EMERY OIL REMOVAL EFFICIENCY (2)

APPLICATION NOTE CI-00072

Background

This application note follows on from CI-00070, but uses an improved experimental setup to negate the impurities of solution associated with atomization.

The Catalytic Stripper (hereon CS) is a vital component of a highly efficient Volatile Particle Remover (VPR) system (shown in the diagram below). Typically, the CS is placed between a two-stage (hot and cold) dilution system, to remove any non-solid particles and gas-phase hydrocarbons. The first dilution stage operates between 150 – 400°C ±10°C, and dilutes by a factor of at least 10. The sample then enters the CS whereby semi volatile organic compounds (SVOCs) in the aerosol and gaseous phase are converted into CO_2 and H_2O. Solid particles (e.g. fractal aggregates such as soot) remain unchanged and pass through the CS into the optional second dilution stage, typically operated at ≤ 35ºC, then the sample passes through to the Particulate Number Counter (PNC).

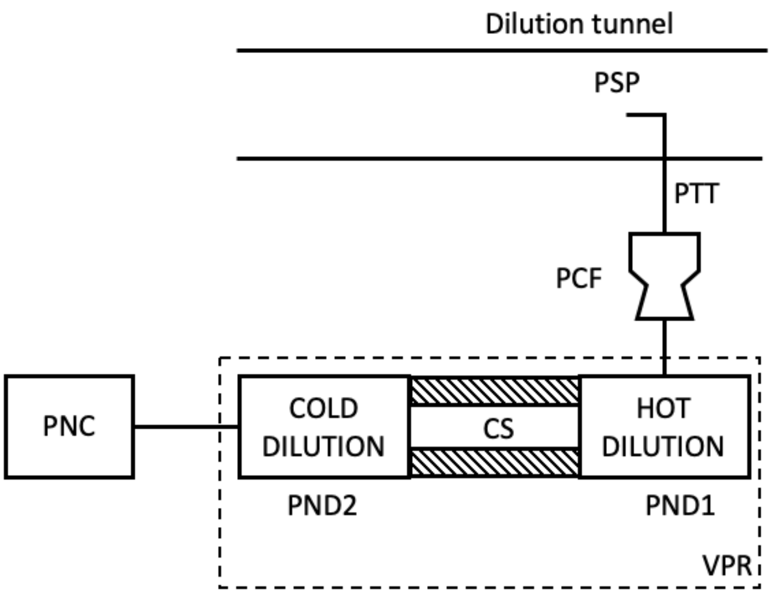

Figure 1: Schematic of the dilution tunnel measurement system in the PMP protocol

Acronym	Definition	Acronym	Definition
PSP	Particle Sampling Probe	VPR	Volatile Particle Remover
PTT	Particle Transfer Tube	PNC	Particle Number Counter
PCF	Particle pre-classifier	CS	Catalytic Stripper
PND	Particle Number Diluter	PND2	Particle Number Diluter 2

It is common to validate the effectiveness of the VPR system by examining the removal efficiency of a single semi-volatile species in a defined mass/size range. The Particle Measurement Programme (PMP) states that a VPR must achieve a > 99.0 % vaporization of 30 nm tetracontane ($CH_3(CH_2)_{38}CH_3$) particles, with an inlet concentration of ≥ 10,000 per cm^3, by means of heating and reduction of partial pressures of the tetracontane. Further, future PMP legislation is likely to include an additional challenge of > 99% removal efficiency of polydisperse alkane (e.g. Eicosane, decane or higher) or emery oil with count median diameter > 50 nm and mass > 1 mg/m^3.

Here, we show the removal efficiency of Emery Oil in the CS015 (1.5 L/min) instrument.

***Note**: the PMP standard dictates the removal efficiency is for the **VPR system as a whole**, and thus will be [even] higher than the results we show here for the undiluted CS.*

Experimental Setup

The experimental apparatus is shown in Figure 2. Emery oil (Polyalphaolefin, or 1-Decene, homopolymer, hydrogenated or 1-Decene, tetramer mixed with 1-decene) was placed inside a Collison nebulizer operated at ~ 2 L/min create a sufficiently concentrated, steady, aerosol flow of 1.5 L/min.

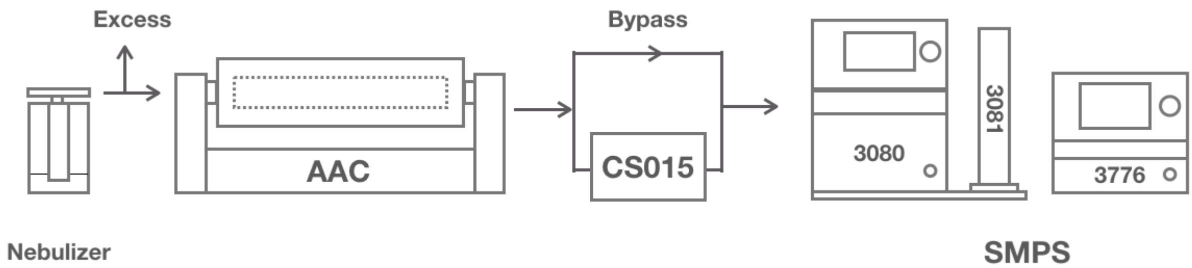

Figure 2: Schematic of the experimental setup

The sample aerosol was passed through an Aerodynamic Aerosol Classifier (AAC, Cambustion Ltd.) with sample flow of 1.5 L/min (defined by the downstream CPC), and sheath flow of 3 L/min, resulting in an effective transfer function of 2:1 (i.e. a broad aerosol distribution). The AAC rotational speeds were set to produce monodisperse aerosol at 70 nm aerodynamic diameter, which is around 85 nm electrical mobility diameter for Emery Oil (density 820 kg/m^3). The experimental setup was first verified with SMPS (TSI 3080 SMPS with long column DMA and 3776 CPC) measurements directly from the AAC, through a bypass line of similar length to that of the CS015. Once the size distribution was confirmed to be stable, data were taken and then the aerosol was sampled through the CS015 (Catalytic Stripper with nominal flow rate of 1.5 L/min).

The first aerosol sample comprised a nominal concentration of 3.79x10^5 #/cm^3 emery oil particles of geometric mean diameter centred around 85 nm, with total mass concentration of 104.7 µg/m^3. The electrical mobility diameter is the same as the geometric as the particles are spherical and electrical mobility measurement is independent of particle density.

The AAC setpoint was then changed to generate a second aerosol sample centred around 130 nm, with a number concentration of 6.48x10^5 #/cm^3 and mass concentration of 566.8 µg/m^3.

The proposed PMP legislation is likely to include: "> 99% removal efficiency of polydisperse alkane (e.g. Eicosane, decane or higher) or emery oil with count median diameter > 50 nm and mass > 1 mg/m^3" for the VPR removal efficiency, *as a whole*. This means that the expected mass at the CS is 100 µg/m^3, and thus the aerosol generated above is a suitable challenge aerosol.

Results

After passing the aerosol through the CS015 and allowing some time for stabilisation, multiple scans were taken on the SMPS. They are very challenging to see in the plot, as the counts were so low per scan (what would be considered noise). For the first

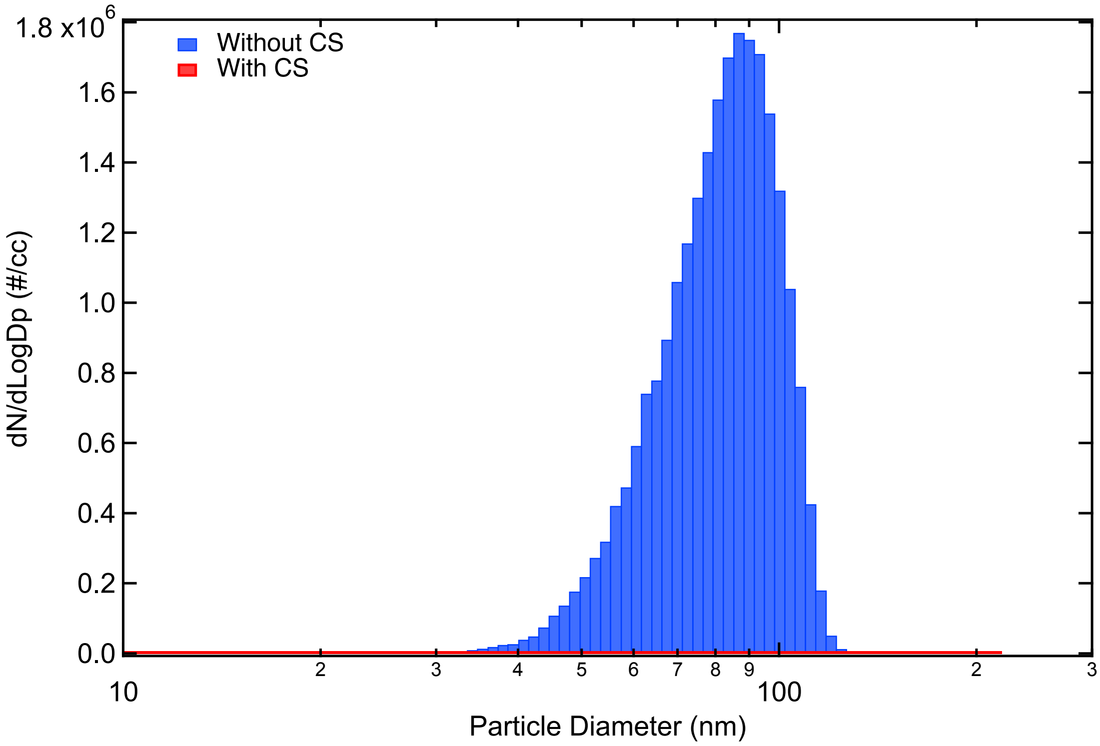

Figure 3: Aerosol number-size distributions as measured by the SMPS through the bypass (blue) and downstream of the CS (red) and Emery Oil concentration centred at 85 nm and total mass 104.7µg/m3

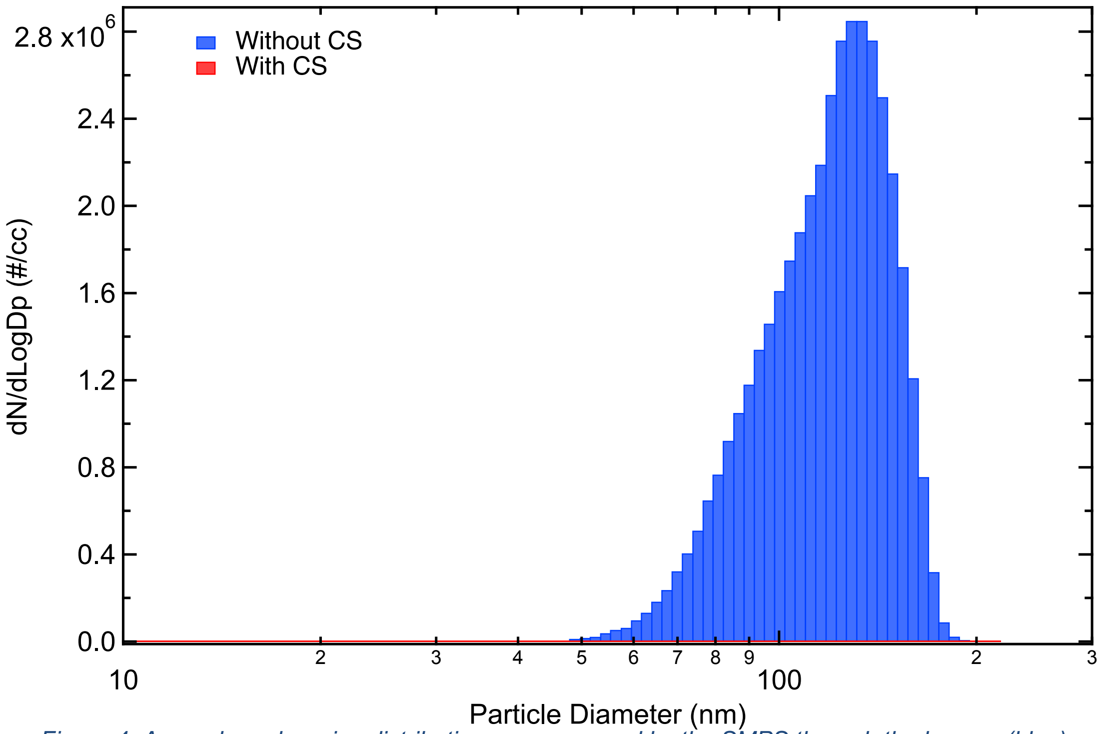

Figure 4: Aerosol number-size distributions as measured by the SMPS through the bypass (blue) and downstream of the CS (red) and Emery Oil concentration centred at 130 nm and total mass 566.8.7µg/m^3

aerosol sample, shown in Fig. 3, the final mass following the CS015 was measured as 0.0272 µg/m^3 and number concentration 27.8 #/cm^3. The calculated removal efficiencies are therefore 99.97% and 99.99% for mass and number, respectively. For the second aerosol sample, shown in Fig. 4, the final mass following the CS015 was 3.75×10^{-5} µg/m^3 and number concentration of 47 #/cm^3, resulting in removal efficiencies of 99.99999% and 99.99%, respectively.

Summary

The results show that the easily CS removes well over 99% by number and mass of the test aerosol proposed for PMP legislation. This is very useful knowledge should this proposed aerosol test be adopted by the PMP workgroup, for future Euro Standards and other emissions regulations.

As the CS easily removes over 99.99% of the test aerosol mass, we can conclude that the CS is a very robust solution for use in a VPR system.

Further Reading

PMP legislation, documentation, and presentations:
https://wiki.unece.org/display/trans/PMP+50th+Session

Application note 00070 on emery oil removal efficiency

References

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