRF values using the three different particle generators is less than 5% (LCU compared to DNP etc.). Results for the PCRF calibration with and without neutralizer differ less than 5% (LCU compared to LCU etc.).

The mean PCRF calibrated by NaCl particle for almost 60 units of VPR calculated has been sufficiently stable. This result suggests that PCRF calibration with NaCl particles can achieve sufficient reproducibility. In addition, VPR calibration exercise has been organised to investigate the comparability of the VPR calibration procedures employed by the different instrument manufacturers and laboratories. The PCRF value among the 60 VPR's shows a coefficient of variation (CV) less than 6,3 % for the dilution of 150, 300 and 3000. All units are calibrated by using the LCU as particle generator and applying the 1-CPC-Method. This shows the stability and reproducibility of the calibration method.

The generated particle output of the MiniCast / DNP / LCU shows a coefficient of variance of 1.6% / 5.1% / 0.8%. A high stability of the generator is necessary when the 1-CPC-Method is applied to avoid high deviations in the PCRF values.

One can extract the following for points from the results:

1.) PCRF calibration is not strongly dependent on the particle generator.
2.) The neutralizer could be removed from the setup. This would simplify the process of PCRF-calibration.
3.) Same kind of VPR show reproducible PCRF-Values when calibrated with LCU and the 1-CPC-Method.
4.) LCU is one of the most stable particle generators.

# Propriety to use NaCl particles on calibration of particle number counting system as reference particles

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## Introduction

The particle number (PN) counting system according to the UNECE Regulation No.83 consists of a Volatile Particle Remover (VPR) and a Condensation Particle Counter (CPC). The VPR is composed of a first diluter (PND1), the Evaporation Tube (ET) and a second diluter (PND2). The regulations require calibrating the Particle Concentration Reduction Factor (PCRF) of the VPR periodically and after major maintenance. The PCRF compensates for the particle losses within the VPR.

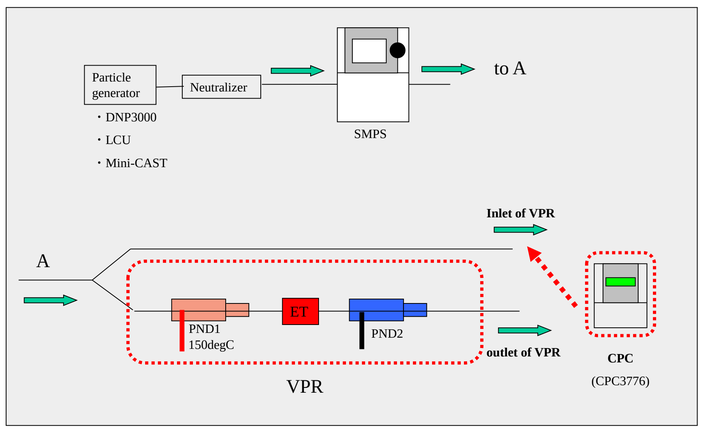


***Figure 1: Flow Schematic of the VPR and Setup for the PCRF Calibration.***

## Questions

The PCRF is used in calculation of PN emission; therefore the improper calibration of the PCRF can cause a large uncertainty of PN emission measurement. Following questions arise:

1.) Dependency of the PCRF on the particle species used during the calibration?
2.) Neutralizer necessary?
3.) Differs the PCRF from VPR to VPR?
4.) Stability of the particle generators?

## Method

To calibrate the VPR according to the UNECE Regulation No. R83 particles of diameter d = 30 nm, 50 nm and 100 nm are used. For each adjustable dilution of the VPR, the PCRF $f_r(d)$ of each particle size is measured. After the generation of the particles, the aerosol sample flows through the neutralizer to establish a natural charge distribution. In the SMPS the needed particle size is cut out of the size distribution provided by the particle generator. The particle number concentration is measured at the VPR inlet and the VPR outlet either successively ( 1-CPC-Method) or simultaneously (2-CPC-Method). The ratio of the obtained inlet concentration $N_{in}(d)$ to the outlet concentration $N_{out}(d)$ results in the PCRF:

$$f_r = \frac{N_{in}(d)}{N_{out}(d)}$$

The average $\overline{f_r}$ of the three obtained PCRF values is than used in the calculation of the particle number measured during a test (e.g NEDC).

$$\overline{f_r} = \frac{f_r(30nm) + f_r(50nm) + f_r(100nm)}{3}$$

For the measurements shown in this poster, three different particle generators were used:

- •DNP3000(Palas): generates a condensation aerosol from graphite monoliths
- •LCU (HORIBA) : generates sodium chloride particles with an atomizer
- •MiniCAST (Jing) : generates diffusion flame soot

## Results

The difference in the obtained PCRF values using the three different particle generators is less than **5% (LCU compared to DNP etc.)**.

Results for the PCRF calibration **with/without neutralizer** differ less than **5% (LCU compared to LCU etc.)**. The results are shown in figure 2.

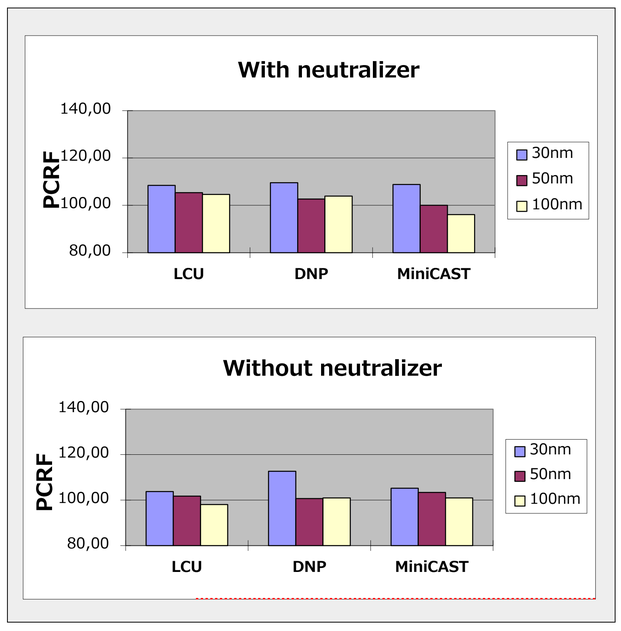


***Figure 2: PCRF values obtained for 30nm, 50nm and 100nm with different particle generators with/without neutralizer at dilution of 100 .***

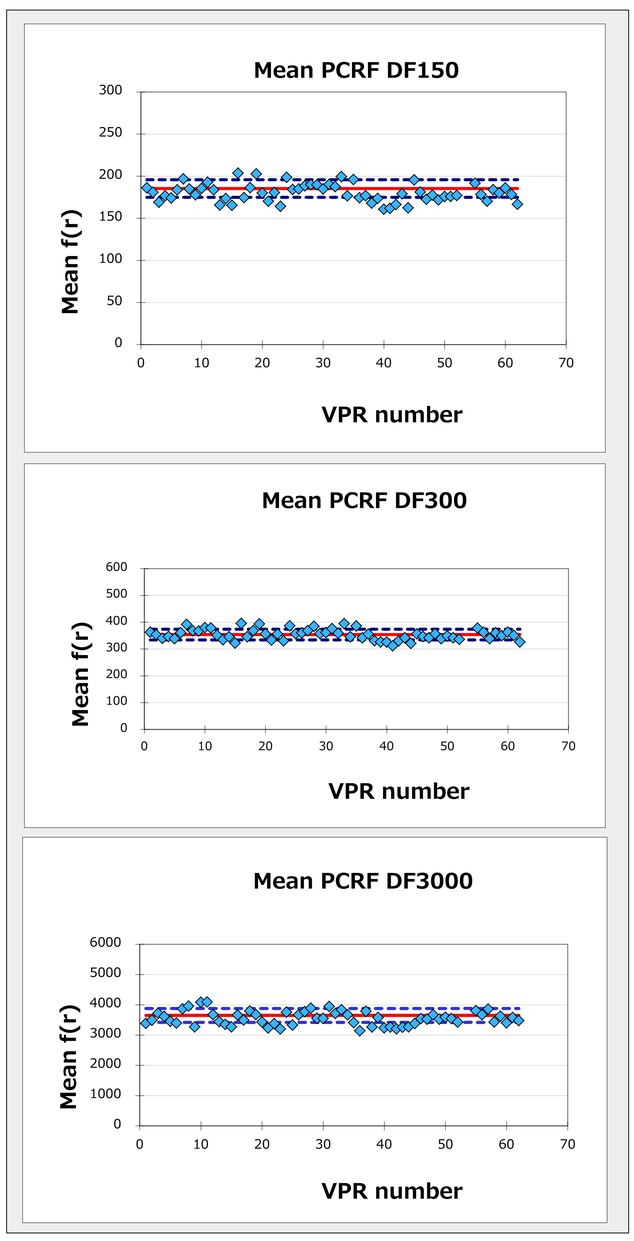


***Figure 3: Results of PCRF calibration from 60 VPR's for a dilution of factor 150, 300 and 3000.***

The PCRF value among 60 VPR's shows a **coefficient of variation (CV)** less than **6,3 %** for the dilution of 150, 300 and 3000. All units are calibrated by using the LCU as particle generator and applying the 1-CPC-Method. This shows the stability and reproducibility of the calibration method. The results are displayed in figure 3.

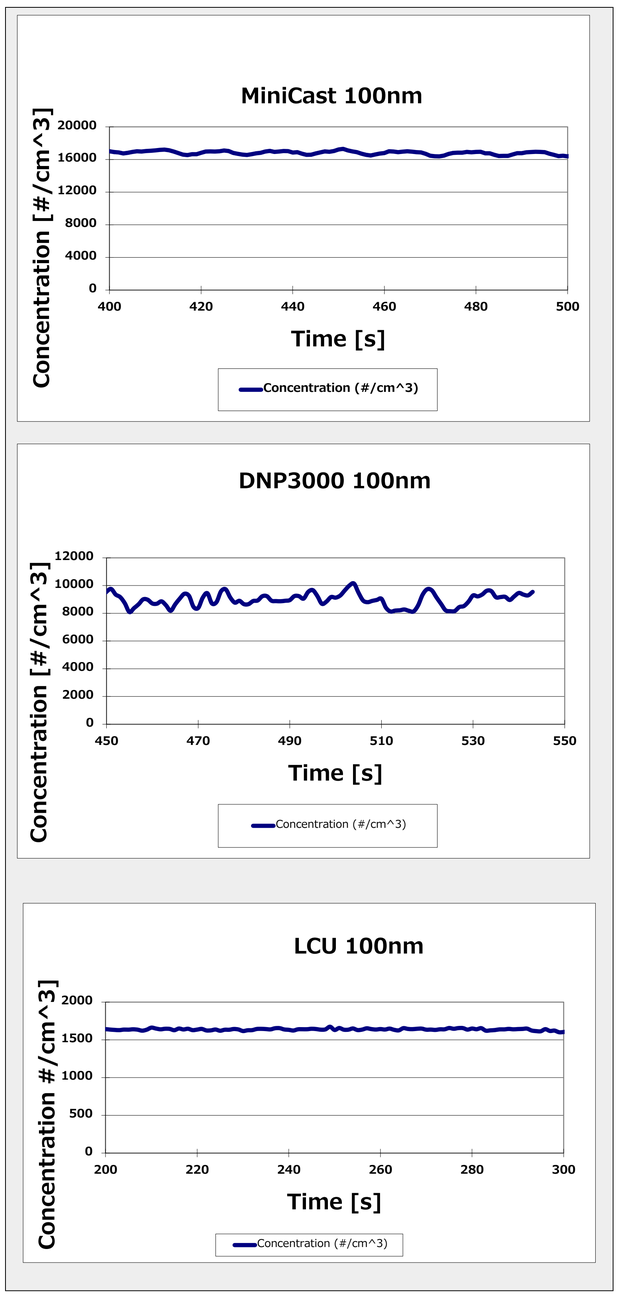


***Figure 4: Stability of the different particle generators at a SMPS setting of 100nm.***

The output of the **MiniCast** / **DNP** / **LCU** shows a CV of **1.6%** / **5.1%** / **0.8%**. A high stability of the generator is necessary when the 1-CPC-Method is applied to avoid high deviations in the PCRF values.

## Conclusion

1.) PCRF calibration is not strongly dependent on the particle generator.
2.) The neutralizer could be removed from the setup.
3.) Same kind of VPR show reproducible PCRF values.
4.) LCU is one of the most stable particle generators.

## Contact

For more information on:

PN measurement in automotive according to UNECE Regulation No. 83 and No. 49, PCRF Calibration and all issues around PN

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