PM CEMS – TECHNOLOGY OPTIONS & DEVICE CALIBRATION

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05-July-2017

Online Real-time Monitoring Technology

M.P. Pollution Control Board

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01

HISTORY

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EARLY AIR POLLUTION CONTROL DEVICE

1556

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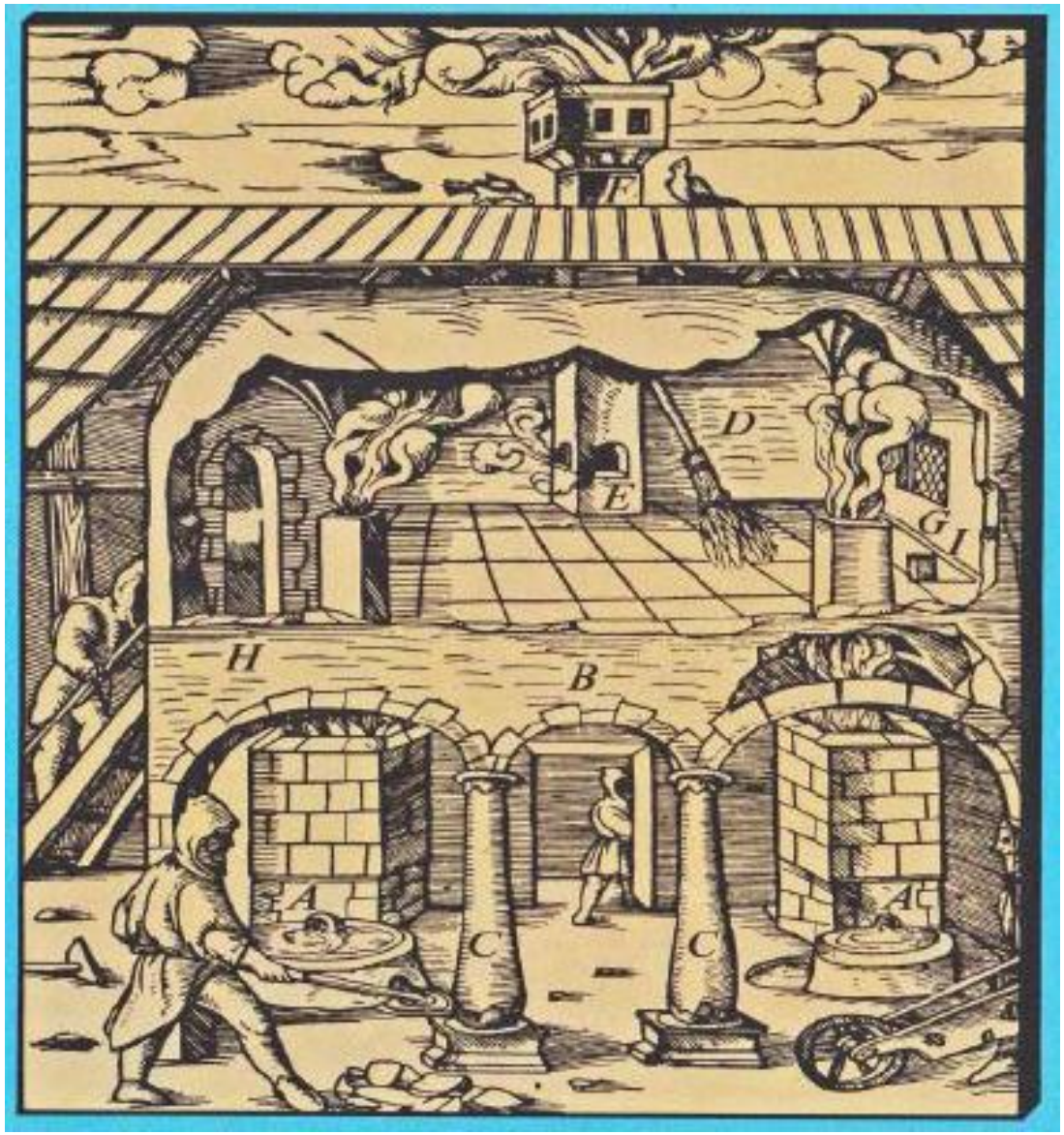
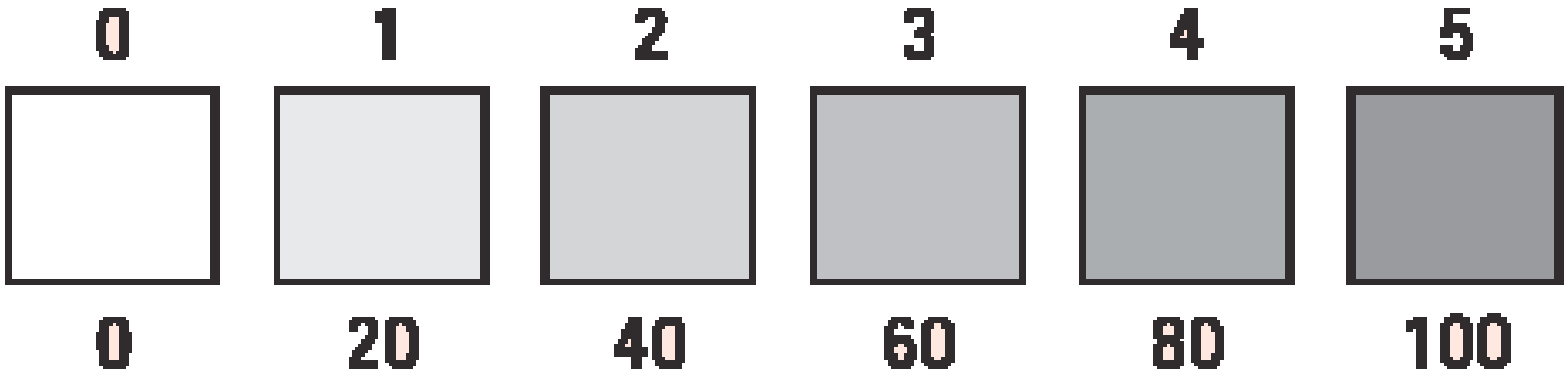


PM CEMS - HISTORY
SIMPLE IDENTIFICATION

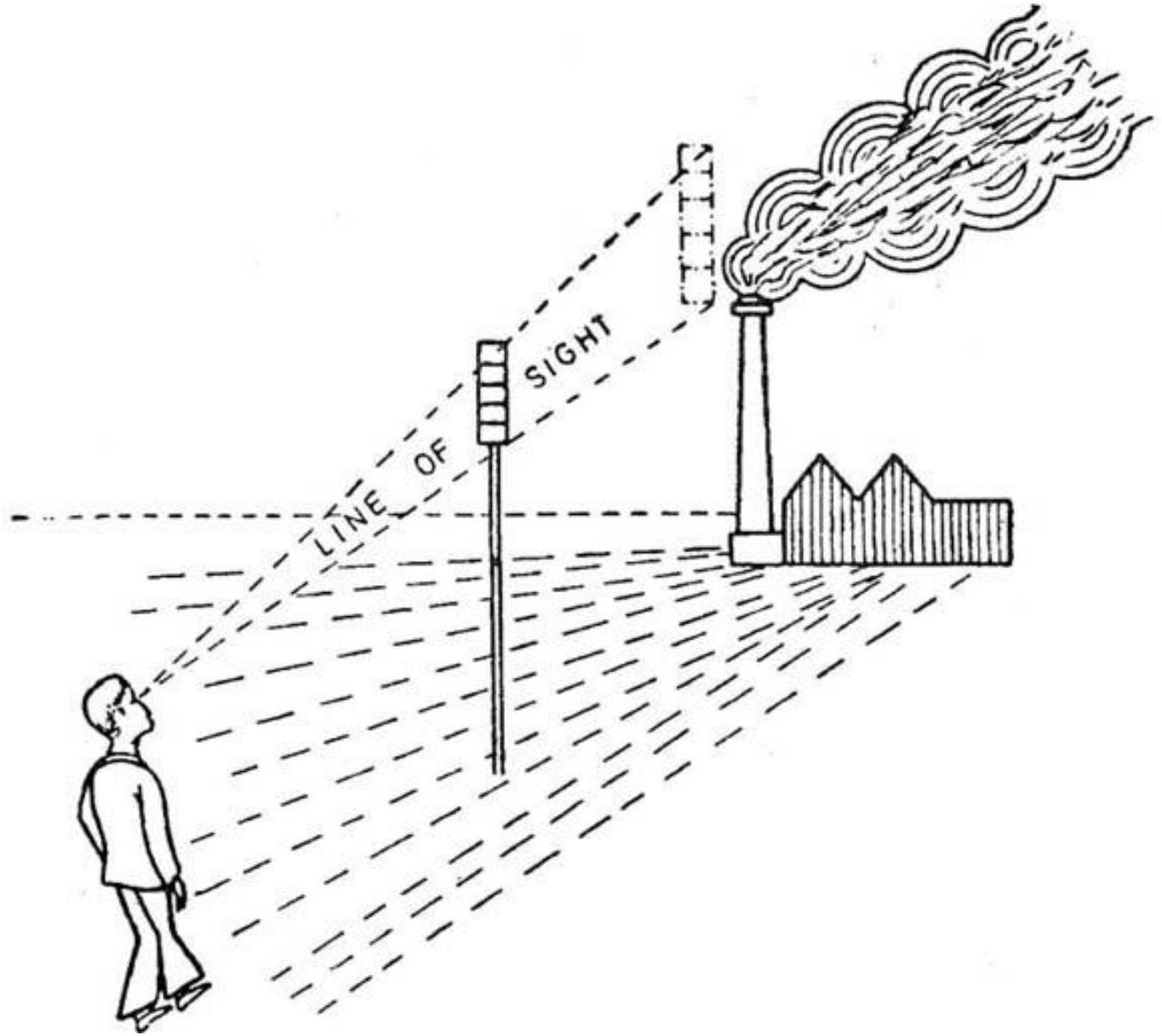
PM CEMS - HISTORY

RINGELMANN SCALE



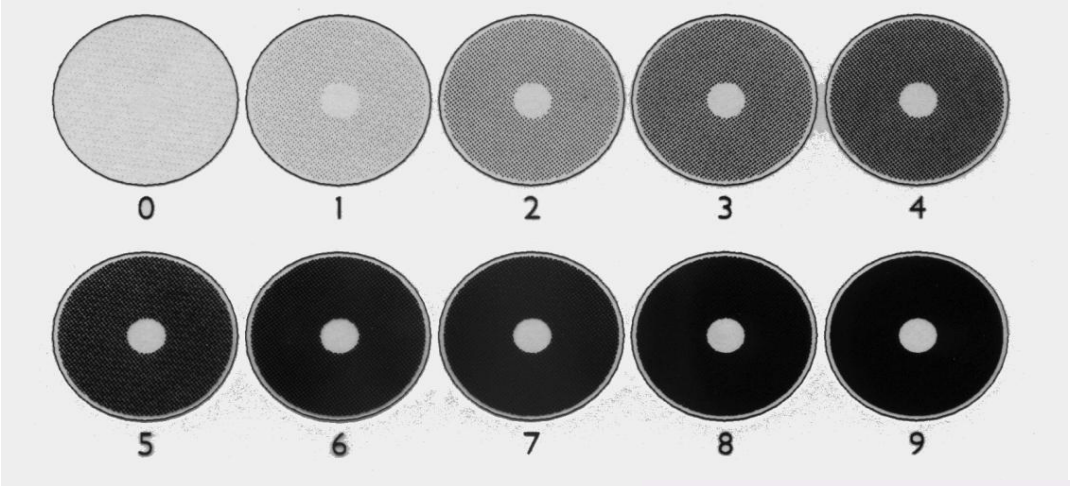
Opacity (%)

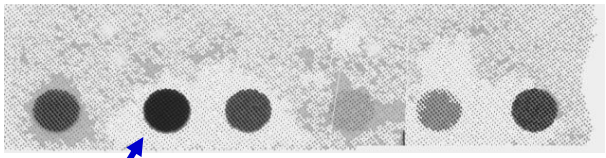
PM CEMS - HISTORY
RINGELMANN SCALE



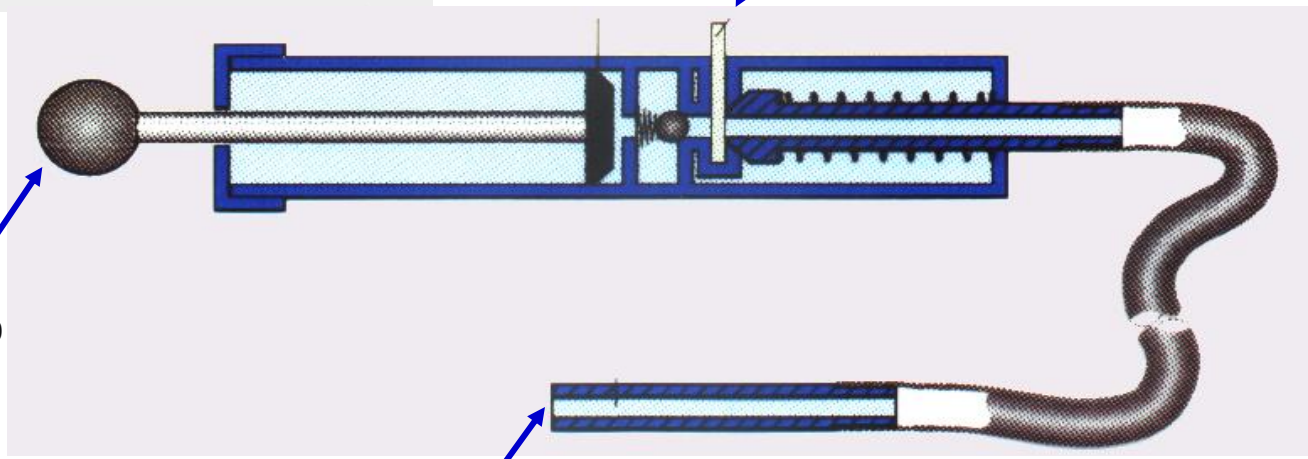
PM CEMS - HISTORY
BACHARACH SCALE - SOOT NUMBER

Reference scale





Filter paper slot



Pump

Sampling pipe

02

TECHNOLOGIES

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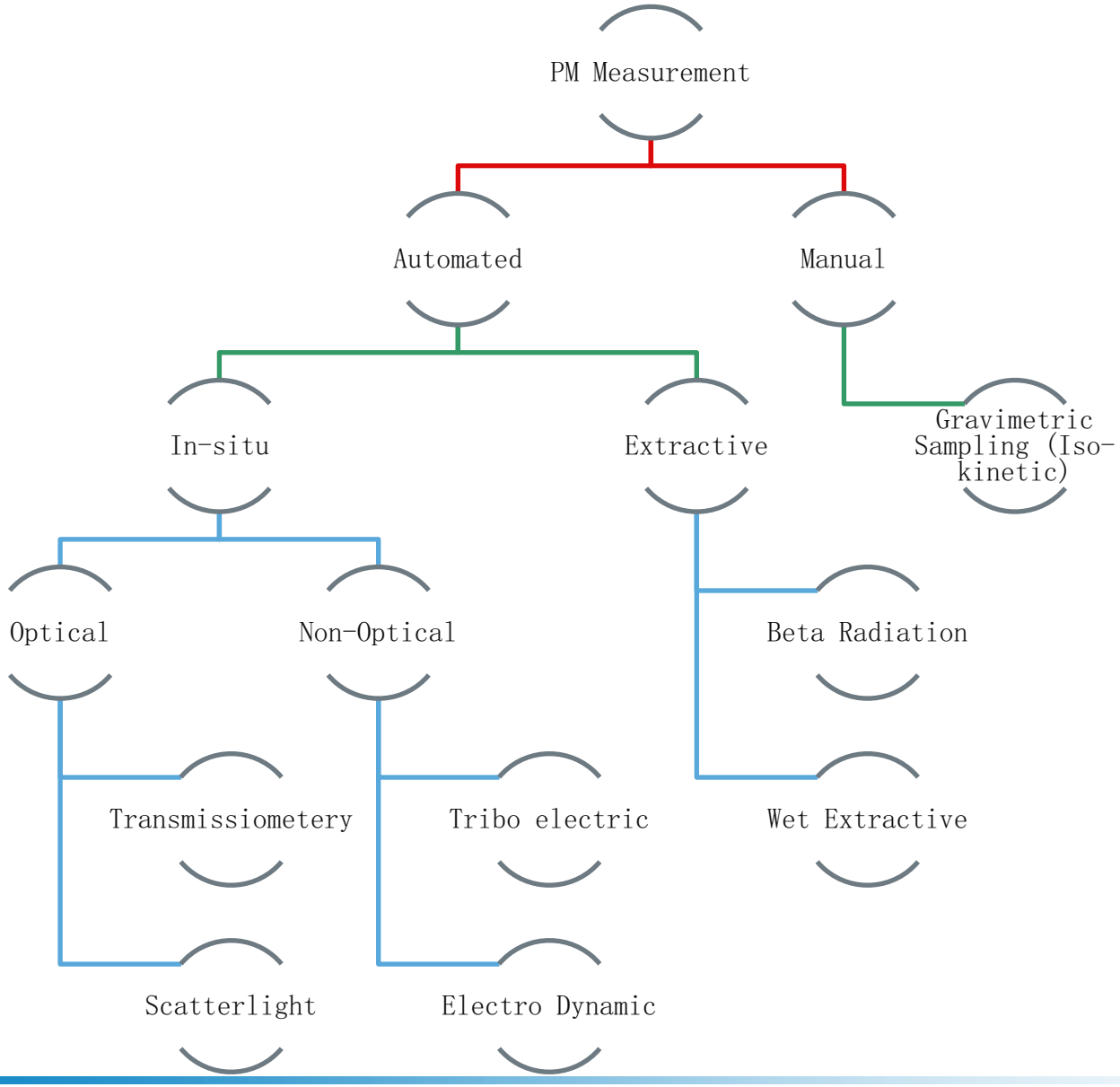
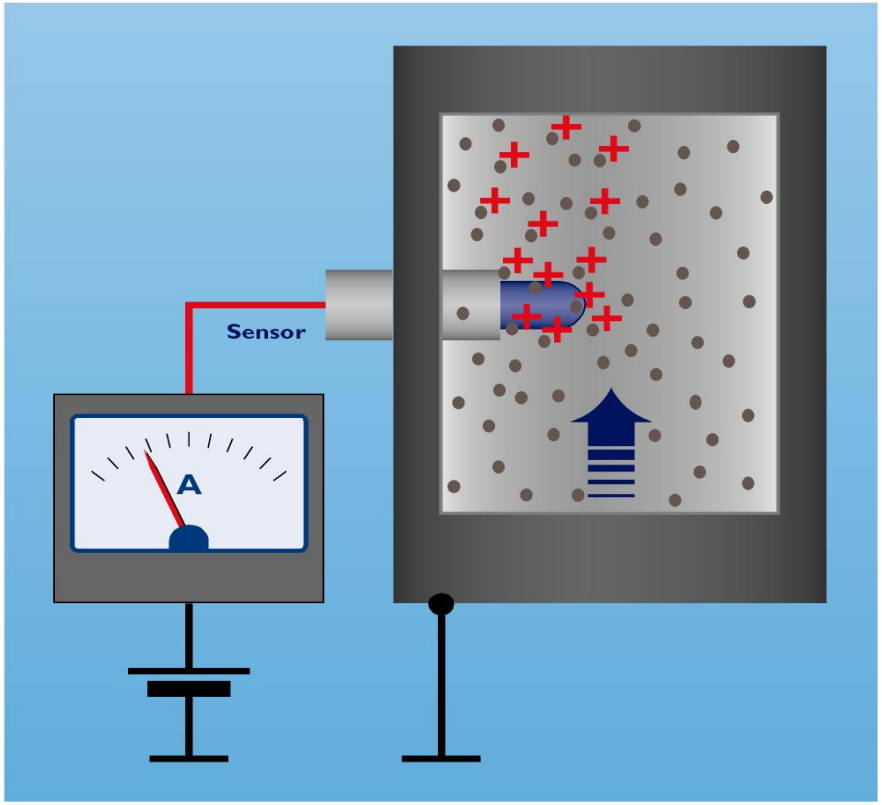
CEMS
VARIOUS TECHNOLOGIES



PM CEMS – TECHNOLOGIES
TRIBO FLOW

Colliding particles exchange their electrical charge with the measuring electrode. The electrical charge transfer depends on the respective mass, velocity and electric charge of the particles

This effect is used by the so-called “Tribo flow effect”



PM CEMS – TECHNOLOGIES
ELECTRODYNAMIC

Particles procedure a charge movement by charge induction.

(Charge on the particle transfer charge in the probe as it passes.)

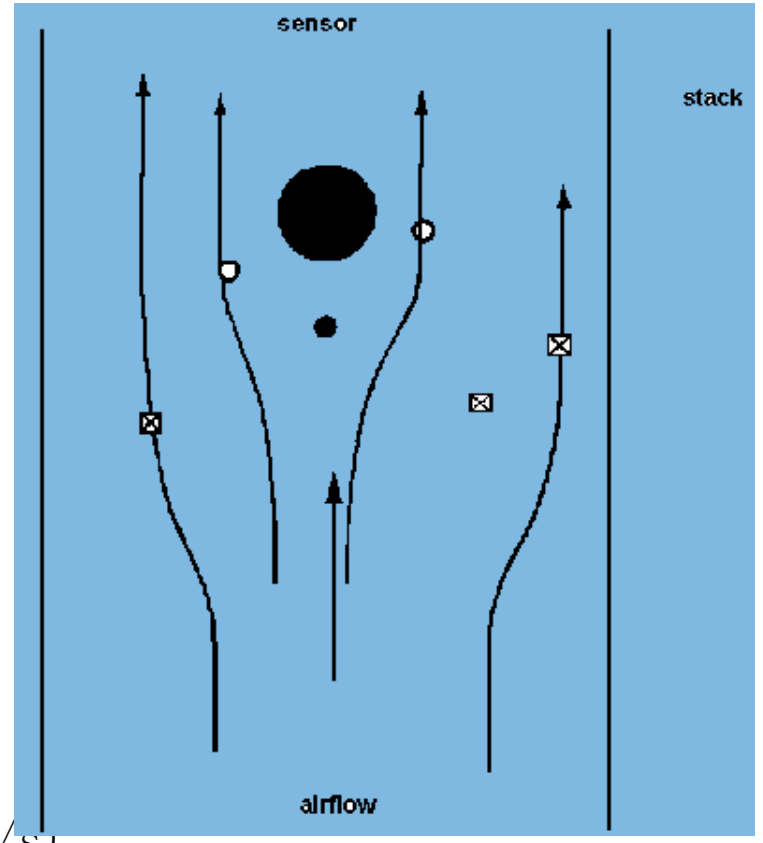
$$I_{AC} = K_I \cdot K_M \cdot m$$

I_{AC} = measured AC-current (A)

K_I = const., function of the geometry of the stack

K_M = material-dependent

m = mass-concentration of particulates (mg/s)



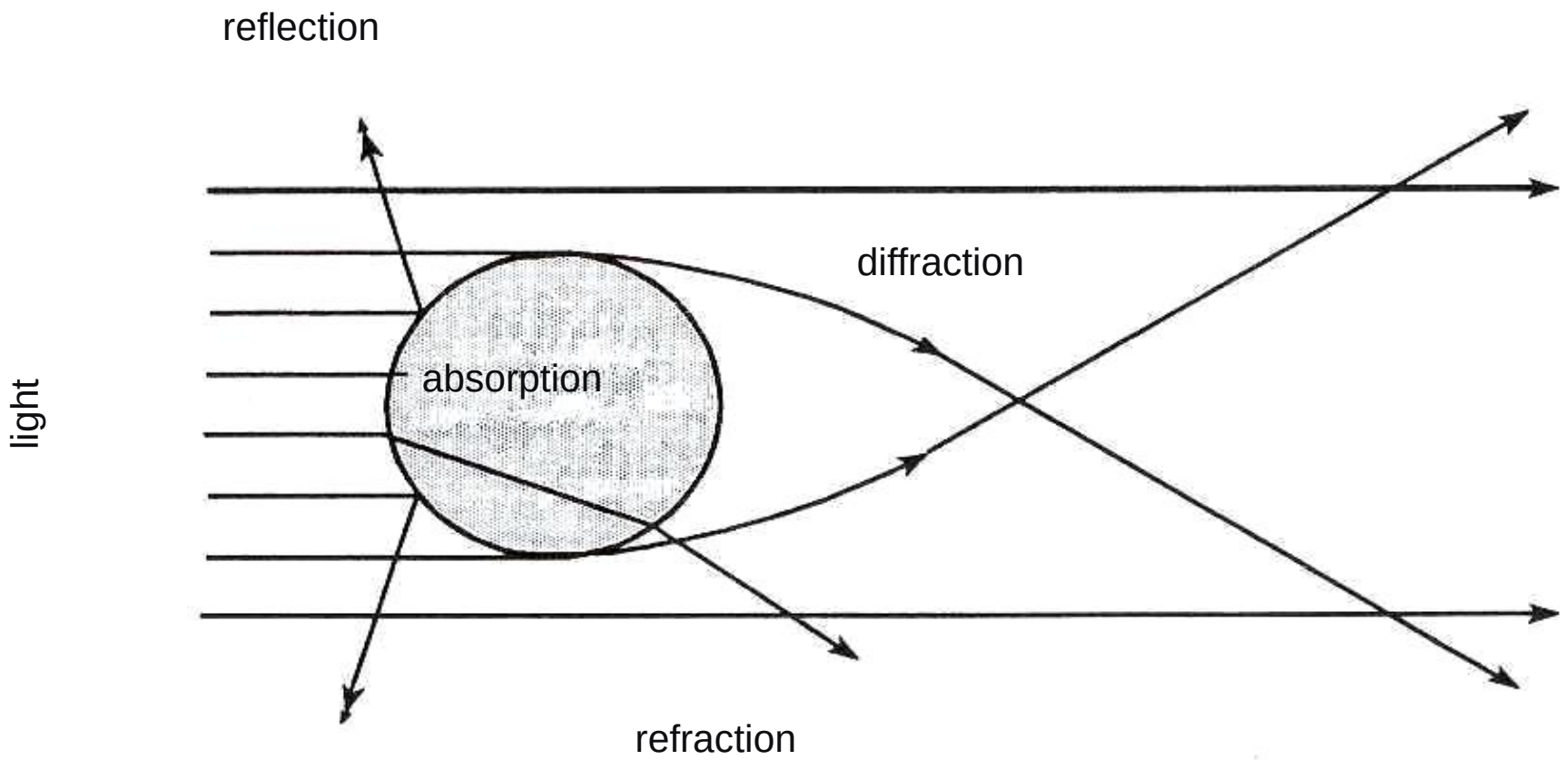
Source: Lecture K. Smolders and J. Baeyens, Belgium, I

Points to ponder

- Triboelectric / Triboflow / Electrodynamic is velocity dependent. So not suitable for any process where there is a variation in the velocity.
- Mostly suitable for mass flow measurement and not for instantaneous concentration measurement.
- Widely used as a switch for detection of filter bag rupture
- Internal Zero & Span check is not possible

PM CEMS – TECHNOLOGIES

DIFFERENT EFFECTS OCCURRING WHEN ILLUMINATING A PARTICLE



"Fortschritt-Berichte VDI" Reihe 8, Nr. 773, Düsseldorf: VDI Verlag 1999

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Transmission

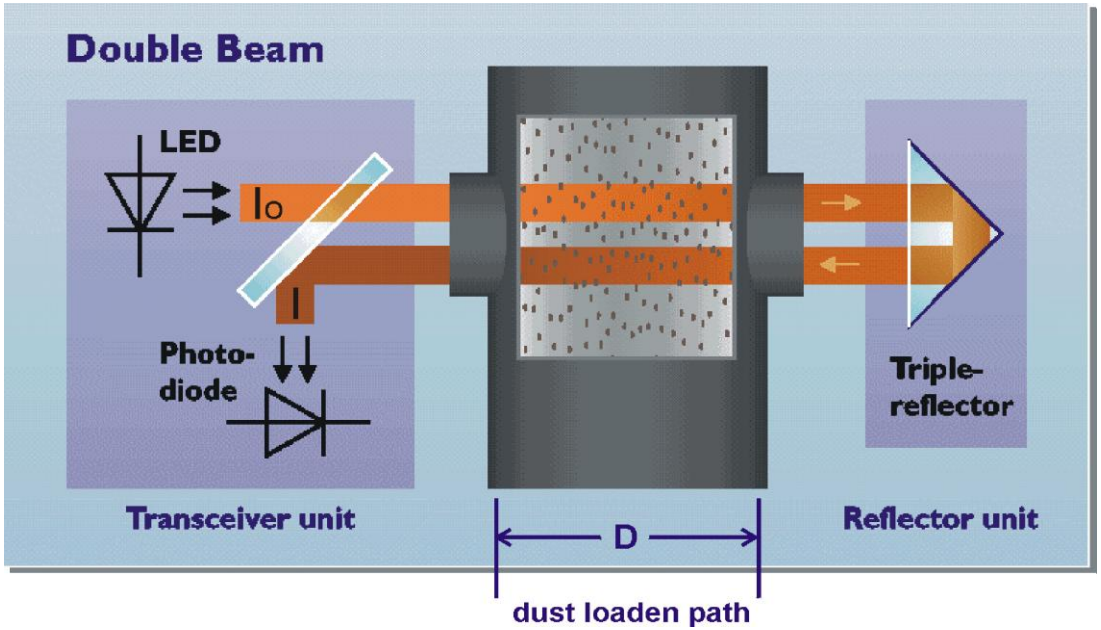
$$T = \frac{I}{I_o}$$

Opacity

$$Opac = 1 - \frac{I}{I_o}$$

Extinction

$$E = \lg\left(\frac{1}{T}\right)$$



I = received light;

I_o = emitted light

k = extinction coefficient

E = extinction

c = dust concentration

L = length of optical measurement path
(auto-collimating: 2 x distance)

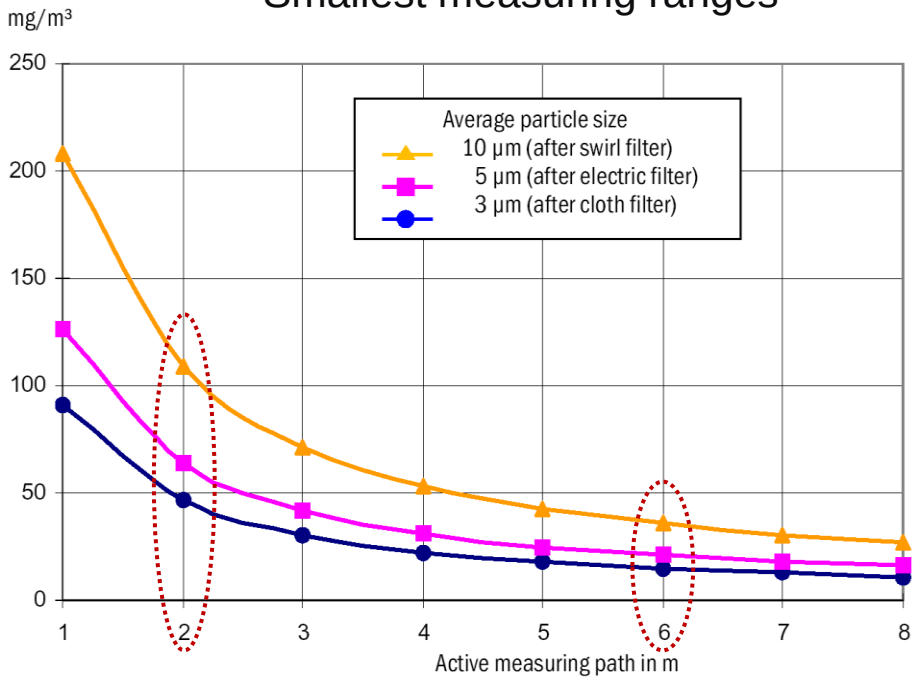
Dust concentration is proportional to Extinction

PM CEMS – TECHNOLOGIES
MEASURING LIMITS – TRANSMISSION / OPACITY

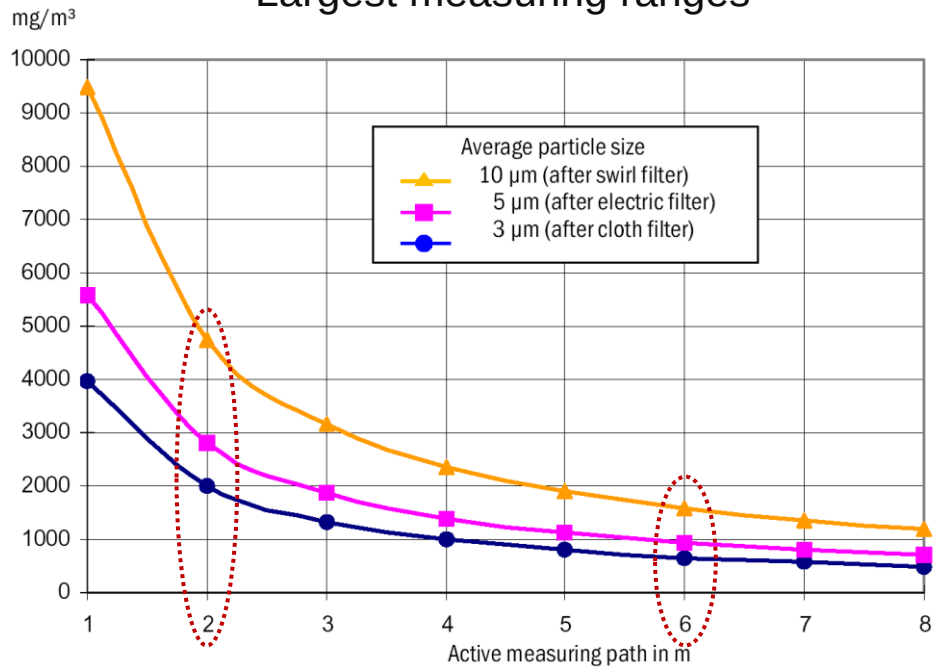
Relationship between

- path length
- particle size
- dust concentration

Smallest measuring ranges

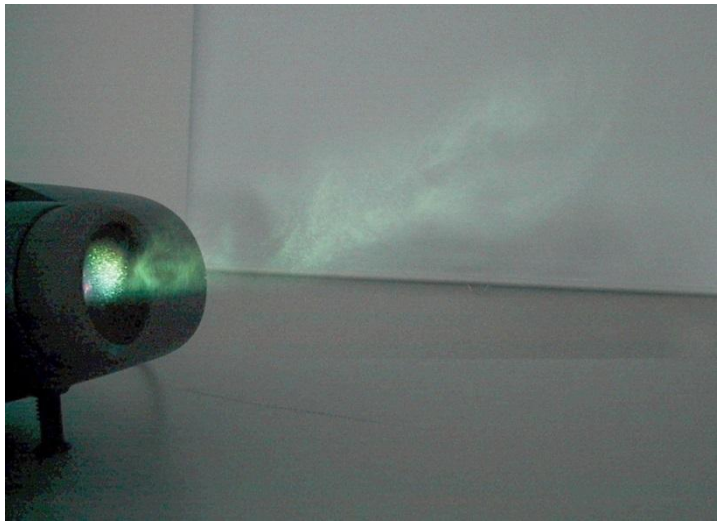


Largest measuring ranges

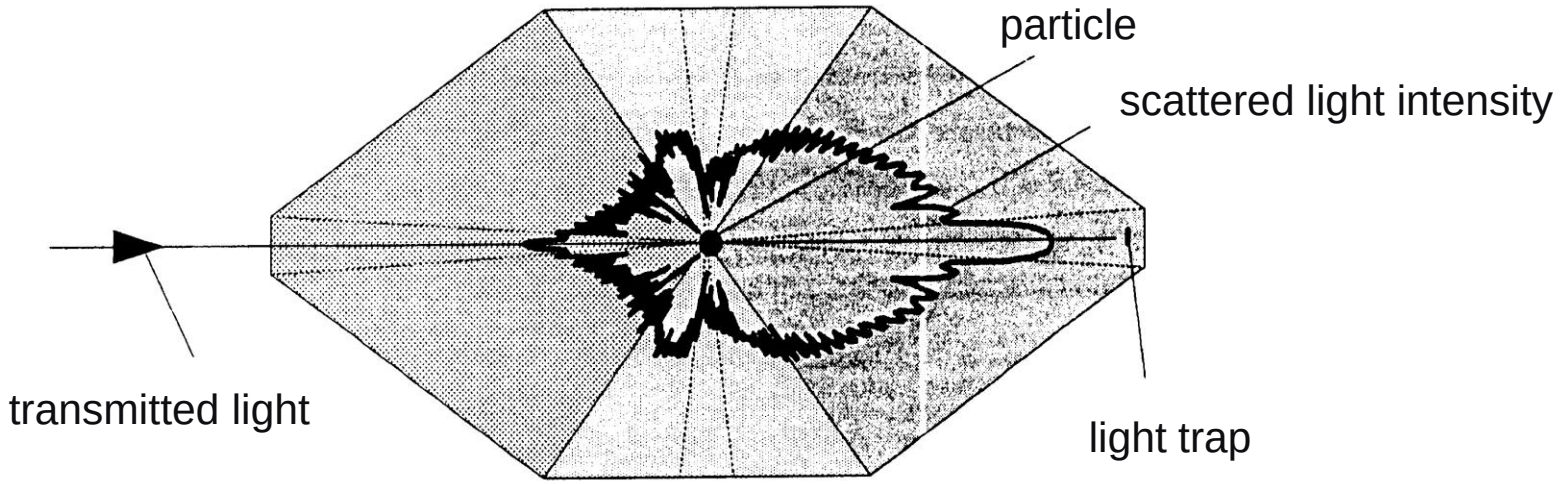


To measure low concentrations → a long measuring path is required

PM CEMS – TECHNOLOGIES
SCATTER LIGHT



PM CEMS - TECHNOLOGIES
DIFFERENT REGIONS OF SCATTERED LIGHT

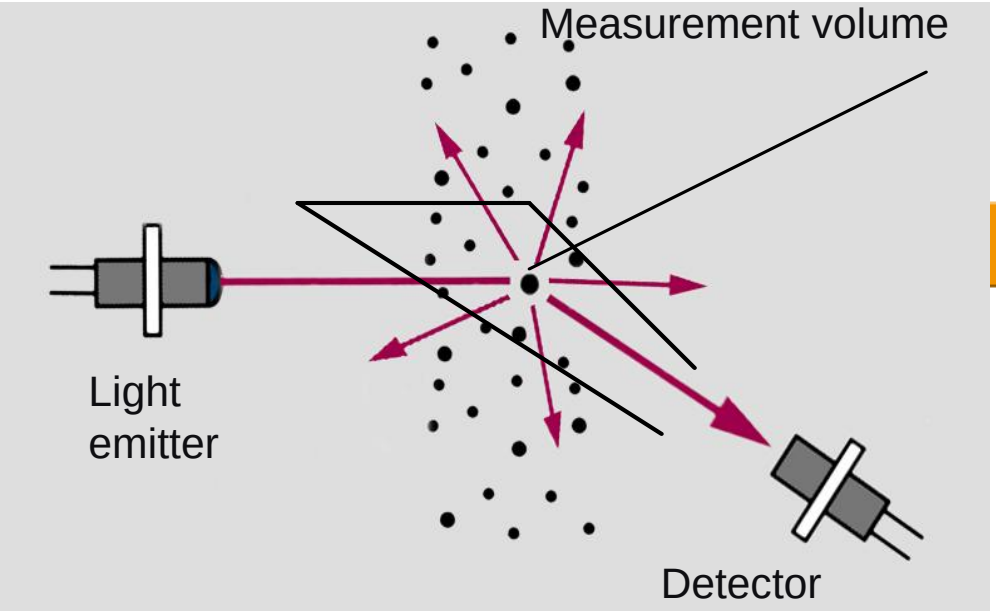


90°-area
forward scattering area(0°)
backward scattering area (180°)

small angel measurement
wide angel measurement

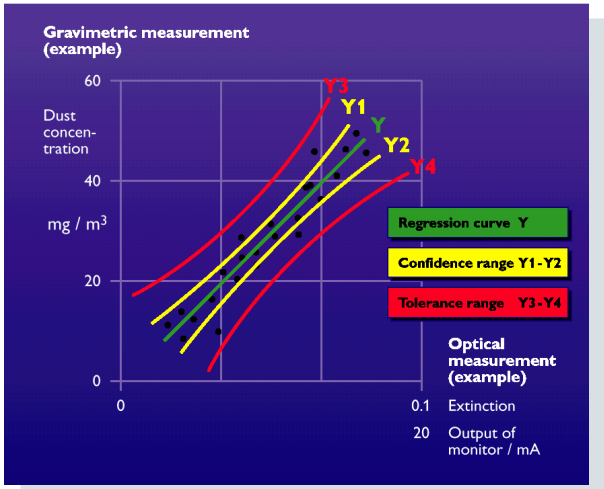
"Fortschritt-Berichte VDI" Reihe 8, Nr. 773, Düsseldorf: VDI Verlag 1999

PM CEMS – TECHNOLOGIES
FORWARD SCATTER LIGHT



Dust concentration in mg/m³

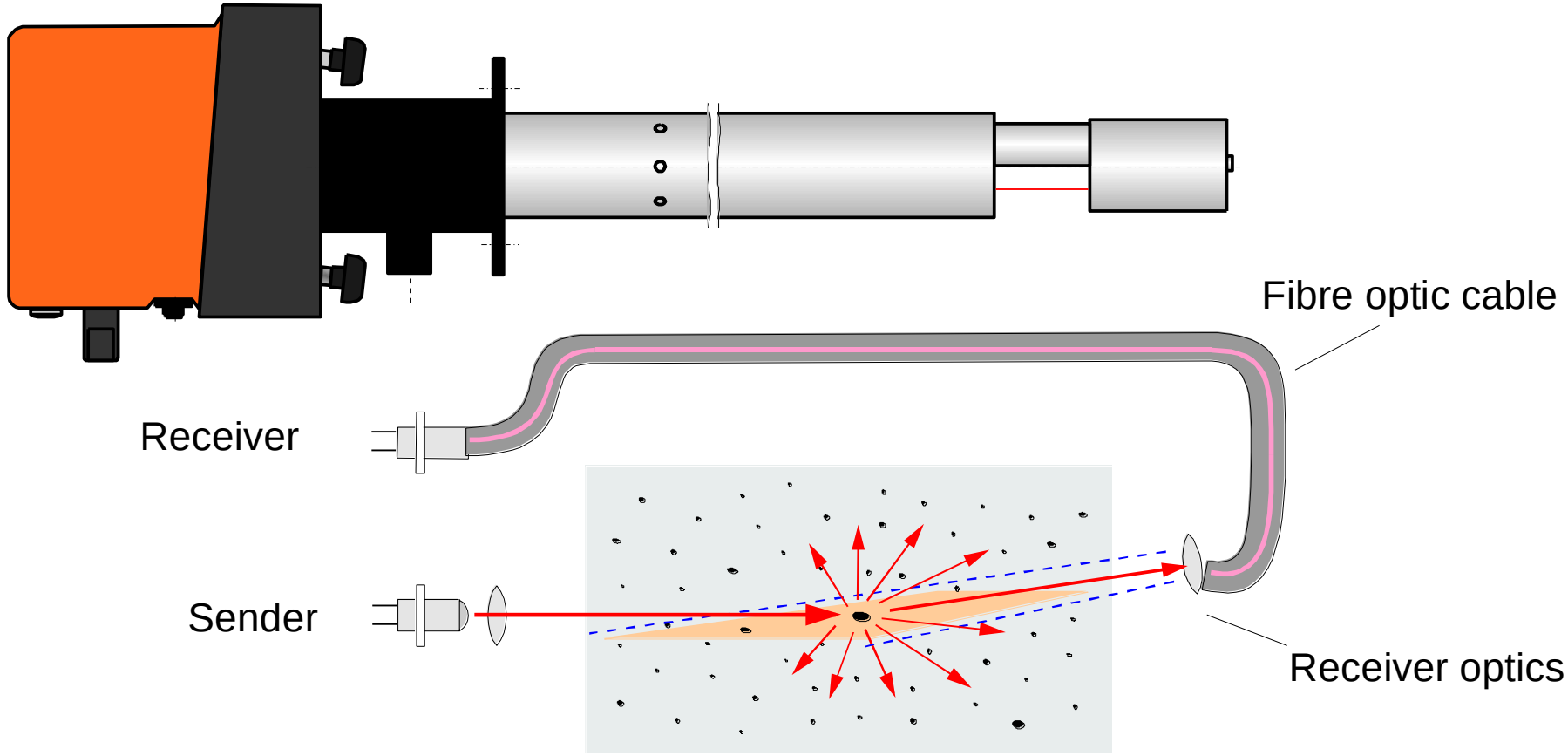
Calibration according to the recommendation of the Guideline VDI 2066.



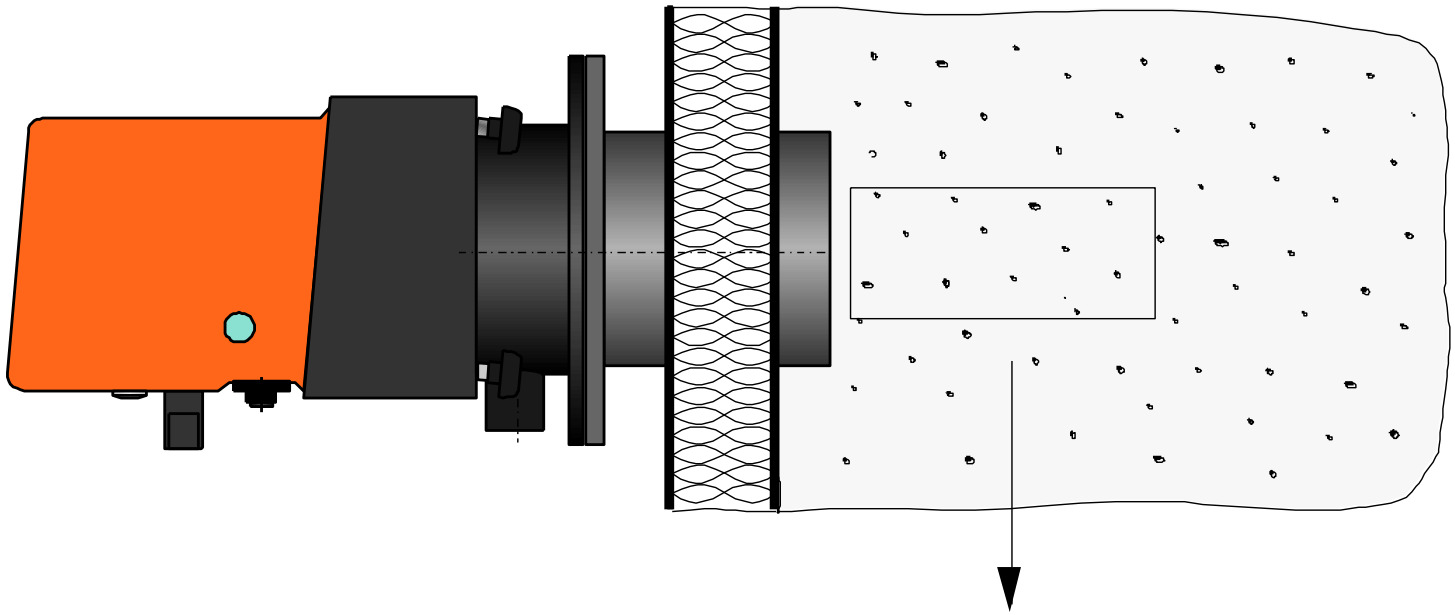
Direct measured light scattered from particles

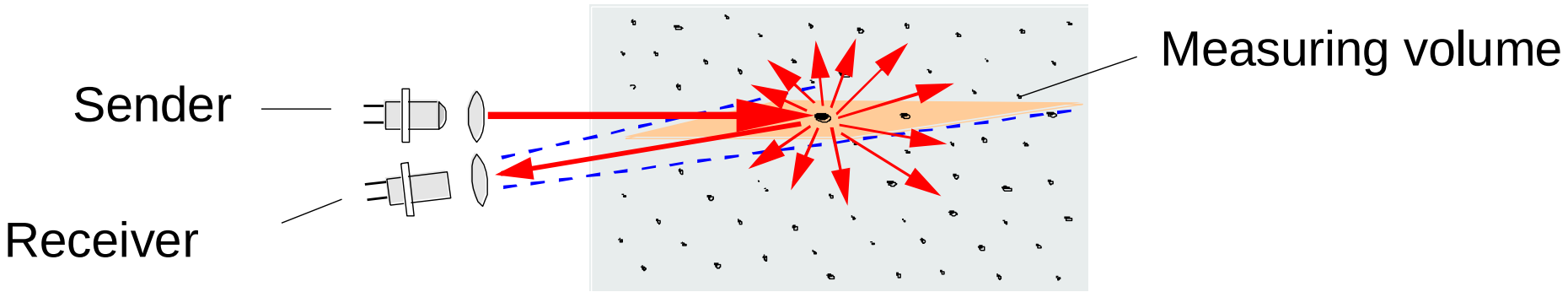
Small scattered light intensity requires high measurement accuracy and sensitivity

PM CEMS TECHNOLOGIES
SCATTERED LIGHT (FORWARD) PROBE



PM CEMS – TECHNOLOGIES
BACKWARD SCATTER LIGHT





Points to ponder

- Both these opto-electric measurement are time tested and used for a long time
- Transmissiometers are suitable for medium to high concentration of dust.
- Scatterlight instruments are used for measurement of very low to medium concentration of dust
- Various standards are available for dust monitors based on these measurement principles

PM CEMS – TECHNOLOGIES
BETA RADIATION

Particles in the extracted partial gas flow are collected on a filter paper in defined time intervals (approx. 5 min).

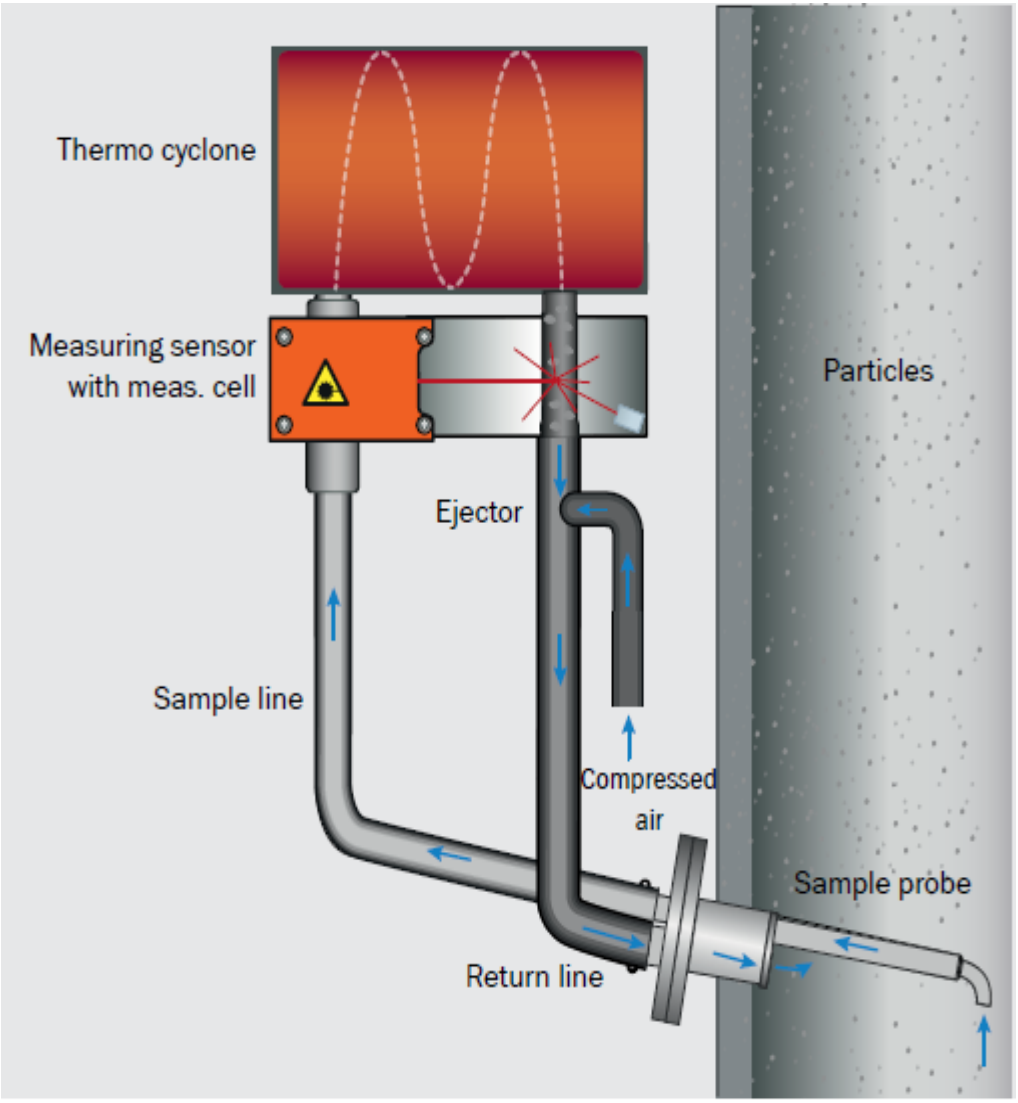
Beta-radiation on the filter paper provides measured values directly proportional to the dust weight, not influenced by particle size and color.

Device provides only mean values (normally 5 to 20 min), no information about actual measured values

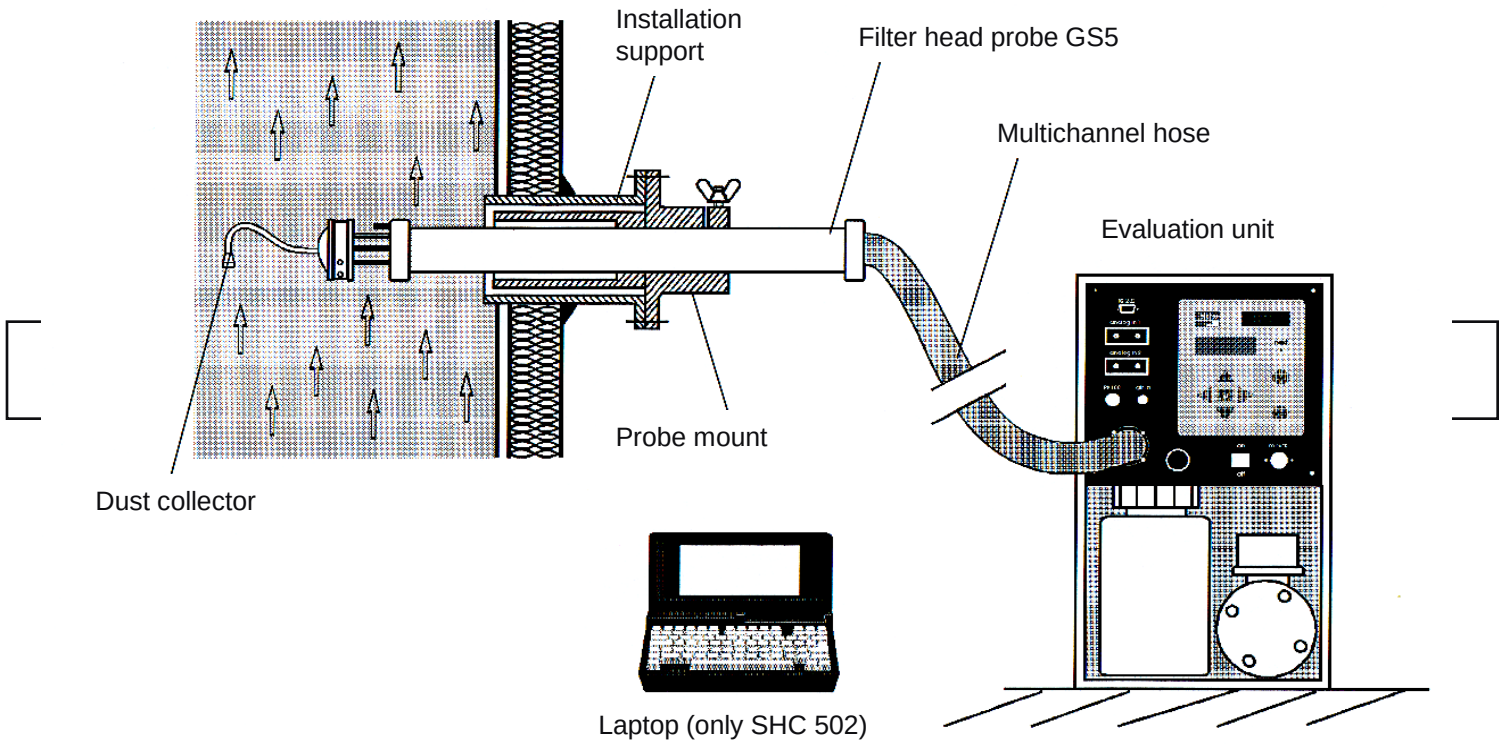
Radiation source needs high safety effort

High costs for consumables

PM CEMS – TECHNOLOGIES
WET EXTRACTIVE



PM CEMS – TECHNOLOGIES
GRAVIMETRIC MEASUREMENT – REFERENCE MEASUREMENT



PM CEMS – TECHNOLOGIES
SUMMARY

Measuring principle	Type	Procedure
Gravimetric measurement	extractive	discontinuous
Beta Ray	extractive	discontinuous
Scatter light wet gas	extractive	continuous
Scatter light dry gas	in - situ	continuous
Triboflow	in - situ	continuous
Transmission	in - situ	continuous

SUMMARY

Summary

Selection of technology depends on the CEMS- and application requirements, e.g.

- Local regulation requirements
- Gas conditions (gas matrix, gas “wet” or “dry”?)
- Certification of Analyzer by a third party
- Reliability of the Analyzer according to gas conditions
- Measurement task
- Maintenance frequency and availability of support personnel

Each solution is also dependant on investment in comparison with operational costs

Local regulation and engineering and consultancy.

03

PM CEMS CALIBRATION

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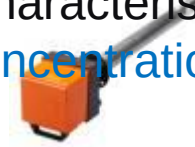
PARTICULATE MEASUREMENT DEVICES
WHY CALIBRATION IS REQUIRED



Optical, electro-dynamic and tribo-electric monitors are indirect measuring methods. They detect an optical effect – not the dust concentration.





Because of the big variety of dust characteristics, for optical dust monitors it is not possible to measure the dust concentration directly.

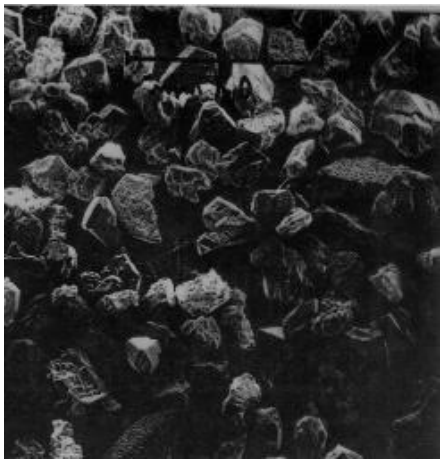
To get a mass concentration output signal in mg/m³ every single dust monitors has to be calibrated by gravimetric measurement equipment.

Different dust characteristics in terms of:

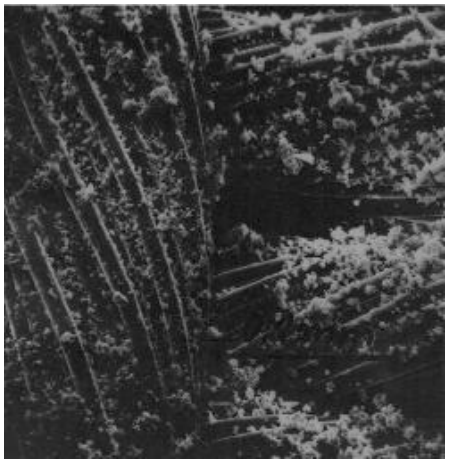
- Colour
- Size
- Sourface structure
- Reflexion ability
- Density …

Examples of dust structures

Asbest dust

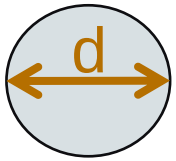
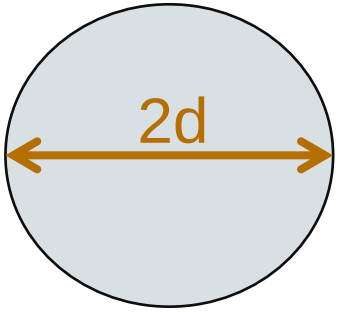


Coal dust

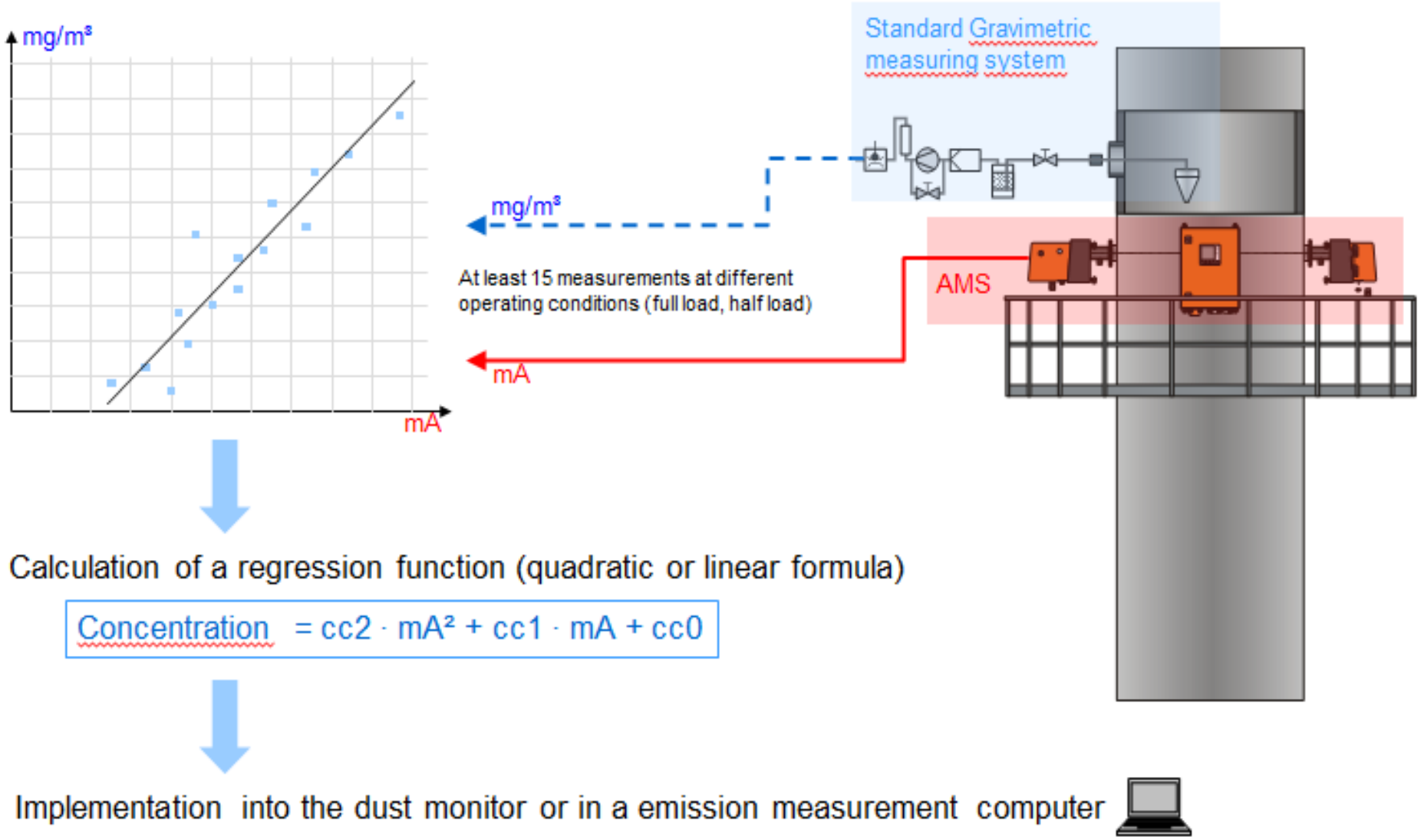


Domestic dust

The relation between particle size and an mass :

Particle size	Diameter	Area	Mass	Relation Mass / Area:
	1	1	1	1
	2	4	8	2

GRAVIMETRIC MEASUREMENT



Calculation of a regression function (quadratic or linear formula)

$$\text{Concentration} = cc2 \cdot mA^2 + cc1 \cdot mA + cc0$$

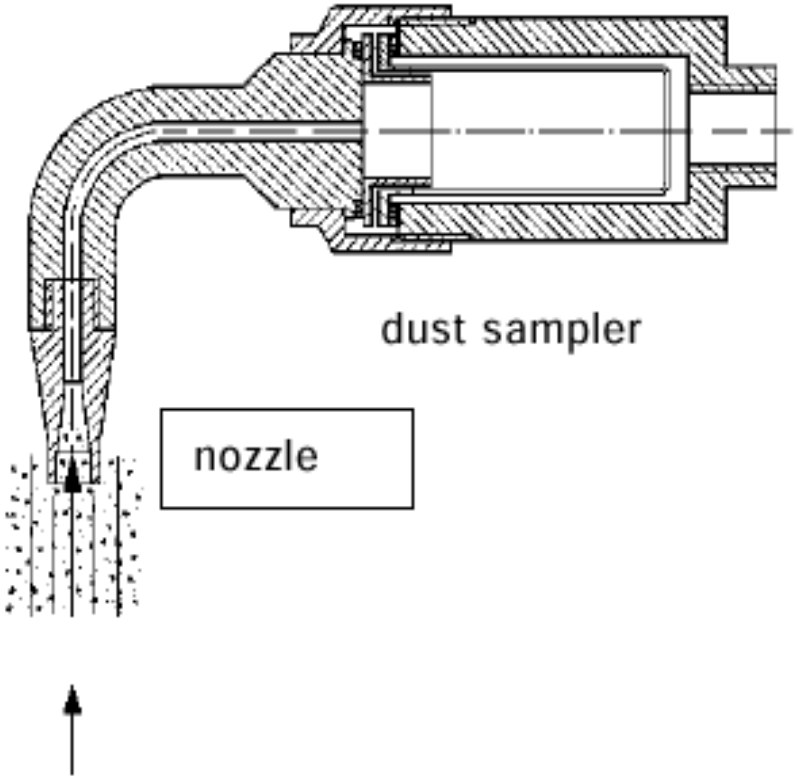
Implementation into the dust monitor or in a emission measurement computer

GRAVIMETRIC MEASUREMENT

Requirements:

- Distance to the dust monitoring level at least 500 mm above in flow direction
- No mutual influencing of dust meter and calibrating device.

PM CEMS CALIBRATION
ISOKINTETIC SAMPLING



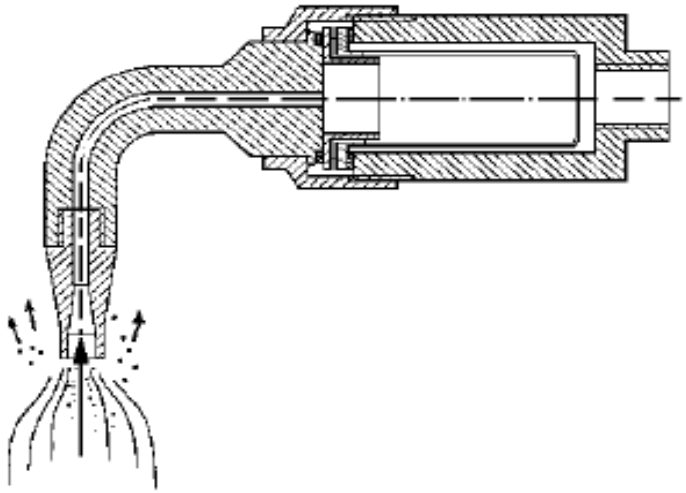
Homogeneous infiltration.
Big and little particles follow the gas stream.

For dust gravimetric comparison according VDI 2066 the gas must be extracted in such

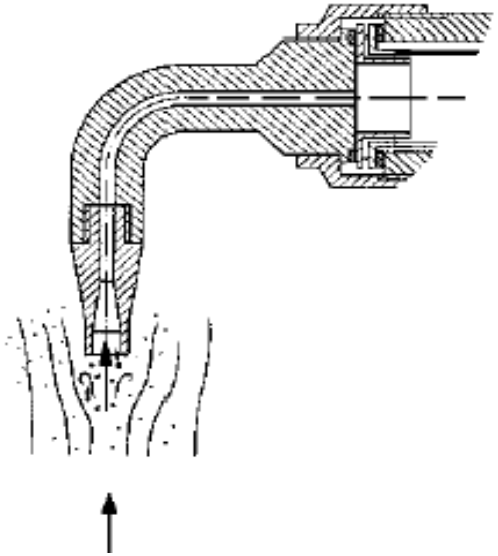
way that the gas velocity in the extraction tube and the gas velocity in the stack are the same.

PM CEMS CALIBRATION
NON – ISO KINETIC SAMPLING

Gas flow too high.
Big particles cannot follow the gas stream = Concentration to low.

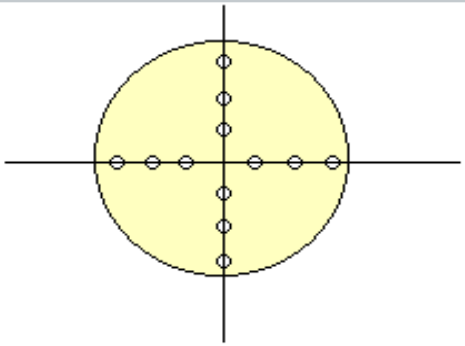


Air flow too low
In relation to much big particles are sucked off = Concentration to high.

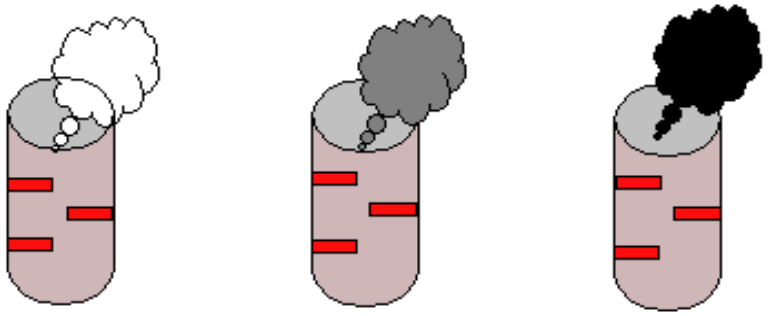


PM CEMS CALIBRATION
VDI 2066

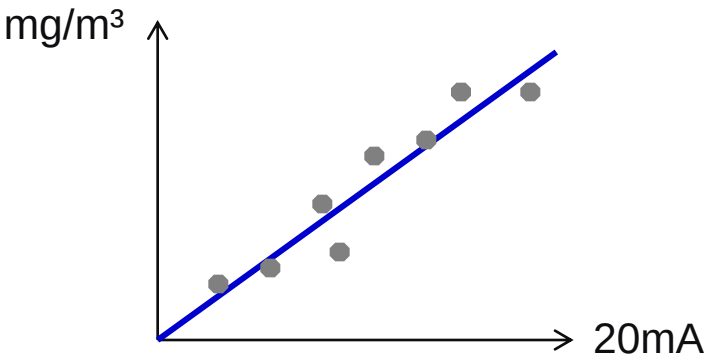
Profile measurements has to be considered.



Calibration is performed under different plant operation and conditions to achieve different dust load.



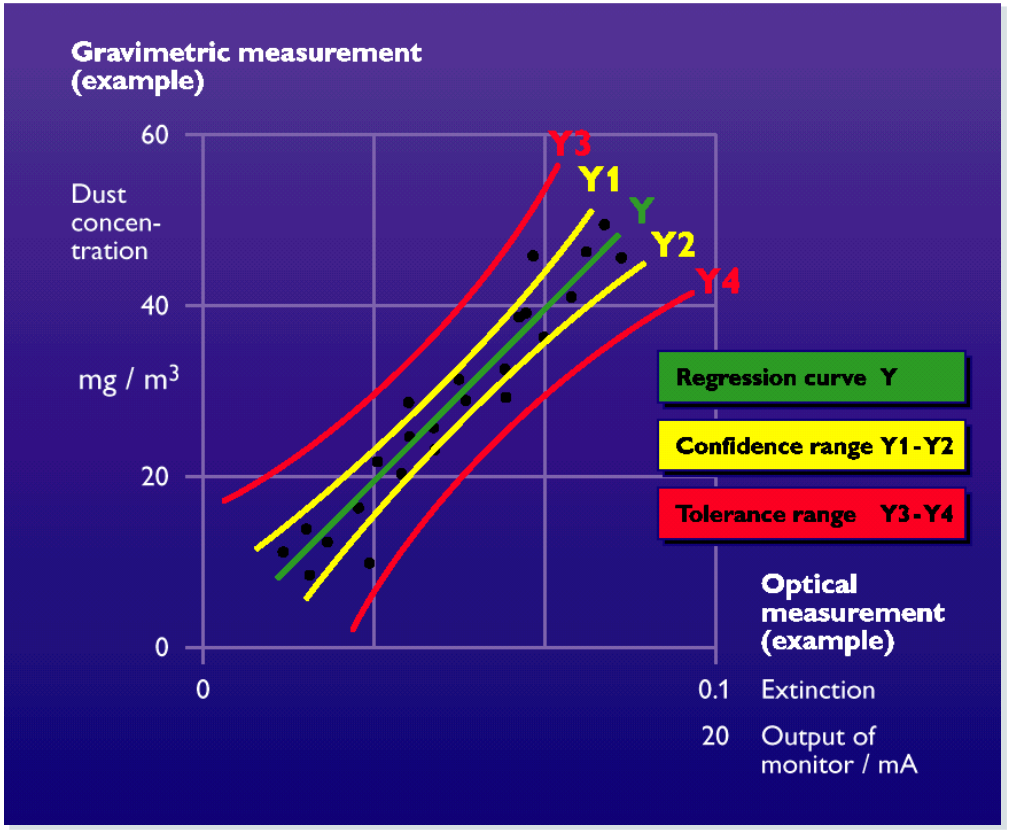
Relationship between dust concentration in mg/m³ and monitor output in mA



PM CEMS CALIBRATION
REGRESSION CURVE

When evaluating a series of gravimetric dust measurements in accordance to VDI 2066, 95% of the measured extinction values have to be within the tolerance range Y3 and Y4 of the actual dust concentration Y.

The extinction value established over a long period of time has a 95% probability of falling inside the confidence range which is defined by Y1 and Y2.

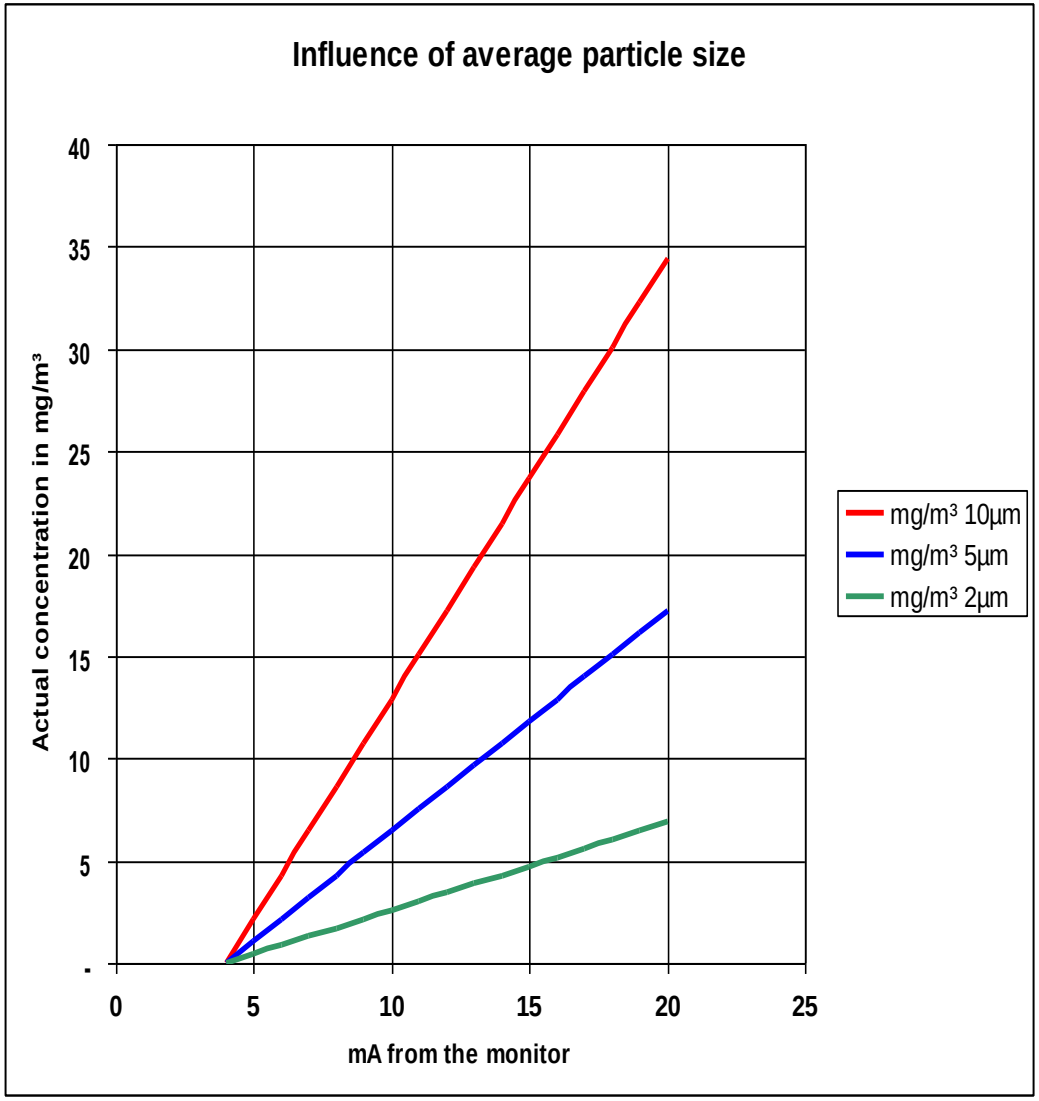


PM CEMS CALIBRATION

The relation between:

- concentration in mg/m³
- and monitor output in mA

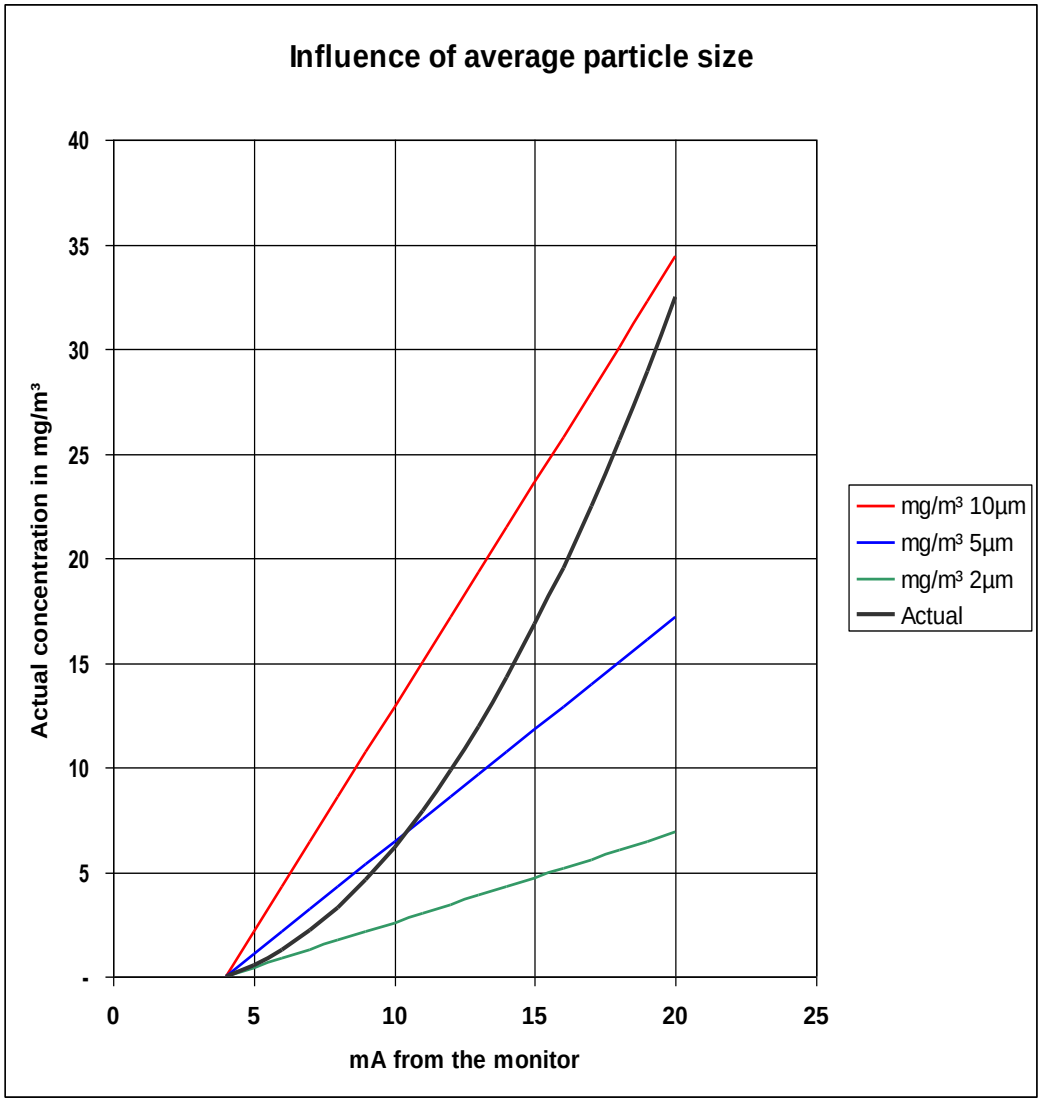
changes proportional with the changes in the average particle size.



PM CEMS CALIBRATION

Because the average particle size often increases with the concentration (sometimes with the plant load), a non-linear upward rising calibration curve is normal (the black curve).

This has to be respected in the data processing system – means: quadratic curves have to be used. (Requirement of EN14181)



LINEARITY TEST
FILTERHOLDER

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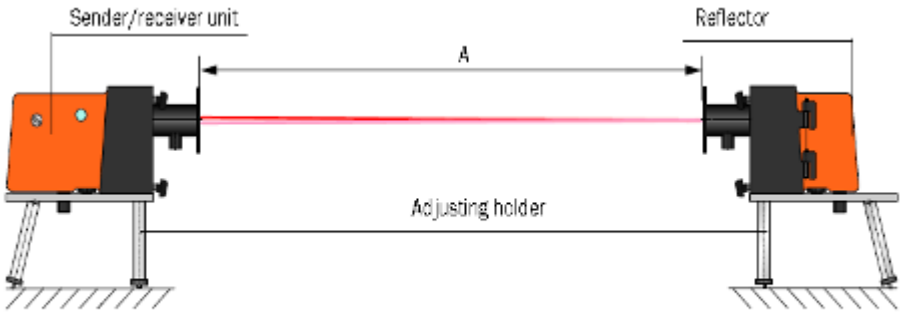
DEVICE FILTER

LINEARITY TEST
COMISSIONING

MAINTENANCE



A = distance flange - flange

MANY THANKS FOR THE ATTENTION

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