8th ETH Confernce on Combustion Generated Nanoparticles
ETH Hönggerberg, Zurich, 16th - 18th August 2004

Particle size resolved analysis of PAHs in diesel soot

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agenda

- equipment @ CUTEC to
  - generate soot particle
  - measure soot particles
    - size
    - composition (PAH)
- test conditions & results
  - PAH species distribution to particle size
  - PAH spectrum @ impactor stage / soot mass
  - PAH spectrum @ particle surface
- conclusion

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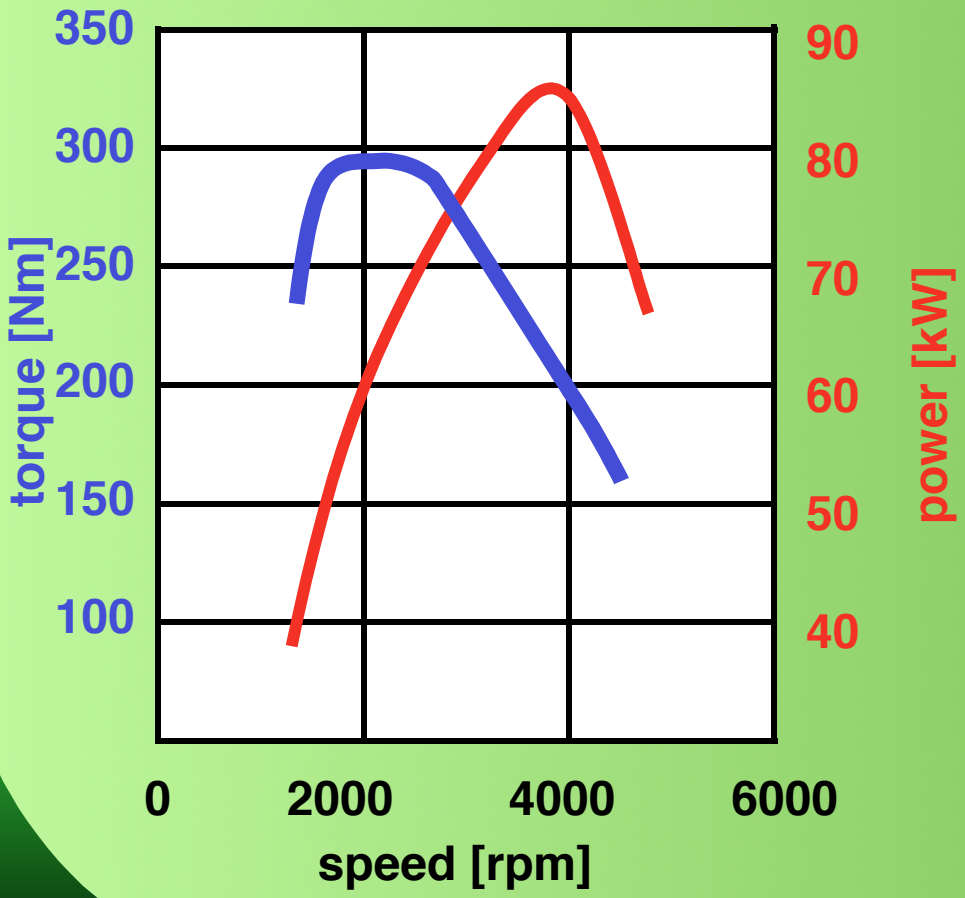
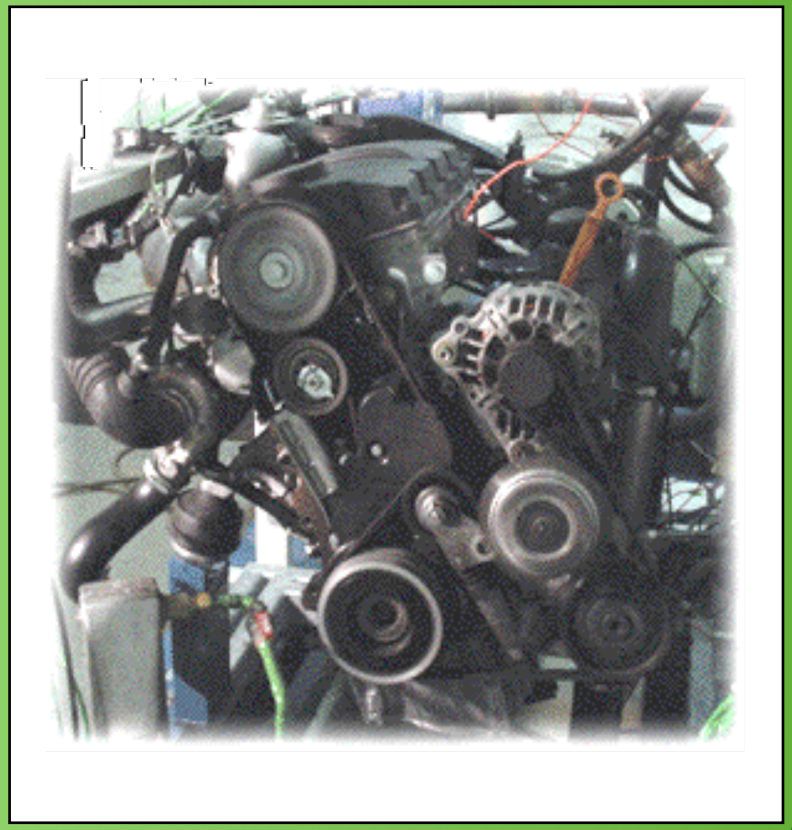
equipment @ CUTEC to generate soot particles

engine

VW TDI-PUI 4 cylinder 1.9 L, 85 kW, 285 Nm, EURO 3





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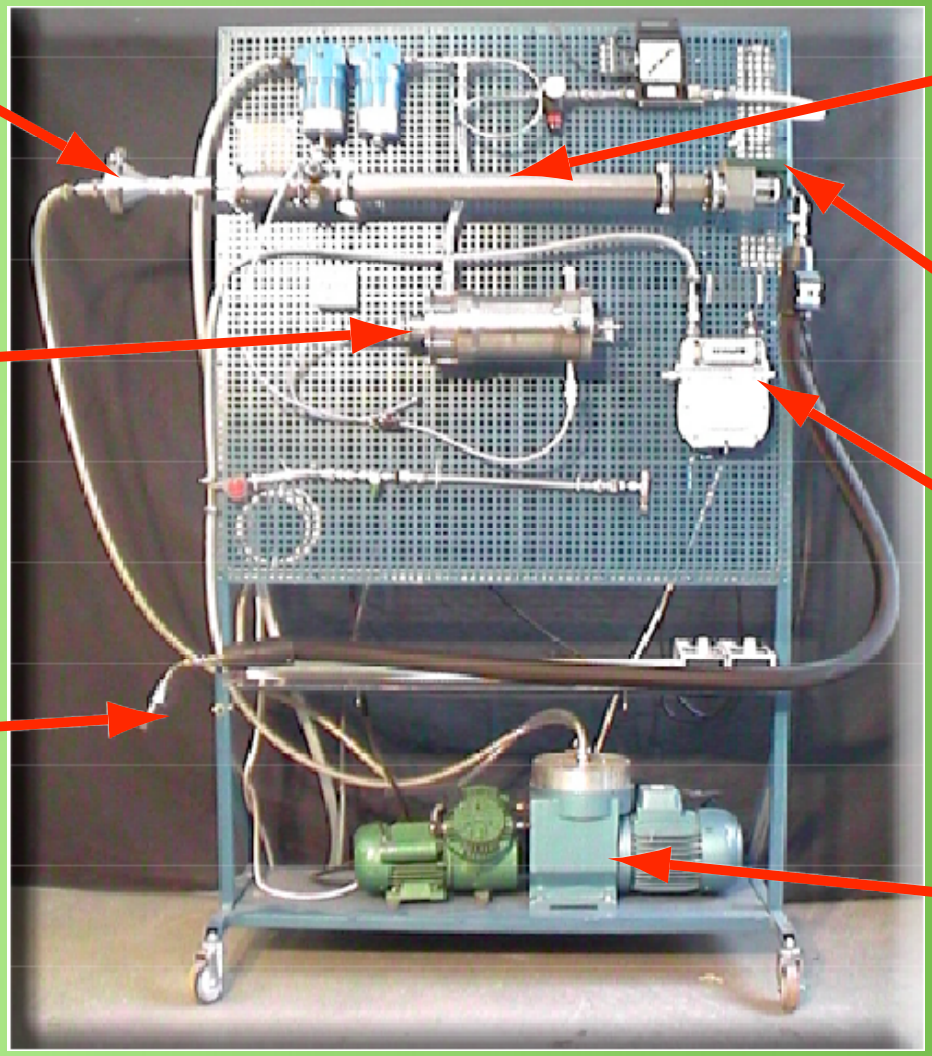
equipment @ CUTEC to measure soot particle size

micro dilution tunnel

filter holder or impactor

Second injector dilution ratio: 1:5 - 1:30

heated hose



micro dilution tunnel

injector dilution ratio: 1:7 - 1:10

flow meter

pump

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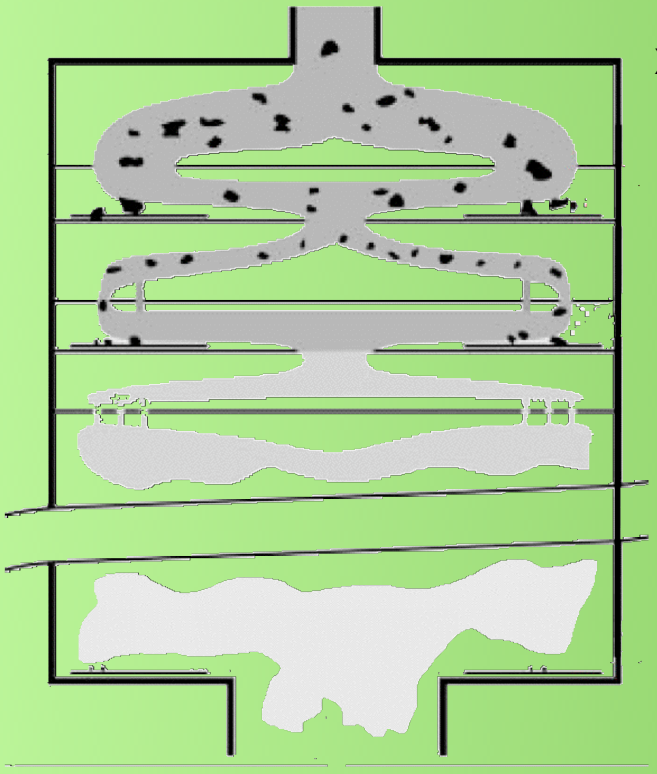
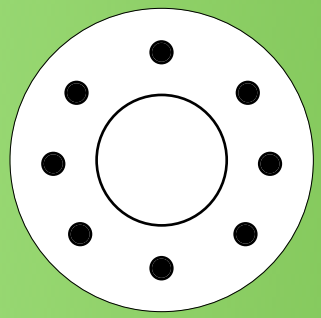
equipment @ CUTEC to measure soot particle size

12-stage low pressure impactor LPI (Berner)



$x_{ae,\ max}$: 16000 nm



substrate for soot deposition & PAH analysis:

blue ribbon paper filter

$x_{ae,\ min}$: 9 nm

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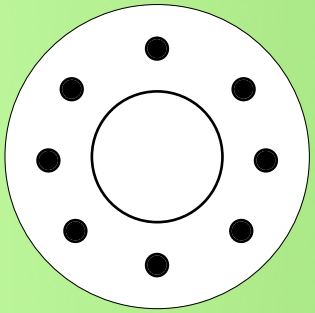
equipment @ CUTEC to measure soot particle composition (PAH)

PAH determination

filter

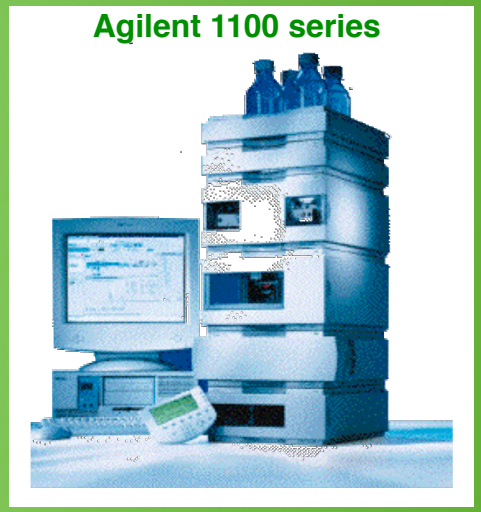


0.03 - 2 mg soot

Microwave assisted extraction
T = 70 °C

solvent: 30 mL dichloromethane

HPLC



peak height

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preliminary test results @ CUTEC

detection limits for PAH

	PAH	Calibration [pg] / [ng/ml]	limit blank filter [pg] / [ng/ml]
1	Naphthalene	≥ 20 / ≥ 1	≥ 20 / ≥ 1
2	Benzo(k)fluoranthene		
3	Benzo(a)pyrene		
4	Dibenzo(a,h)anthracene		
5	Benzp(g,h,i)perylene		
6	Acenaphthalene		≥ 40 / ≥ 2
7	Chrysene		
8	Benzo(b)fluoranthene		
9	Fluorene		≥ 200 / ≥ 10
10	Anthracene		
11	Fluoranthene		
12	Pyrene		
13	Phenanthrene		≥ 660 / ≥ 33
14	Benzo(a)anthracene		
15	Indendo(1,2,3-cd)pyrene	≥ 200 / ≥ 10	≥ 200 / ≥ 10

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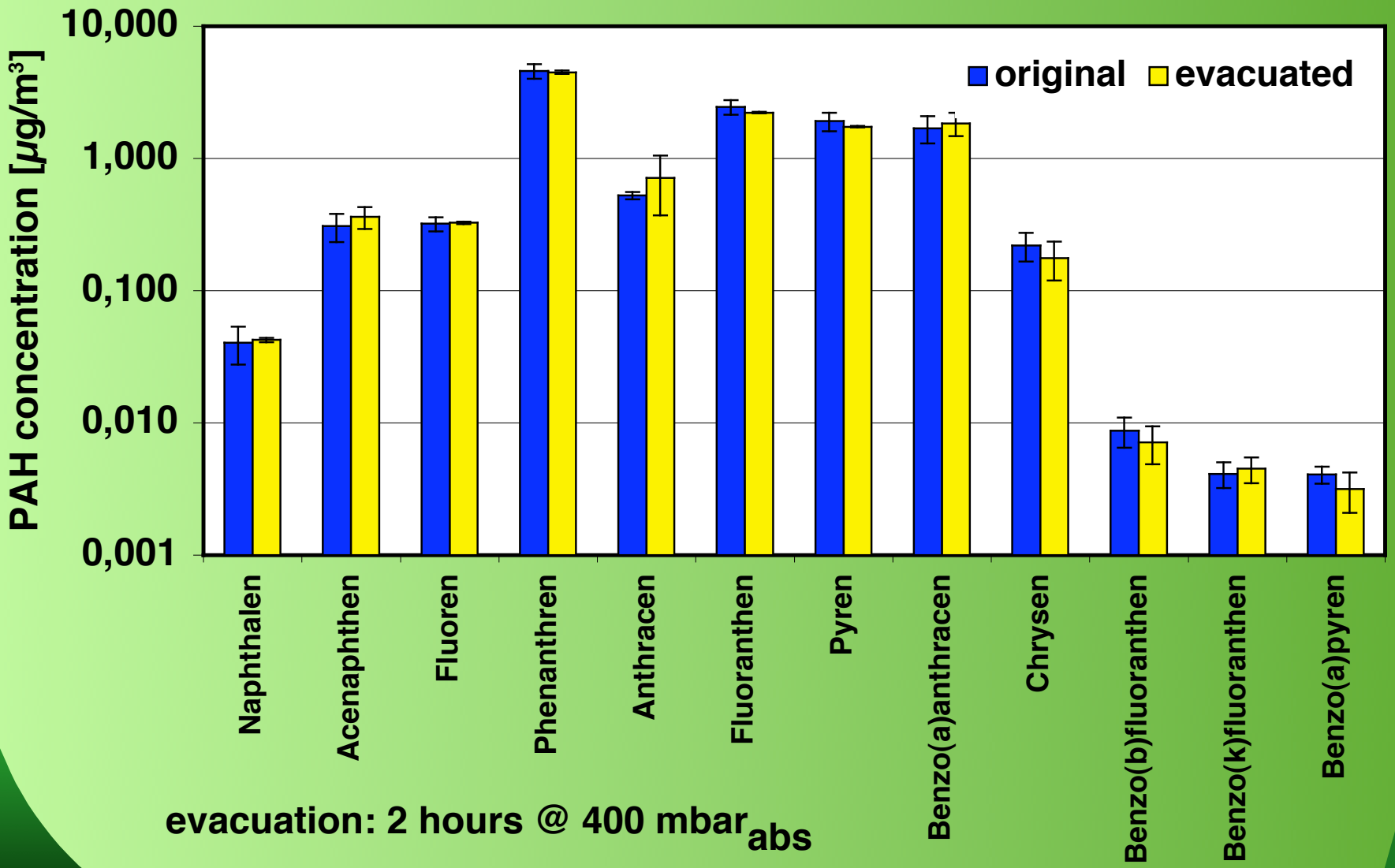
preliminary test results @ CUTEC

PAH detection



evacuation: 2 hours @ 400 $mbar_{abs}$

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test conditions @ CUTEC

engine settings

speed [rpm]	torque [Nm]	BMEP [bar]	exhaust gas temperature [°C]
1600	34	2.3	260
1800	80	5	360
2000	186	12	460

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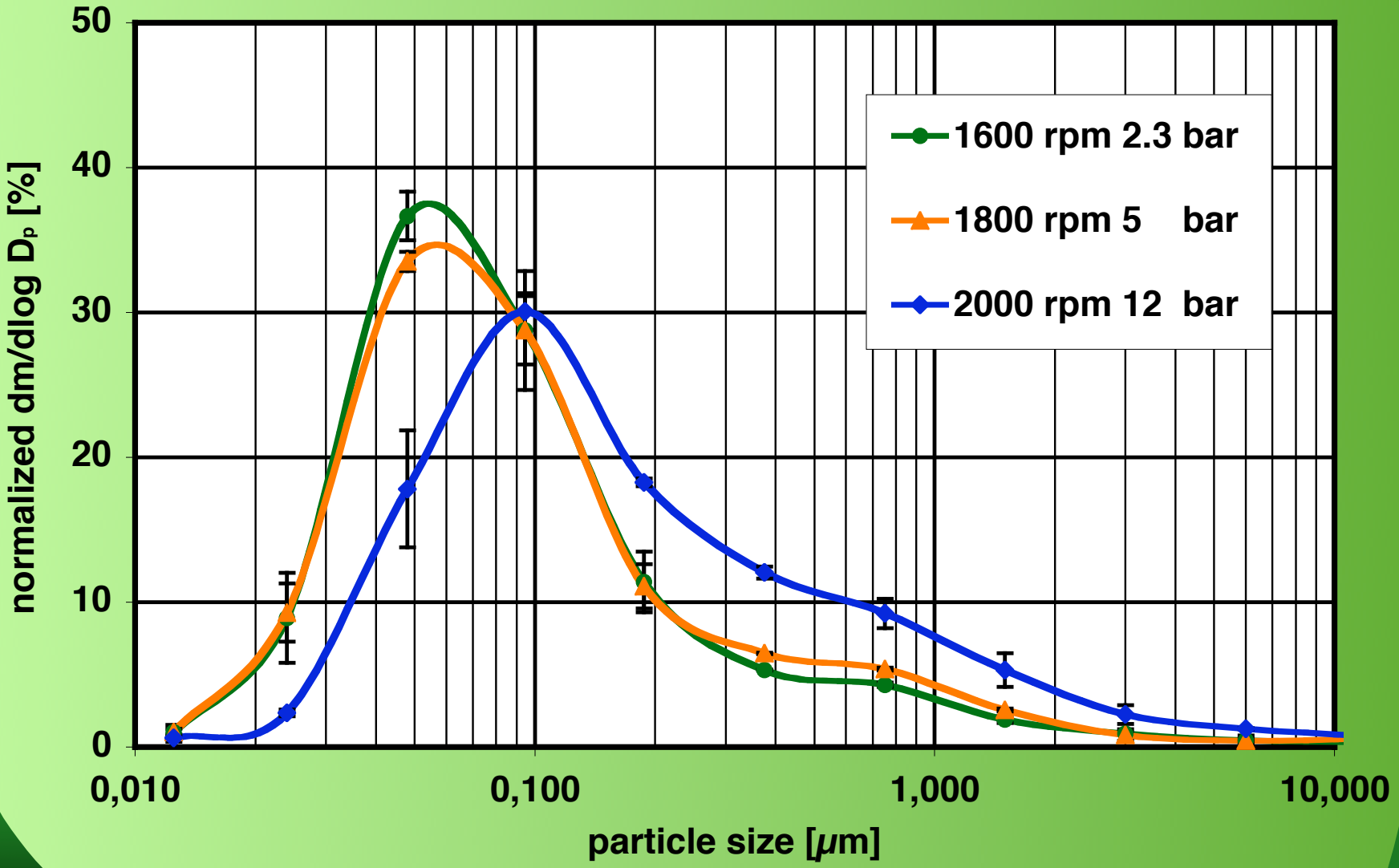
test results @ CUTEC

particle mass distribution



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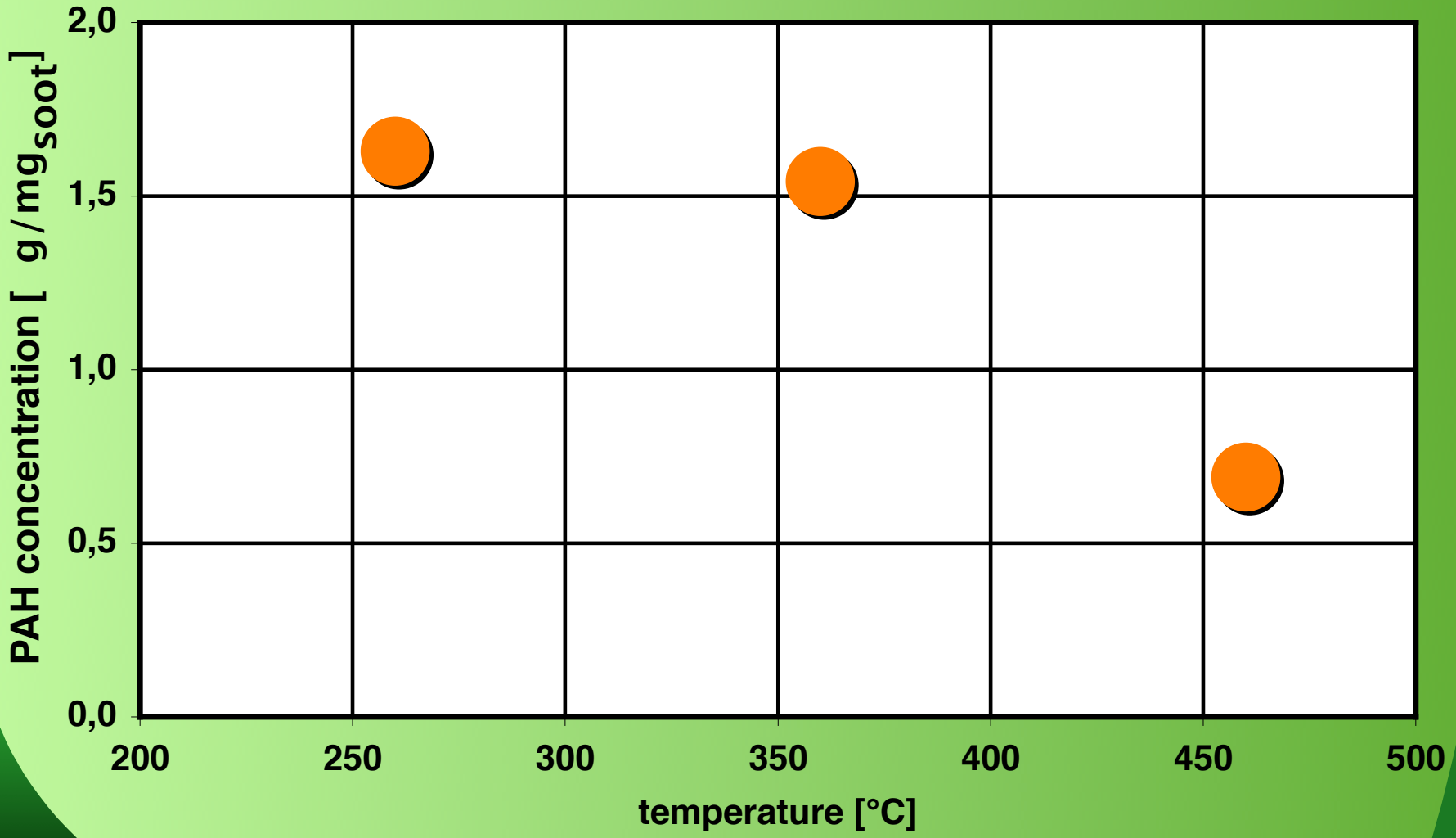
test results @ CUTEC

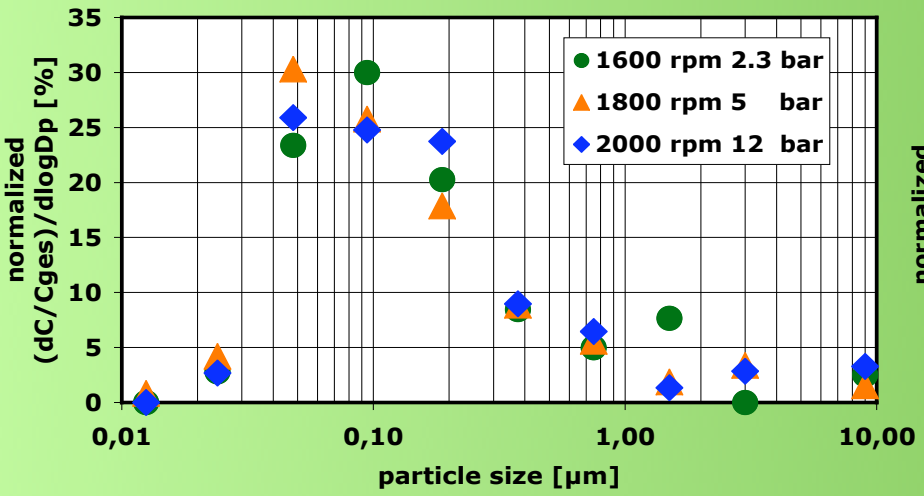
Σ PAH = f (temperature)



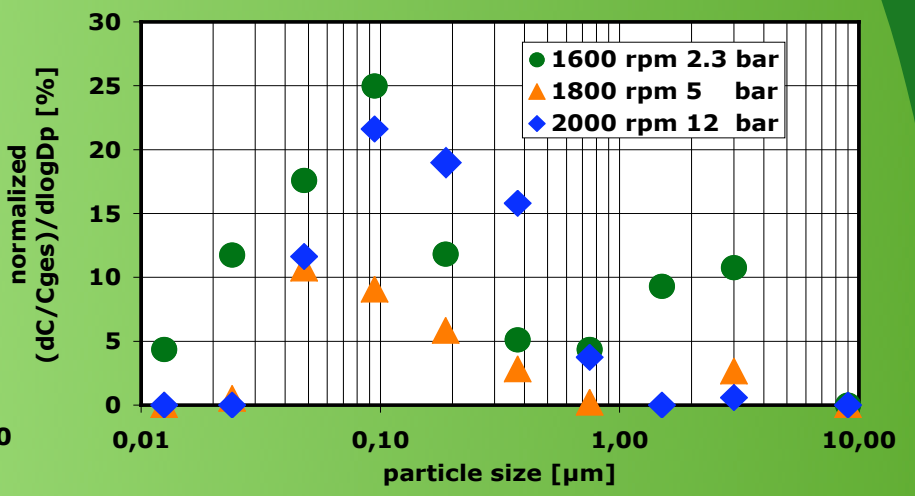
test results @ CUTEC

[PAH] = f (particle size, temperature)

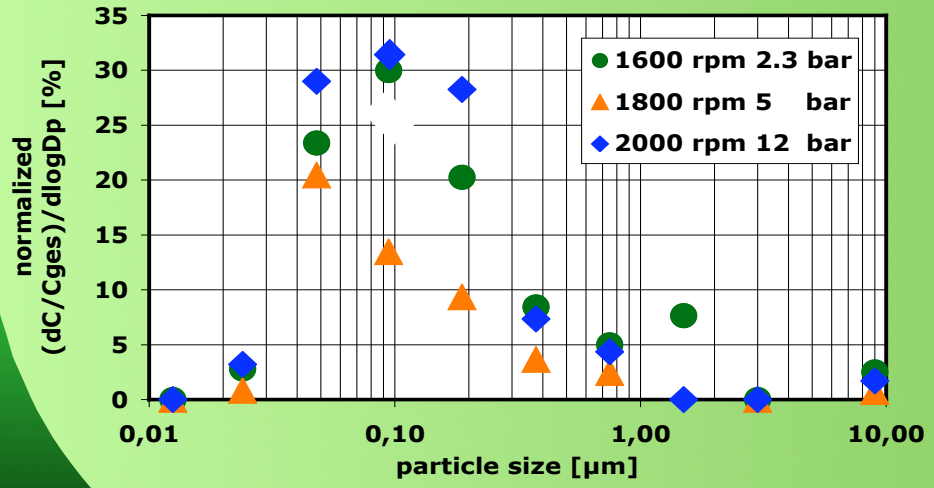
Pyrene



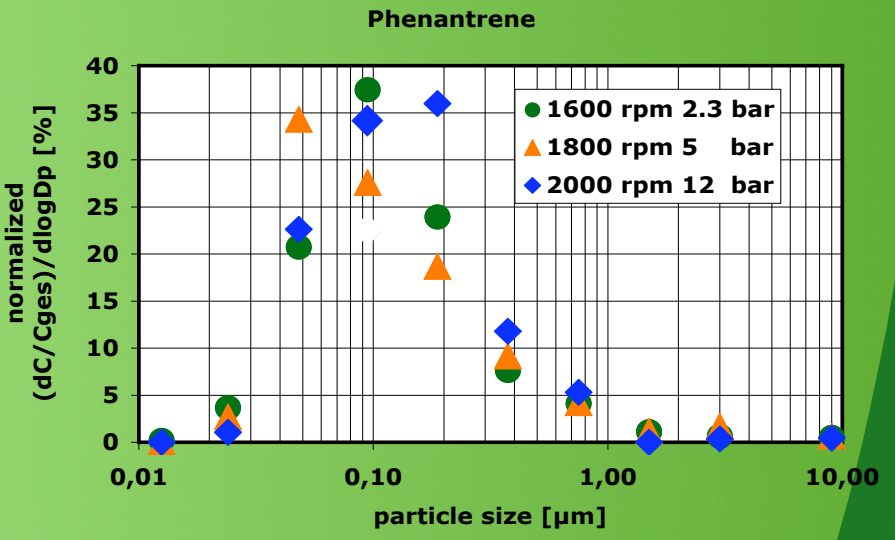
Anthracene



Benzo(a)anthracene



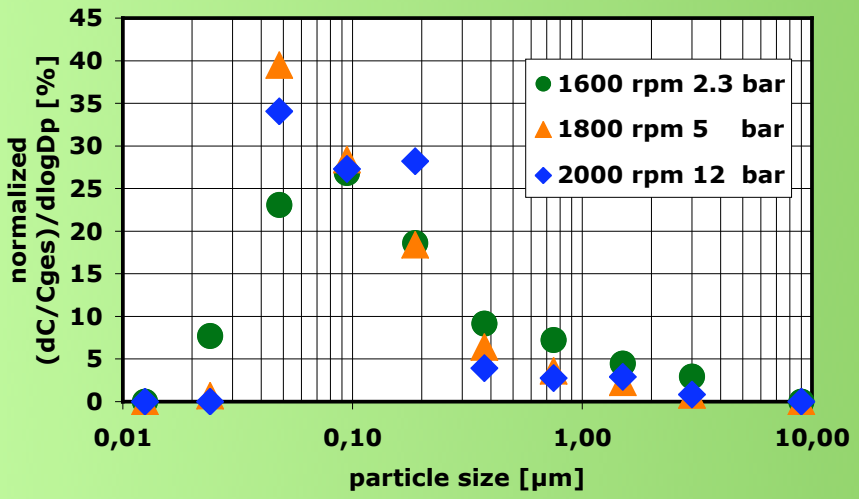
Phenantrene



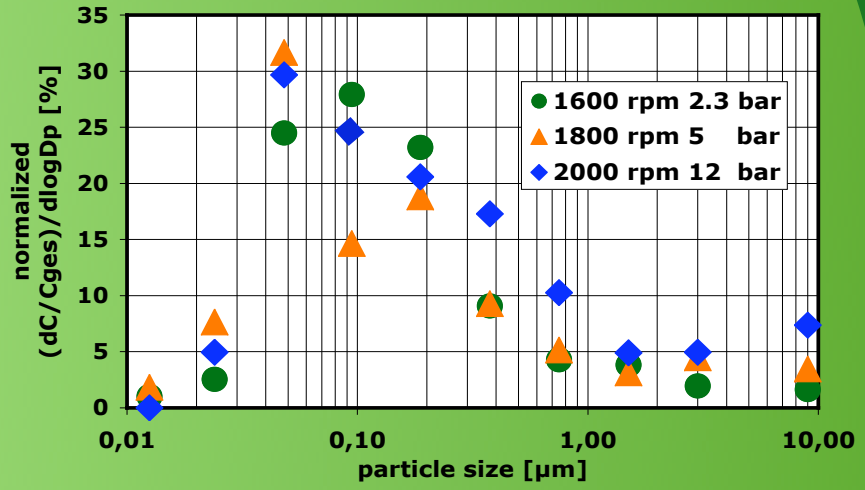
test results @ CUTEC

[PAH] = f (particle size, temperature)

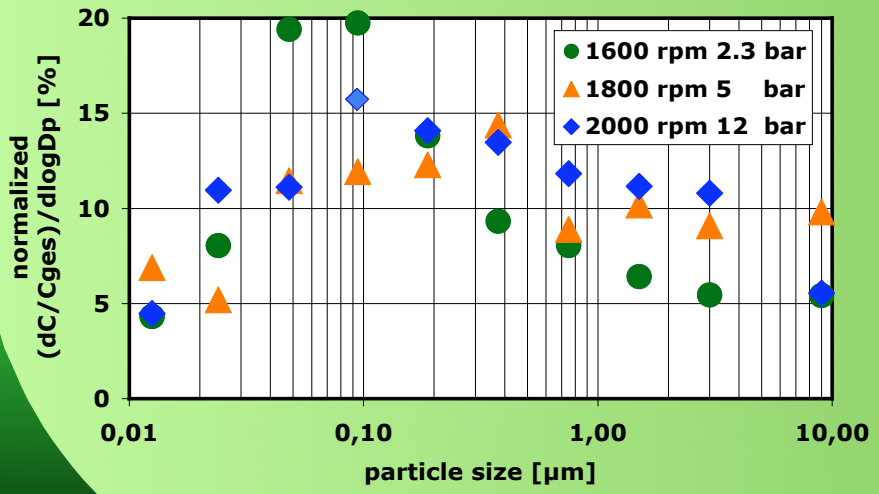
Chrysene



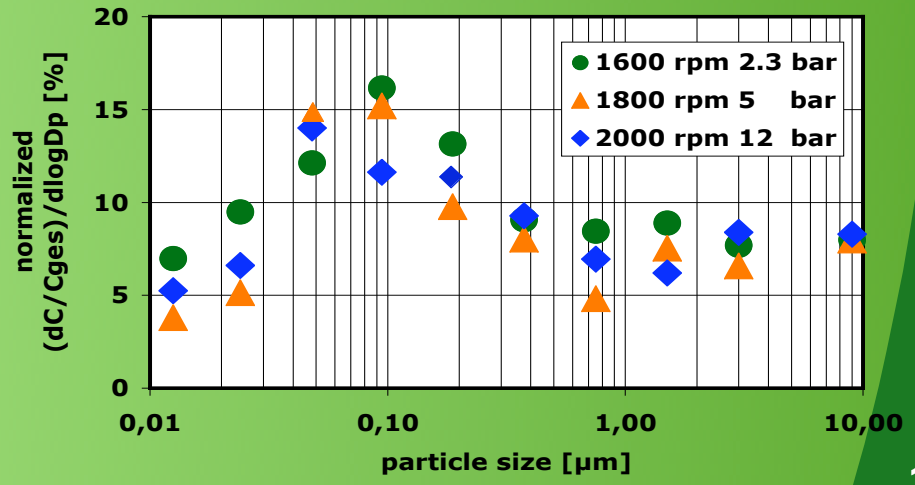
Fluoranthene



Benzo(b)fluoranthene



Fluorene



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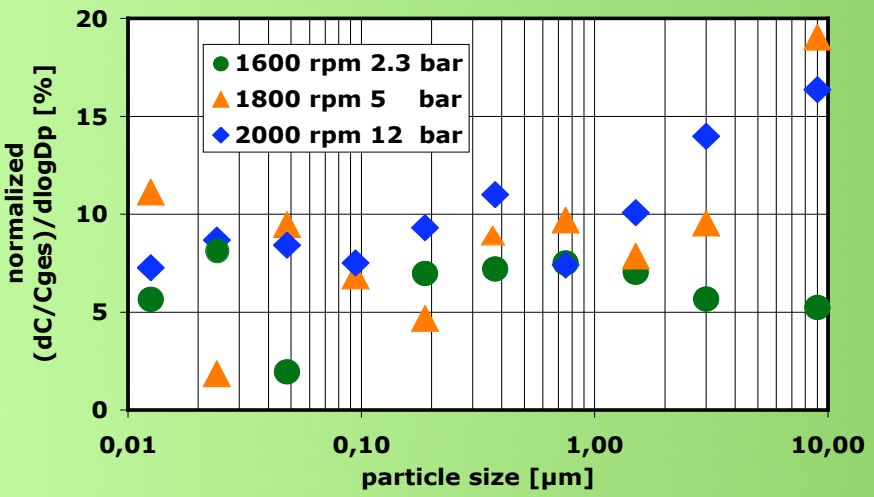
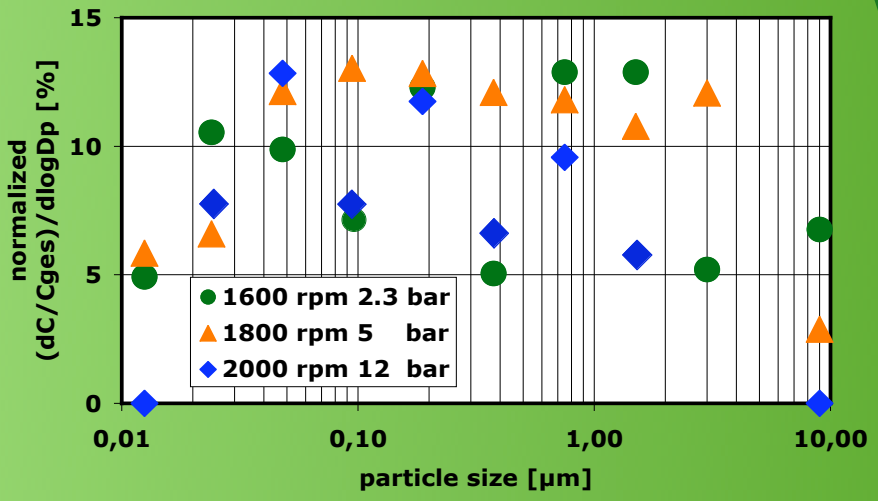
test results @ CUTEC

[PAH] = f (particle size, temperature)

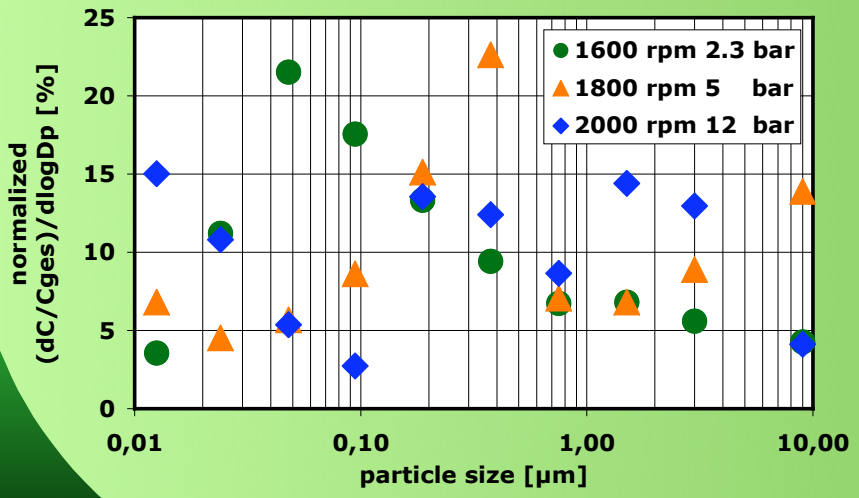
Naphthalene



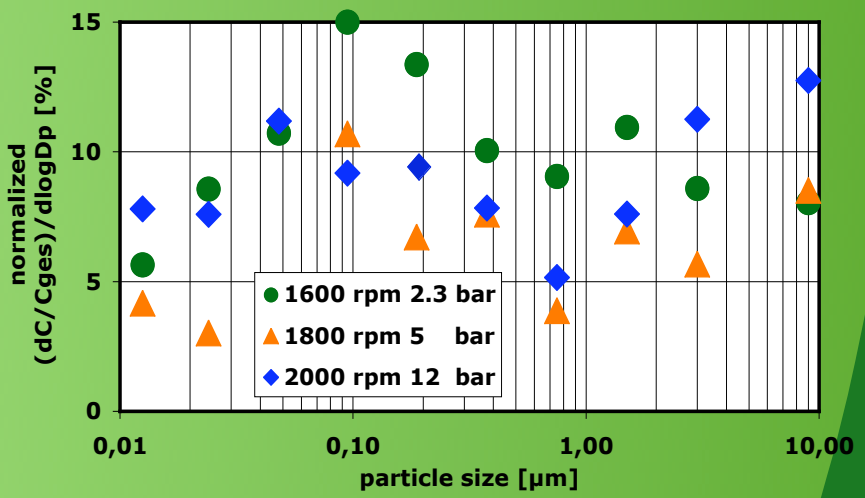
Benzo(a)pyrene



Benzo(k)fluoranthene



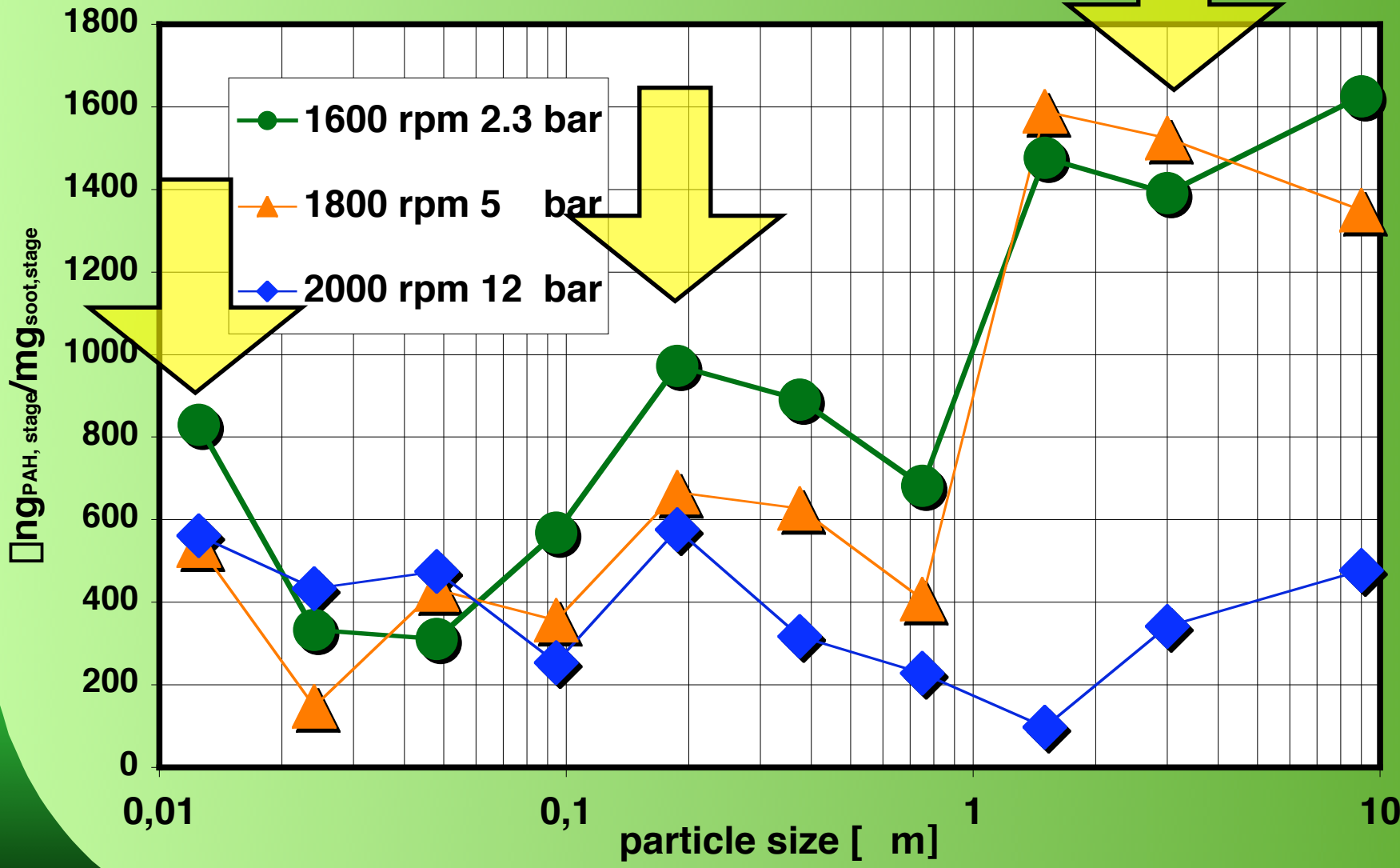
Acenaphthene



test results @ CUTEC

CU TEC

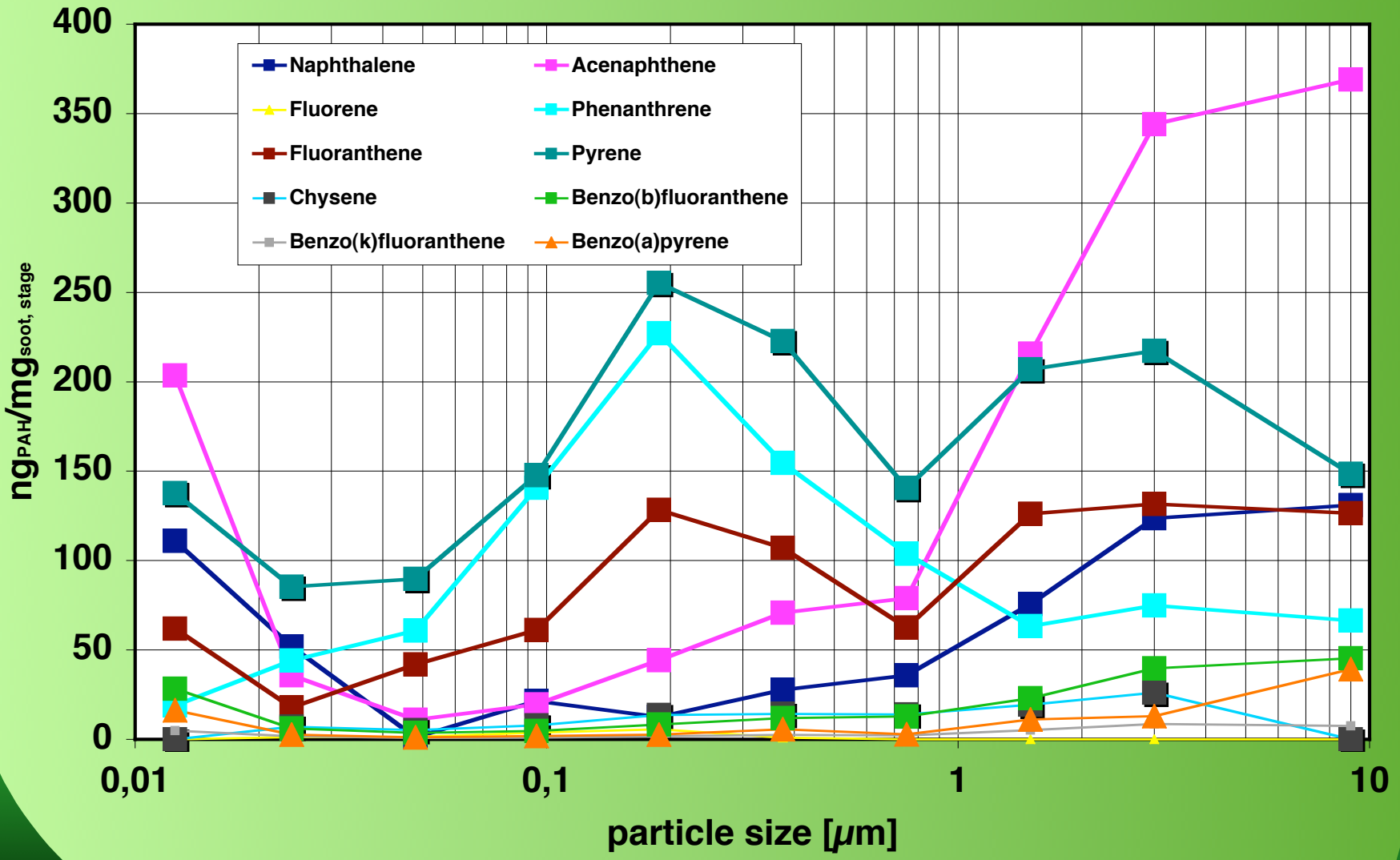
Σ PAH = f (impactor stage)



CU TEC

test results 1600 rpm 2.3 bar @ CUTEC

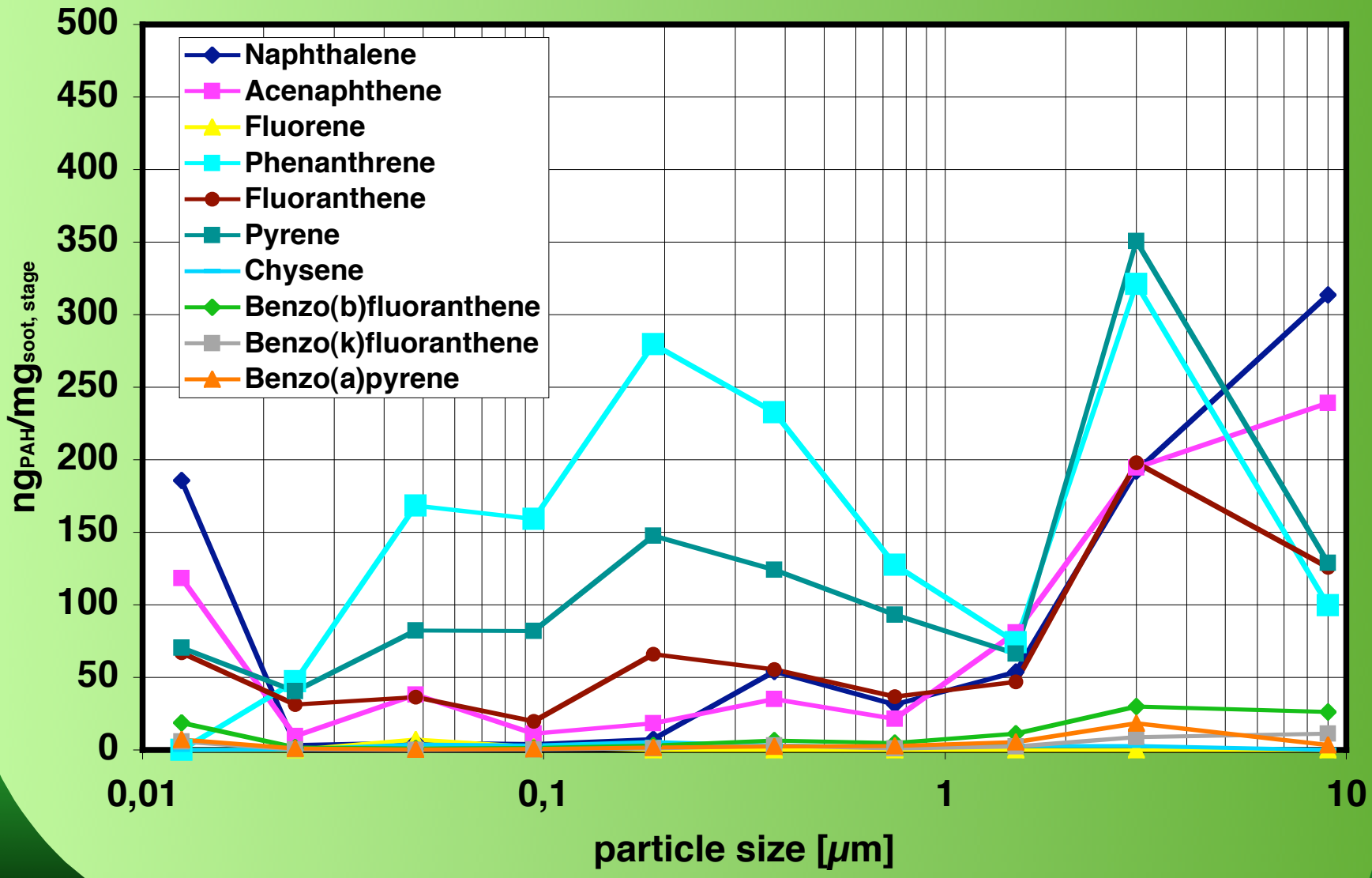
PAH = f (impactor stage) [ng_{PAHi} / mg_{Soot}]



CU TEC

test results 1800 rpm 5 bar @ CUTEC

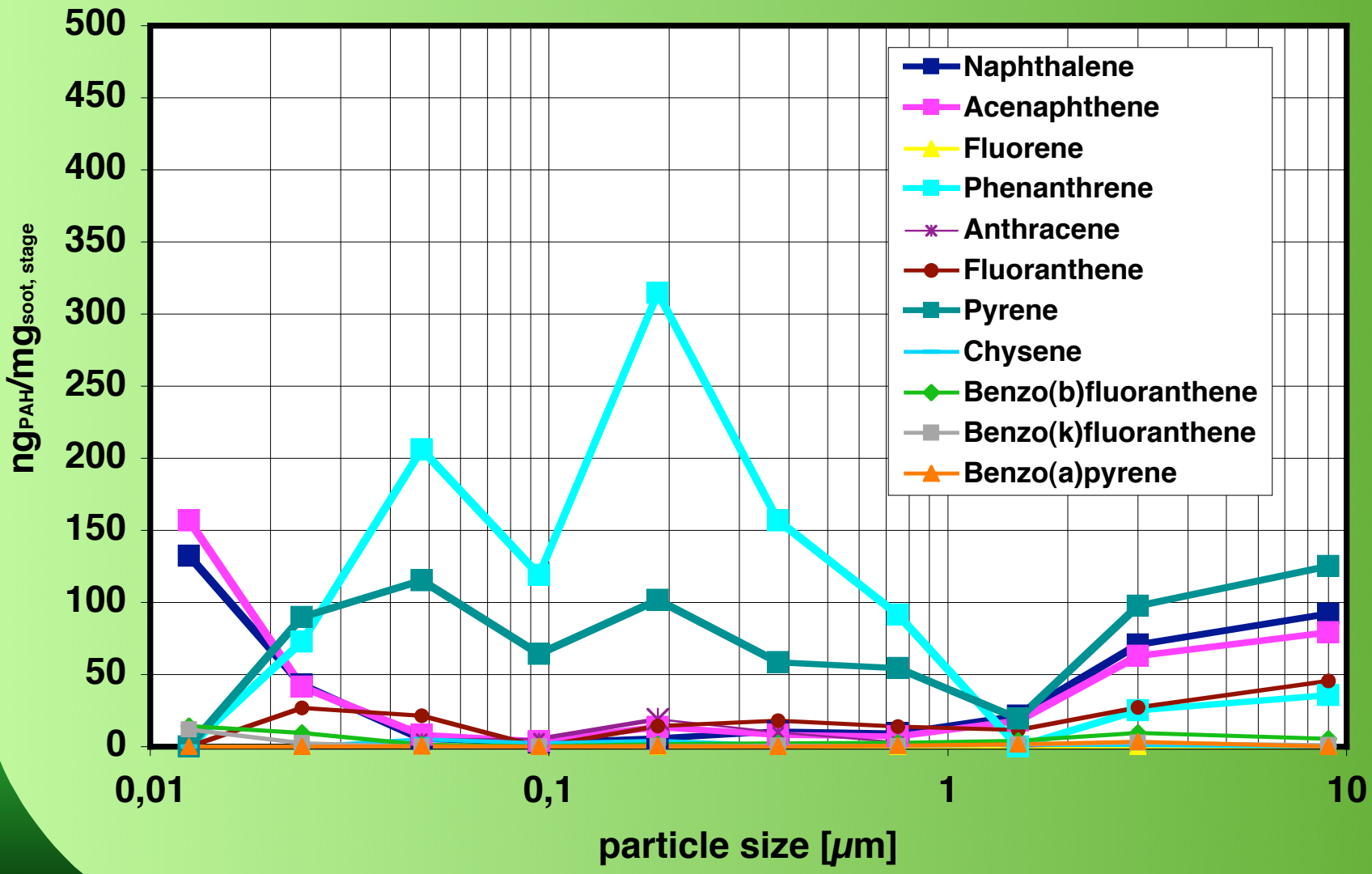
PAH = f (impactor stage) [ng_{PAHi} / mg_{Soot}]



CU TEC

test results 2000 rpm 12 bar @ CUTEC

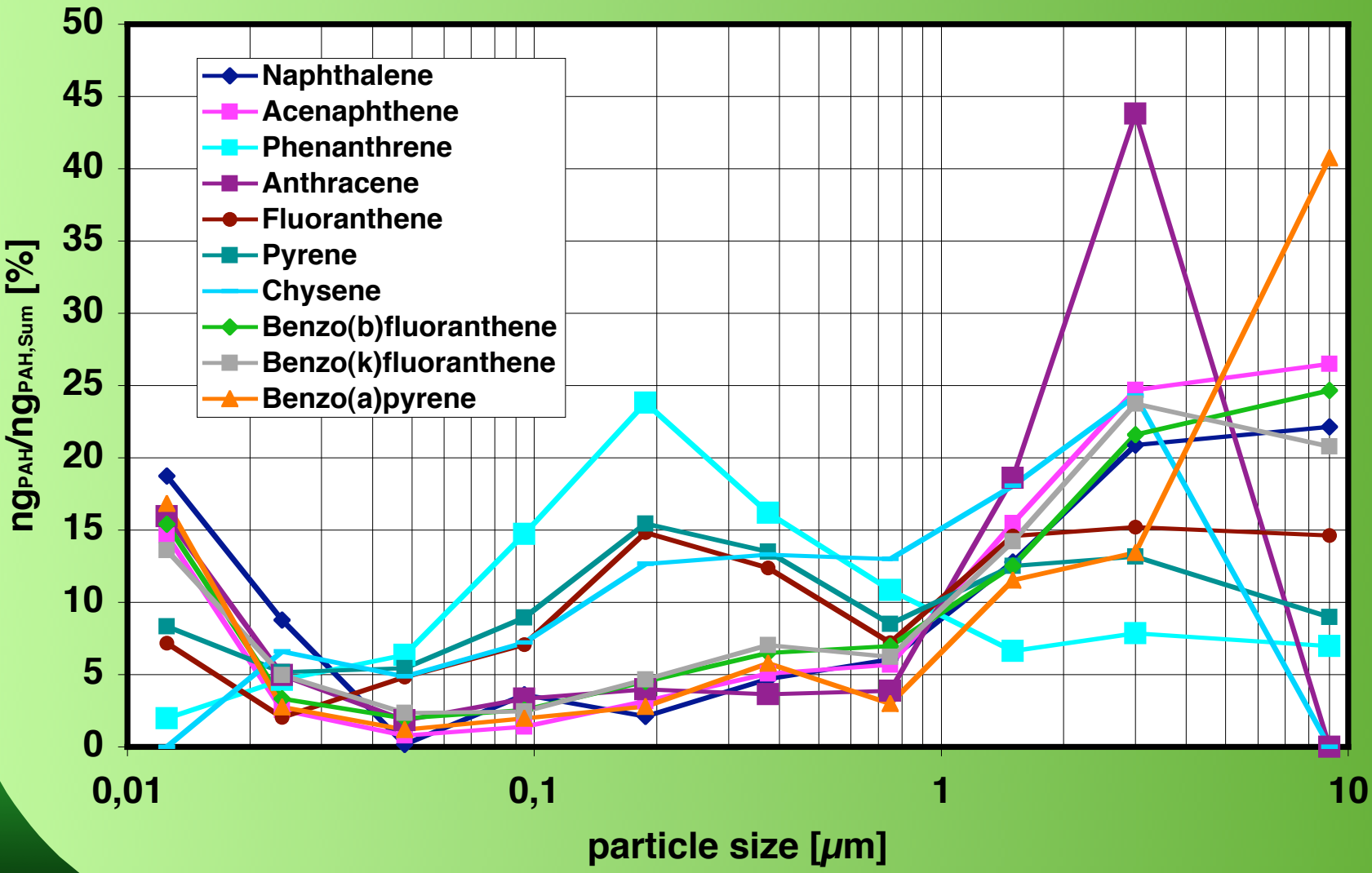
PAH = f (impactor stage) [ng_{PAHi} / mg_{Soot}]



CU TEC

test results 1600 rpm 2.3 bar @ CUTEC

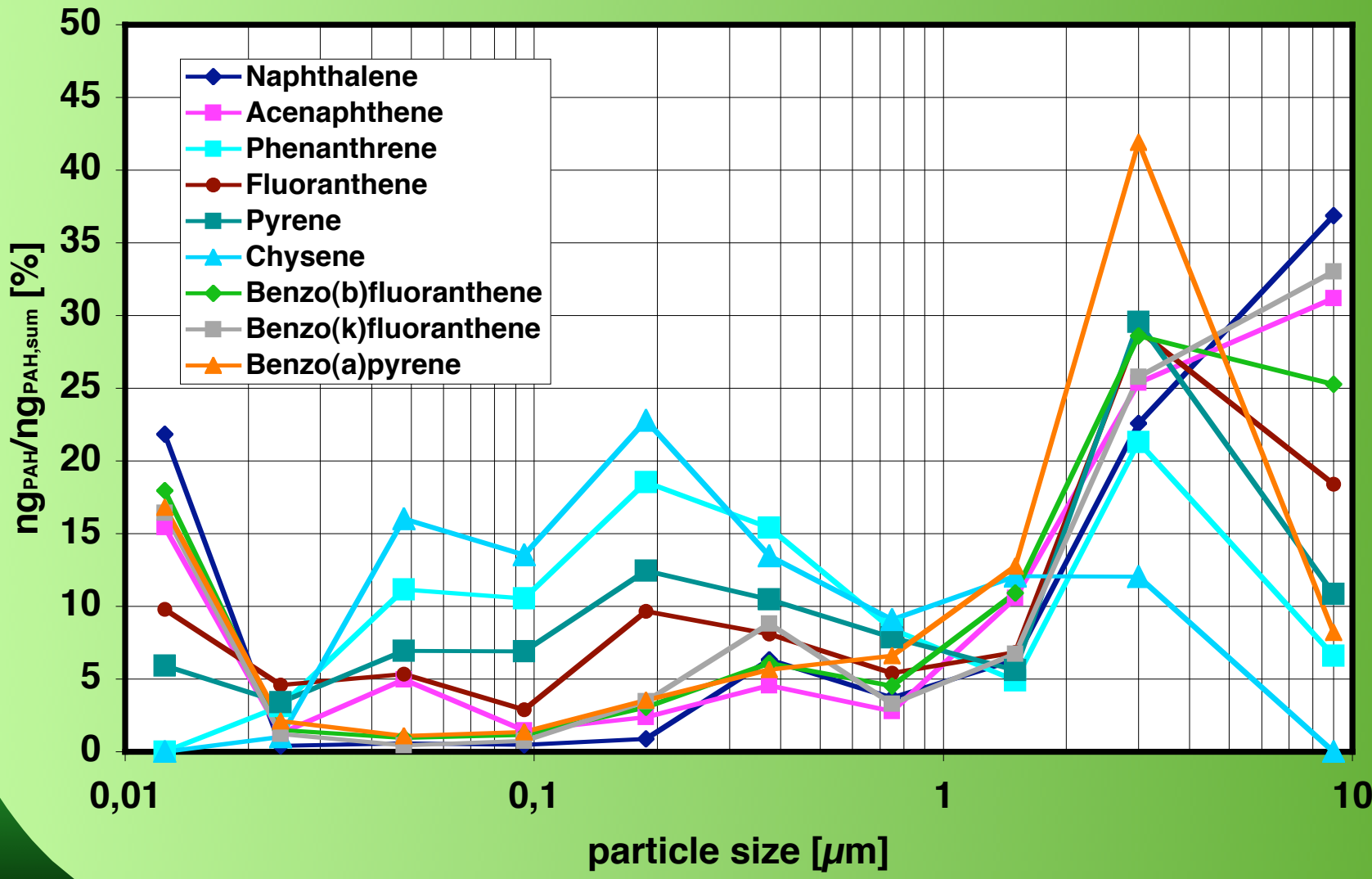
PAH = f (impactor stage) [ng_{PAHi} / Σng_{PAH}]



CU TEC

test results 1800 rpm 5 bar @ CUTEC

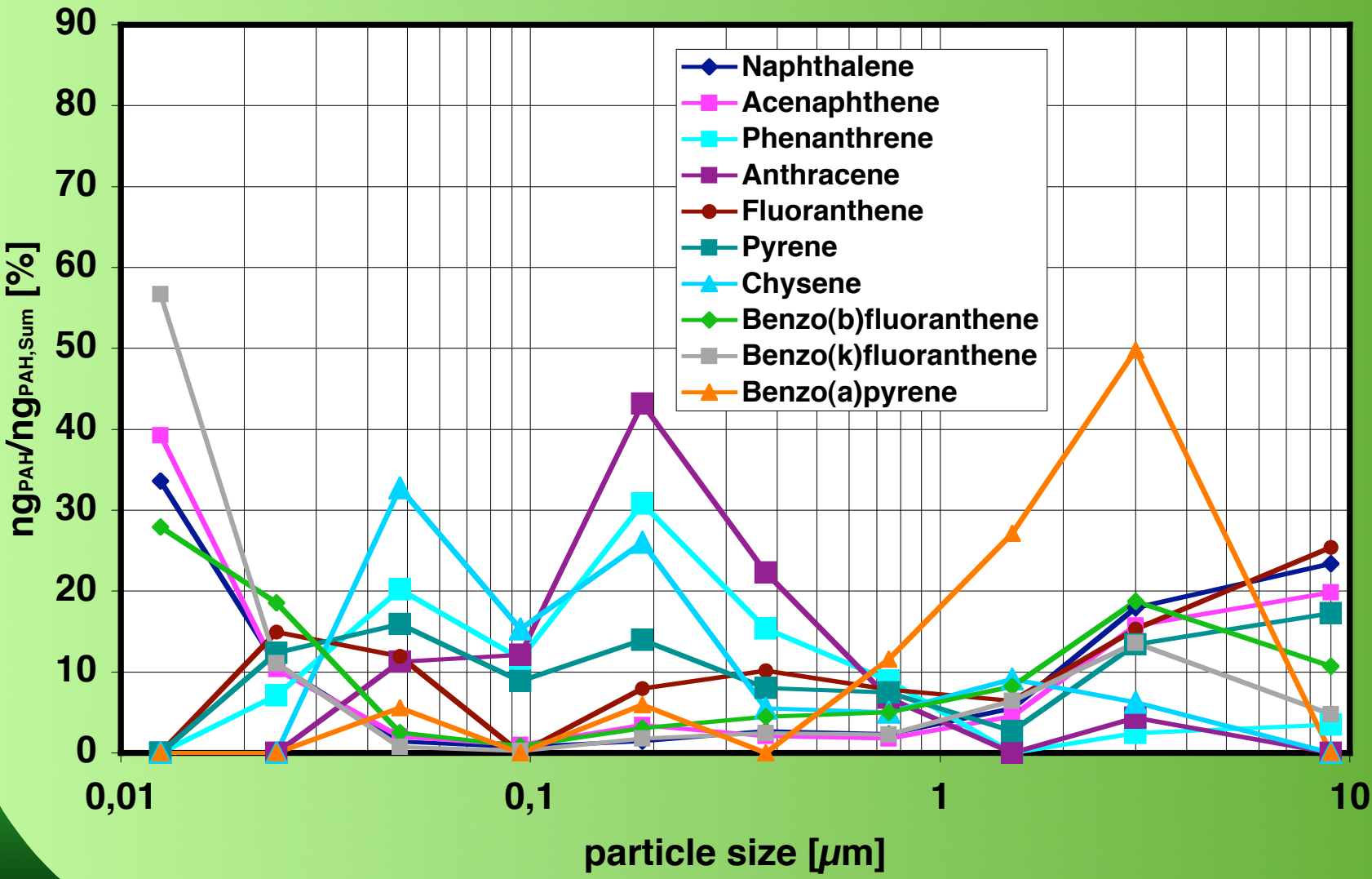
PAH = f (impactor stage) [ng_{PAHi} / Σng_{PAH}]



CU TEC

test results 2000 rpm 12 bar @ CUTEC

PAH = f (impactor stage) [ng_{PAHi} / Σng_{PAH}]



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PAH = f (particle surface)

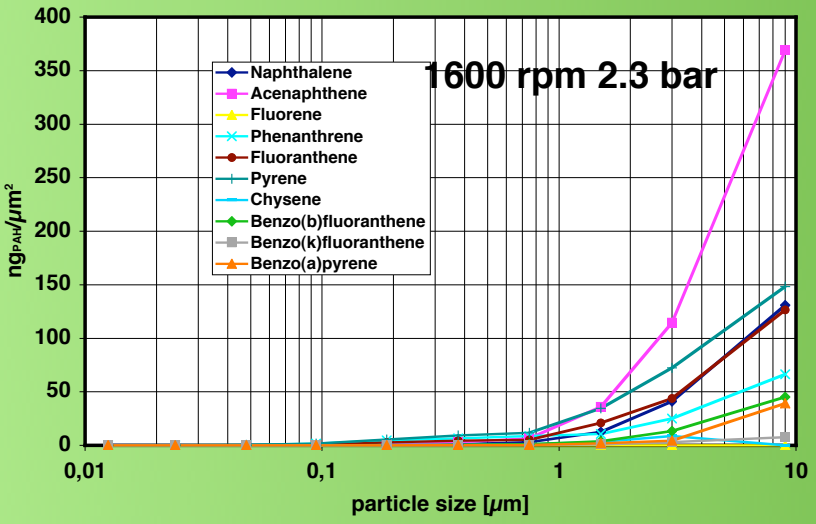
$[ng_{PAHi} / m^2]$

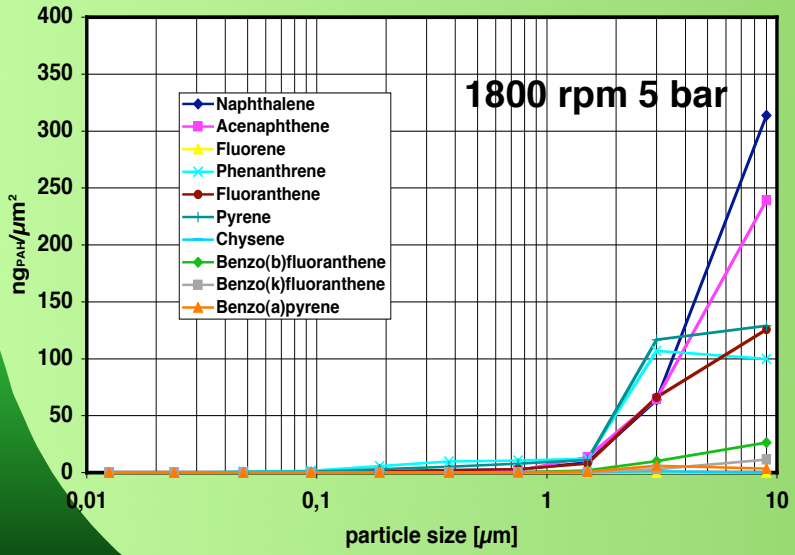
- simple assumptions
  - particles as spheres, no fractals
  - constant particle density per size class
  - PAH molecules as spheres
- but particle are fractals !!! $D_{f\ mean}$: 2.4
  - more information
    - B.Benker, A. Wollmann, M. Claussen: *Comparision of diesel soot particle size distributions measured with a cascade impactor and a mobility spectrometer*, SAE_NA 2003-01-55
    - Journal Aerosol Science , EAC 2003 Madrid

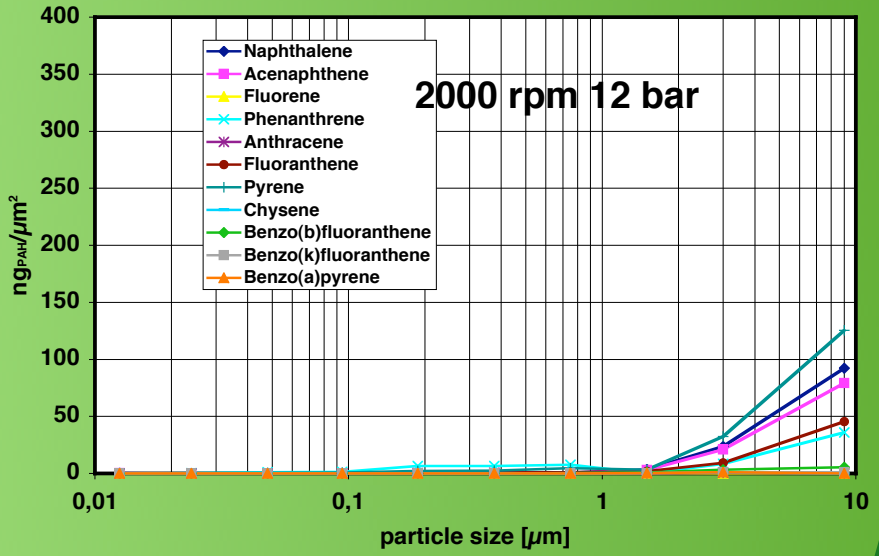
test results @ CUTEC

PAH = f (particle surface)

[ng_{PAH}/ m^2]







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conclusion

- high resolution PAH measurement technique
- PAH distribution ≅ particle mass distribution
  - not significant effected by temperature
- PAH accumulation
  - particle ≤ 20 nm
  - 100 ≤ particle ≤ 200 nm
  - particle ≥ 1000 nm
- PAH condensed on particles ≥ 1000 nm

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