A Particle Generator for on-site Checks of PN and PM Measurement Devices

Michael Arndt, Barouch Giechaskiel, Roman Davok, Katia Melz-Giovanella, Verena Vescoli, Robert Diewald, Manfred Linke (AVL List GmbH, Graz, Austria)

Particle number (PN) measurement systems (e.g. AVL APC) are calibrated annually with complex procedures that require electrostatic classifiers and radioactive sources. However more frequent quality assurance checks are necessary and demanded by the market. A poly-disperse aerosol of known size distribution is fully suitable for the majority of these checks [1]. To produce such an aerosol a stable and easy to use particle generator is needed. Such a device should also be useful for checks of soot measurement instruments (e.g. AVL Micro Soot Sensor). The only particle source fulfilling the requirements for such an application range (particle sizes from 10nm to 90nm plus chemical, optical and morphological properties similar to diesel soot) is a diffusion flame burner combined with thermal treatment and additional dilution stages. The miniCAST burners from Jing ltd. [2] basically offer these abilities, but for industry use an encapsulated instrument with a built-in user interface and pre-calibrated ready-to-use set points is required. Therefore AVL developed the AVL Particle Generator (APG).

Working principle of the AVL Particle Generator

Figure 1 shows a schematic diagram of the AVL Particle Generator. The APG consists of a burner, a VPR (Volatile Particle Remover) and a DBS (Dilution Bridge State) for further dilution.

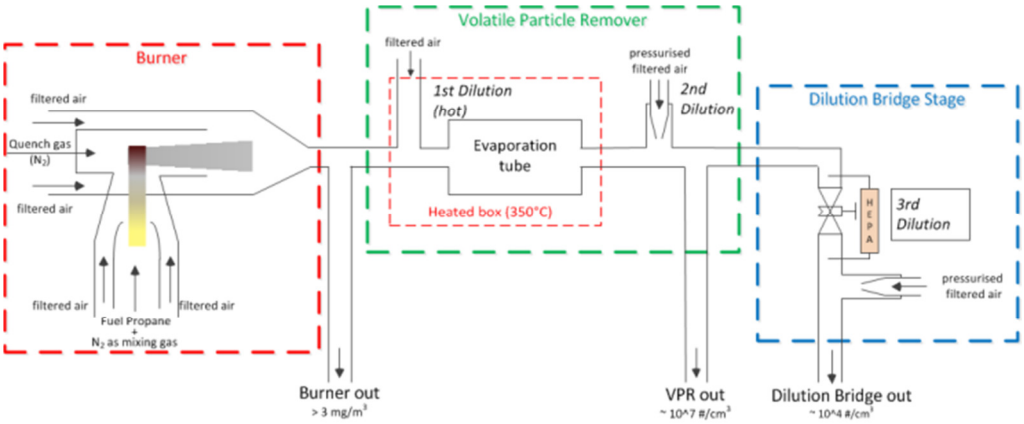

Figure 1: Schematic diagram of the APG

The characteristics of particles generated by the burner mainly depend on the flow conditions of the operating gases:
Fuel (propane)
Mixing Nitrogen N2
Oxidation air
Dilution air at the burner

The VPR modifies the chemical properties and the size of the particles by thermal treatment and dilution. The DBS only affects the particle concentration and not the size distribution or the chemical properties. The particle size distribution was measured downstream of the VPR for approximately 6 h. During this time the particle number concentration was to be constant with a CoV <4%.

The APG currently offers four pre-configured operating points:
Cut-off (On-Site PNC check)
PCRF (On-Site VPR check)
Linearity (On-Site PNC check)
Micro Soot Sensor comparison/validation
In addition an expert mode allows individual settings of all parameters.

Application Examples

1.) PNC cut-off check (23 nm)

The APG produces a particle size distribution with a mean diameter around 10 nm and a concentration >$1x10^5$ p/cm^3. If the PNC measures <500 p/cm^3 then the cut-off size of the PNC is OK. Concentrations in the order of $1x10^3$ p/cm^3 or higher indicate a drift to lower cut-off sizes.

2.) PCRF check

The APG produces a size distribution with mean around 50nm and the concentration is adjusted to $1x10^4$ p/cm^3. The reference PNC measures upstream and downstream of the dilution system (VPR). The ratio should be within 10% of the set PCRF value, which is the mean of the 30, 50 and 100 nm monodisperse PCRFs.

3.) Linearity check by comparing two Particle Number Counters (PNC)

Using a reference PNC, the linearity of the internal PNC from the particle counting device can be checked in a direct comparison.

4.) Aligning two Micro Soot Sensors

Two MSS are connected to the burner-out sampling point via a flow splitter. One instrument serves as reference and the second instrument's calibration factor is adjusted to match the reference. Note that the particle properties of the pre-defined MSS set point are not yet suitable for a direct gravimetric or OC/EC based calibration of the instrument. The optical properties of the particles are still slightly different from typical diesel soot.

References

[1] Giechaskiel B., and Bergmann A. On-Site Checks of the Particle Number Measurement Systems with Polydisperse Aerosol. *SAE* 2012-01-0873 (2012).
[2] Jing L. Combustion Aerosol Standard CAST
[3] Davok R. Characterization of a Particle Generator for the Validation of Particle Number Measurement Systems. Diploma Thesis, Graz University of Technology (2013)

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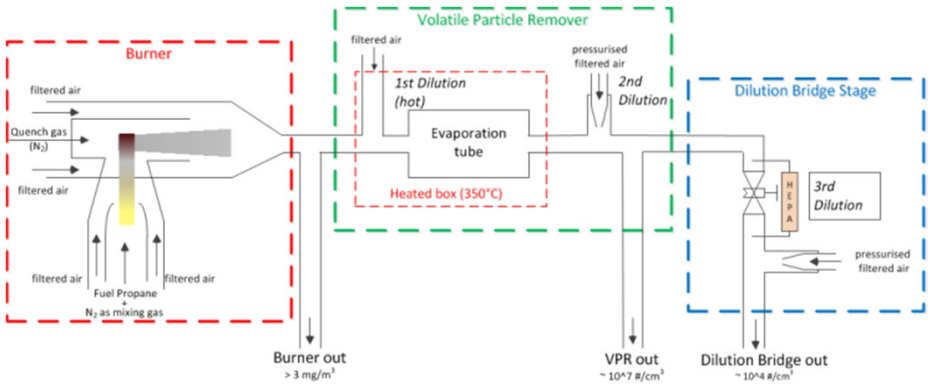
Working principle of the AVL Particle Generator



The AVL Particle Generator (APG) [3] consists of the following components:

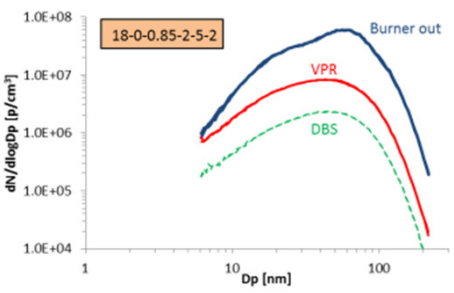
- BURNER is a generator that produces soot particles with adjustable and repeatable size, concentration and chemical composition. It is supplied by Jing ltd. [2]
- VPR (Volatile Particle Remover) is an aerosol dilution and thermal preconditioning unit.
- DBS (Dilution Bridge Stage) is a dilution system that can decrease the soot concentration down to very low levels.

Properties of the generated Particles

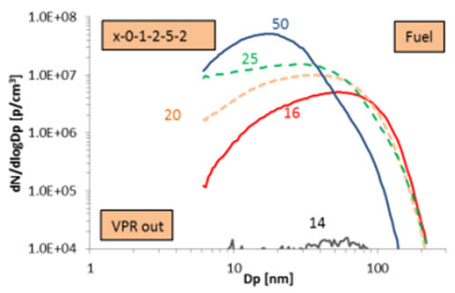
The characteristics of particles generated by the BURNER mainly depend on the flow conditions of the operating gases.

- Fuel (propane)
- Mixing Nitrogen N_2
- Oxidation air
- Dilution air at the BURNER

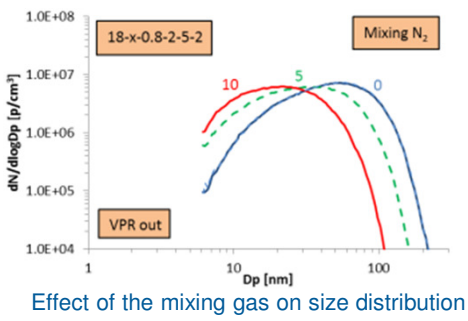
The VPR modifies the chemical properties and the size of the particles by thermal treatment and dilution. The DBS only affects the particle concentration and not the size distribution or the chemical properties. The particle size distribution was measured downstream of the VPR for approximately 6 h. After the heat up time of the VPR the concentration remained constant with a CoV <4%.



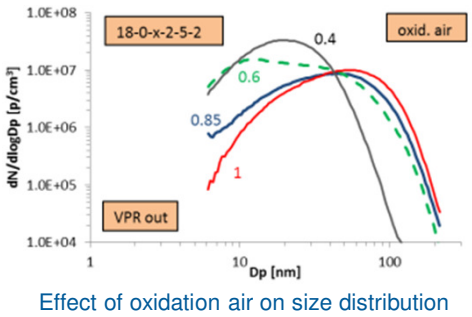
Effect of sampling location on size distribution



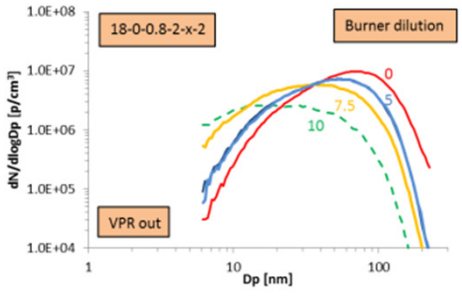
Effect of propane flow on size distribution



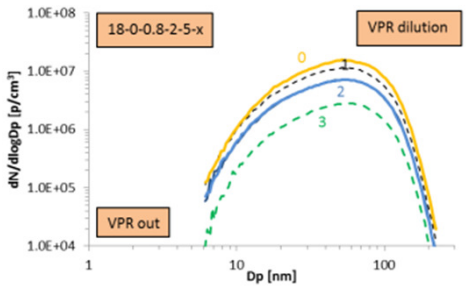
Effect of the mixing gas on size distribution



Effect of oxidation air on size distribution



Effect of burner dilution on size distribution



Effect of VPR dilution on size distribution

Application

The APG currently offers four pre-defined operating points:

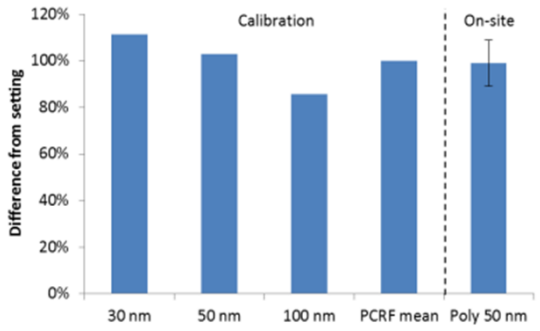
- Cut-off (On-Site PNC check)
- PCRF (On-Site VPR check)
- Linearity (On-Site PNC check)
- Micro Soot Sensor comparison/validation

Application Example 1

PNC cut-off check (23 nm): The APG produces a particle size distribution with a mean diameter around 10 nm and a concentration >1x10^5 p/cm^3. If the PNC measures <500 p/cm^3 then the cut-off size of the PNC is OK. Concentrations in the order of 1x10^3 p/cm^3 or higher indicate a drift to lower cut-off sizes.

Application Example 2

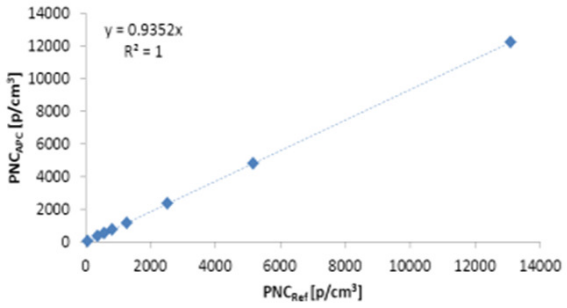
PCRF check: The APG produces a size distribution with mean around 50nm and the concentration is adjusted to 1x10^4 p/cm^3. The reference PNC measures upstream and downstream of the dilution system (VPR). The ratio should be within 10% of the set PCRF value, which is the mean of the 30, 50 and 100 nm monodisperse PCRFs.



Polydisperse aerosol vs. monodiperse aerosol

Application Example 3

Linearity check by comparison of two Particle Number Counters (PNC): Using a reference PNC for a direct comparison with the internal PNC from the particle counting device.



Linearity check: candidate vs. reference PNC

Application Example 4

Aligning two Micro Soot Sensors: Two MSS are connected to the burner-out sampling point via a flow splitter. One instrument serves as reference and the second instrument's calibration factor is adjusted to match the reference. Note that the particle properties of the pre-defined MSS set point are not yet suitable for a direct gravimetric or OC/EC based calibration of the instrument. The optical properties of the particles are still slightly different from typical diesel soot.

References

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