

An On-site Check Methodology of a Particle Number Counting System with a Particle Generator

Kazuki Nakamura ¹⁾ Christos Dardiotis ²⁾ Madlen Pramstrahler ²⁾

1) AVL Japan K.K.

3-1200 Shinmaruko Higashi, Nakahara-ku, Kawasaki-shi, Kanagawa-ken, 211-0004, Japan
(E-mail: kazuki.nakamura@avl.com)

2) AVL List GmbH

Hans-List-Platz 1, Graz, 8020, Austria

KEY WORDS: environment, emissions, on-site checks, particle number counting system, particle generator (D2)

Following the recommendations of the Particle Measurement Programme group, a Solid Particle Number (SPN) emission limit as well as the respective sampling and measuring procedures have been implemented in Europe since 2011. The methodology and the test procedures for certification of Light-Duty vehicles in Europe are described in the United Nations – Economic Commission for Europe (UNECE) Regulation 154. An SPN counter shall consist of two main components: a dilution system which is a so-called Volatile Particle Remover (VPR) and a sensor for counting the particles (Condensation Particle Counter: CPC). The VPR dilutes and heats the exhaust sample gas to remove volatile particles. A dilution factor of the VPR including particle losses is described as a Particle Concentration Reduction Factor (PCRF) which is calibrated with monodisperse aerosol in diameter of 30, 50, and 100 nm. The solid particles through the VPR are subsequently counted by the CPC which is calibrated so that its counting efficiencies can be $50 \pm 12\%$ and $> 90\%$ at 23 nm and at 41 nm, respectively. Although the legislation requires an annual calibration or validation of the SPN counter as well as their specific checks before a certification test, the lack of a particle number concentration standard makes it difficult to validate the performances of the SPN counter on site in contrast to gaseous emission analyzers for which respective span gases of a nominal concentration are available. In this paper, we present how quality checks of the VPR and the CPC can be conducted on site with polydisperse soot-like aerosol.

The AVL Particle Generator (APG) (model 499) was used for the quality checks as a particle generator. The AVL Particle Counter (APC) (model 489), which consists of the VPR and an AVL CPC (model 488), were tested as an example. The quality checks were verified in comparison with the reference equipment of an additional AVL CPC, “Ref. CPC”, which has not been used for any tests of vehicles and engines.

The CPC linearity check of the CPC under test, “Test CPC”, was conducted as shown in Fig. 1. In total 8 concentration steps were performed in the range of 0 to 30,000 particles/cm³. The values of the “Test CPC” were deviated by 2.6 % to 4.0 % from the “Ref. CPC” in all the steps. This “Test CPC” was successfully verified because the following criteria were attained; 1. The value of zero checks is ≤ 0.02 particles/cm³, 2. All the levels of the averaged concentration of the “Test CPC” deviate $\leq \pm 10\%$ compared to those of the “Ref. CPC”, 3. The slope is equal to or between 0.9 and 1.1, 4. The value of R^2 is ≥ 0.97 .

The PCRFs of the VPR of the APC under test were also confirmed as the following reference and relative PCRF verification checks. The reference PCRF verification check was implemented with a nominal PCRF setting of 250 as a reference. Three repetitions of the “upstream of VPR” and the “downstream of VPR” measurements were performed. The estimated PCRF was 241 while the PCRF setting was 250. It indicates a deviation of the estimation from the setting was 3.5 %. The verification was considered successful because the deviation remained within the limits of $\leq \pm 10\%$. It is always recommended to demonstrate the relative PCRF check of the remaining PCRF stages. The test was successful because the deviations of each PCRF stage were within $\pm 10\%$ and $\pm 15\%$ for the low and high Particle Number Diluter 1 ranges, respectively, compared to those with the reference PCRF = 250 which was verified by the abovementioned reference PCRF check.

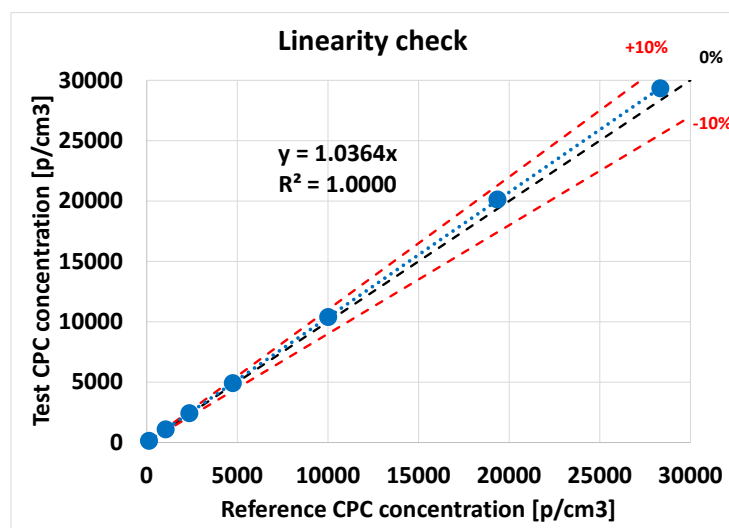


Fig. 1 Results of the CPC linearity check.