Measurement of solid particle concentration is aided by catalytic stripper technology

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Diesel, locomotive, and gas turbine exhaust contains a complex mixture of solid particles and semi-volatile material that is found in both the particle and the vapor phase. Physical and chemical characterization of these exhaust aerosols in the environment enables a better understanding of potential health effects, effectiveness of alternative combustion technologies and emission control devices, and also the impact of new fuel and lubricant formulations on emissions. To reflect the growing consensus that solid, elemental carbon is a relevant metric and to force the use of diesel particulate filters, Euro 5b regulations introduced a protocol for measuring the solid particle number concentration for particles larger than 23 nm. Similarly, the aerospace SAE E-31 program aims to develop a methodology to measure solid particle mass and number concentration in gas turbine exhaust.

While the aforementioned efforts are generally successful, issues remain with regards to the standard heated tube approach (“evaporation tube” or “thermal denuder”) for separating solid and semi-volatile material due to the formation of artifacts that manifest as incomplete evaporation and/or vapor renucleation. An alternative to this is the catalytic stripper (CS)[1], which has the potential to allow reliable extension of solid particle methods to a lower size range in the absence of artifacts.

The objectives of this paper are two-fold. First, recent advances in CS technology that have been presented in successful “demonstration studies” are discussed. These include 1) design of a miniature CS[2], 2) laboratory validation of a CS when challenged with very high concentrations of semi-volatile hydrocarbon and sulfuric acid aerosols[3], and 3) performance of the CS compared to other methods[3]. While demonstration studies have validated the technology, standardizing the approach is the next step to move forward. Thus, the second objective is to describe current efforts to improve both the design of the catalytic element and choice of components as well as methods used for evaluation.

The CS geometry is fixed though the choice of cell density and physical dimensions. For a fixed geometry, the operating temperature and flowrate dictate performance, although performance needs may vary depending on application. Fig. 1 shows typical solid particle loss curves for a CS operating at 1.5 l/min and 350°C. Design parameters for the CS reflect a balance between solid particle loss, flowrate, residence time, operating temperature, and vapor removal. Fig. 1 shows how the removal of tetracontane vapor increases at the expense of decreased penetration of solid material – this effect is magnified for the smallest particles.

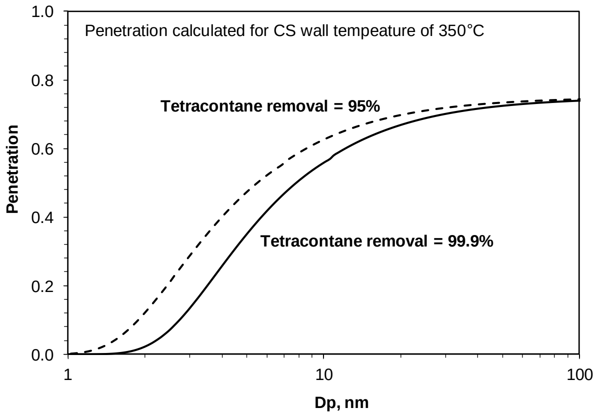

Figure 1 Typical solid particle loss curves (including diffusion and thermophoresis) for CS designed to remove 95% and 99.9% of tetracontane ($C_{40}H_{82}$).

Fig. 2 shows a cross-sectional view of a typical catalytic element including heating, insulation, and the catalytic material.

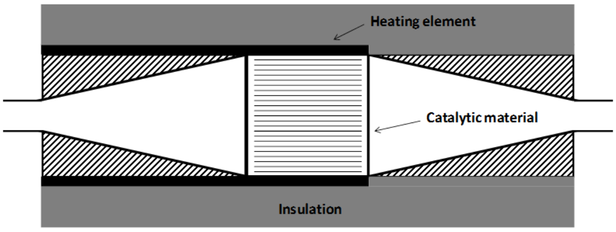

Figure 2 Schematic of catalytic element. Aerosol flow is from left to right.

Overall, results show CS technology is a robust means to separate solid and semi-volatile material. The combination of CS technology and any traditional particle instrument can then be used to provide a real-time measure of solid particle number, size, surface area, or mass concentration. Further to this, the standardization of catalytic element design and performance evaluation techniques provides a basic platform for the design for new aerosol instrumentation.

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