Cold Flow Testing
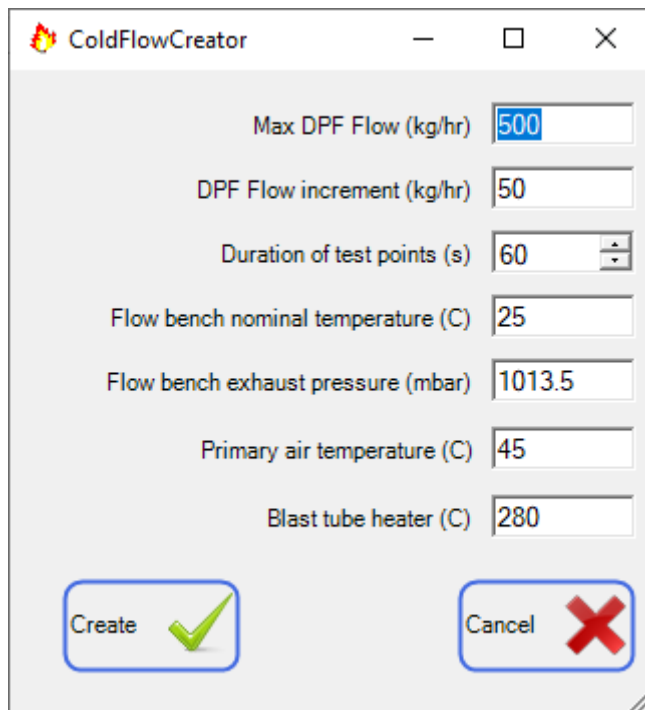
Introduction

The DPG allows the characterisation of pressure drop vs flow for a particle filter. Note that if the part is loaded, there may be significant hysteresis observed – this is discussed below).

The part is exposed to a selectable range of flows (close to ambient temperature) which increase from zero to a selectable maximum in selectable increments and then reduce again back down to zero. The results from the DPG may be corrected to general inlet conditions. Note that for loaded parts, this characteristic for a DPF may show significant hysteresis (This is discussed in more detail in Application note DPG 006).

A pre-programmed schedule allows the user to rapidly construct an automatic schedule using the parameters shown in the table below – including the conversion of the data to selectable 'standard conditions'


The DPG logs the pressure, temperature and mass flow to a standard format datafile and also constructs an automatically generated .pdf report (see example below).

DPG Test Report

Test information

Start time	30-Jan-2023 13:21:34
Part type	10.42L
Volume	10.42
Nozzle	0.6
Serial number	SN39
Test reference	cold flow 700
Operator	dyntest
Test rig number	18
Schedule	AutomaticFlowSweep
Target soot mass	.0
DPF Control	Test section inlet
Software version	9.4.0.0

Comments

Pre test comments	0:100:700 - 5 min each
Post test comments	

Test validity: Pass

Independent	Dependent	Value	Min	Max	Function	Status

DPF dP corr
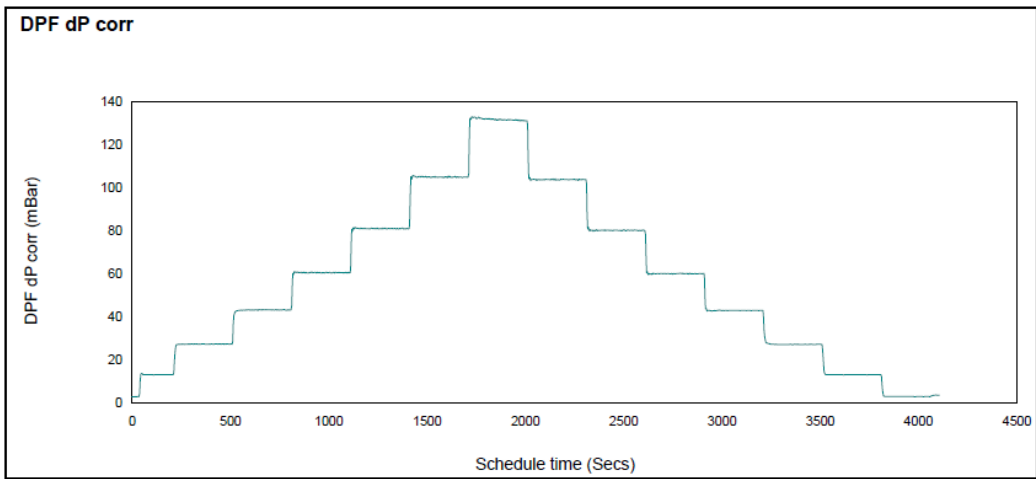
Flow sweep Report parameters

Description	Value
Flow bench exhaust pressure (mbar)	1,013.50
Flow bench nominal temperature (C)	25.00

Flow sweep Report results

	DPF flow mmt (kg/hr)	DPF temp mmt (C)	DPF entry pressure (mbar)	DPF dP (mbar)	BBE Flow (m3/hr)	BBE dP (mbar)
0kg/hr	23.44	23.44	1,000.42	3.16	19.86	3.15
100kg/hr	100.28	23.40	998.80	13.38	84.97	13.19
200kg/hr	200.53	23.78	994.72	27.57	169.76	26.61
300kg/hr	299.69	23.66	988.93	43.39	253.77	41.05
400kg/hr	400.00	23.40	981.12	60.70	338.95	56.17
500kg/hr	499.99	23.42	971.20	81.04	423.66	72.81
600kg/hr	600.00	23.20	959.08	104.95	508.70	91.23
700kg/hr	700.00	23.43	944.90	131.18	593.12	109.44
600kg/hr	599.90	23.57	959.13	103.81	508.12	90.06
500kg/hr	499.94	23.65	971.18	80.31	423.36	72.07
400kg/hr	399.92	23.73	981.35	60.20	338.59	55.59
300kg/hr	299.99	23.83	989.11	43.15	253.92	40.78
200kg/hr	200.87	23.86	995.07	27.45	170.01	26.49
100kg/hr	100.61	23.65	999.20	13.36	85.20	13.15
0kg/hr	28.99	23.08	1,000.56	3.82	24.58	3.82

Flow sweep Chart
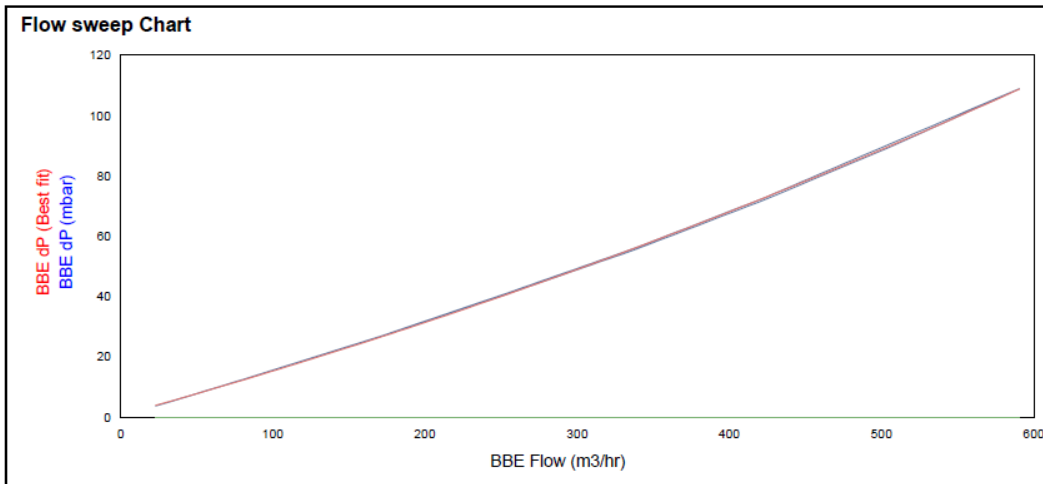
Hysteresis observed with loaded parts

DPFs are often flow tested when loaded with a prescribed amount of soot (e.g. 10g/litre). This may be done on an engine by monitoring the particle filter pressure drop while varying the exhaust flow rate (correcting for particle filter pressure and temperature variations). Alternatively, a cold flow test bench can characterise the ΔP vs flowrate for the loaded particle filter. The DPG has a schedule which automatically-generates a ΔP vs flowrate curve for loaded (or empty) particle filters.

It has been observed that there may be a significant hysteresis effect when a part is flow tested after being freshly loaded with soot.

DPF loading

A 5.66" x 10" cylindrical DPF was loaded with 40g (~10g/l) of soot on a DPG following a "de-green" regeneration to ensure that the brick was empty and correctly conditioned (see application note DPG001 for soot loading procedure). The DPG soot loading rate was set to 2g/hour at standard conditions of 250kg/hour, 240ºC.

DPF flow testing results

The DPF was then cooled to approximately 25°C and cold flow tested up the maximum flow capacity of the DPG (~550kg/hr for this part and soot load). The DPG stabilises for 20s at each flow point and the ΔP is recorded and averaged over the subsequent 35s.

The flow test procedure for the loaded part was then repeated.

Figure 1 shows the measure pressure drop across the DPF (ΔP) vs time during the first cold flow test. The total flow setpoint is gradually increased to the maximum flow and then gradually reduced to zero.

Figure 2 shows the averaged ΔP measurement vs flow rate for the increasing and reducing flow for both the loaded DPF (red curve – 1st flow test, blue curve – repeat flow test) and the clean DPF (green).
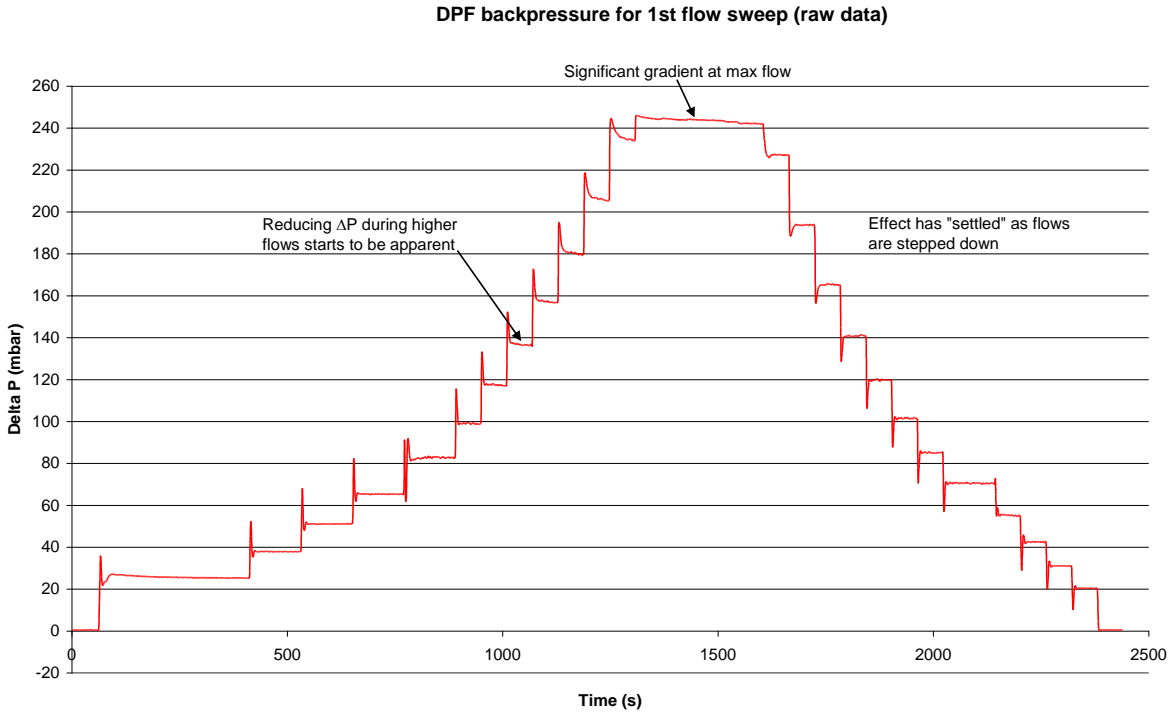
DPF backpressure for 1st flow sweep (raw data)

Figure 1: Raw pressure data during first flow sweep indicating reduction of □P during high flow test points.
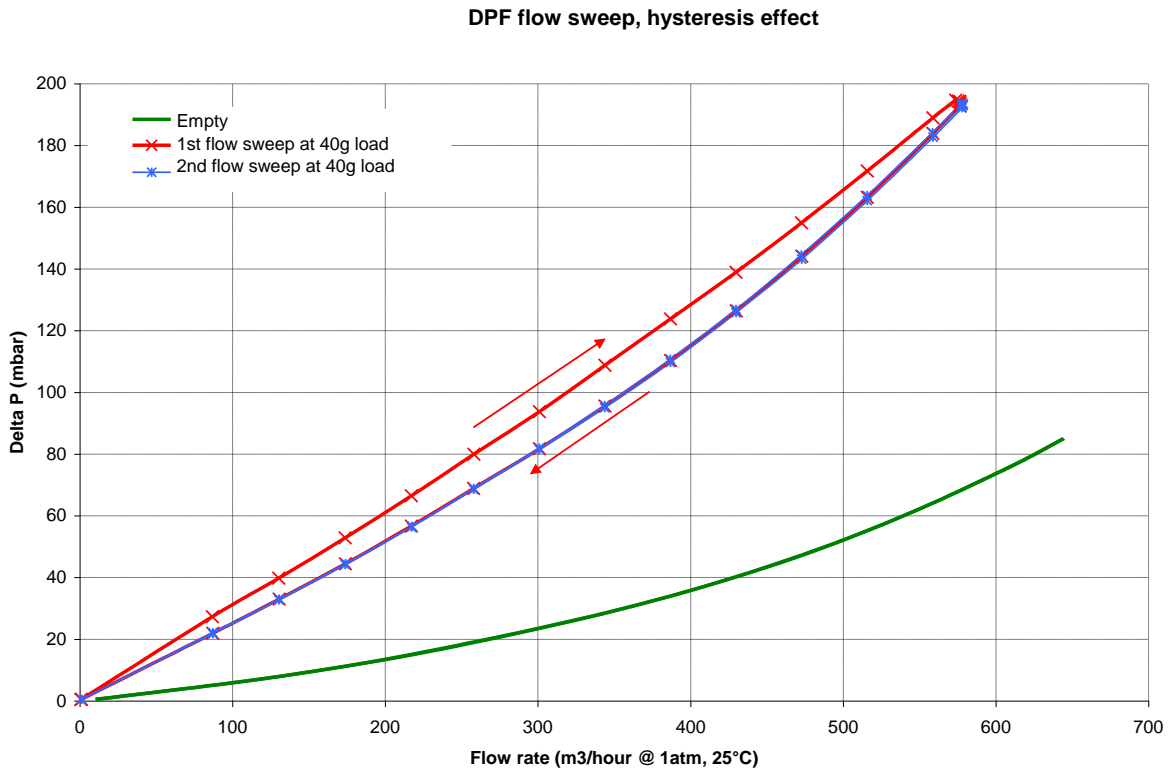
DPF flow sweep, hysteresis effect

Figure 2: Flow sweep data showing hysteresis

It is clear from *Figure 2* that the initial flow curve (recorded during increasing flow) up to the maximum flow rate (580m3/hr) is significantly higher than the ΔP recorded during the reducing flow sweep and the subsequent repeat.

On inspection of the raw ΔP vs flow data (see *Figure 1*), one can see that at about 1000s (corresponding to a flow of about 250m3/hr) the ΔP is continuing to reduce *within each step* despite the DPGs flow having stabilised. During the reducing flow steps, this effect is less pronounced and, indeed, the repeat of this flow sweep (see *Figure 2*, conducted immediately afterwards) shows little deviation from this line.

Discussion

The stability and repeatability of the DPG allows for this effect to be studied in greater details than might be achieved on an engine.

Two possible explanations are offered for this hysteresis:

1. Changes in the bulk density of the soot (compaction/softness/fluffiness) may be a factor. The soot structure may well be "collapsing" under the increasing flow - resulting in altered ΔP characteristics.
2. There may be a "drying" effect where water, HC or some other volatile compound is removed during the flow test.

Other factors may also be significant and further investigative work is required to identify and quantify them.

In order to minimise the effects of hysteresis we recommend customer calculate the Reynolds number they will operate the particle filter on-engine and use this to generate a cold flow sweep range of similar Reynolds number. This will prevent very high flow cold flow sweeps from altering the backpressure of the soot load.