# Effective density of particulate matter emitted from aircraft gas turbine engine sources

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Keywords: effective density, particle mass, aircraft, exhaust
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Growing air travel and airport operations pose potential hazards both for local air quality and global climate. The study of physical and chemical properties of aviation-produced PM advances our understanding of its behaviour and potential negative effects. Recent research has been also motivated by the prepared legislation for PM emissions from aircraft gas turbine engines.

Particle effective density establishes the relationship between mobility size and aerodynamic size. It is also required for conversion of size distributions to mass distributions. Several studies have focused on determination of effective density of combustion aerosols (*e.g.* Park *et al*, 2003).

This study presents initial results of effective density measurements of aircraft gas turbine PM using Centrifugal particle mass analyzer (CPMA, Cambustion). Only particles in a narrow range of mass-to-charge ratio penetrate the CPMA (Olfert *et al*, 2005).

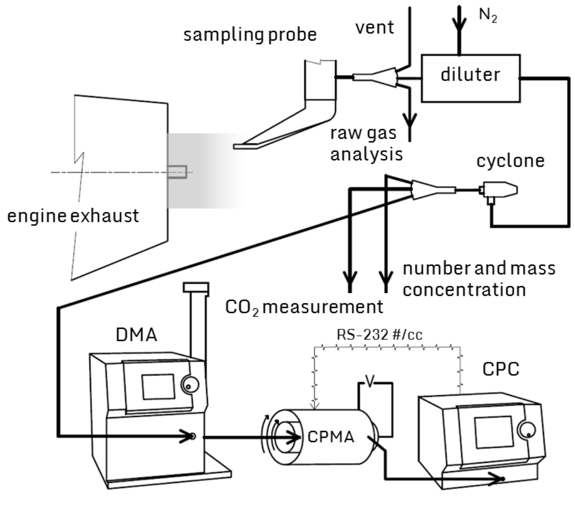

Figure 1. Schematic of the experimental setup.

Experiments were performed in an aircraft engine test cell at SR Technics, Zurich airport. Schematic of the system and experimental setup for particle effective density measurement is seen in Fig. 1.

Particles were sampled from the diluted particle transfer line of the PM sampling system at 1.5 l/min. They were passed through a radioactive charge neutralizer and then classified in a differential mobility analyzer (DMA, Model 3080, TSI Inc.) by mobility diameter. The DMA was set on 10 l/min sheath flow. Aerosol then entered the CPMA where the particles were classified by mass. Exiting particles of the CPMA were counted by a condensation particle counter (CPC, Model 3775, TSI Inc.).

Two CPMA-DMA-CPC setups were run in parallel with the aim to obtain particle mass data for more particle sizes during the limited time of one engine test point. The selected particle sizes lied in the range of highest number concentration of the engine PM. Effective density was then calculated as the mode of the particle mass distribution divided by the volume of the mobility-equivalent spherical particle.

Effective density results from a CFM56-5B series engine are presented in Fig 2. The engine test cycle consisted of a series of power conditions defined by the turbine inlet temperature T3 and engine rotational speed.

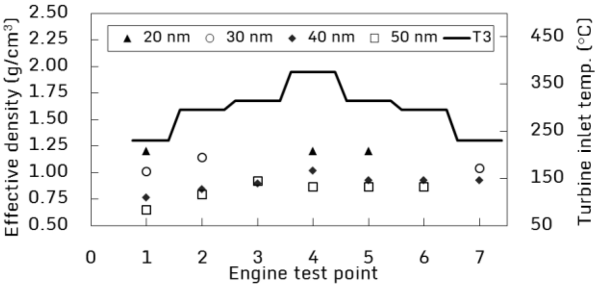

Figure 2. Effective density of particles for individual engine test points and mobility diameters.

A decreasing particle effective density with increasing size was observed due to the structural nature of fractal agglomerate (Fig. 2). Particle effective density was found to be in the range of 0.65 - 1.25 g/cm$^3$. An increase of effective density with engine speed can be observed especially for 40 and 50 nm particles. However, with decreasing engine power in the second half of the engine test effective density did not return to previous values. In order to investigate whether this finding is related to engine warm-up or fits within the measurement uncertainty, more tests are required.

Due to transient nature of the emitted PM (short test point duration) an experimental setup allowing faster measurement is needed and currently under investigation.

This work is sponsored by the Swiss Federal Office of Civil Aviation (BAZL). We thank SR Technics for the use of their facilities.

Park, K., Cao, F., Kittelson, D.B. and McMurry, P.H. (2003) *Environ. Sci. Technol.* **37**, 577-583

Olfert, J.S. and Collings, N. (2005) *J. Aer. Sci.* **36**, 1338-1352.