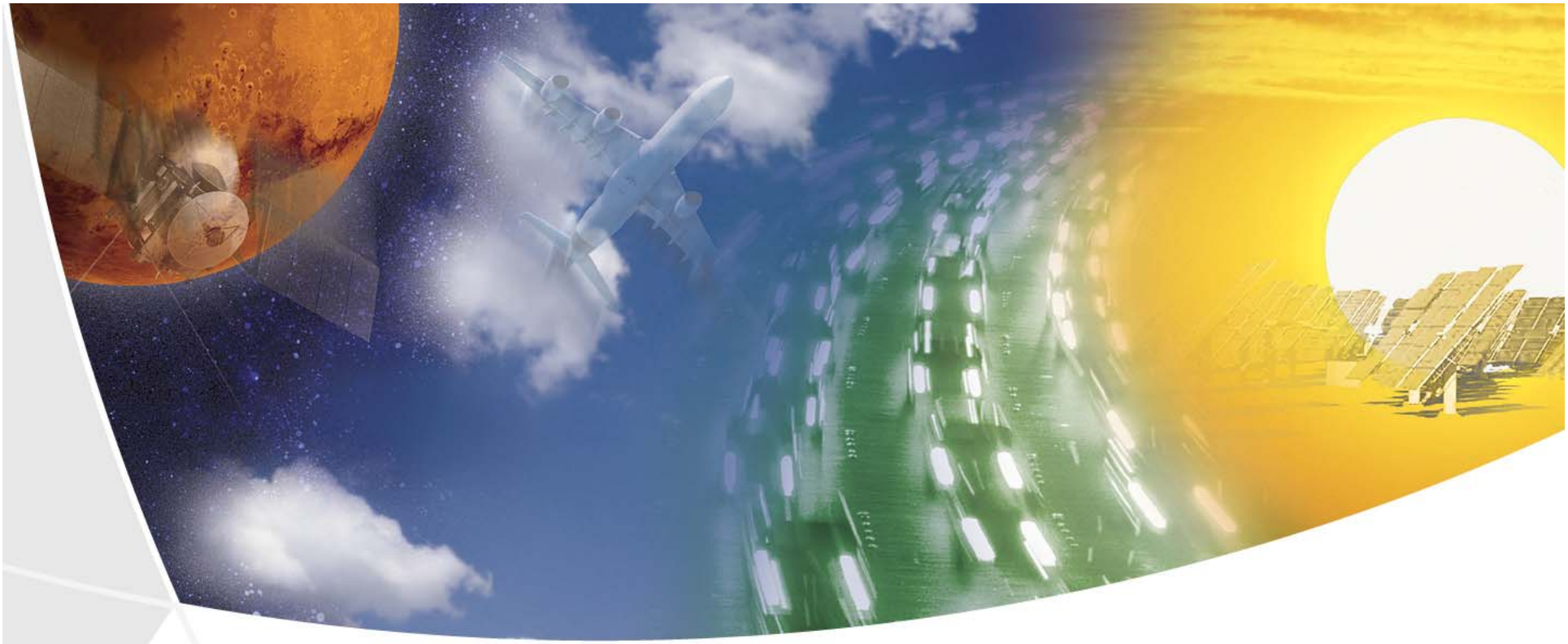


DLR / FOCA Line Loss Study

2009 /2010

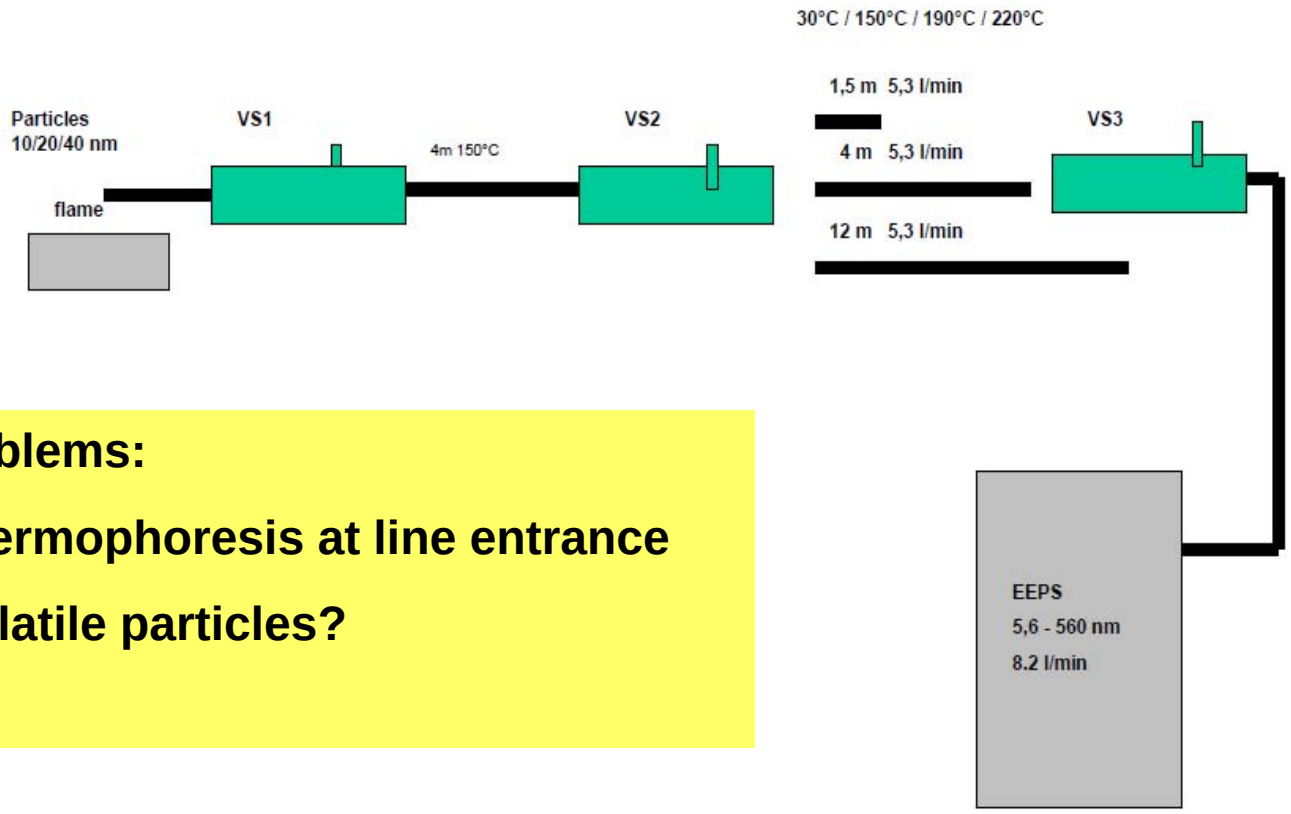
SAE E-31 Cardiff Nov 2010

C. Wahl*, M. Kapernaum*, T. Zornek*, Th. Rindlisbacher#,

* Deutsches Zentrum für Luft- und Raumfahrt e.V. in der Helmholtz-Gemeinschaft

\# **Bundesamt für Zivilluftfahrt BAZL**
Abteilung Luftfahrtentwickung

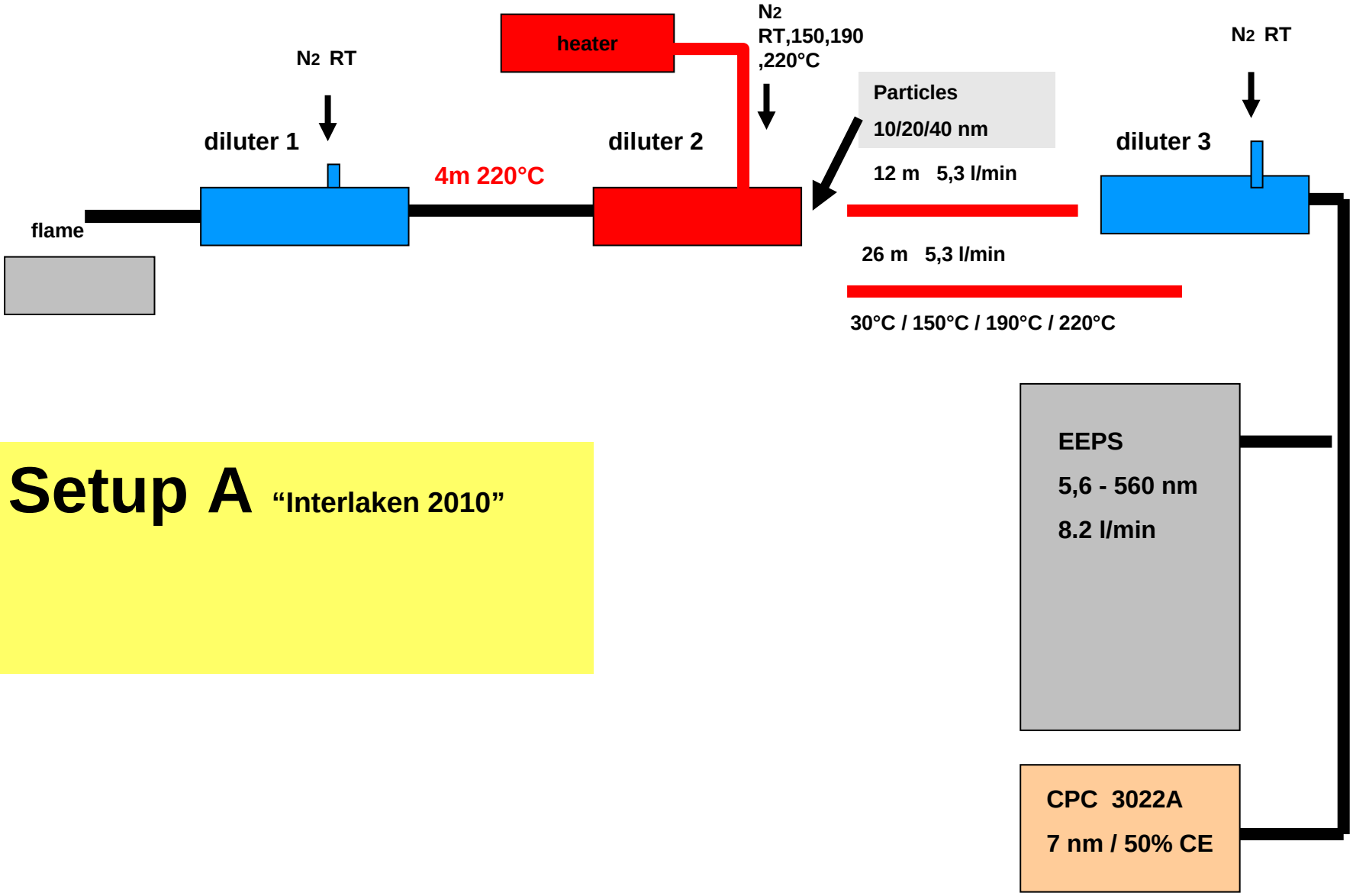
SETUP 2009 // all diluters at ambient temperature



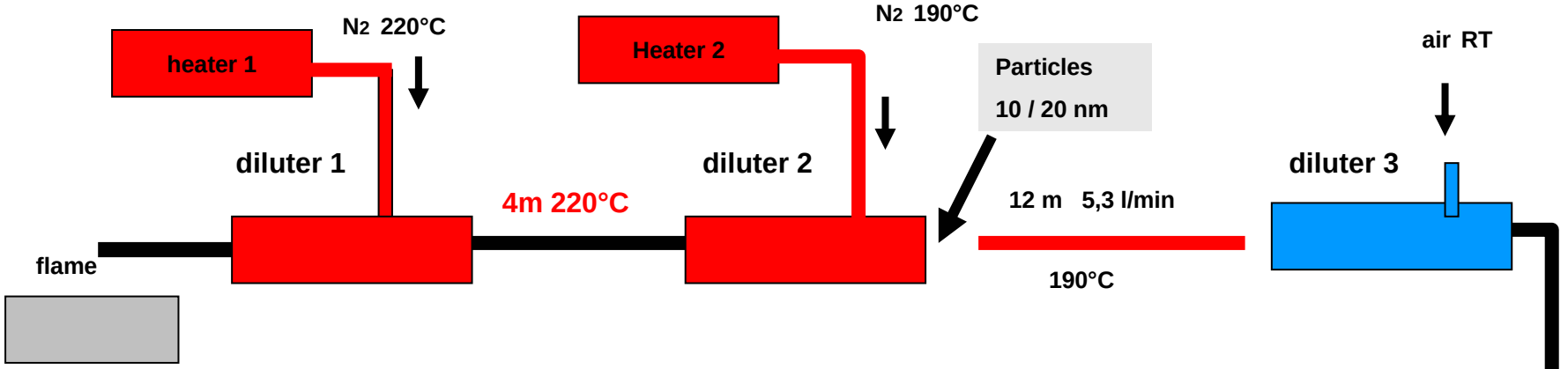
Problems:

-Thermophoresis at line entrance

- volatile particles?



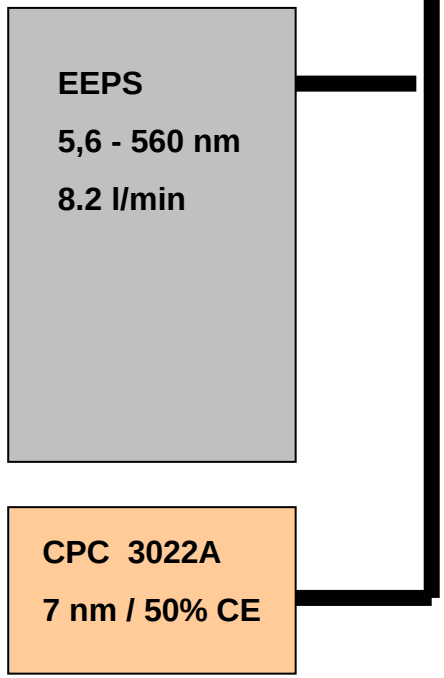
Setup A "Interlaken 2010"

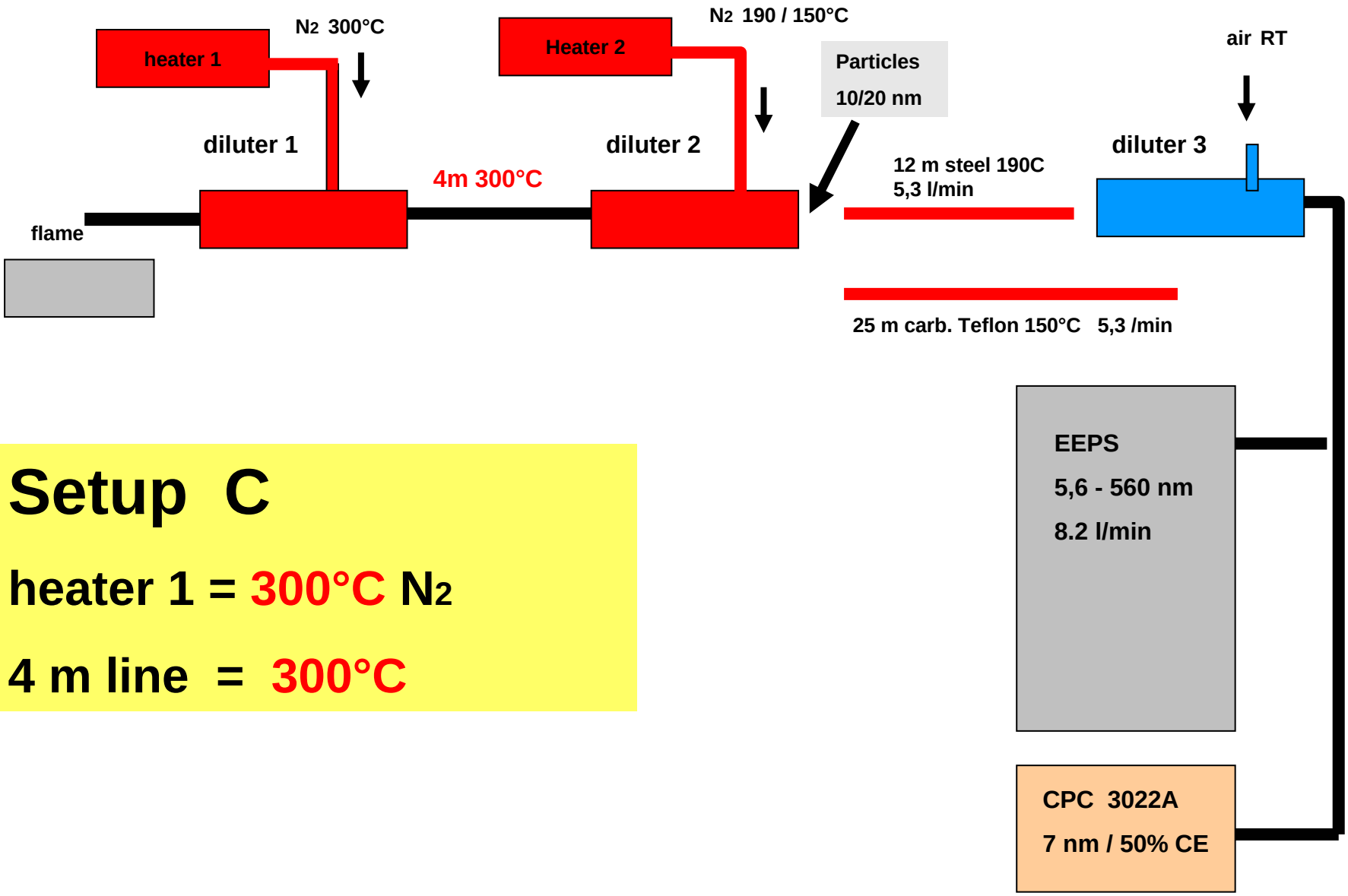


Setup B

heater 1 = 220°C N_2

4 m line = 220°C





Setup C

heater 1 = 300°C N_2

4 m line = 300°C

Line Ageing Effect

12 m stainless steel

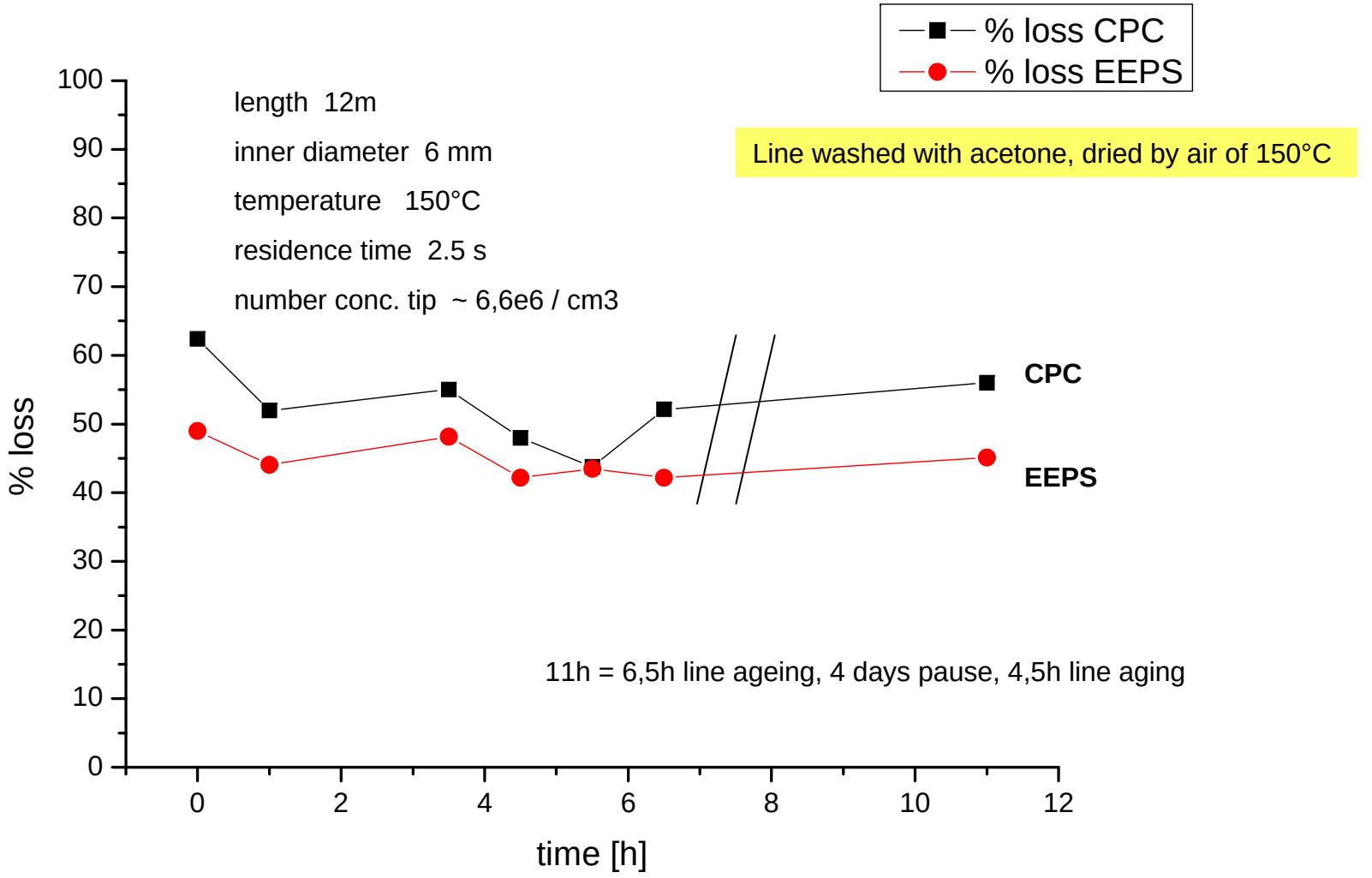
150°C

id = 6mm

SETUP C (300°C precond.)

“Line ageing effect“ 12 m stainless steel particle diameter 20 nm

SETUP C (300°C preconditioning of the particles)



line ageing // 12m stainless steel // inner diameter = 6mm // residence time = 2,5 sec // line temperature 150°C // SETUP C

time [h]	Geo.Mean d	Mass	number EEPS	number CPC	precond.	sampling line	Position	diluter 2	exit diluter 2	loss EEPS	loss EEPS	loss CPC
[-]	[nm]	[µg/m³]	[#/cm³]	[#/cm³]	[°C]	[°C]		°C	[°C]	#[%]	mass %	#[%]
0	19,8	9,58	8,27E+05	8,5E+05	300	-	tip	150	150			
0	22,2	6,14	4,22E+05	3,2E+05	300	150	exit	150	150	48,97	35,91	62,35
1	18,8	7,2	7,17E+05	7,7E+05	300	-	tip	150	150			
1	22,0	5,81	4,01E+05	3,7E+05	300	150	exit	150	150	44,07	19,31	51,95
3,5	18,3	6,07	6,46E+05	6,0E+05	300		tip	150	150			
3,5	21,1	4,24	3,35E+05	2,7E+05	300	150	exit	150	150	48,14	30,15	55,00
4,5	19,5	8,14	7,61E+05	7,50E+05	300		tip	150	150			
4,5	21,7	5,85	4,40E+05	3,60E+05	300	150	exit	150	150	42,18	28,13	48
5,5	17,8	2,2	2,76E+05	2,4E+05	300		tip	150	150			
5,5	19,5	1,55	1,56E+05	1,4E+05	300	150	exit	150	150	43,47	29,5	43,75
6,5	18,0	6,17	7,21E+05	7,1E+05	300		tip	150	150			
6,5	21,2	5,1	4,17E+05	3,4E+05	300	150	exit	150	150	42,16	17,34	52,11
11	17,3	4,71	7,29E+05	7,5E+05	300		tip	150	150			
11	20,1	3,85	4,00E+05	3,3E+05	300	150	exit	150	150	45,13	18,26	56,00

11h = 6,5h line ageing, 4 days pause, 4,5h line aging

Line Loss Measurements

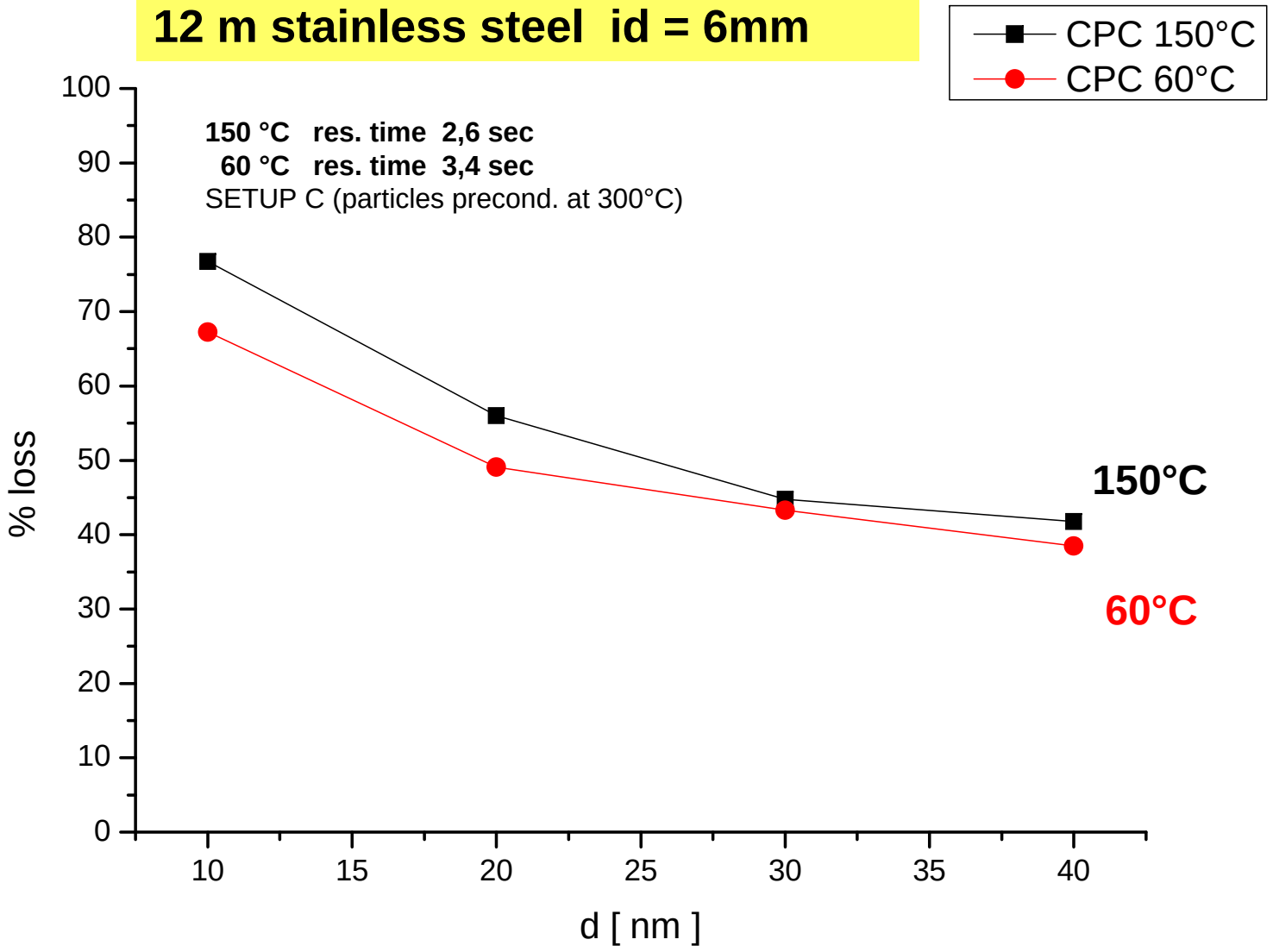
12m stainless steel

60°C // 150°C

id = 6mm

SETUP C

12 m stainless steel id = 6mm



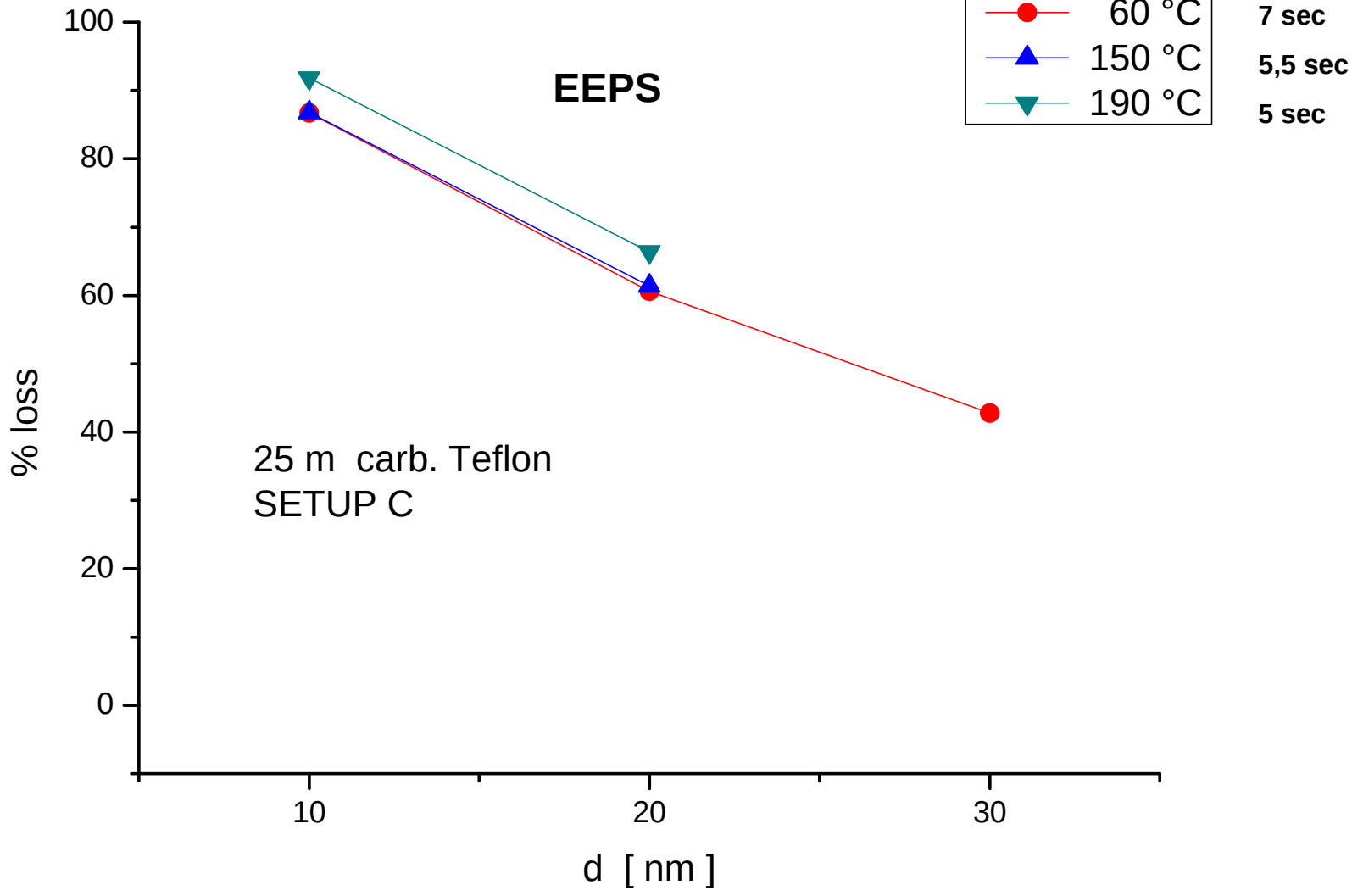
Line Losses 25 m carb. Teflon

10, 20, 30 nm

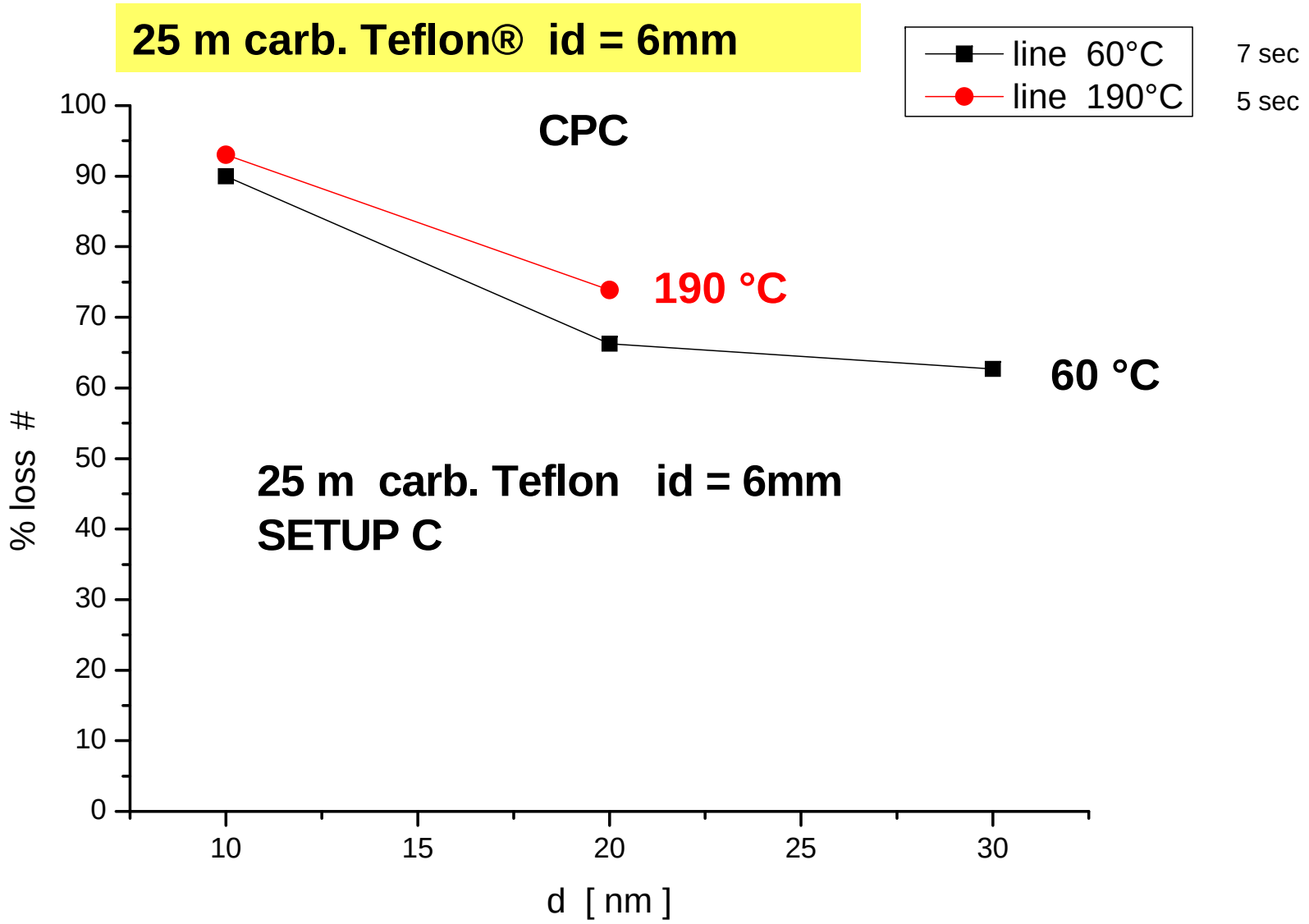
60°C, 150°C 190°C
ID 6 mm

SETUP C

25 m carb. Teflon® id = 6mm



25 m carb. Teflon® id = 6mm



Main results of the 2nd FOCA / DLR line loss study

- **line aging is not a problem**
- **high line losses for small particles are real (< 20 nm)**

  (SETUP C 300°C)
- **everybody should use the same sampling system**

  (length, diameter, temperature, flow, dilution……)
- **sampling system should be as simple as possible**

Thank you for your attention

	25 m carb. Teflon ID 6mm SETUP C 60°C / 150°C / 190°C 10, 20, 30 nm											
	std dev	Geo Mean d	mass	# EEPS	# CPC	precond.	sampling line	position	exit diluter 2	loss EEPS	loss EEPS	loss CPC
		nm	µg/m3	#(cm3	/cm3	°C	°C		°C	#[%]	mass [%]	# [%]
1,825	1,35	9,5	5,97E-02	7,42E+04	1,30E+05	300		tip	60			
1,825	1,32	10,2	7,83E-03	1,00E+04	1,30E+04	300	60	exit	60	86,52		90
1,825	1,32	10,2	8,25E-03	9,78E+03	1,30E+04	300	60	exit	60	86,82		90
1,975	1,67	19,4	9,06	7,92E+05	8,30E+05	300		tip	60			
1,975	1,61	24,4	5,7	3,12E+05	2,80E+05	300	60	exit	60	60,61		66,27
2,125	1,75	31	50,5	1,05E+06	1,50E+06	300		tip				
2,125	1,59	40,1	44,1	6,01E+05	5,60E+05	300	60	exit	60	42,76		62,66
##########												
1,825	1,27	8,8	1,01E-02	2,18E+04		300		tip	150			
1,825	1,29	9,5	1,77E-03	2,87E+03		300	150	exit	150	86,83		
1,85	1,33	9,7	4,17E-02	5,73E+04	1,00E+05	300		tip	150			
1,85	1,34	11,3	1,38E-02	1,18E+04	1,20E+04	300	150	exit	150	79,41		88
2,05	1,67	19,6	7,66	5,93E+05	7,10E+05	300		tip	150			
2,05	1,64	23,9	4,51	2,29E+05	2,10E+05	300	150	exit	150	61,38		70,4
##########												
1,825	1,29	9,06	3,28E-02	5,96E+04	1,20E+05	300		tip	190			
1,825	1,29	9,84	3,44E-03	4,87E+03	8,00E+03	300	190	exit	190	91,83		93,3
1,975	1,62	19	7,24	7,44E+05	8,80E+05	300		tip	190			
1,975	1,57	23,2	3,71	2,50E+05	2,30E+05	300	190	exit	190	66,39		73,86

60°C // 150°C // 12m stainless steel // inner diameter = 6mm // SETUP C

geo.std.dev.	Geo.Mean d	Mass	number EEPS	number CPC	precond.	sampling line	Position	diluter 2	exit diluter 2	loss EEPS	loss EEPS	loss CPC
	[nm]	[µg/m³]	[#/cm³]	[#/cm³]	[°C]	[°C]		°C	[°C]	#[%]	mass %	#[%]
1,32	10,0	0,188	2,32E+05	2,20E+05	300	-	tip	60	60			
1,29	10,0	3,84E-02	5,10E+04	7,20E+04	300	60	exit	60	60	78,02	79,57	67,27
1,54	17,1	3,72	5,98E+05	5,50E+05	300	-	tip	60	60			
1,53	19,0	3,66	4,62E+05	2,80E+05	300	60	exit	60	60	22,74	1,61	49,09
1,64	30,5	34,8	9,71E+05	1,20E+06	300		tip	60	60			
1,56	34,4	30,5	6,87E+05	6,80E+05	300	60	exit	60	60	29,25	12,36	43,30
1,56	39,8	72,2	1,03E+06	1,30E+06	300		tip	60	60			
1,5	41,7	57,8	7,84E+05	8,00E+05	300	60	exit	60	60	23,88	19,94	38,46
1,32	10,1	0,166	2,05E+05	2,15E+05	300		tip	150	150			
1,31	10,3	3,81E-02	4,53E+04	5,00E+04	300	150	exit	150	150	77,9	77,05	76,74
1,55	17,3	4,71	7,29E+05	7,50E+05	300		tip	150	150			
1,54	19,9	3,75	4,04E+05	3,30E+05	300	150	exit	150	150	44,58	20,38	56
1,63	30,9	32,7	8,97E+05	1,05E+06	300		tip	150	150			
1,55	35,0	28,3	6,10E+05	5,80E+05	300	150	exit	150	150	31,99	13,46	44,76
1,55	39,8	64,6	9,46E+05	1,15E+06	300		tip	150	150			
1,49	42,6	54,6	7,05E+05	6,70E+05	300	150	exit	150	150	25,48	15,48	41,74

Specifications

CPC

TSI-3022A

The following specifications—which are subject to change—describe the most important data of the major components.

Table B-1
Specifications of the Model 3022A CPC

Minimum particle size	50% detection at .007 µm 90% detection at 0.015 µm
Flowrate	
Sensor	0.3 L/min ± 0.015 L/min
Inlet, high-flow	1.5 L/min ± 0.15 L/min
Inlet, low-flow	0.3 L/min ±.0.015 L/min
Working fluid	
n-butyl alcohol	
saturator temperature	35°C ±0.3°C
condenser temperature ...	10°C ±0.3°C
optics temperature	36°C ±2.0°C
Concentration	0 to 9.99 × 10^6 particles/cm^3
Accuracy	±10% up to 5 × 10^5/cm^3 ±20% from 5 × 10^5 to 9.99 × 10^6/cm^3
Particle-pulse height of the photodetector	≅1.4 V typical
Laser power	≅3–5 mW
Detector	See calibration data, Appendix E
Environmental conditions	Indoor use Altitude up to 2000 m (6500 ft) Ambient temperature range n-butyl alcohol 10–37°C Ambient humidity 0–90% RH noncondensing Overvoltage category II Pollution degree II
False background counts	0.01 particle/cm^3
Response time	<13 seconds for 95% to concentration step changes

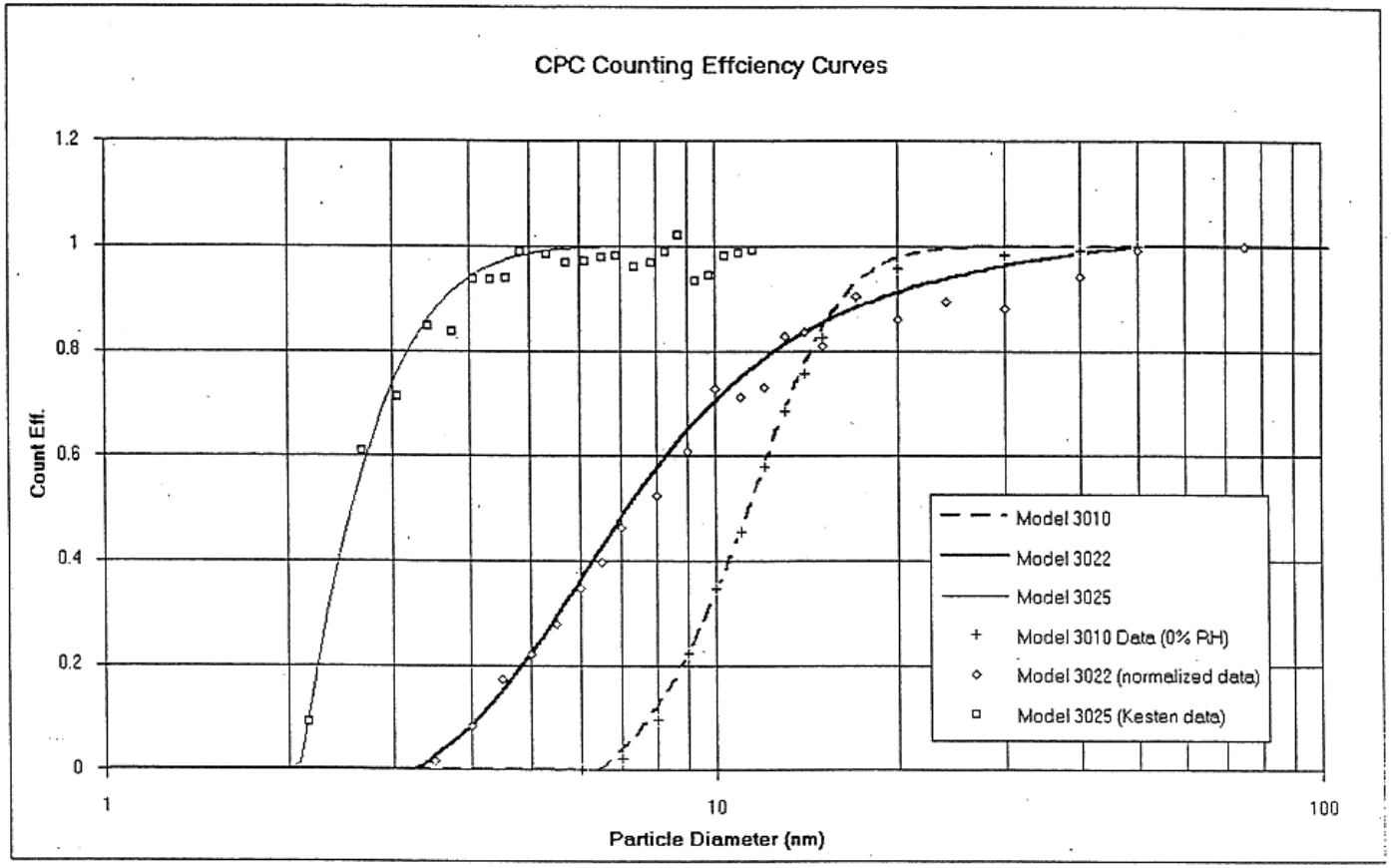


Figure B-9
Graph of the CPC Counting Efficiency Curves

Specifications TSI-EEPS Model 3090

Model 3090 Engine Exhaust Particle Sizer™ (EEPS™) spectrometer operating specifications are as follows (specifications are subject to change):

Particle Size Range	5.6 to 560 nanometers
Particle Size Resolution	16 channels per decade (32 total)
Electrometer Channels	22
Charger Mode of Operation	Unipolar diffusion charger
Inlet Cyclone 50% Cutpoint	1 µm
Maximum Data Rate	10 size distributions per second
Flow Rates	
Aerosol Inlet	10 L/min
Sheath Air	40 L/min
Inlet Aerosol Temperature	10 to 52°C
Storage Temperature	-20 to 50°C
Atmospheric Pressure Correction Range	700 to 1034 mbar
User Interface	Rotary knob and display/EEPS software
Front Panel Display	6.4-in. color VGA LCD
Data Averaging	0.1 to 60 sec