Particle Filter – Empty, Soot Load and Regen Filtration Efficiency

Introduction

The DPG package can include particle mass and/or particle number monitoring both upstream and downstream. The filtration performance of a particle filter can be measured by the DPG under a huge range of controlled conditions.

The Efficiency % may be defined as:

$$\eta = 100 \times \left(1 - Outlet / Inlet \right)$$

Soot Load Filtration Efficiency

The filtration efficiency of a particle filter varies significantly with soot load. For monitoring mass-based filtration efficiency during a soot load the DPG samples the penetration downstream three or four times more frequently then the upstream. Operating under the assumption the upstream concentration is stable.

When monitoring particle number-based filtration efficiency, two condensation particle counters (CPCs) are employed. CPCs require a dilution system to bring the particle concentration down within the working range of the instrument. The Cambustion Dual Simultaneous Diluter (DSD) with dual CPCs is the solution to allow continuous particle number measurement both upstream and downstream.

Figure 1 shows a typical particle number filtration efficiency curve in black. The upstream (green) and downstream (red) show typical concentrations during soot loading of a clean particle filter.

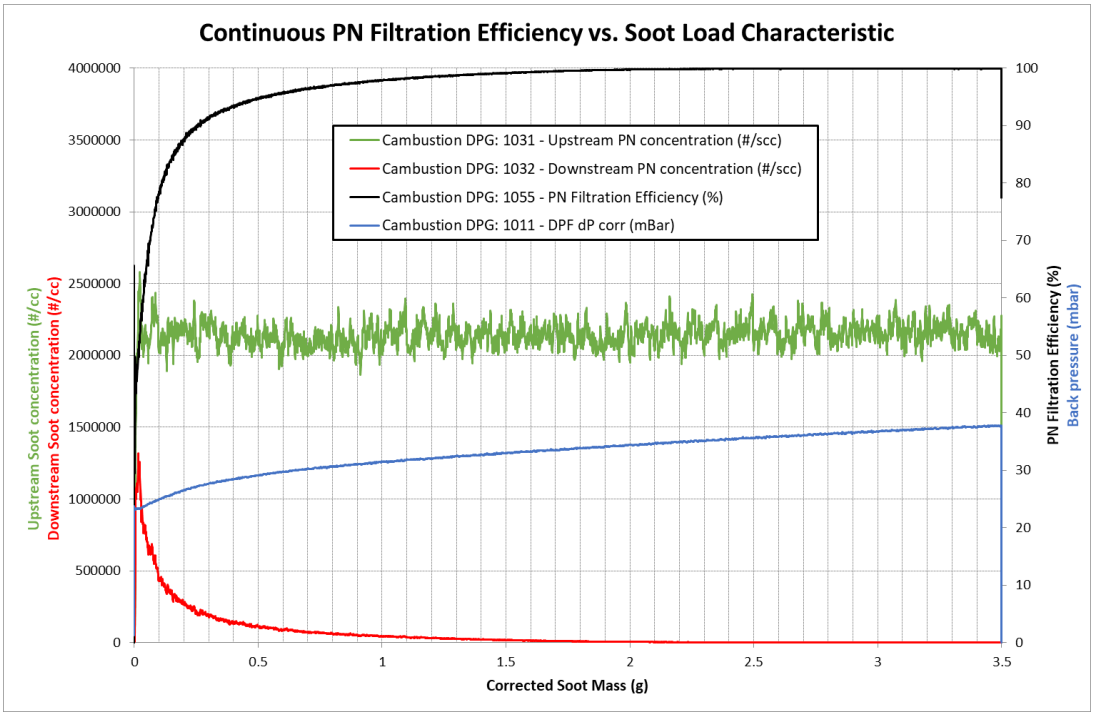

Figure 1 - Continuous Particle Number Filtration

Empty Filtration Efficiency

Gasoline particulate filters (GPFs) are different to Diesel Particle Filters (DPFs) in that they are required to perform without a soot cake acting as a high efficiency filter membrane. The empty filtration efficiency of a GPF is a key characteristic when comparing technologies. In order to measure the real empty filtration efficiency Cambustion have developed a new split primary air system which allows the new generation of stage 7 DPGs to operate at very clean conditions with the flame lit. This ultra clean burner-on mode allows the DPG to warmup GPFs without adding any mass and therefore preserving the empty filtration efficiency performance during a warmup mode.

The DPG can produce a controlled burst of particles which along with a Cambustion DSD can measure the empty filtration in a very repeatable manor. The size, duration and number of bursts can be configured to suit the application. Figure 2 Below is example data showing two bursts with a significant amount of downstream signal.

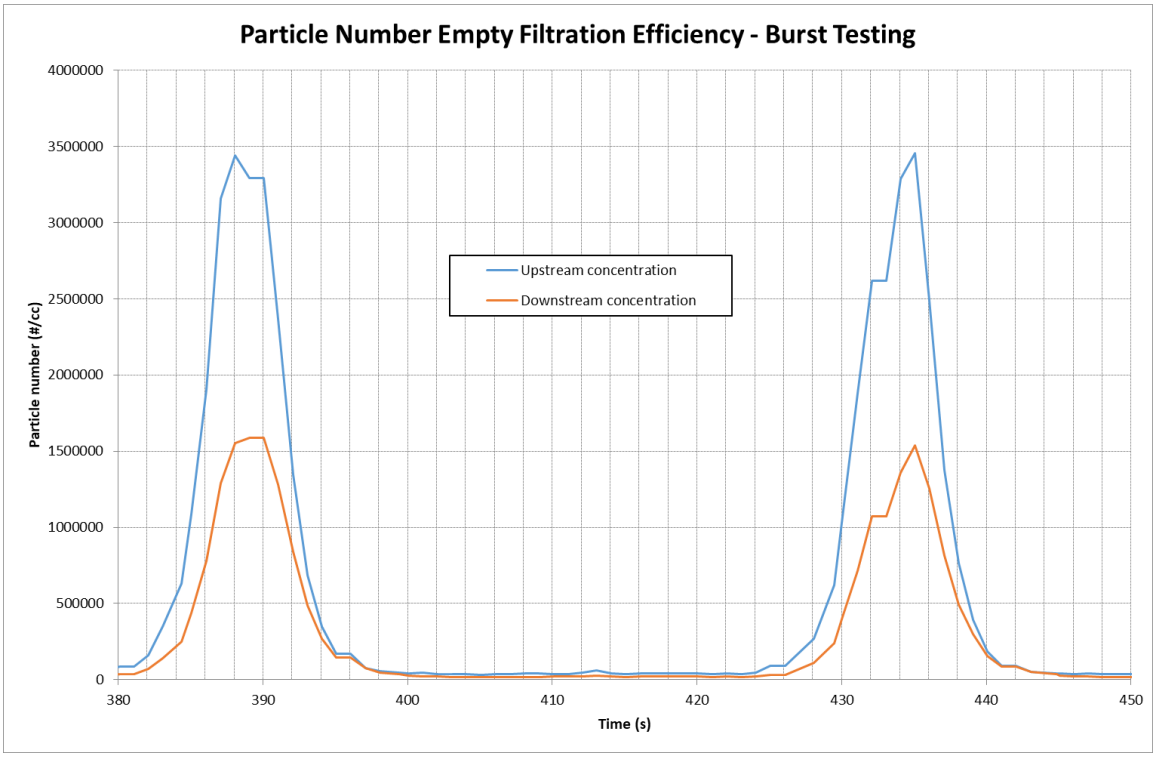

Figure 2 - Particle Number Empty Filtration - Burst Test

Due to the time delay between the upstream and downstream measurements, the live filtration efficiency cannot be trusted. Therefore, the DPG software integrates the particle number upstream and downstream to calculate the integrated filtration efficiency. This produces a single value for empty filtration efficiency.

Regeneration Filtration Efficiency

The DPG can be equipped with different levels of electrical heater inside which can raise the temperature within a filter without burning diesel. Below is a graph showing the particles shedding off of a particle filter, when heated electronically. The upstream concentration is clean.

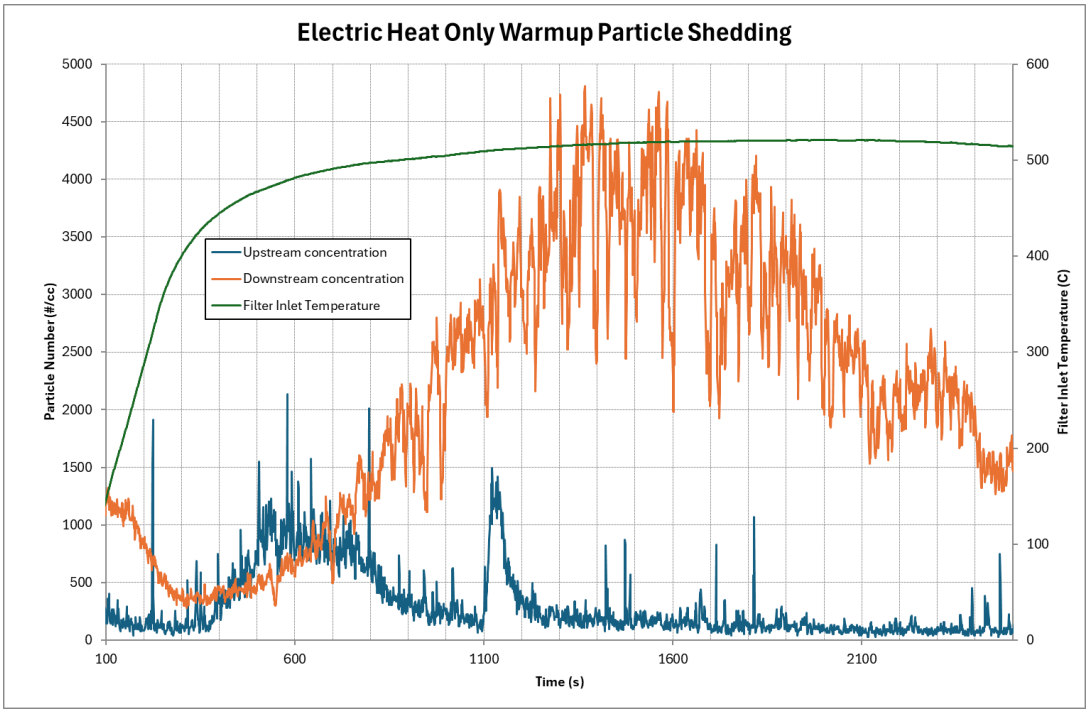

Figure 3 - Clean Regen Particle Shedding

A more widely used regeneration filtration efficiency test utilises the burner and electrical heater power available to gradually ramp up the particle filter temperature until oxidation occurs, the burner conditions are changed to create soot which is loaded onto the regenerating filter. This is a very demanding condition for a particle filter. This test was created to mimic real world particle emissions under load from a loaded particle filter.

- A special high temperature tertiary heater is required to run this regeneration filtration test.

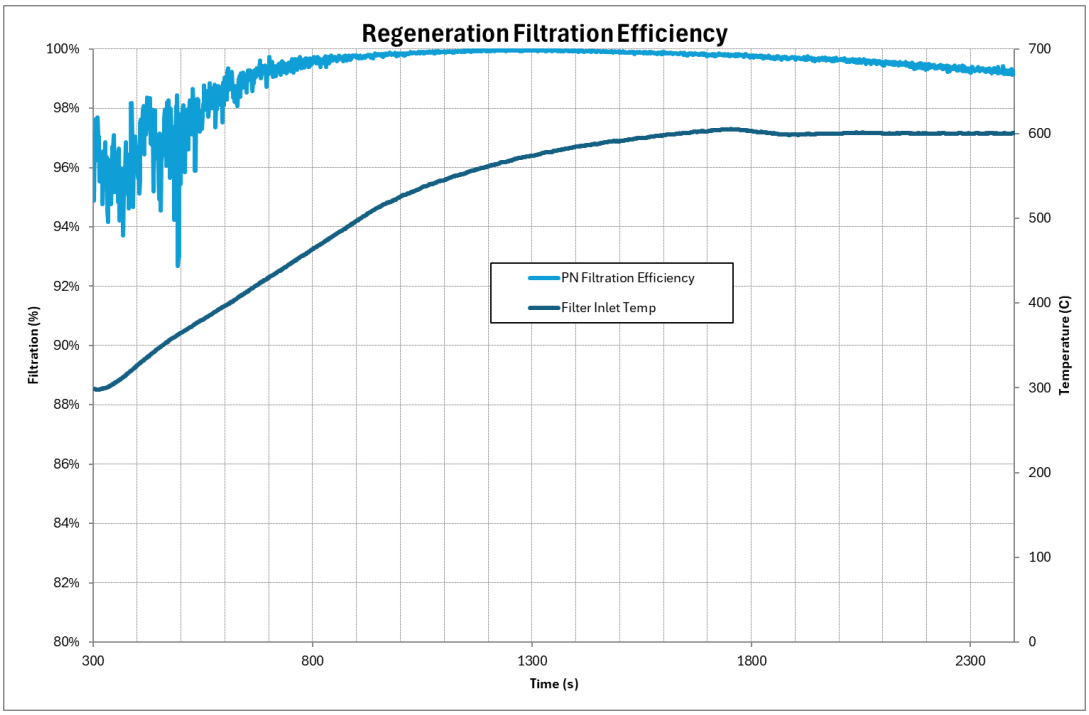

Figure 4 - Regen Filtration Efficiency