Effect of exhaust oxygen concentration on the performance of a catalytic stripper

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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, as well as the impact of new fuel and lubricant formulations on emissions. To reflect the growing consensus that solid (mostly 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.

The methodologies for determining the solid fraction of an aerosol by separating solid and semi-volatile material include the standard heated tube approach ("evaporation tube" or "thermal denuder") and an alternative referred to as a "catalytic stripper" (CS)[1-3]. In some cases the standard methods do not fully remove all semi-volatile material, which can lead to renucleation. A catalytic stripper is a heated catalytic element used to remove the semi-volatile fraction by oxidation, leaving the solid fraction to be further quantified[1-3]. Because the CS relies on a robust oxidation process, the result is more reliable and thus this technology has the potential to improve solid particle measurements or allow an extension of solid particle methods to a lower size range in the absence of artifacts. Fig. 1 shows an example of a commercially available CS instrument.

Figure 1. Catalytic stripper in a stand-alone enclosure.

While efforts in optimizing CS geometry and composition for oxidation and solid particle penetration have been successful, some issues remain. Previous work has shown that CS performance is nearly unaffected by gas composition up to nearly 100,000 ppm, for low molecular weight gases[4]. This concentration is much higher than what would ever be expected in combustion engine exhaust. However, it is less understood how oxygen concentration effects the CS performance. Combustion stoichiometry limits the amount of hydrocarbon that can be combusted given some amount of oxygen but it has not been shown that combustion stoichiometry is the only factor that limits CS performance for very low oxygen concentrations. Exhaust oxygen concentration at the point of CS measurement is influenced by dilution ratio, dilution gas composition (air or nitrogen), and combustion source (diesel or gasoline).

The goal of this proposed research is to better understand the effect of oxygen concentration and hydrocarbon gas composition on the oxidation performance of a catalytic stripper. Tests were conducted with a specific catalyst formulation and typical prevailing conditions (e.g. temperature, flowrate, etc). Test hydrocarbon gases were propane, butane, and butanol. The oxygen concentration was varied from 0.01% to 10% in factor of 10 increments. For each oxygen concentration, hydrocarbon concentration was varied from lean to stoichiometric to rich with respect to the oxygen available. The test apparatus used to conduct these experiments is shown in Fig. 2.

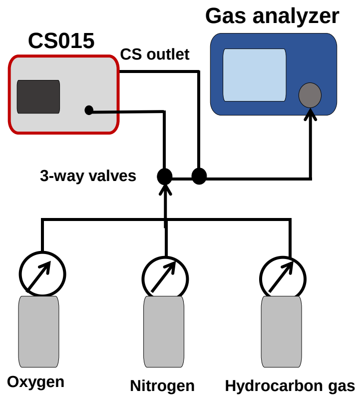

Figure 2. Test schematic showing the CS015 challenged with simulated exhaust with varying concentrations of oxygen and hydrocarbons.

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