

Standalone particulate filter test system



Tests GPFs and Light, Medium & Heavy Duty DPFs at full scale flows

PM & PN filtration efficiency & catalytic activity tests

Ash deposition during loading or regeneration

Empty filtration efficiency characterisation

Measurement of Δp vs soot mass

Soot Mass Limit & regeneration

Minimal installation requirements

Accelerated testing & unattended operation

Soot generated from Diesel fuel: results correlated with engine test data

Introduction

Particulate Filter Test System

The Cambustion DPG is a system for the complete automated testing of Diesel and Gasoline Particulate Filters.

Based around a Diesel burner and accurate flow bench, the DPG facilitates testing of GPFs and Light, Medium and Heavy Duty DPFs at full scale flows and temperatures, with the capability to load soot, regenerate the filter and conduct flow tests.

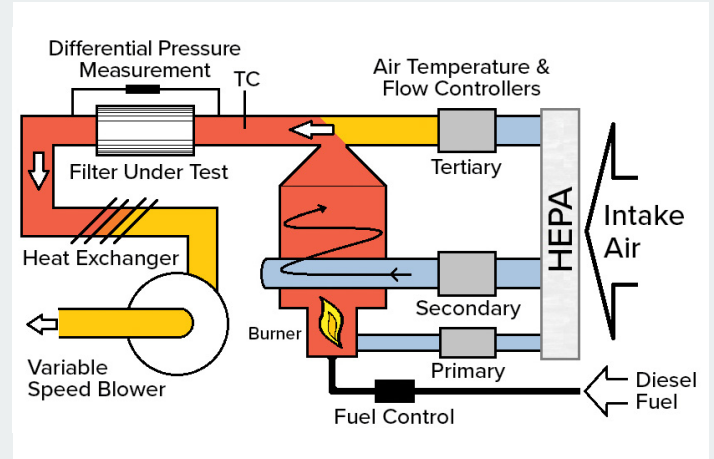
The DPG is used in both Quality Assurance testing and for R&D applications:

- In QA applications, the DPG offers a standard characterization of Δp and filtration efficiency vs soot load, reproducible across different laboratories, and a standardized and automated method for comparing the Soot Mass Limit (SML).
- In R&D, the DPG offers filter developers a faster and more repeatable comparison of different filter designs and coatings than engine testing, while for vehicle and engine developers it provides fast soot loading of filters for regeneration strategy and calibration development. Optional extras such as online ash doping or particle number measurement upstream and downstream are now available.

Compared with engine testing, the DPG offers significantly improved repeatability and much lower capital and operating costs than an engine test facility: infrastructure requirements are minimal, tests are highly automated and high soot generation rates maximise throughput while minimising fuel and energy consumption.

Operating Principle

The DPG burns diesel fuel in a controlled primary air flow which mainly determines the soot rate. A flow of secondary air is introduced around the flame, keeping the soot away from the chamber walls and quenching the flame. The primary and secondary air flow, fuel flow and air temperatures are all controlled to ensure stability of the soot generation.



A tertiary air flow is mixed with the burner flow. This can be controlled over a wide range of flow and temperature to give control of the overall test filter temperature and flow independent of the burner parameters, and therefore soot generation is not affected. The mixed flow is drawn through the test filter by a downstream blower. This ensures that the burner conditions are unaffected by the filter backpressure, and in particular that the soot rate therefore does not vary during loading.

For measurement of the filter parameters, the DPG includes measurement of the inlet pressure and filter Δp , gas flow and inlet & exhaust temperatures.

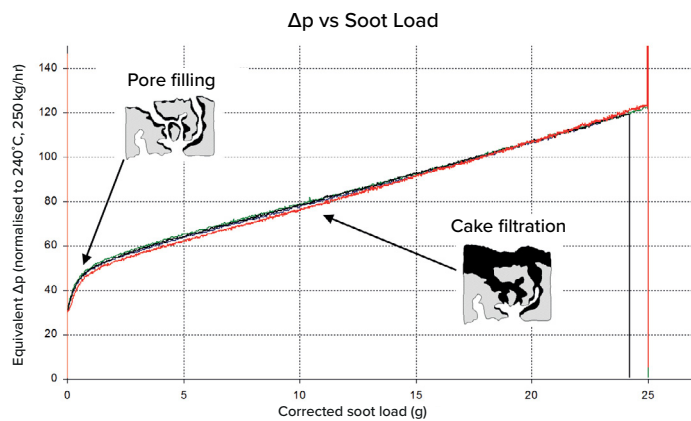


Applications

Δp vs Soot Load Characterisation

The DPG loads a filter from an empty state and continually monitors Δp and automatically processes the results using loaded and empty weighings of the filter to provide a far better measurement of loading behaviour than is achievable with engine testing; in particular:

- The flow and temperature of the filter are independently controlled and more stable than in an engine test.
- The soot rate is stable and unaffected by the backpressure of the filter.
- The DPG can warm the filter up in a clean combustion mode so that the effect of filter warm up and the critical initial 'pore filling' phase of the loading characteristic are well distinguished. This allows weighing of the filter to occur at elevated temperature, to avoid errors due to the uncertainty of water absorption.
- The test program, report generation and checking against acceptance limits is automated in the DPG, with operator intervention only required to initiate the test and unload the filter for weighing.
- With the Filter Test Housing accessory (see page 5), the DPG allows rapid testing of uncanned filters.

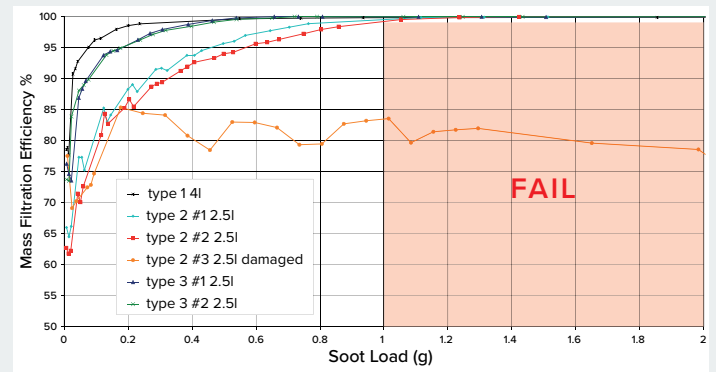


The preceding example shows the backpressure characteristic of the same filter measured on four different DPG systems.

Compared with other filter test rigs, the DPG is unique in being able to perform these measurements at the full scale flow and temperature of the engine application, at a soot generation rate of 20g/h (or more), which significantly shortens test duration. The diesel burner produces soot more representative of engine soot than non-combustion sources.

PM Filtration Efficiency Measurement

With the optional efficiency monitoring system (incorporating a smoke meter), the DPG can automatically measure the mass based filtration efficiency of the filter.



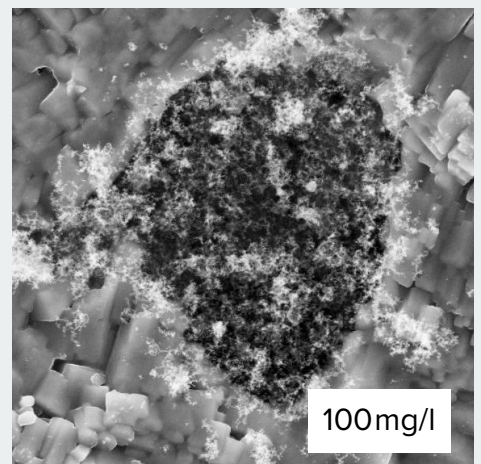
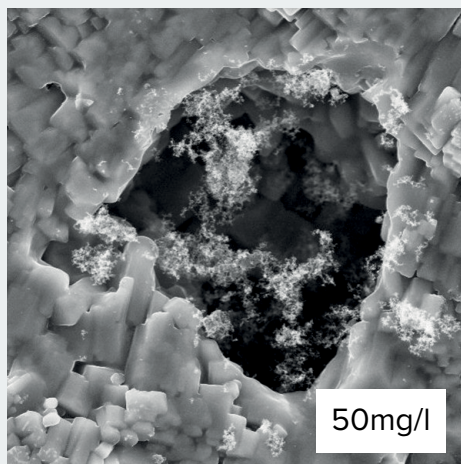
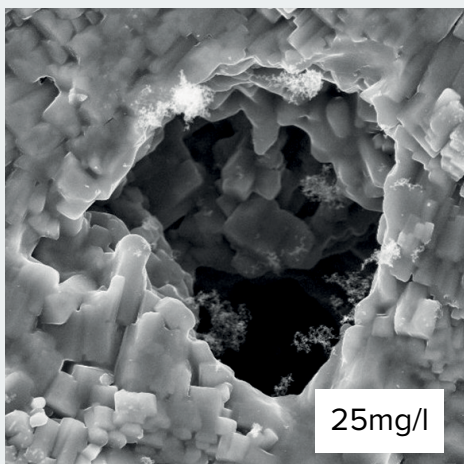
This test resolves the high stabilised efficiency of a loaded filter, (used to identify damaged filters).

This test can then be used to automatically detect whether a filter has cracked under thermal stresses during regeneration testing.

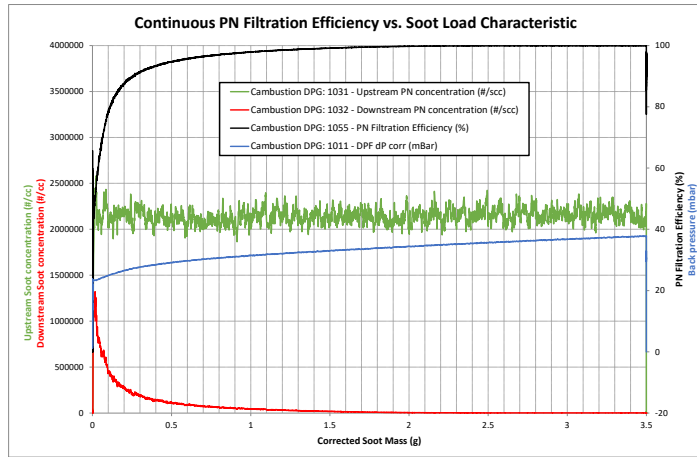
PN Filtration Efficiency Measurement

The DPG can be integrated with dual condensation particle counters using the Dual Simultaneous Diluter (DSD) system - see page 5. The DSD provides the DPG with continuous PN filtration efficiency measurement.

SEM images of cordierite filter core courtesy of Dr S. Payne



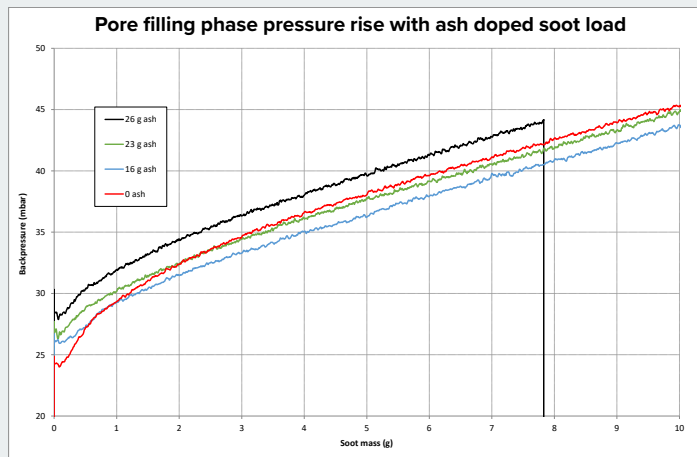
The most popular application of this technology is to characterise the empty filtration efficiency of a clean filter. This can also be used to measure the filtration efficiency



performance over a soot load, defining the complete range of PN filtration performance.

Online Ash Doping System

The online Ash Doping System is used to inject a mixture of ash additive and diesel into the diesel burner within a DPG. The major advantage of this system is isolating the ash doped diesel, reducing contamination of the DPG fuel system should



the DPG be required for non-ash related work. The Online Ash doping system is controlled via the DPG UI and can be programmed to add doped fuel in at different rates at any given burner conditions. This allows the user to study the different types of ash deposition.

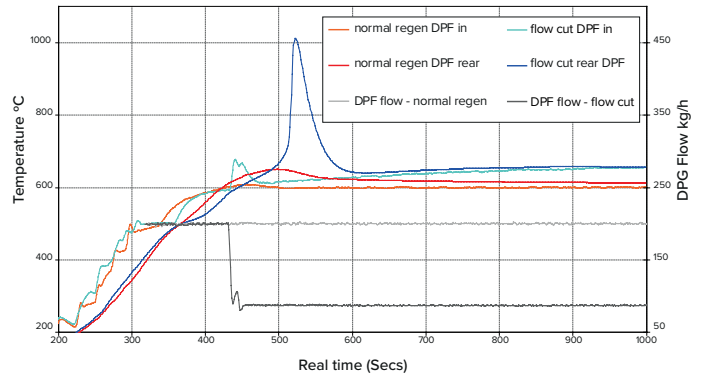
Soot Mass Limit Testing

The unique capability of the DPG to both load a filter with soot and regenerate it enables an automated cycle to establish the soot mass limit (SML) for a given filter.

In this test, a filter is repeatedly loaded and severely regenerated, with an increased soot mass for each loading cycle. After each regeneration, the filtration efficiency is

automatically measured to confirm whether the filter was damaged in the regeneration.

Exothermic temperature peaks produced in severe regeneration on DPG



The DPG also includes up to 32 thermocouple inputs for monitoring temperature gradients within the filter. This test is typically run entirely automatically, 24 hours per day, achieving dramatically better productivity than engine testing.

Durability Testing

With a high soot generation rate and the capability to automatically run sequences of tests, the DPG is ideal for durability testing of filters.

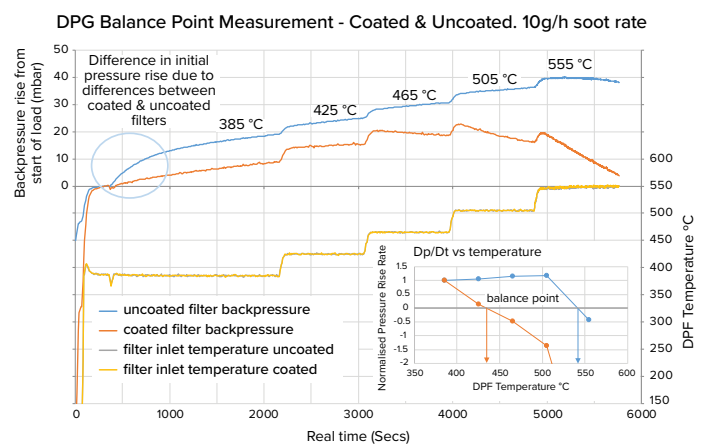
Each cycle of load to full capacity followed by regeneration can usually be reproduced in less than three hours, with any damage automatically detected by monitoring the filtration efficiency during filter loading.

Flow Sweep Testing

The DPG can also characterise the Δp vs flow rate behaviour as performed on a flow bench. The DPG includes correction for fluctuations in ambient temperature and barometric pressure.

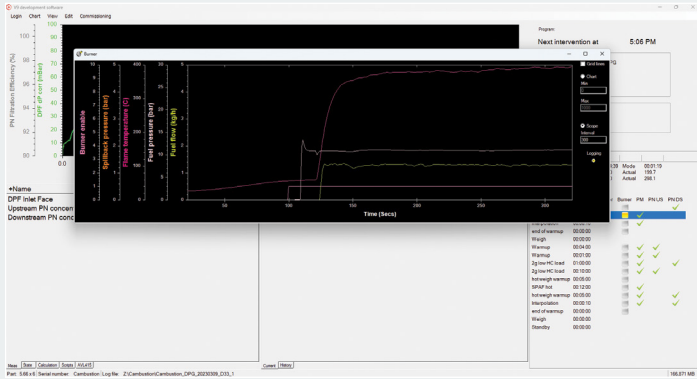
Filter Catalytic Activity Testing

Operation of the DPG at temperatures below full regeneration allows measurement of soot oxidation catalyst effectiveness either by mass loss or backpressure balance point.



Control Software

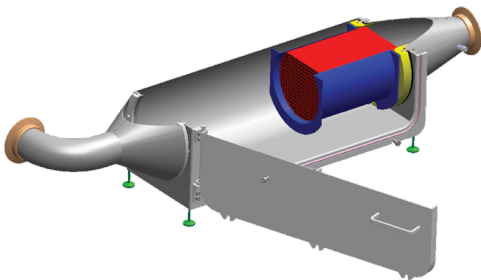
All operation of the DPG is controlled remotely from software running on a PC. The software automatically runs complex test sequences, logs data files from testing and provides feedback to the operators on the state of the test. The software can also communicate automatically with weighing scales, eliminating operator error in the weighing of soot deposited on a filter.



The system can be configured with different specifications for different filter types and can then automatically assess a test pass/fail on the basis of filtration efficiency or Δp vs soot load. A .pdf report is automatically generated with the results of the test.

Filter mounting options & Filter Test Housing

The DPG can be used for testing whole vehicle exhaust systems, or canned filters up to approximately 13" diameter. The Filter Test Housing (FTH) - shown below - is an accessory which allows rapid testing of uncanned filters.



This saves the time and cost associated with the canning process, and removes the influence of poor flow distribution on the test results.

The filter is held in an adaptor in a flexible ceramic seal. Adaptors are available for a wide range of filter sizes up to 9" diameter, and custom shapes can easily be supplied as required.

Dual Simultaneous Diluter (DSD) (see separate brochure)



Filter Loading for Strategy Development

Development and testing of regeneration strategies in vehicles requires many tests to be run on filters with high soot loads. Traditionally, each of these tests of only a few minutes must be preceded by many hours of expensive dynamometer time to accumulate the required soot load on the filter, a process made more difficult by the variability of engine soot generation and the need for a closely controlled soot load to ensure repeatability of the testing.

The DPG can load filters rapidly and repeatably, leaving expensive engine or vehicle test facilities to operate efficiently on high value development work.

Alternatively, Cambustion can supply adaptors for testing filters in their production cans.



DPG Installation

DPG installation requires only minimal external services.

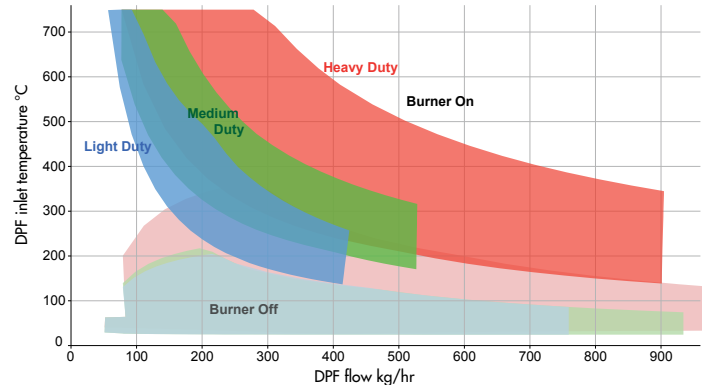
The system includes its own cooling air fan and controller, plus filtering and temperature control of all inlet flows. It will draw and filter fuel directly from a tank or barrel.

Ducts for cooling air inlet and exhaust, a stack for the burner exhaust, 3-phase electrical supply and a fuel tank are the only customer infrastructure requirements.



Specifications

DPG - LD - MD - HD Temperature & Flow Ranges



Flow control	Variable speed blower(s)
Soot generation rate	<0.001g/h (warm-up mode) Std. 2 – 20g/h (loading mode) 10000-20E6 n/cc
Soot generation	Diesel burner
Fuel compatibility	Diesel fuel, up to 10% biodiesel (EN590 or ASTM D 975 No.2-D)
Soot rate repeatability	+/- 20%
User thermocouples	16, type K (32 optional)
Aux. analogue inputs	2, 16 bit -10 to +10V
Data logging	User defined, max 10 Hz
Safety system interlocks	Fire, Ambient CO, Temperature, Fuel leak and Systems faults
Measurement accuracy:	
Flow	±5% of reading above 100kg/h
Temperature	±1% reading (K)
Filter Backpressure	±0.05 mbar ± 1% reading
Test section size	Std. 1700mm length × 622mm height × 518mm depth Extended test sections available
All specifications subject to change without notice	

Cambustion is an independent, privately owned company with headquarters in Cambridge, UK and customers in more than 30 countries worldwide

Cambustion continue to research & develop novel instrumentation, and now also offer Measurement Consultancy; helping our global clients to solve a wide range of particle and gas measurement issues.



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