



Cold Flow testing on the DPG including hysteresis discussion

Introduction

The DPG allows the characterisation of pressure drop vs flow for a DPF part. 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 DPF 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’

Parameter	Value
Max DPF Flow (kg/hr)	400
DPF Flow increment (kg/hr)	50
Duration of test points (s)	120
Blown bench nominal temperature (C)	25
Blown bench exhaust pressure (mbar)	1013.5

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



DPG Test Report

Test information

Test date 07-Jan-2010 11:01:46
 Part type
 Serial number
 Test reference
 Operator
 Test rig number
 Schedule

Comments

Pre test comments:
 Post test comments:

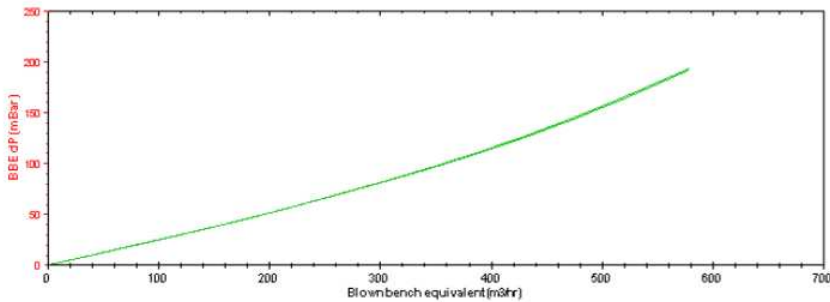
Flow sweep

Equivalent flow (m3/hr)	Equivalent DP (mbar)	DPF flow (kg/hr)	DPF entry temperature (C)	DPF inlet pressure (mbar)	DPF DP (mbar)
1.0	0.5	1.2	13.6	1010.6	0
87.0	22.2	99.9	13.3	1008.5	21
130.6	33.0	149.9	13.2	1006.3	31
174.0	44.5	199.9	13.2	1003.4	42
217.5	56.6	249.8	13.3	999.8	55
257.9	68.9	300.0	17.8	999.1	70
301.0	82.0	350.2	18.0	995.3	85
343.7	95.8	399.9	18.1	990.9	102
386.7	110.8	450.0	18.1	985.9	121
429.7	126.9	499.9	18.0	980.0	142
472.5	144.5	549.9	18.1	973.2	166
515.6	163.8	599.9	18.0	965.2	195
558.6	184.2	649.9	18.0	956.0	228
577.2	193.2	671.5	18.0	952.9	243
578.0	193.3	672.4	18.0	953.7	243
578.6	193.5	673.1	18.0	954.2	243
578.5	193.0	673.0	18.0	953.7	242
577.8	192.2	672.3	18.0	952.7	241
558.7	182.7	650.1	18.0	956.0	225
515.8	162.2	600.0	18.0	965.2	192
472.8	143.2	550.0	17.9	973.1	164
429.8	125.8	500.0	18.0	979.8	140
386.8	109.7	449.9	17.9	985.7	119
343.8	95.0	399.9	17.9	990.8	101
300.9	81.5	350.0	17.9	995.2	85
257.9	68.5	300.0	18.0	999.0	70
217.1	56.3	249.9	14.1	999.7	55
173.8	44.2	199.9	13.8	1003.3	42
130.4	32.8	149.9	13.6	1006.2	31
87.0	21.8	100.0	13.6	1008.5	20
1.0	0.6	1.2	15.0	1010.6	0

Blown bench reference conditions

Temperature (C) 25
 Pressure (mBar) 1013.5

Blown bench equivalent



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 DPF pressure drop while varying the exhaust flow rate (correcting for DPF pressure and temperature variations). Alternatively, a cold flow test bench can characterise the ΔP vs flowrate for the loaded DPF. The DPG has a schedule which automatically-generates a ΔP vs flowrate curve for loaded (or empty) DPF parts.

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, 240°C.

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).

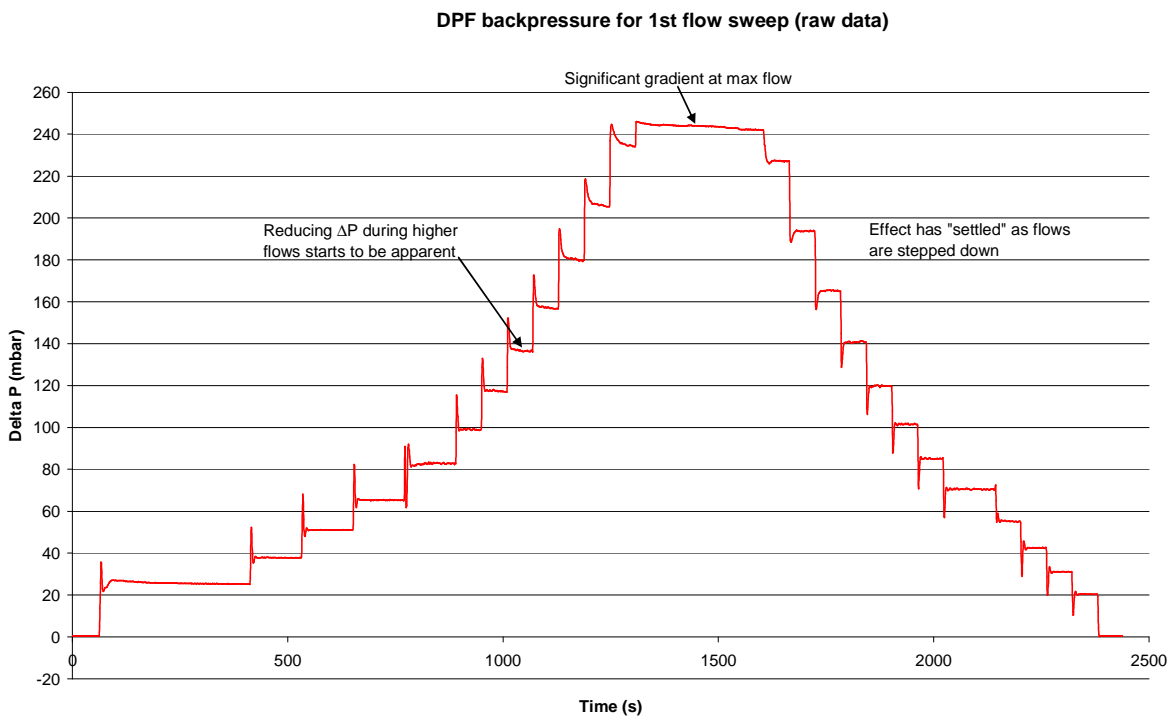


Figure 1: Raw pressure data during first flow sweep indicating reduction of ΔP during high flow test points.

DPF flow sweep, hysteresis effect

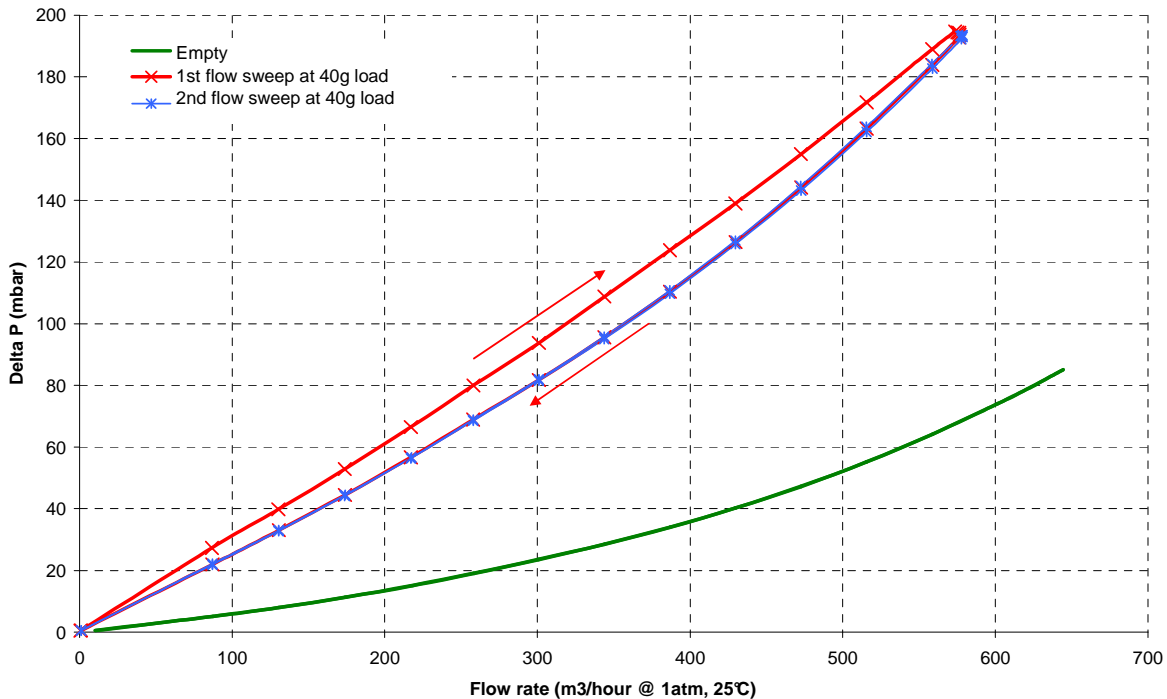


Figure 2: Flow sweep data showing hysteresis

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 effects 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.