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Performance Evaluation of Diesel Particulate Filters during Loading from Clean

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Contents

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- Need for rig based DPF testing
- Equipment Used
  - Cambustion DPG – DPF Test System
  - AVL 415 Smoke meter
  - VPR + CPC system
  - Filter test housing
- System capability & validation data
- Measurements of DPF Behaviour
  - Δp vs soot load
  - Repeatability & reproducibility
  - DPF Filtration efficiency measurements
  - Mass based and PMP number based efficiency
  - Backpressure vs flow and temperature
- Regeneration comparison with engine behaviour

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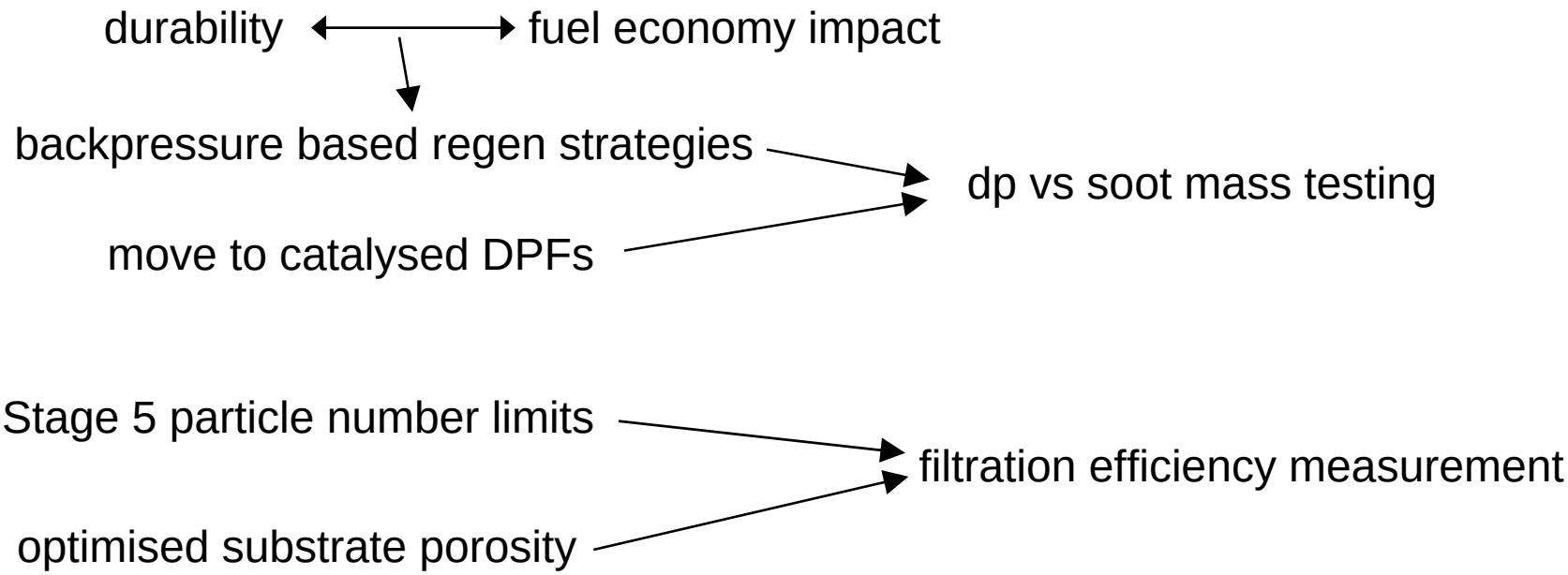
Motivation



Issues with engine testing

- cost of engine, dynamometer + infrastructure
- repeatability of engine based testing
- compounding of warm up and soot load formation

- Solution : rig based testing: DPG developed from Johnson Matthey's ISG technology.

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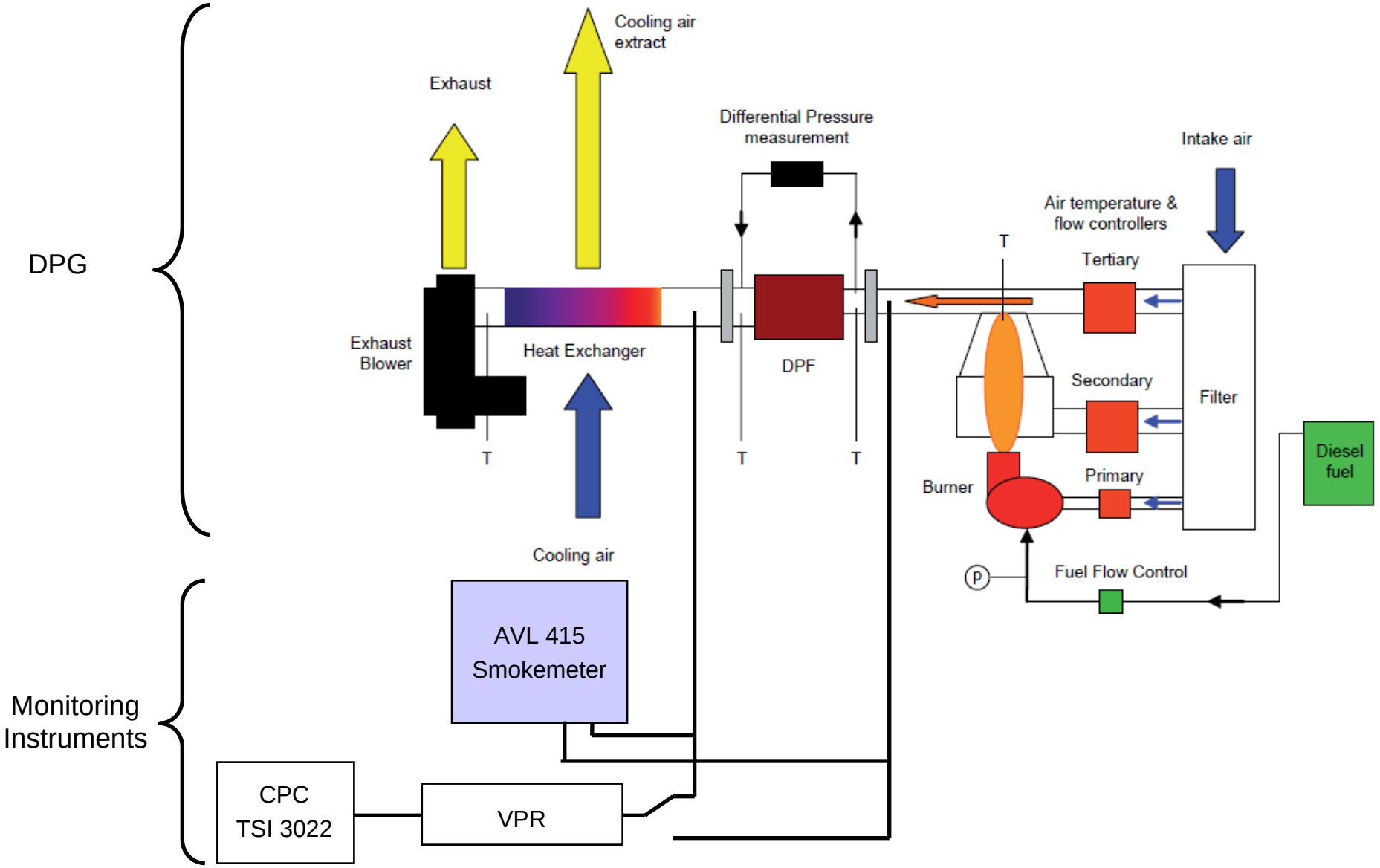
System Configuration



Filter Test Housing for Uncanned Substrates

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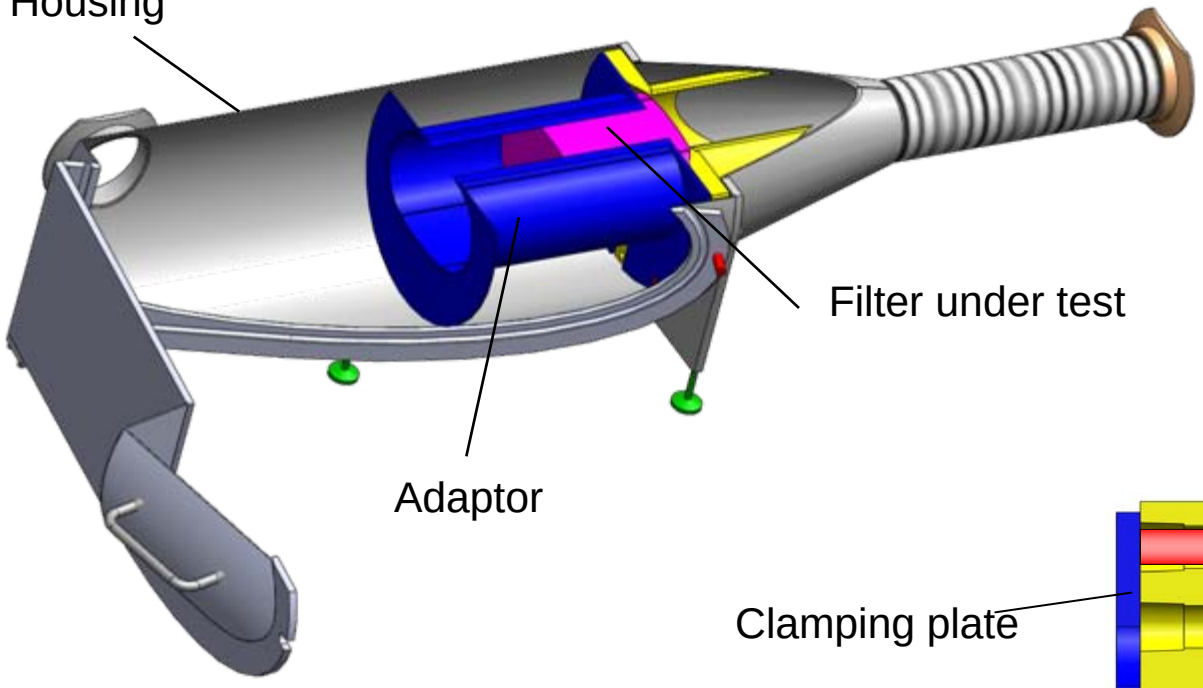

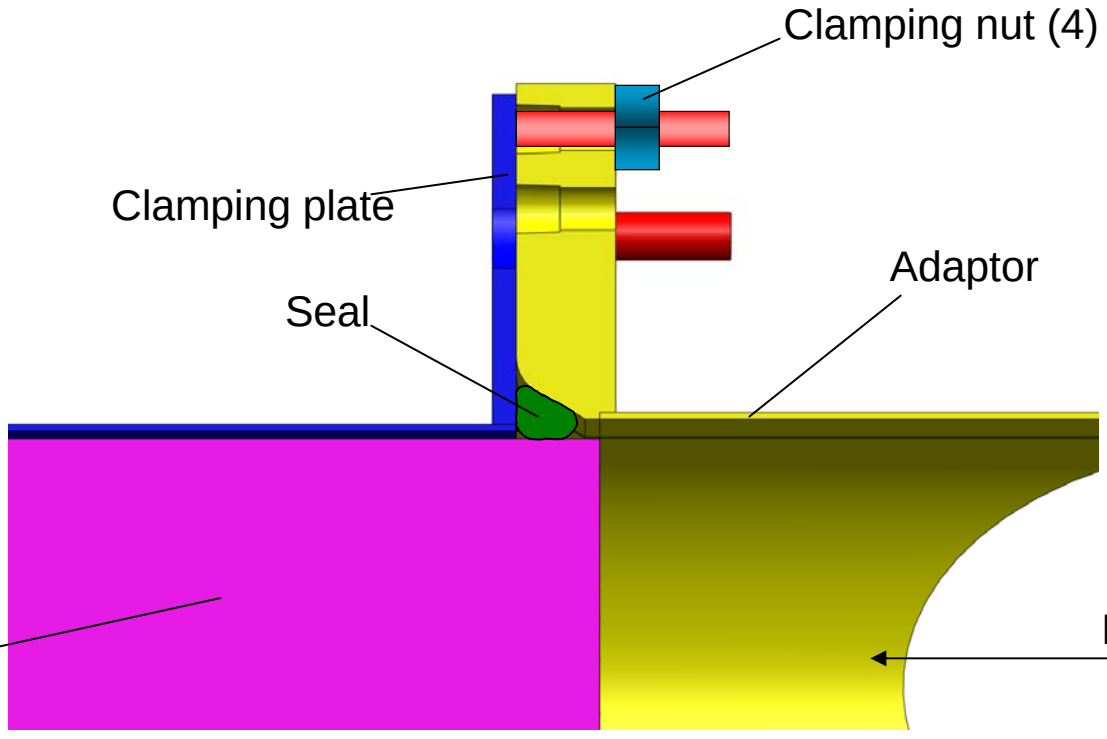

Close up of sealing:

seal is aluminiumized glass fibre fabric with stainless steel mesh or ceramic rope filling

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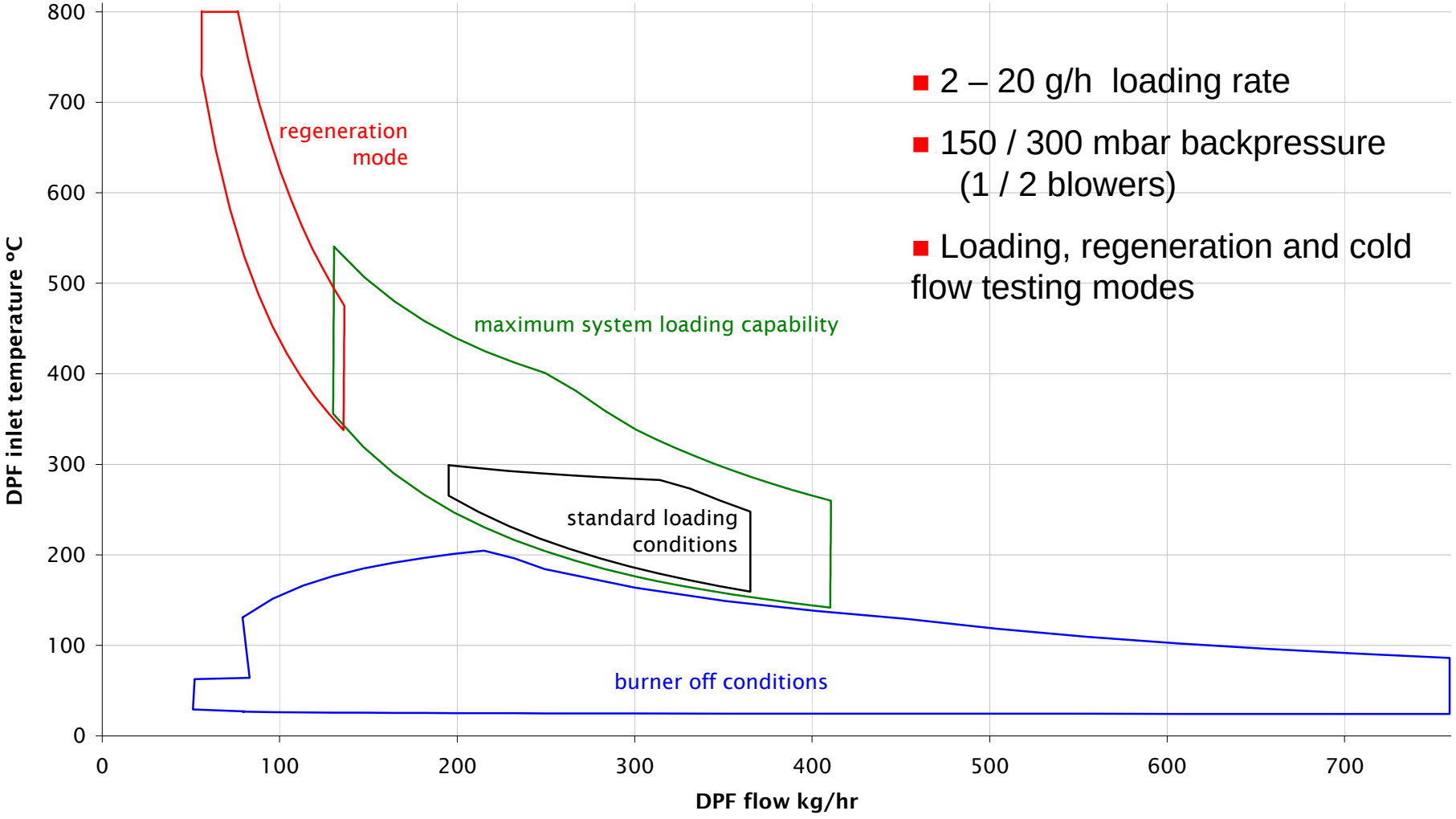
Operating Capability

DPG Operating Temperature : Flow Rate Capability



- 2 – 20 g/h loading rate
- 150 / 300 mbar backpressure (1 / 2 blowers)
- Loading, regeneration and cold flow testing modes

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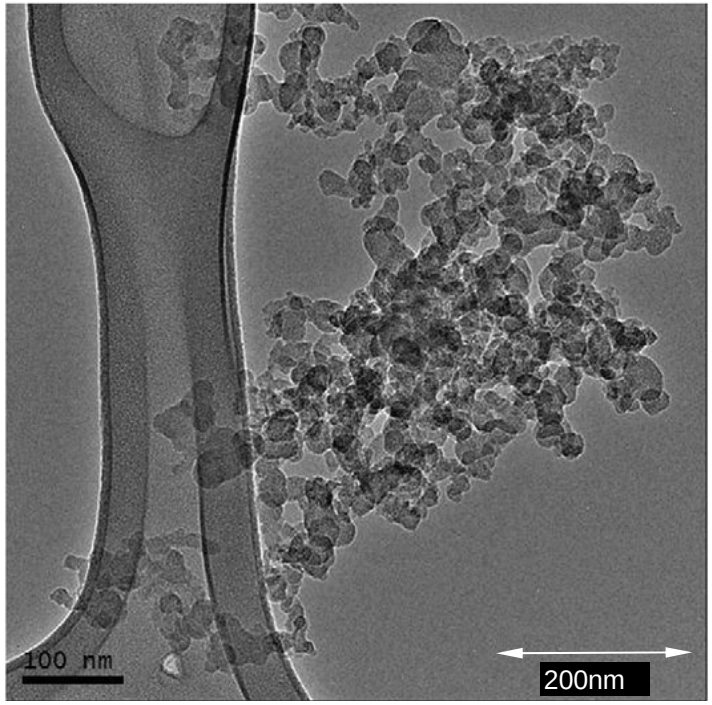
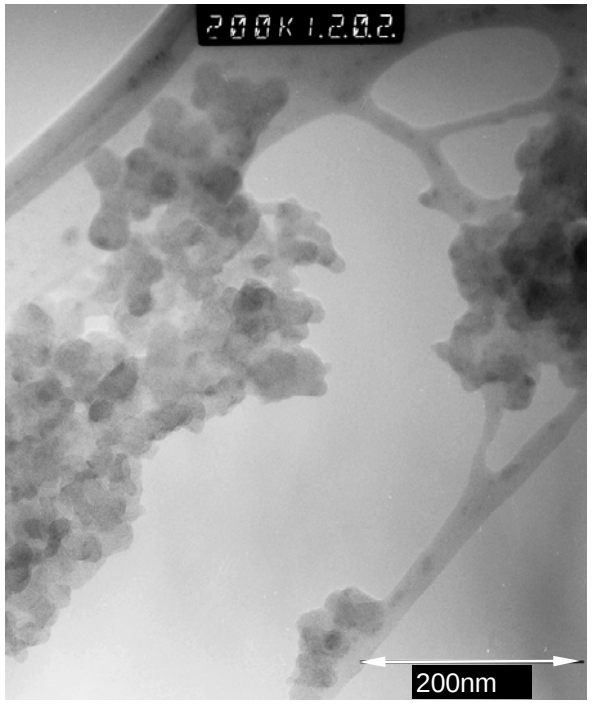
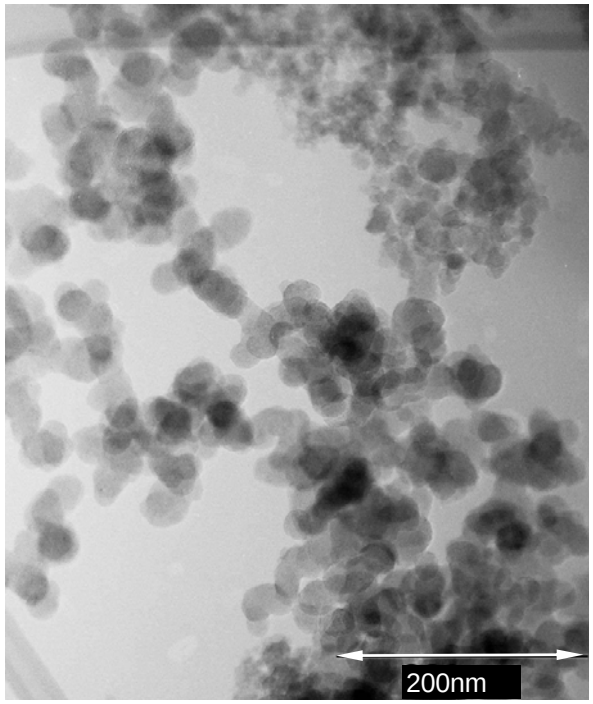
Transmission Electron Microscopy Images of Diesel Soot



Light Duty Diesel engine soot



Heavy Duty Diesel engine soot



Cambustion DPG soot

Khalid Al Qurashi, EMS Energy Inst, Penn State Uni

Dr Peter Harris, Centre for Advanced Microscopy, University of Reading

- Primary particle size close to 20nm for DPG and engine soot
- Morphology appears similar

Backpressure vs Soot Load

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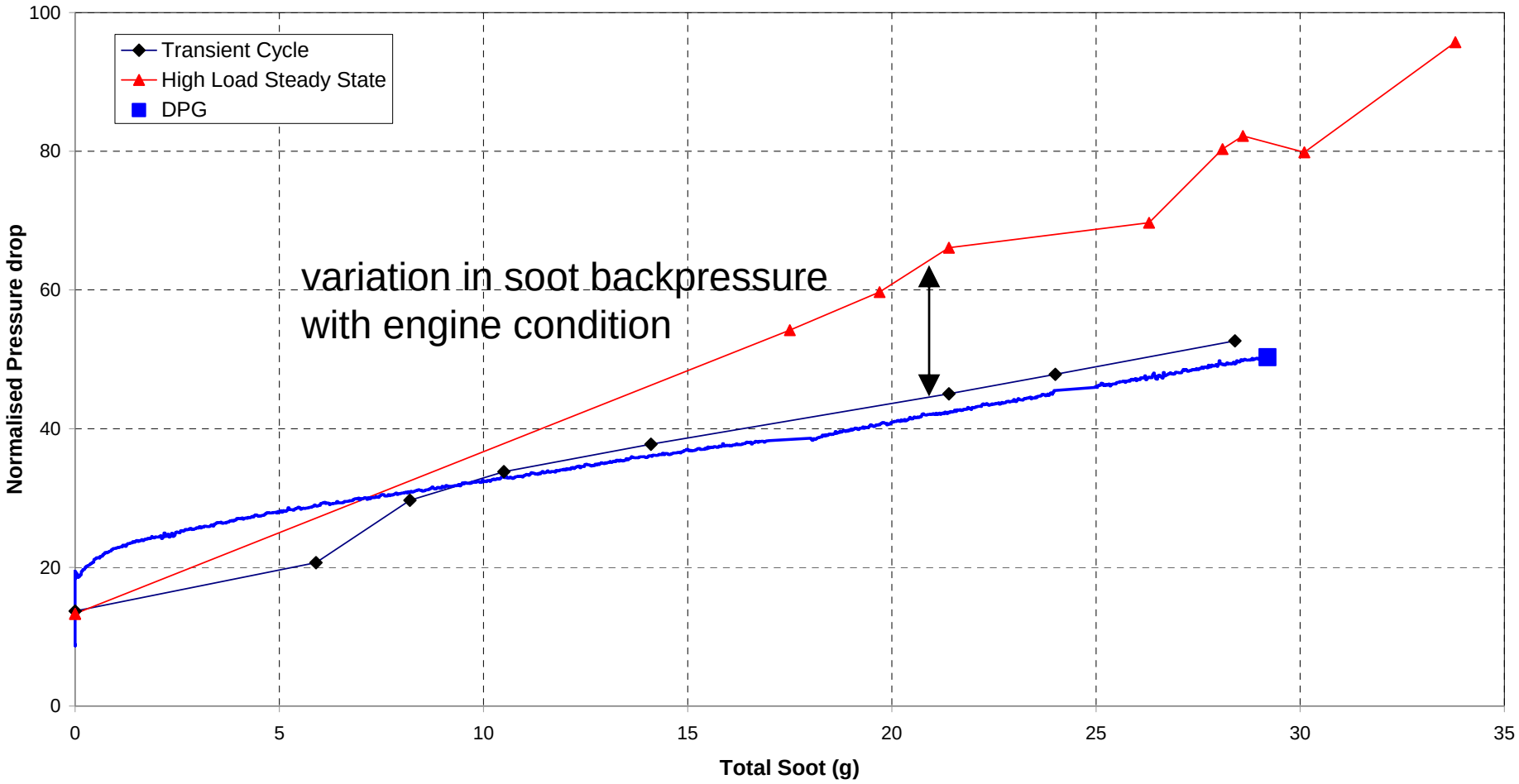
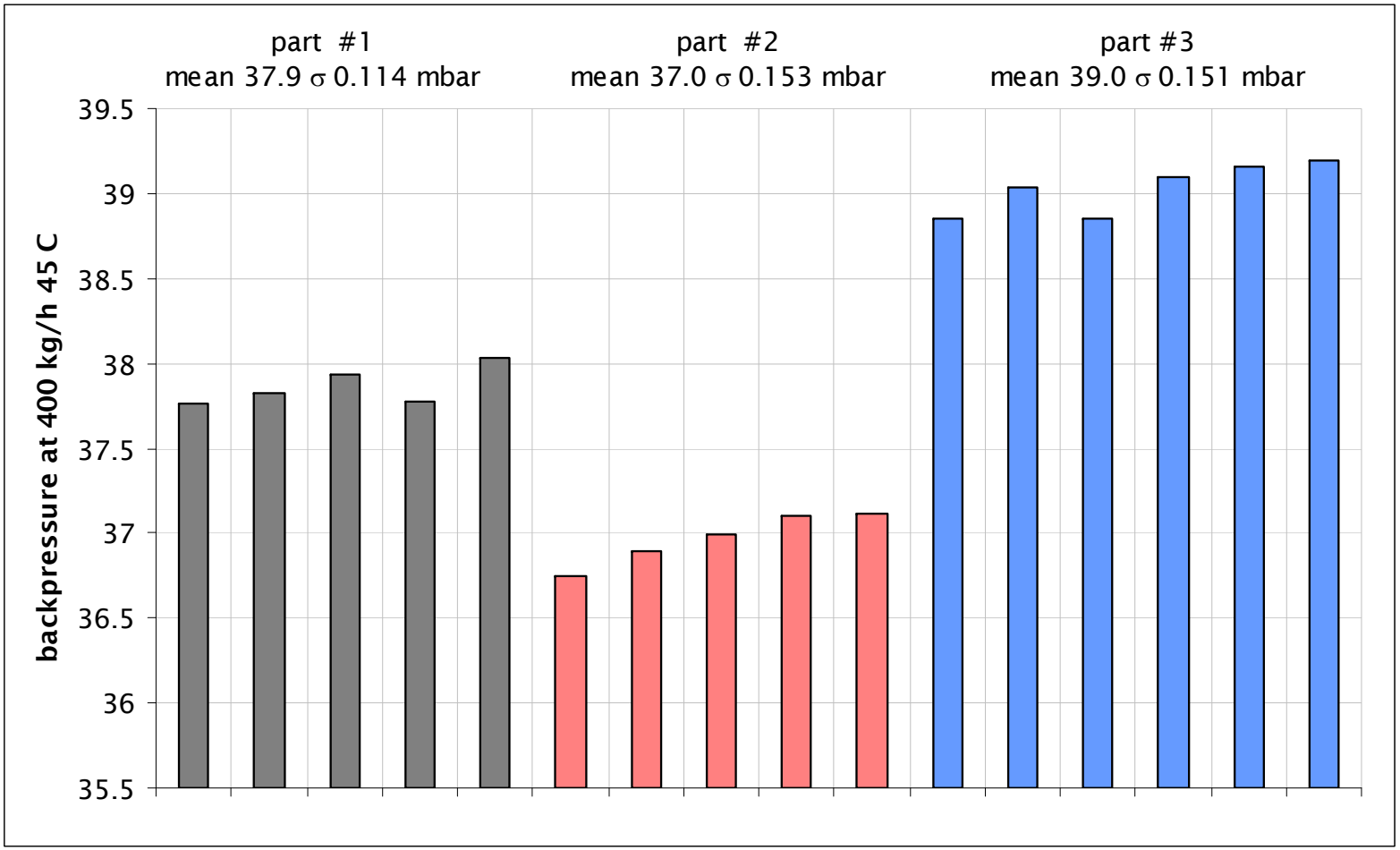
Backpressure vs Soot Load : Engine vs DPG



Except for initial transient due to warm up differences, rig backpressure is close to soot produced from transient cycle operation of engine.

Empty filter, cold flow repeatability

- 3 parts, nominally identical, no soot load repeated 5/6 times
- 45ºC, 400 kg/h
- average standard deviation 0.14 mbar / 0.37%
- production variation clearly detected



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Reproducibility of Dp vs Soot Load

- Accurate Measurement of Dp vs Soot Load Characteristic:
  - ‘no soot’ warm-up phase followed by soot load
  - discriminates warm-up from pore filling effects in initial pressure rise

- Two nominally identical parts
- Loaded to approximately 15g
- Loaded on 4 DPG systems – on site and at Cambustion
- Repeated loads on one instrument
- Soot load established by weighing at > 200ºC
- Backpressure measurements referred to common conditions: 240ºC, 250 kg/hr and corrected for differences in barometric pressure

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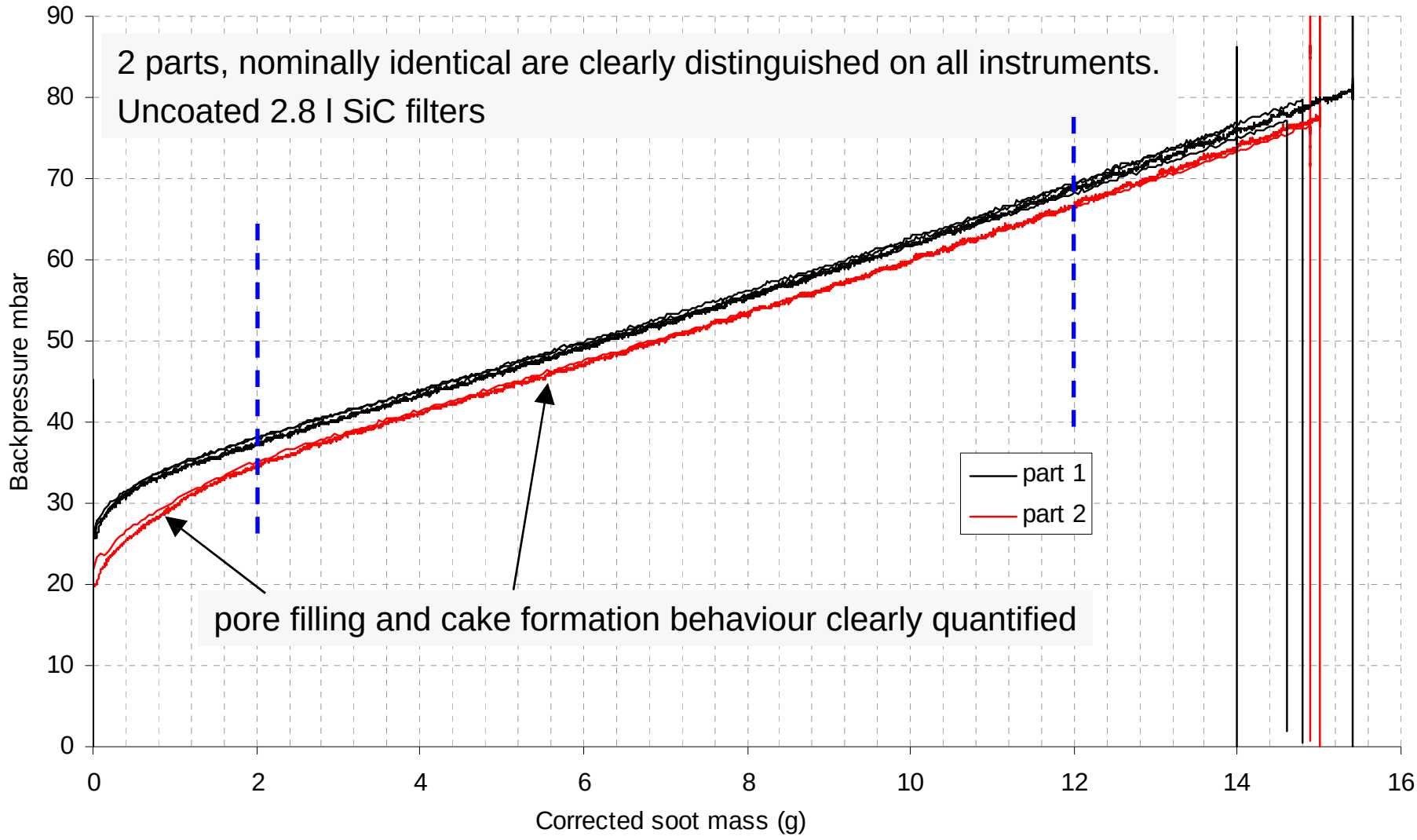
Delta P vs Soot Load Repeatability
4 Instruments, 2 parts

Instrument : instrument repeatability



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Repeatability Test Results

Test Part	System Number	2 g backpressure mbar	deviation from mean	12 g backpressure mbar	deviation from mean
1	1	38.0	+0.9%	69.4	+0.5%
1	2	38.1	+1.1%	68.2	-1.4%
1	3	37.2	-1.2%	68.7	-0.6%
1	1	37.4	-0.8%	69.3	+0.2%
1	4	37.7	0%	70.0	+1.3%
		mean = 37.3 mbar σ **= 0.39 mbar**		**mean = 69.1 mbar** σ **= 0.70 mbar**	
2	1	35.3	+0.8%	67.0	+0.4%
2	3	34.6	-1.2%	66.8	0%
2	2	35.1	+0.4%	66.5	-0.4%
		mean = 35.0 mbar σ **= 0.24 mbar**		**mean = 66.8 mbar** σ **= 0.24 mbar**	

In these tests, measurements for backpressure of a given part at given load were all within ± 2% across all systems, 95% confidence interval < ± 3%

DPF Filtration Efficiency Measurement

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Controlled rig conditions allows the relatively slow AVL smokemeter (paper blackening type, sample time 10 – 120s) to resolve particulate concentration downstream of DPF.

Correlated with soot mass measurement.

Stage 5 like CPC + VPR system produces number based filtration efficiency.

CPC does not have 23nm cut, but DPG does not produce solid particles in this size range.

Filtration Efficiency with AVL415

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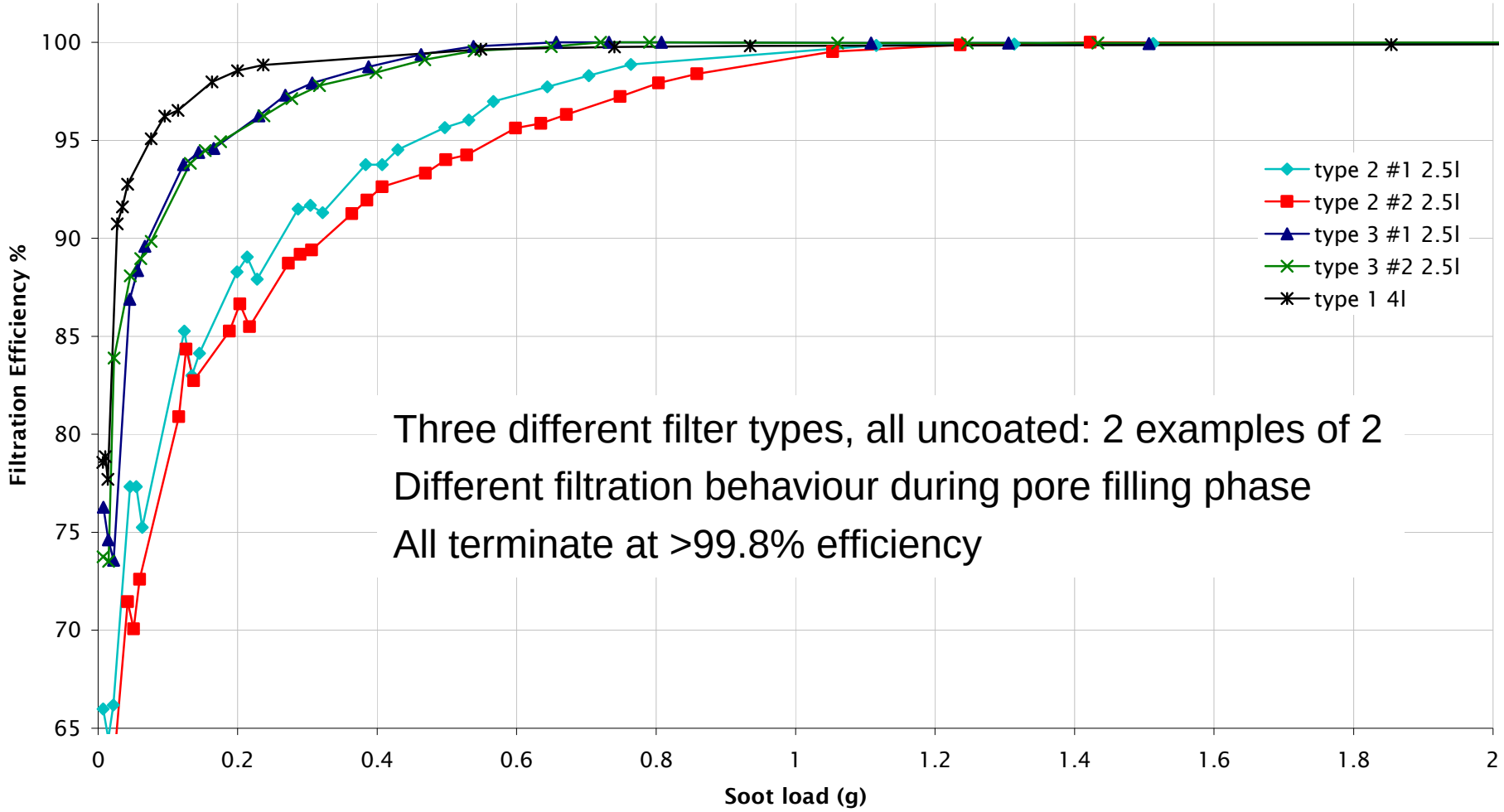
Mass based filter efficiency with AVL 415



CPC+VPR filtration efficiency

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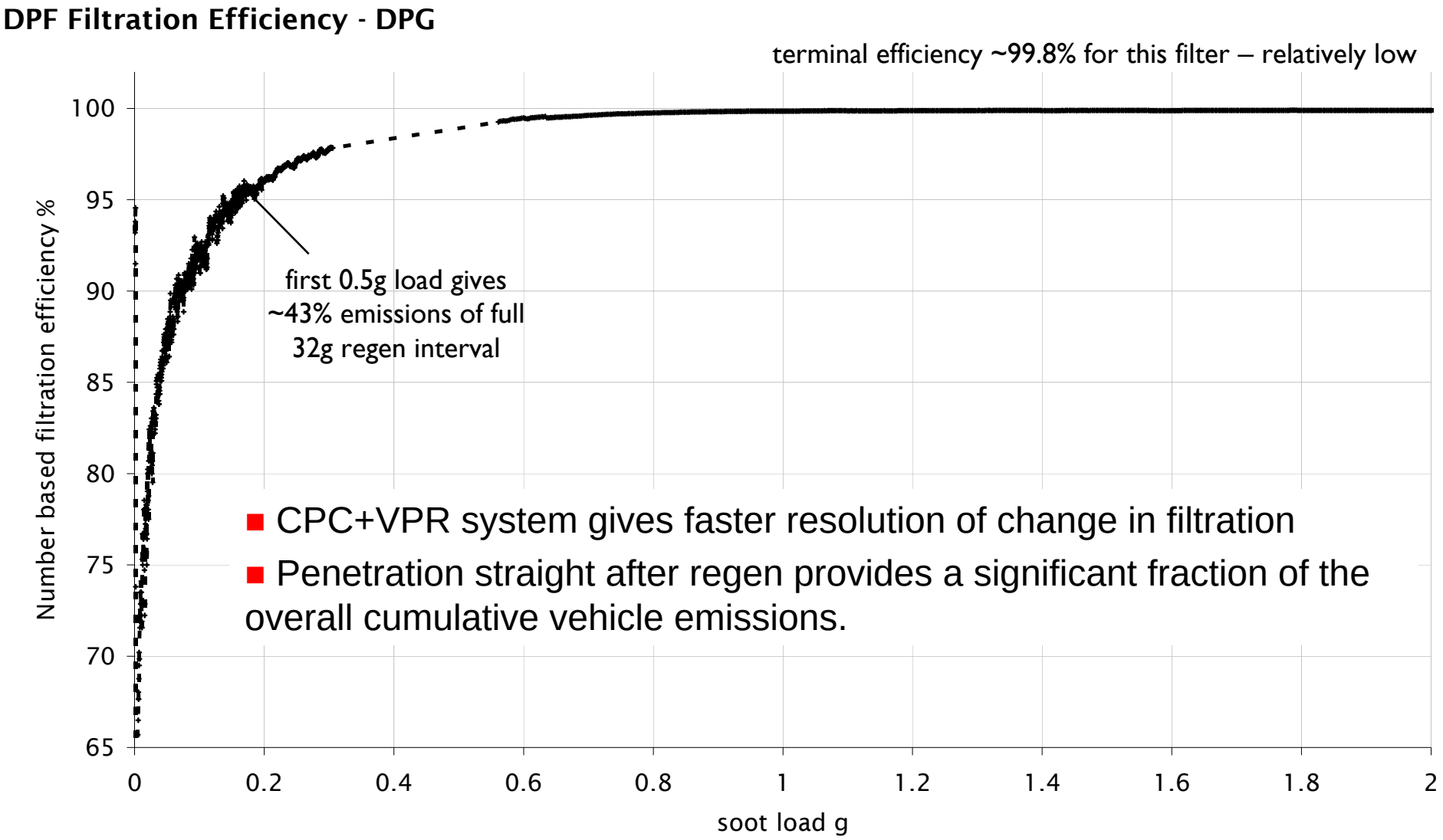

- CPC+VPR system gives faster resolution of change in filtration
- Penetration straight after regen provides a significant fraction of the overall cumulative vehicle emissions.

Effect of flow rate & temperature on DPF Backpressure

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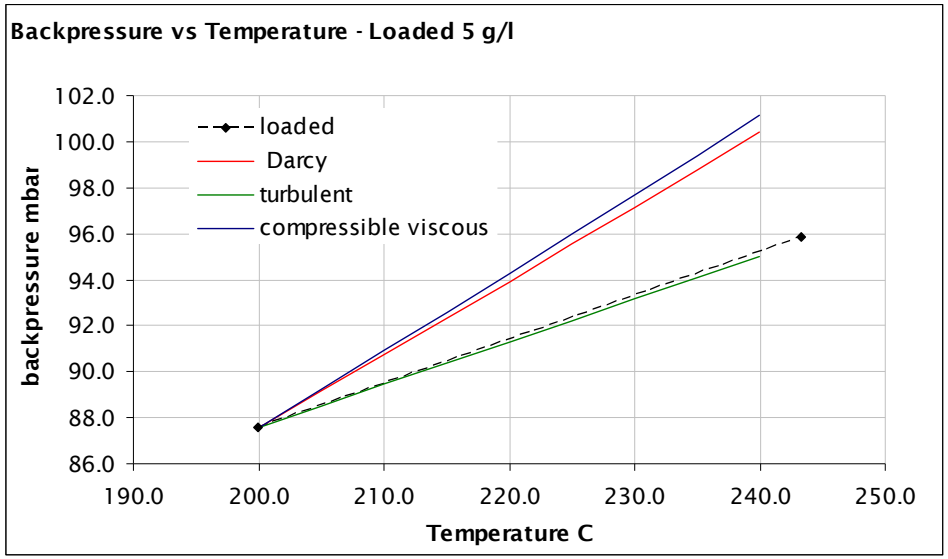
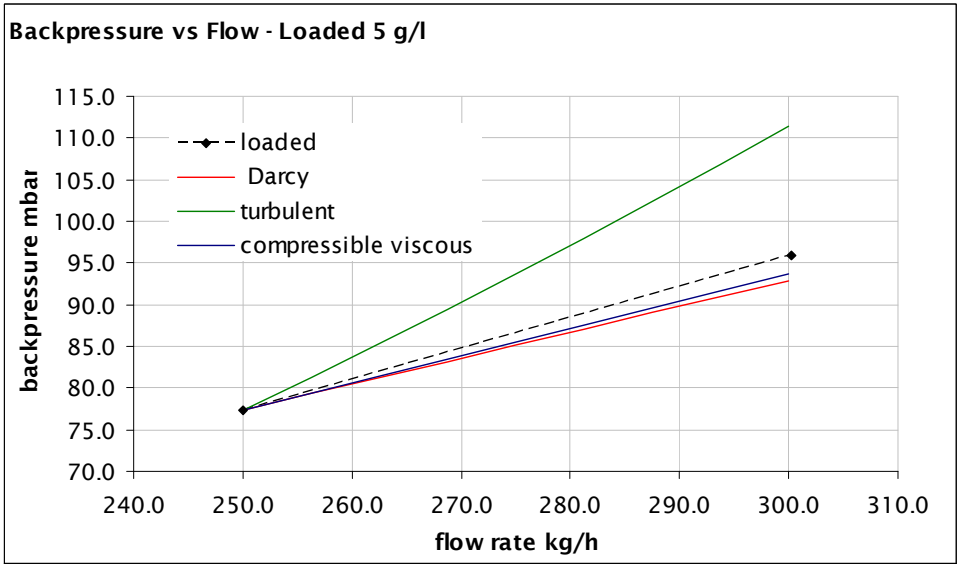
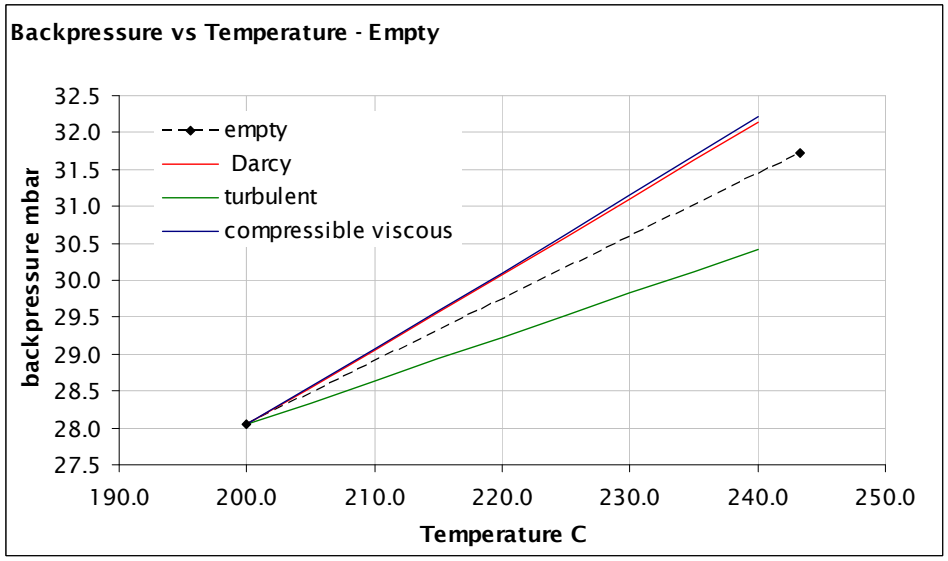
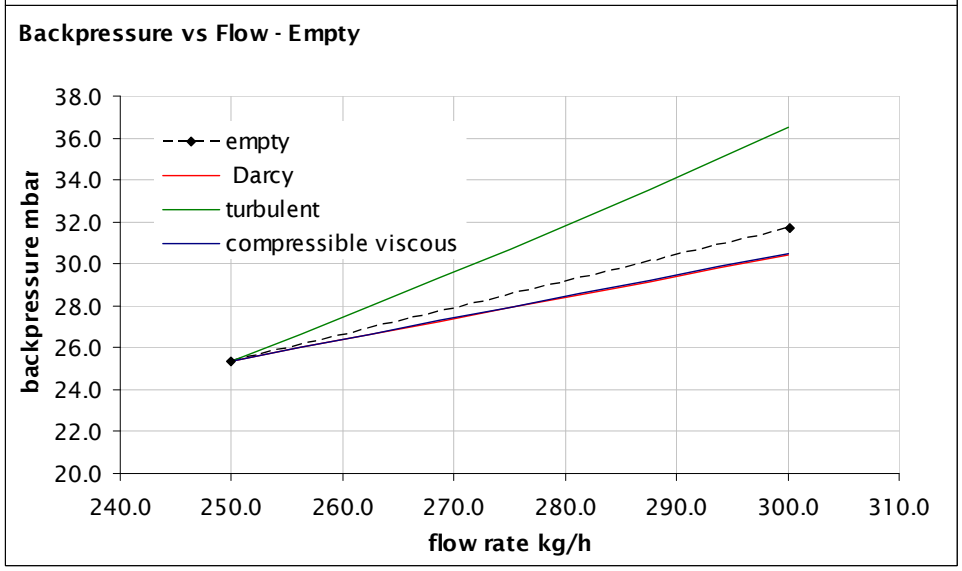
Compare measured dp vs flow and backpressure with Darcy and turbulent assumptions









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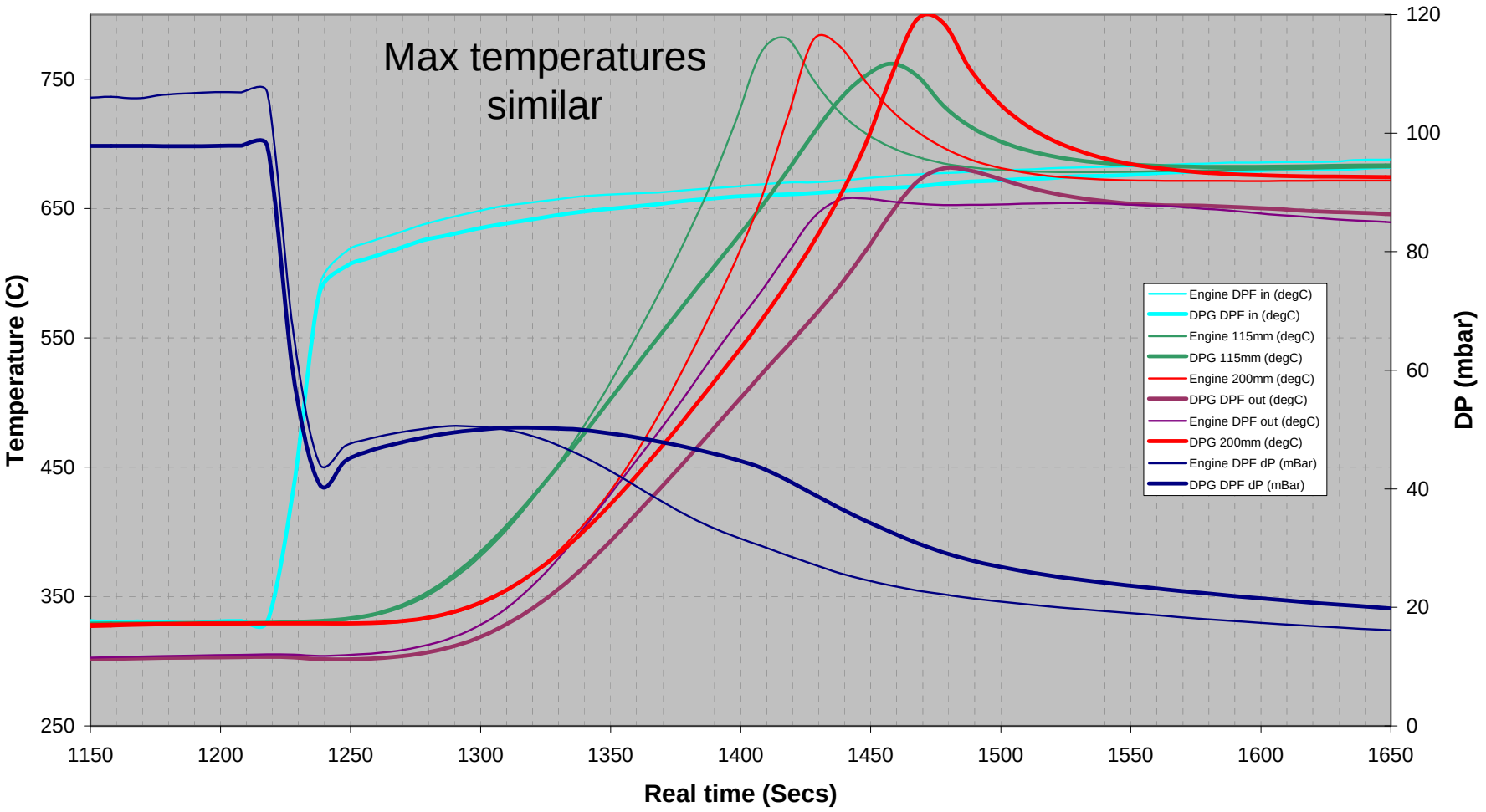
Comparison to Engine – regeneration

DPG MSL regen 330C for engine soot (thin line) and DPG soot (thick line)



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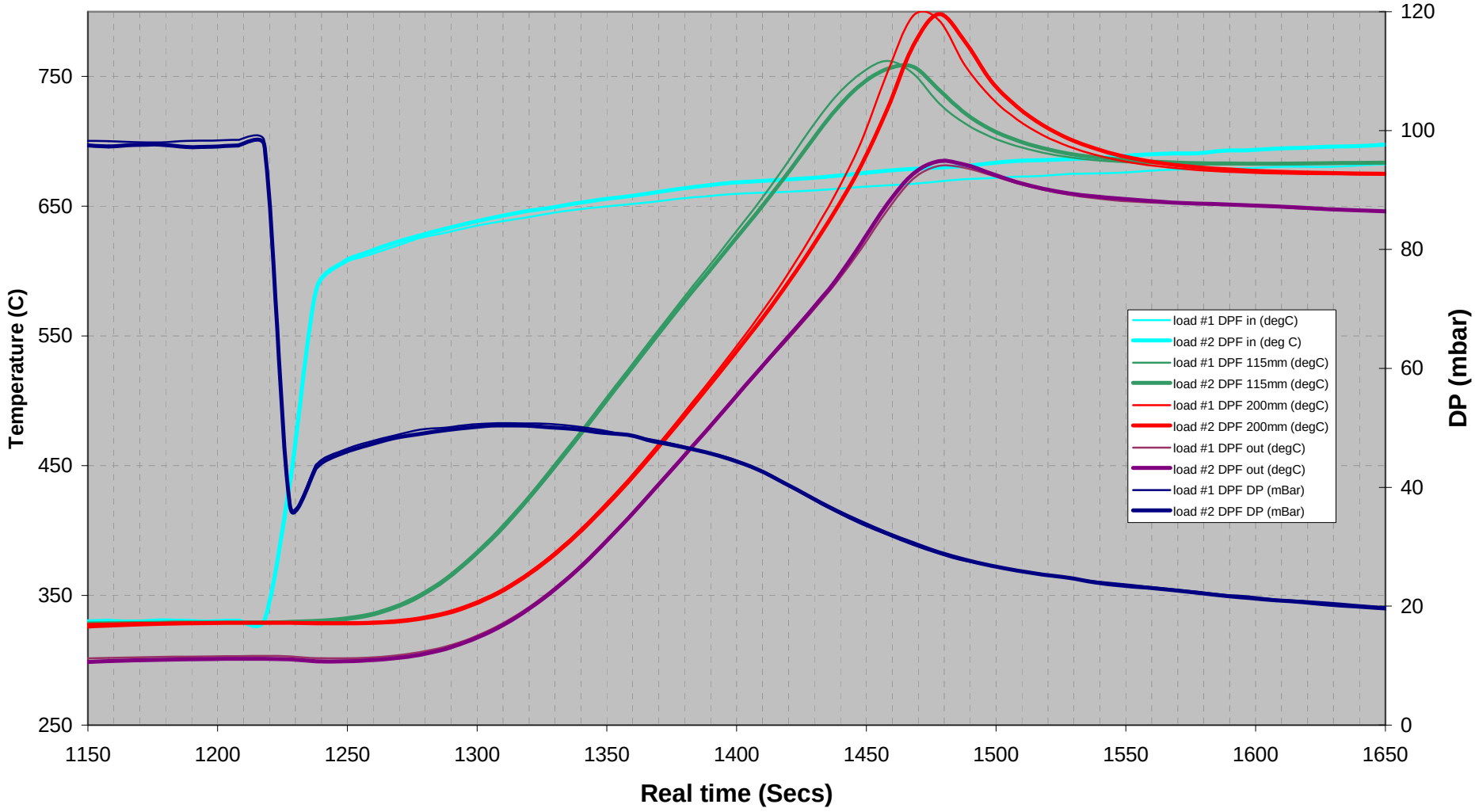
Repeatability of Regen on DPG at 7.5 g/l soot; 2 tests; temperatures at inlet, exit + 3 locations in brick



Conclusions

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- The Cambustion DPG allows testing of Diesel Particulate Filters at conditions representative of engine operation.
- The backpressure vs soot load characteristic is shown to be repeatable for a given filter to within less than 3%, but sample : sample variation is seen.
- Filtration efficiency can be measured either with an AVL415 smokemeter or CPC + VPR system. Due to size sensitivity, efficiency measurements are different for the two techniques.
- The penetration during initial loading for this filter would almost double the number emissions if averaged over all cycles
  - and if such complete regeneration is obtained in normal use.
- Variation of backpressure of a DPF with flow and temperature lies somewhere between laminar (Darcy) and turbulent assumptions:
  - cannot ignore inertial effects at entry / exit face when considering whole filter behaviour.
  - variation with soot load surprising

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Acknowledgements

Collaborators at Cambustion:

Tim Hands
Ray Brand
Mark Rushton
Nick Collings
Bruce Campbell

Johnson Matthey and other DPG customers

And the organisers of the ETH conference

Thank you.

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Testing Uncanned Parts: Cambustion FTH Filter Test Housing

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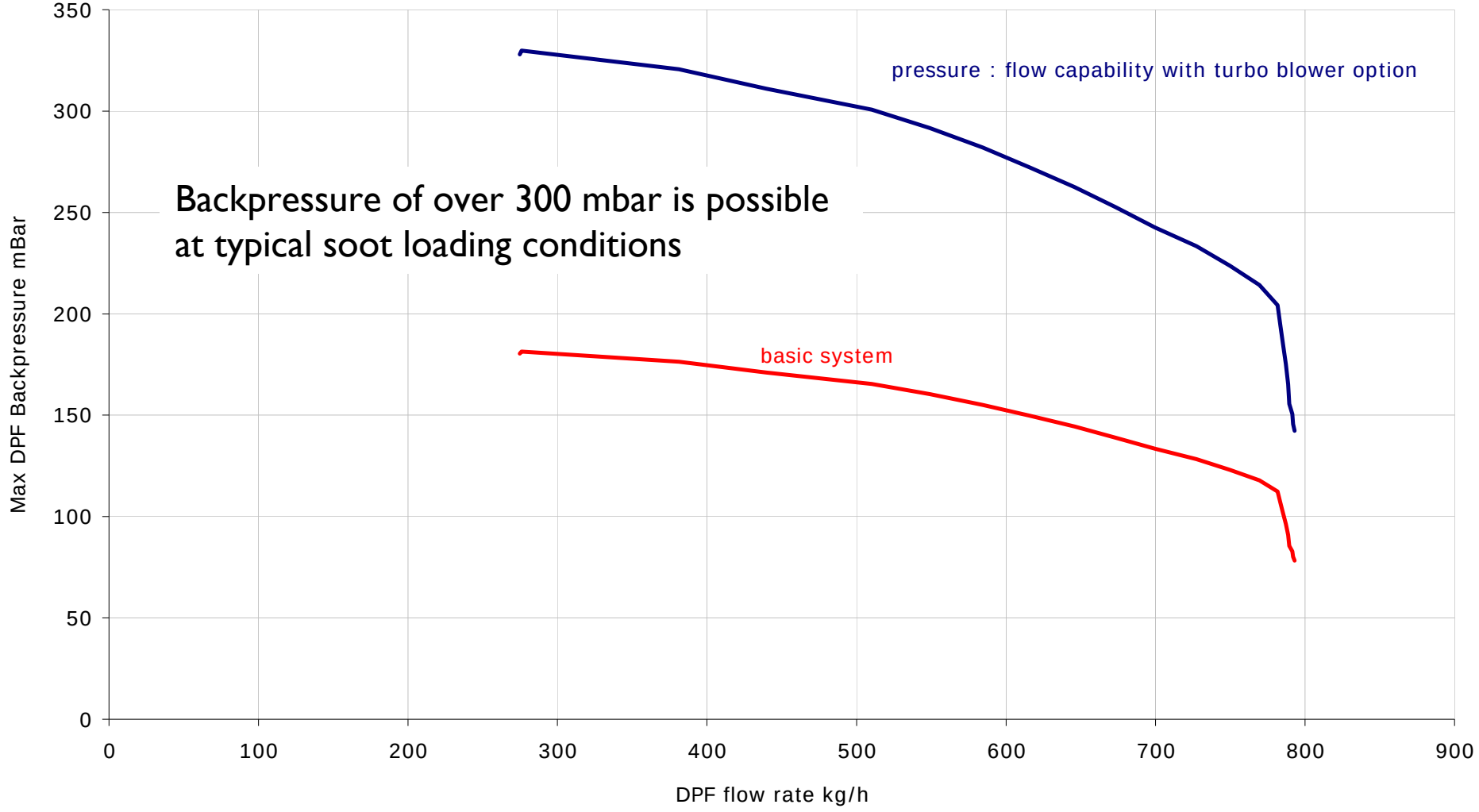
Backpressure Capability

Maximum DPF Flow Rate vs Backpressure
(ambient temperature)



Effect of Soot Load on Exothermic temperature rise at DPF exit: 4, 6 and 8 g/l

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