PAUL SCHERRER INSTITUT

PSI

Wir schaffen Wissen – heute für morgen

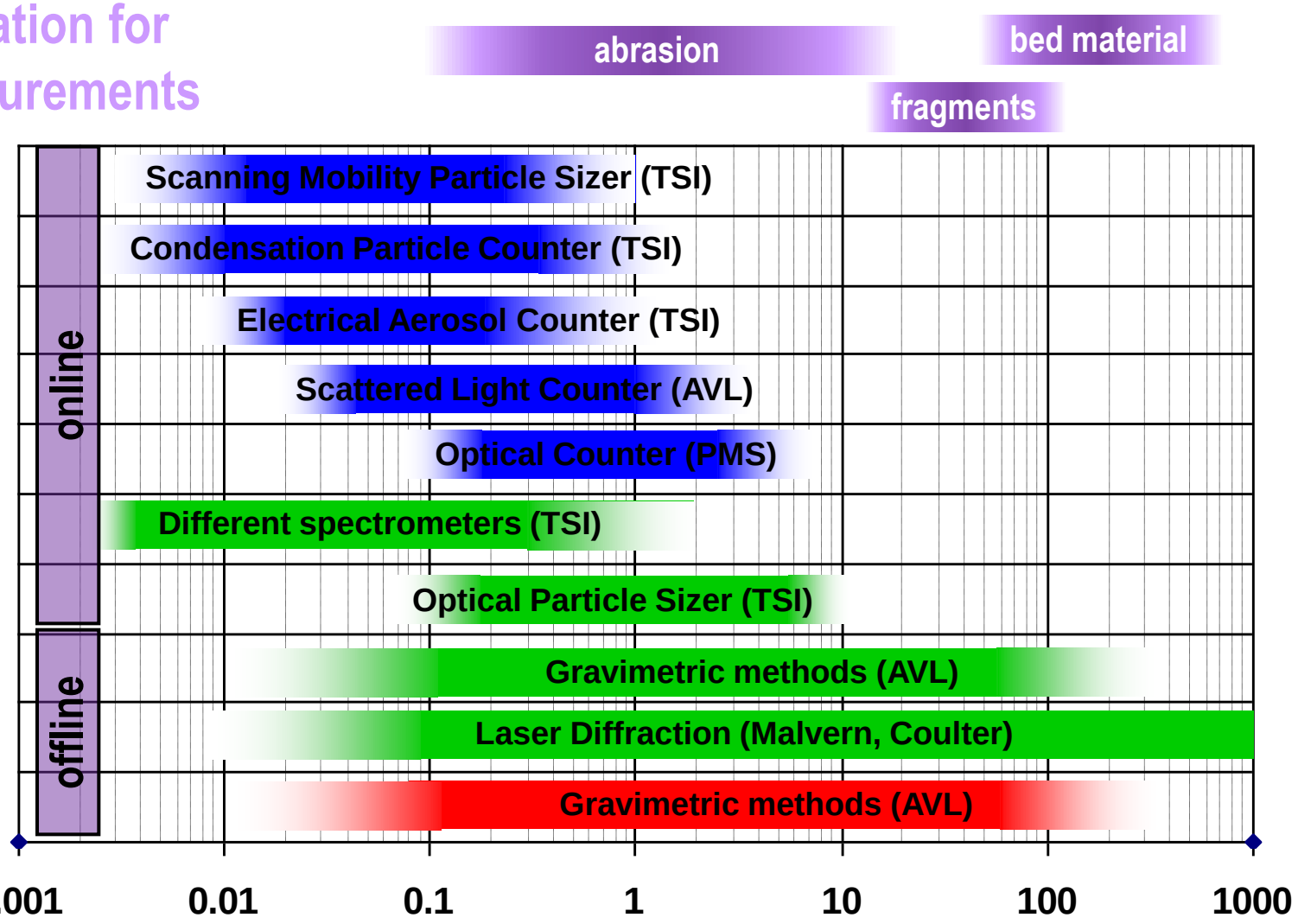
Paul Scherrer Institut

Martin Künstle

Particle measurement in gases, for particles larger than 1 micron

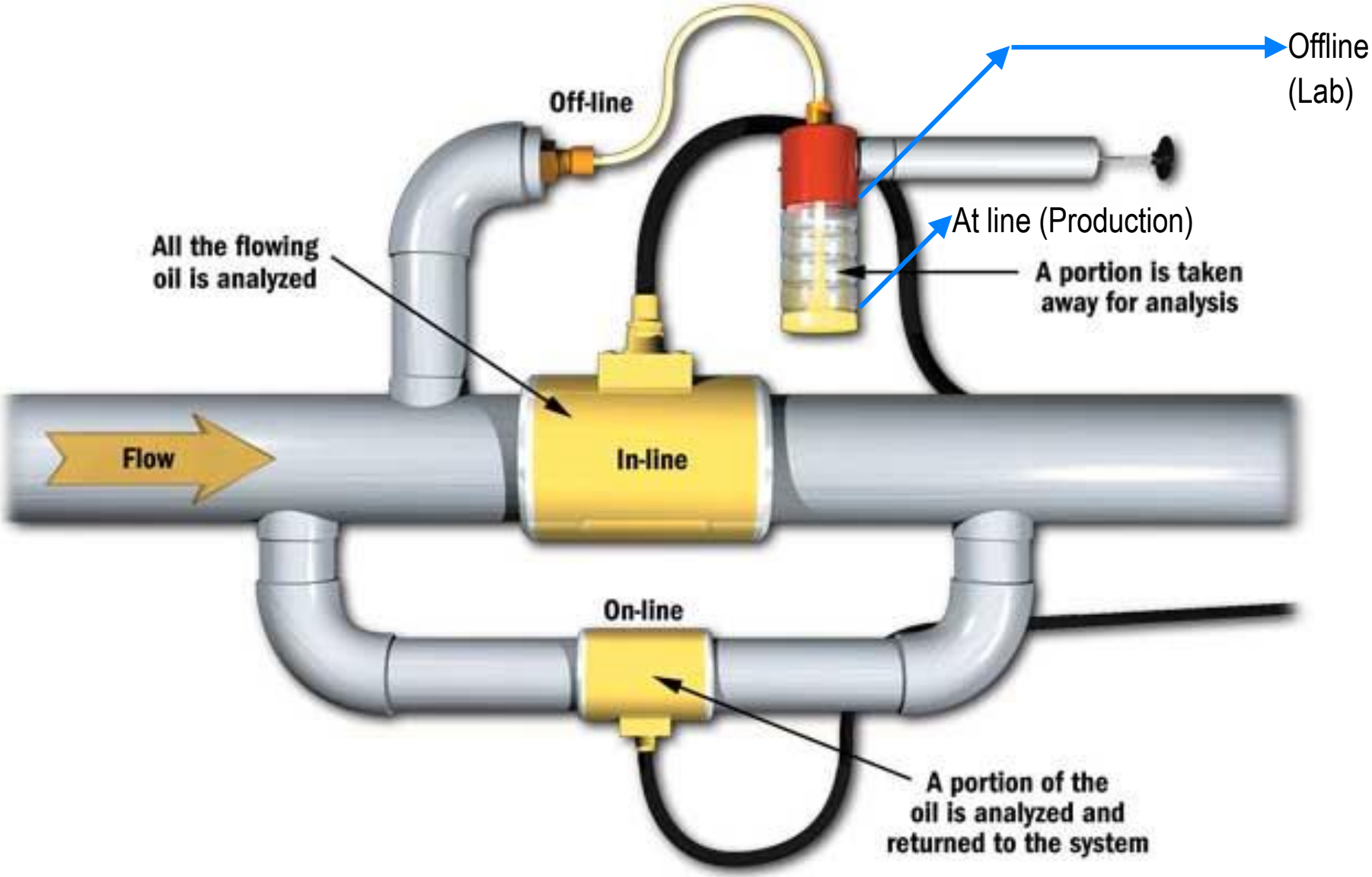
Particle measurement principles/technologies

Needs/application for particle measurements



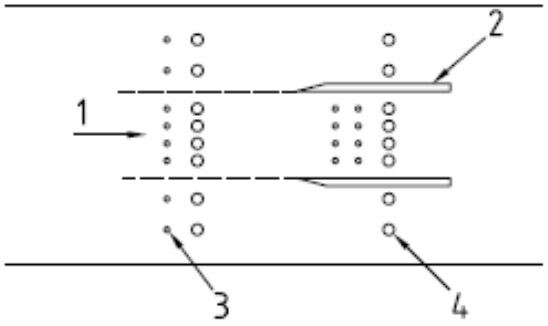
A selection of technologies for particle measurements

Theory: Sampling Methods

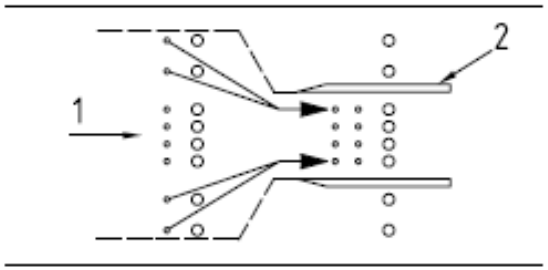


http://www.machinerylubrication.com/Read/521/in-line-wear-debris-detectors , 20140401

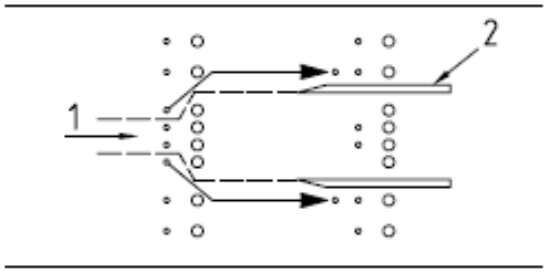
Theory: Isokinetic Sampling



a) 100 % isokinetic conditions



b) 200 % isokinetic conditions



c) 50 % isokinetic conditions

- The basis of all particle sampling
- Isokinetic = same speed of full stream and sample stream
- Allowable flow according VDI 2066-1
  $95\% < v_{iso} < 115\%$
- Different nozzles are necessary to adapt different flows in one pipe

ISO 9096:2003

Theory: Attrition

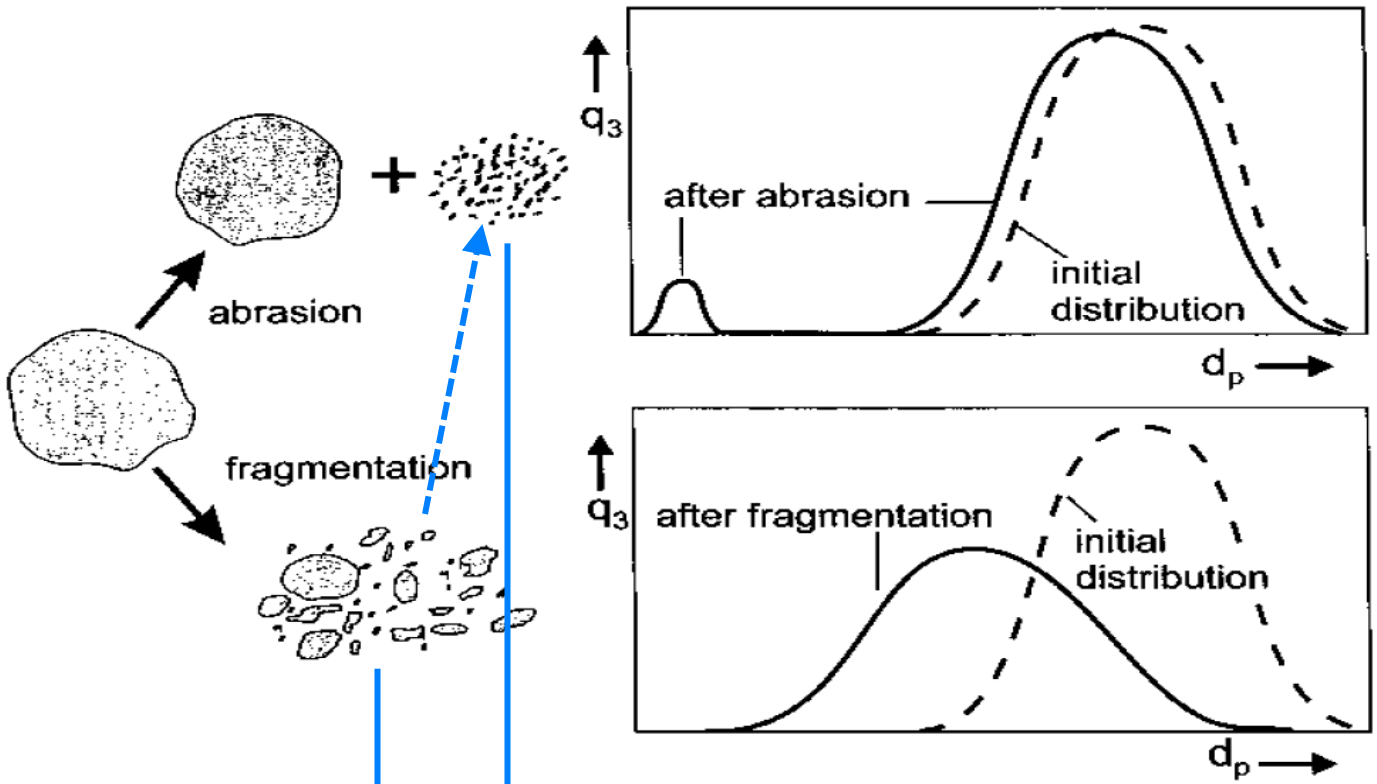


Figure 1 Attrition modes and their effects on the particle size distribution (q_3 = mass density distribution of particle sizes d_p).

Handbook of Fluidization and Fluid-Particle Systems, Wen-Ching Yang, Series: Chemical Industries (Book 91) CRC Press

Size = “natural particle size” or depending on the type of stress?

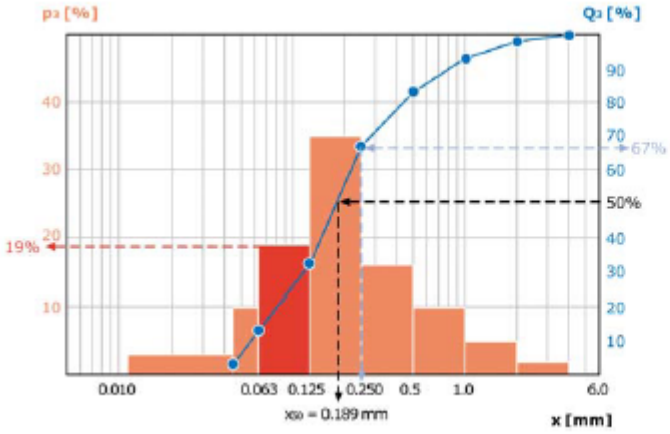
Measuring Principles

Possible Suppliers

Measuring Principles - Overview

- Sieve Analysis
- Filtration
- Laser Diffraction
- Aerodynamic Particle Sizer
- Light-Scattering Spectrometers

Measuring Principles – Sieve Analysis



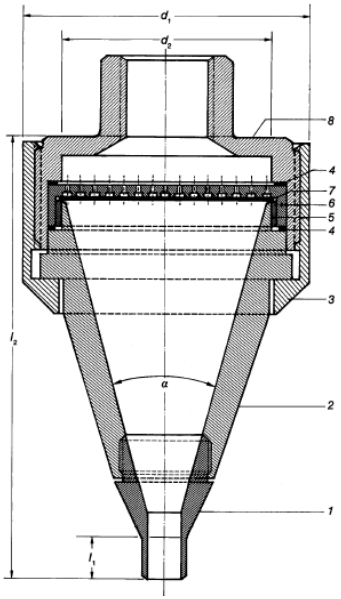
Size class [mm]	p_3 [%]	Q_3 [%]
< 0.045	3.0	3.0
0.045 - 0.063	10.0	13.0
0.063 - 0.125	**19.0**	**32.0**
0.125 - 0.250	35.0	67.0
0.250 - 0.500	16.0	83.0
0.500 - 1.000	10.0	93.0
1.000 - 2.000	5.0	98.0
2.000 - 4.000	2.0	100.0
> 4.000	0.0	100.0

x_{50} = 0.189 mm

Source: Retsch homepage, The Basic Principles of Sieve Analysis

- Still a standard offline analysis
- No problems with sampling (if there is enough material)
- Above approx. 0.063 mm (dry)
- Be aware what graph you present!

Measuring Principles – Filtration



1 Removable entry nozzle
2 Inlet cone
3 Union nut
4 Seal
5 Clamping ring
6 Filter holder
7 Plane filter
8 End case
d_1 Case diameter (66 mm)
d_2 Filter diameter (50 mm)
l_1 Inlet length of the nozzle (10 mm)
l_2 Length of the plane filter head device (100 mm)
α Aperture angle of the inlet cone (30°)

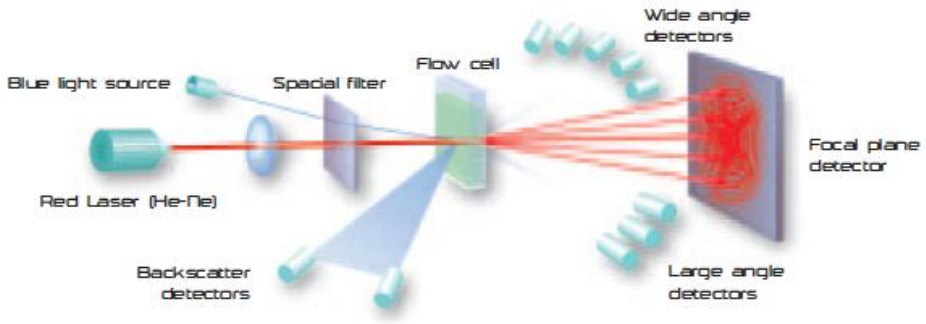
Source: VDI 2066 Blatt 1

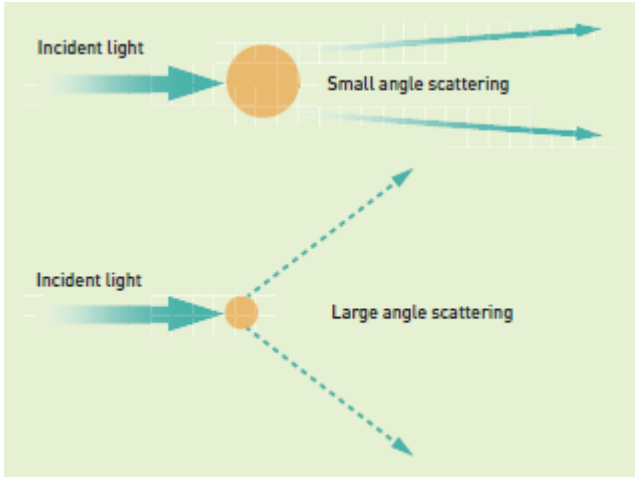
- Total mass over time
- No size distribution

- Only total mass of collected solids are measured
- Condensation has to be prevented (heat or dilute)
- Additional cross-check after online measurement
- Collection of samples for offline analysis

Measuring Principles – Laser Diffraction

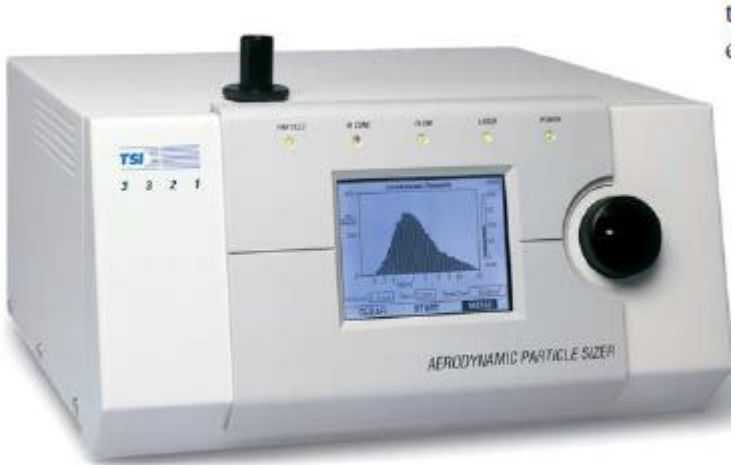
- Standard technology for liquid offline analysis
- Below 1 um … 3.5 mm

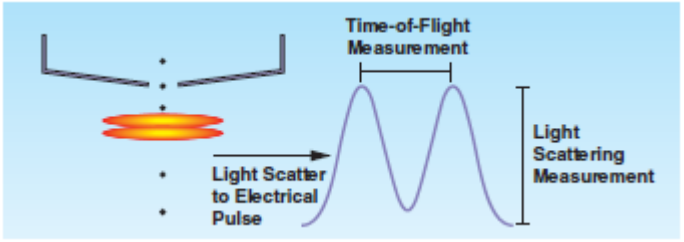




Homepage:
Malvern Instruments

Measuring Principles – APS





TSI Model 3321

- Measurement of particles during acceleration
- The speed is a function of the **aerodynamic** diameter
- Approx. 0.5 … 30 um
- Approx. 2ooo – 20 Mio. P/cm3

Measuring Principles – Spectroscopy

Sensor series 2000

Sensor series 1000

Sensor 27300

Overview of the available welas® sensors:

The sensors of the series 1000 can be combined with the welas® digital 1000 System.

The sensors of the series 2000 and 27300 can be combined with the welas® digital 2000/3000 System and Promo.

Aerosol sensors	C_{max} [P/cm³]	Particle size ranges [µm]				
welas® 1100	500.000*	0,12-3,5	0,2-10	0,25-17	0,6-40	Series 1000
welas® 1200	50.000*	0,12-3,5	0,2-10	0,25-17	0,6-40	
Series 1000 optionally available: pressure-resistant up to 10 bar (sensortype ending P) and additionally heatable up to 120°C (sensortype ending HP)						
welas® 2070	1.000.000*	0,2-10	0,3-17,5		0,6-40	Series 2000
welas® 2100	500.000*	0,2-10	0,3-17,5		0,6-40	
welas® 2200	80.000*	0,2-10	0,3-17,5		0,6-40	
welas® 2300	40.000*	0,2-10	0,3-17,5	0,6-40	2-105	
welas® 2500	4.000*	0,3-17,5	0,6-40		2-105	
Series 2000 optionally available: pressure-resistant up to 10 bar (sensortype ending P), additionally heatable up to 120°C (sensortype ending HP) and heatable up to 250°C (sensortype ending H)						
Spezialsensor welas® 27300	80.000*	---	0,5-17,5		1-40	Sensor 27300
Sensor for particles in liquids	**C_{max} [P/ml]**	**Particle size ranges [µm]**				
welas® 2100 FL	100.000	0,7-40 µm				Sensor 2100 FL

- Developed for filter characterisation
- Flexible in size ranges and number concentration