Particulate Matter CEMS

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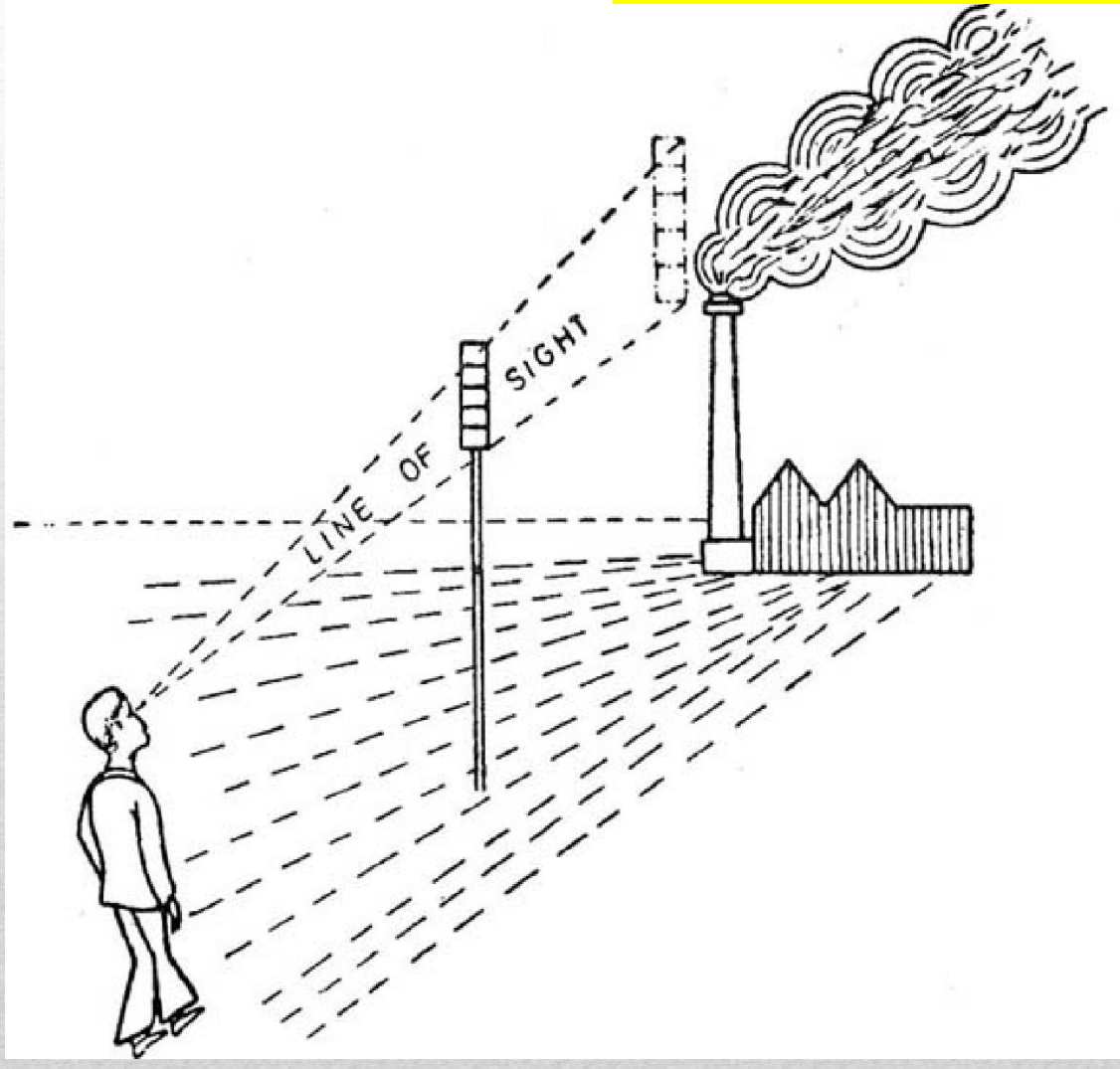
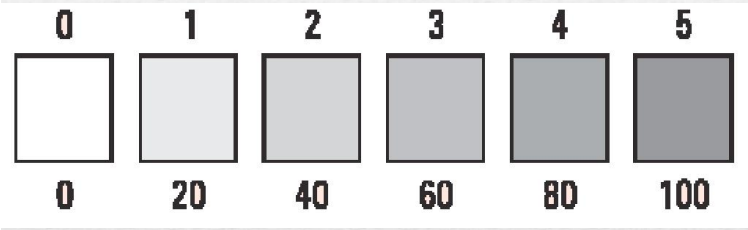
Ringelmann Scale



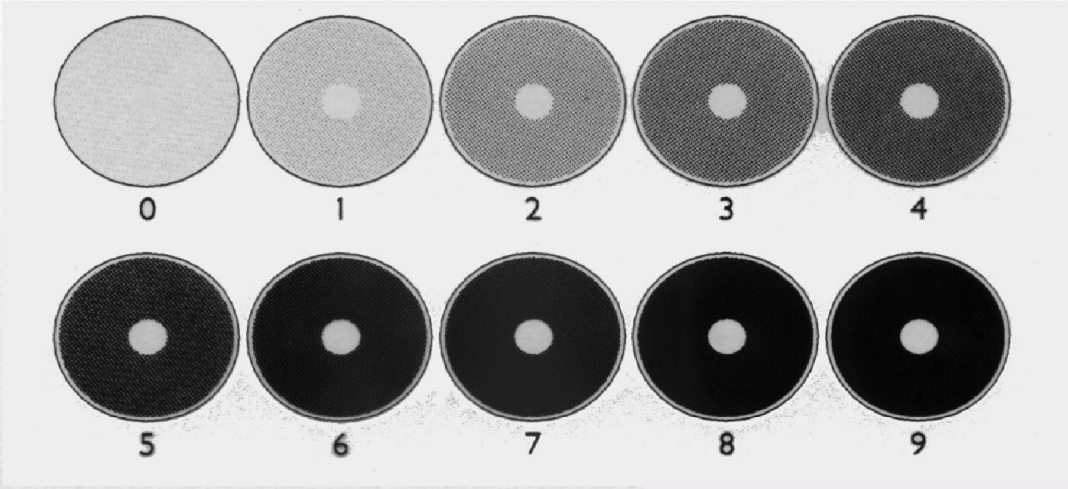
Opacity (%)

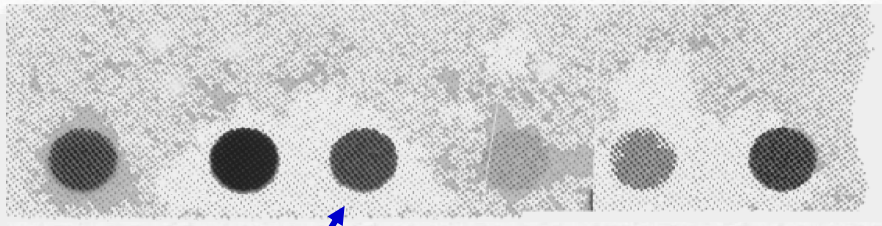


Historical approach of dust monitoring

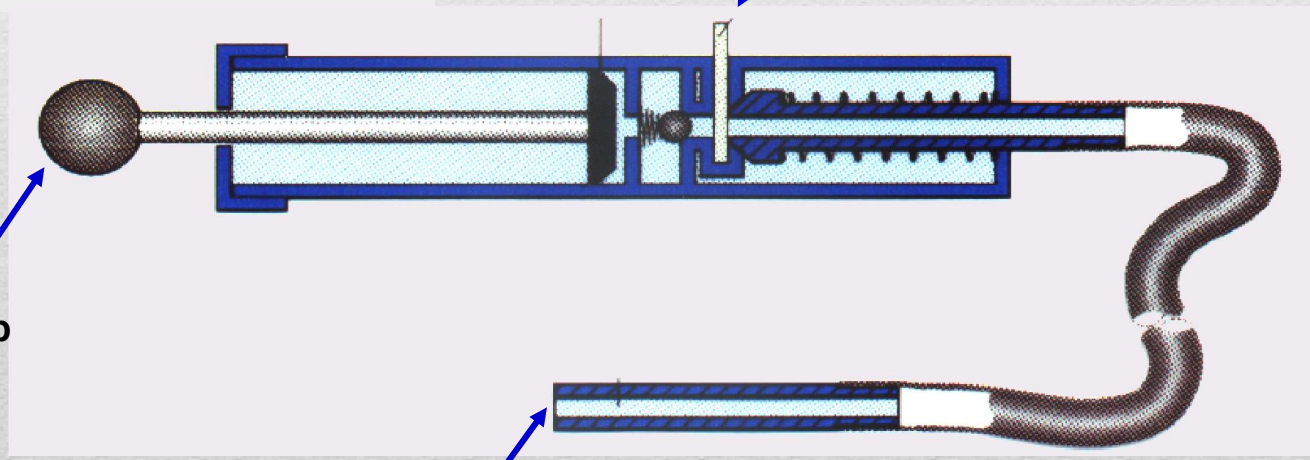
Bacharach Scale

Reference scale





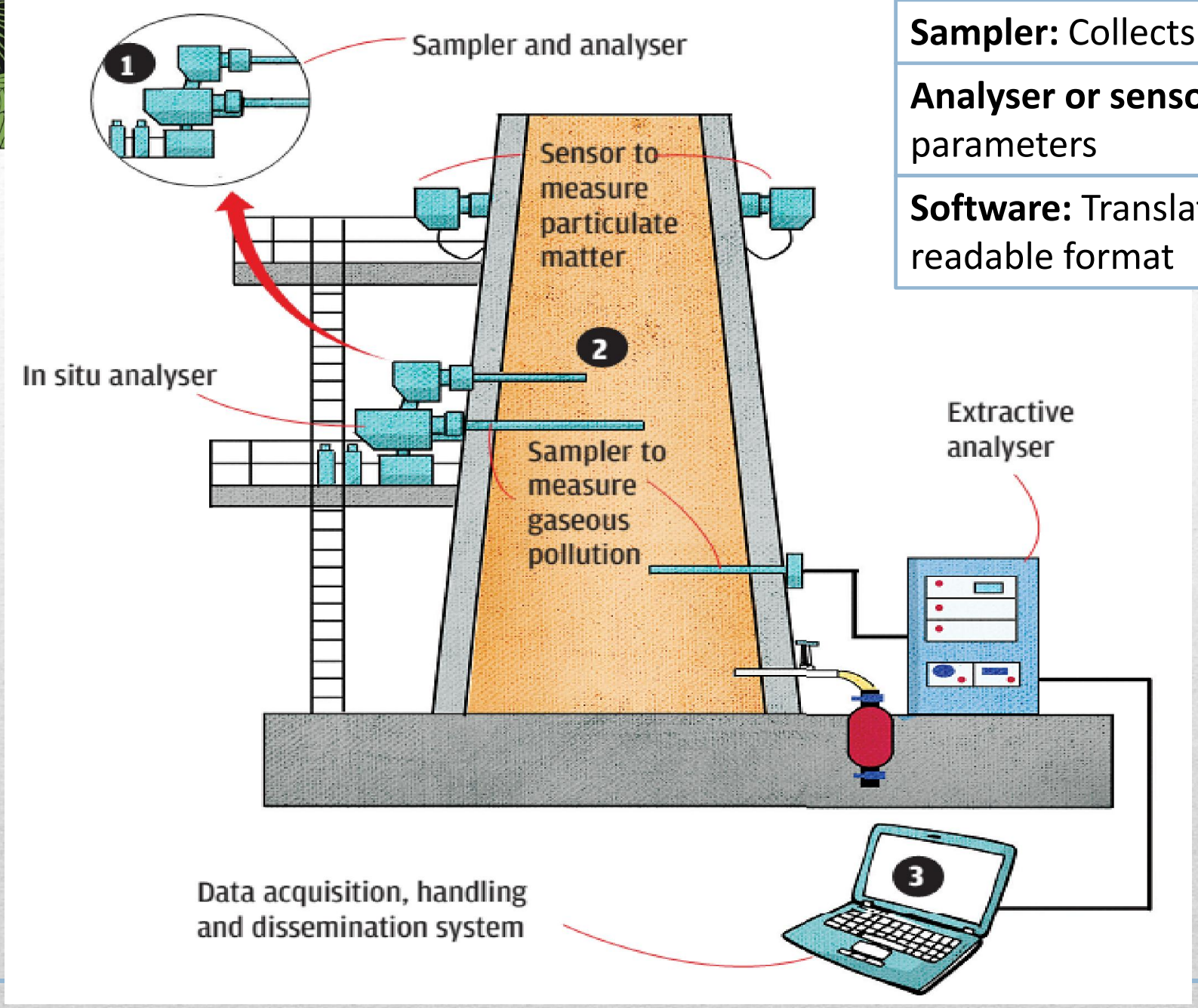
Filter paper slot



Pump

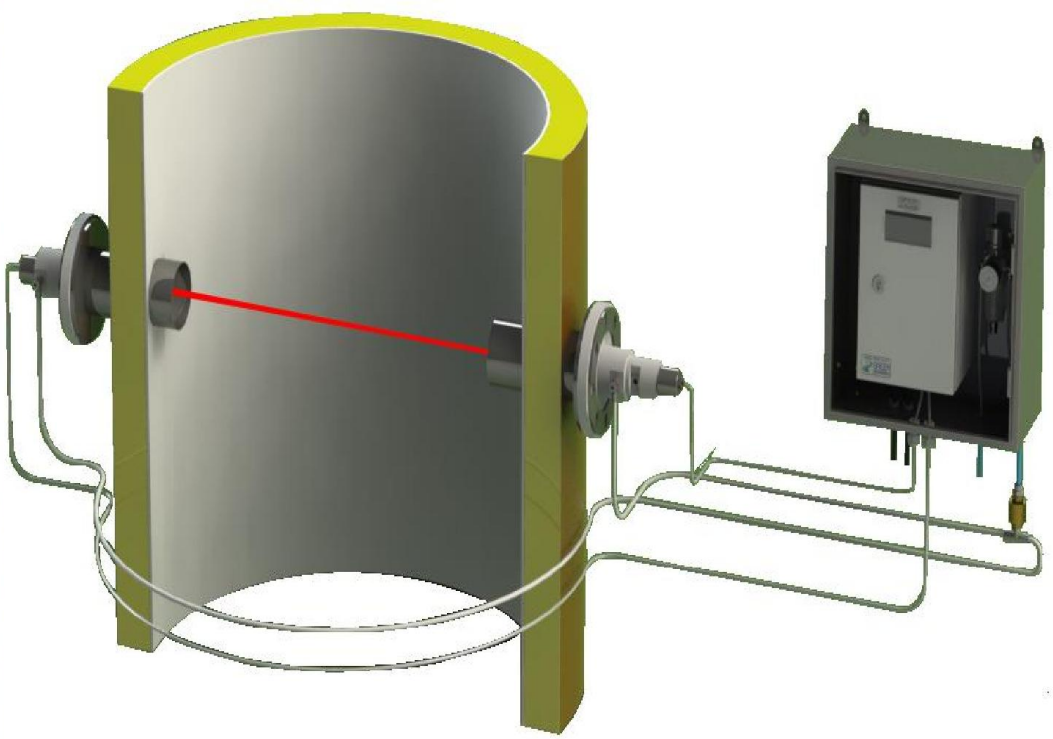
Sampling pipe

Historical approach of dust monitoring



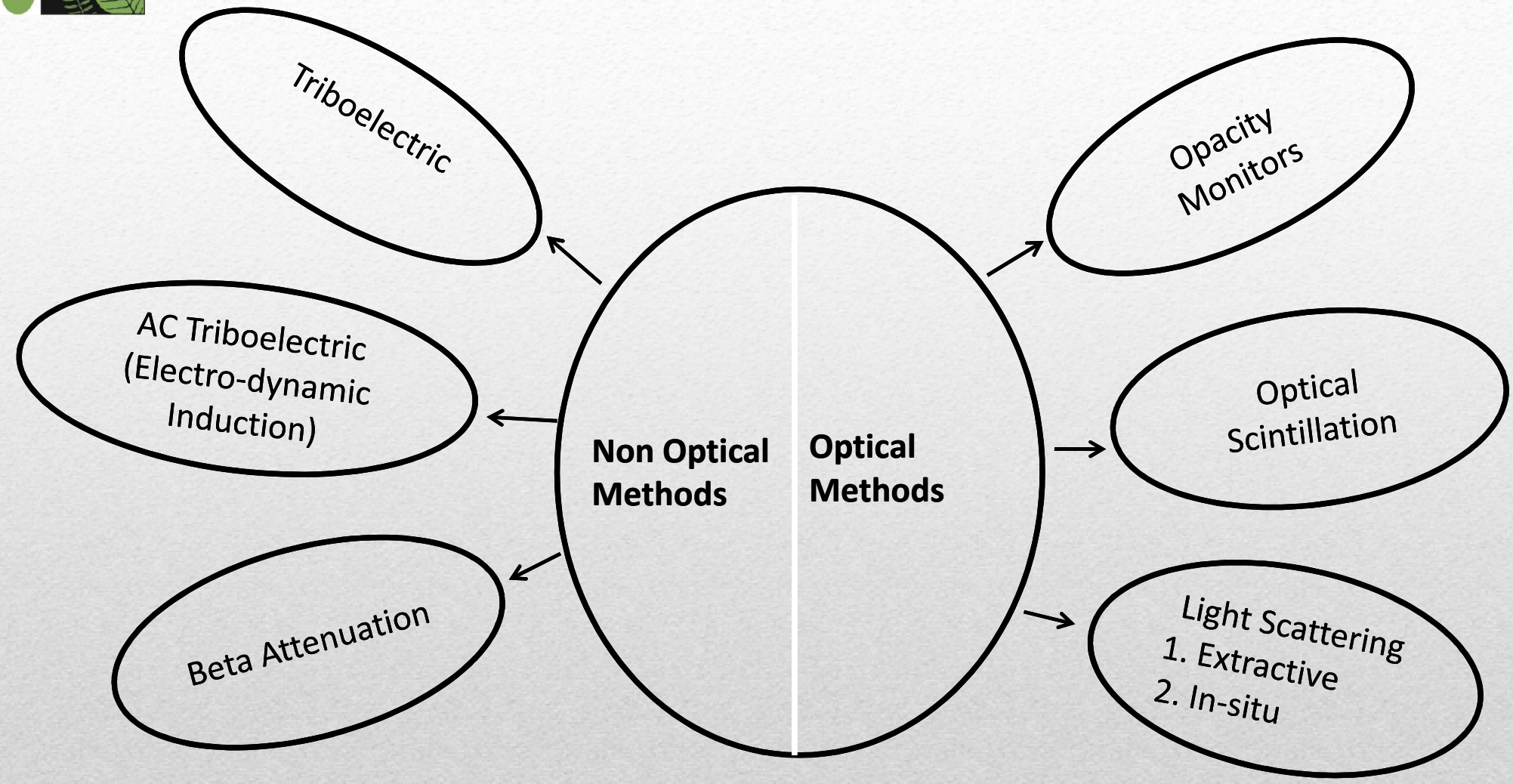
Sampler: Collects sample
Analyser or sensor : Measure parameters
Software: Translates data into readable format

Continuous Emission Monitoring System (CEMS)

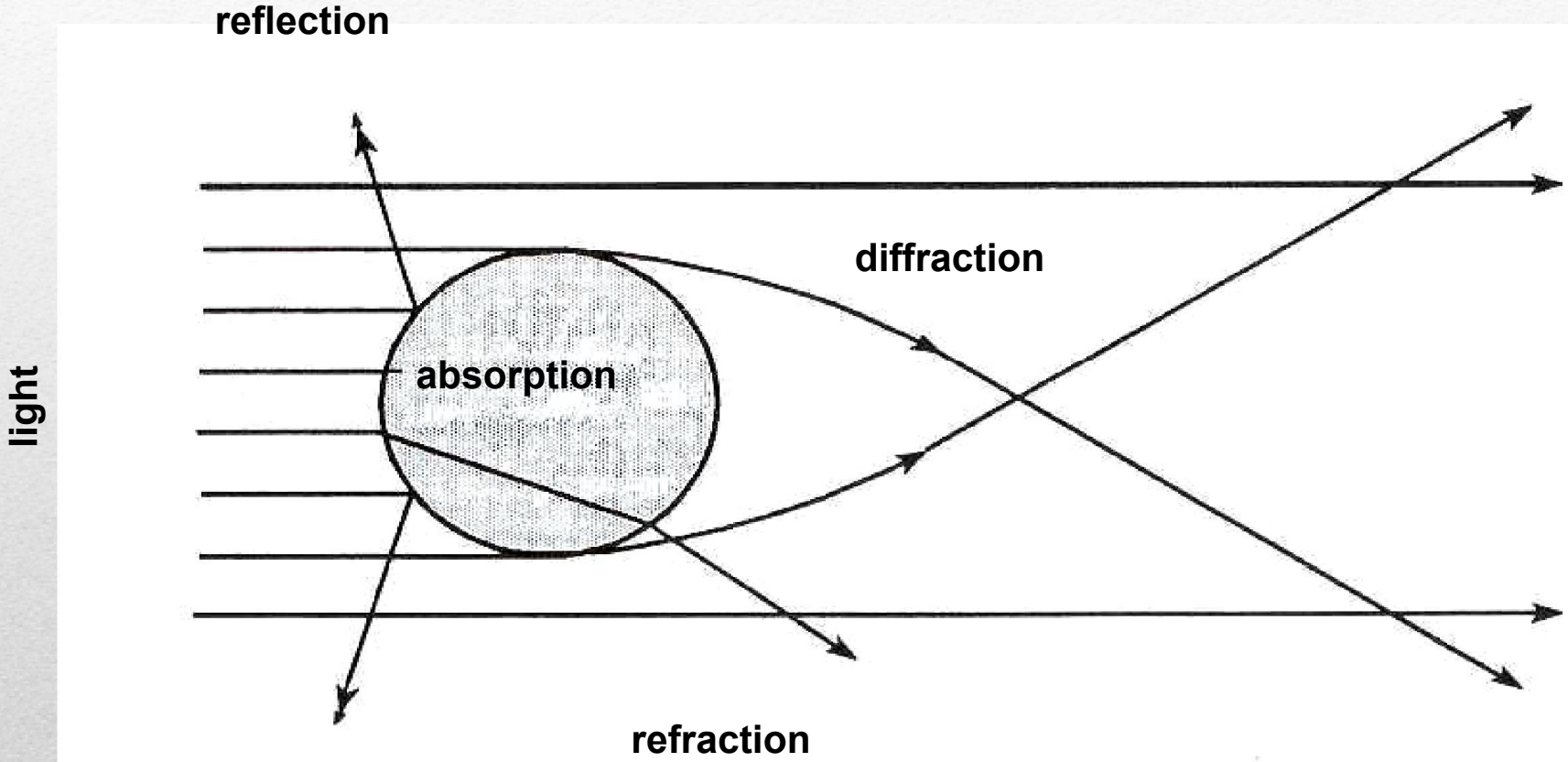


PM (dust) CEMS

Technology option



Methods for PM CEMS



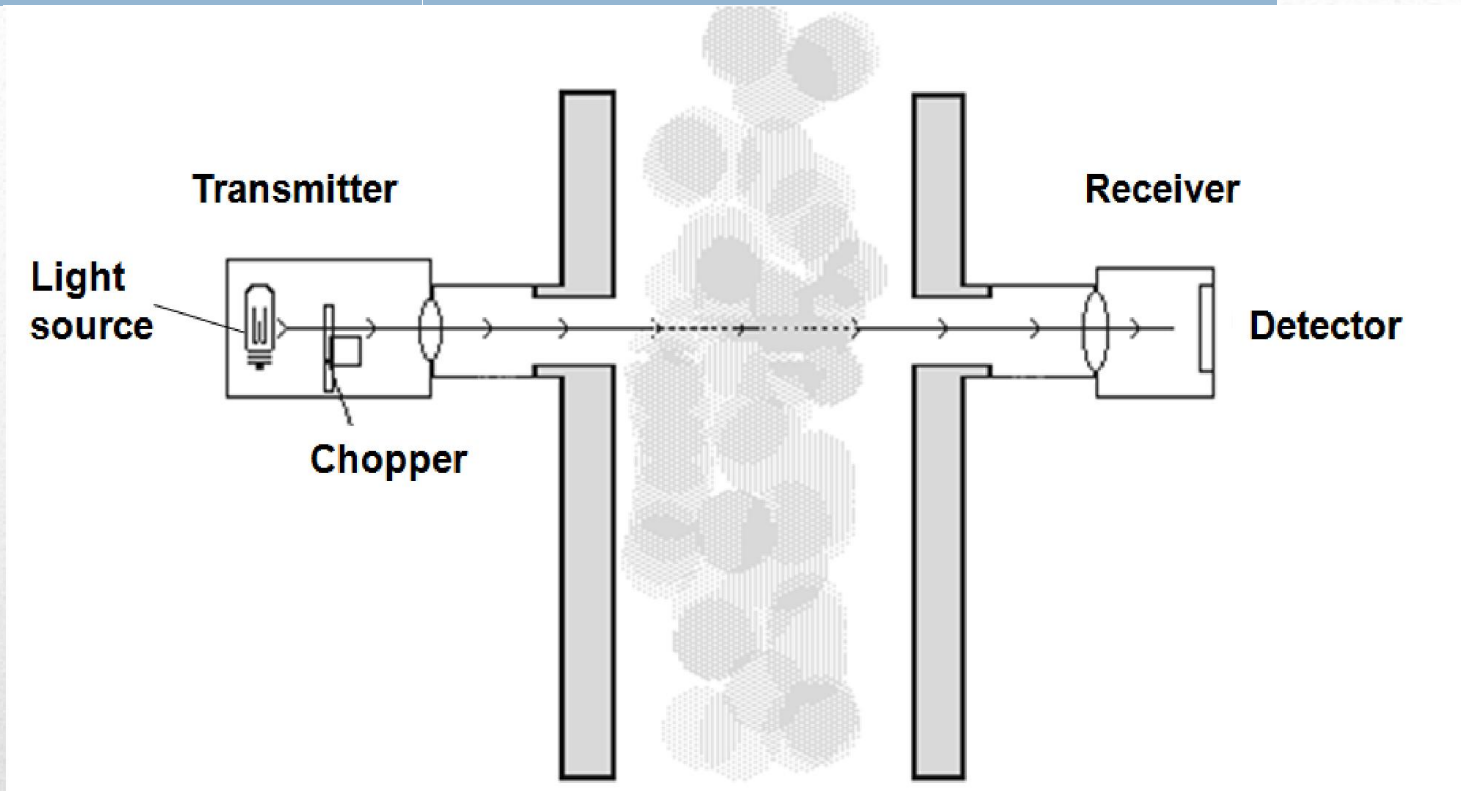
Different effects on illuminating a particle

Transmission

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

Opacity

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



Dust concentration is proportional to Extinction

Extinction = loge 1/T = e $^{k.n.a.L}$

I = received light;

I_o = emitted light

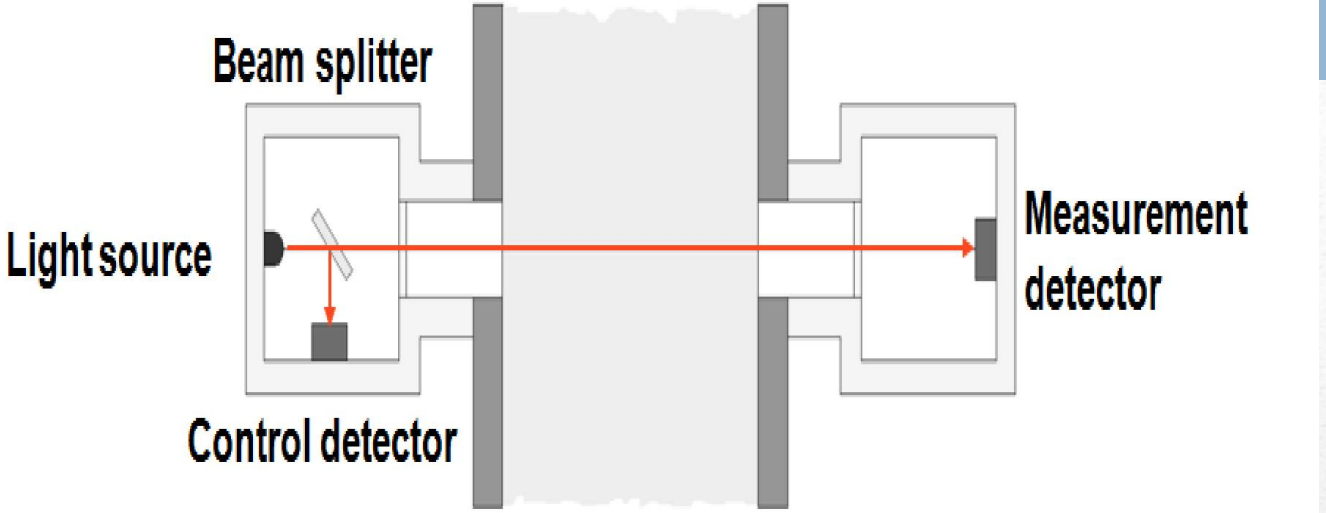
k = extinction coefficient

n = dust concentration

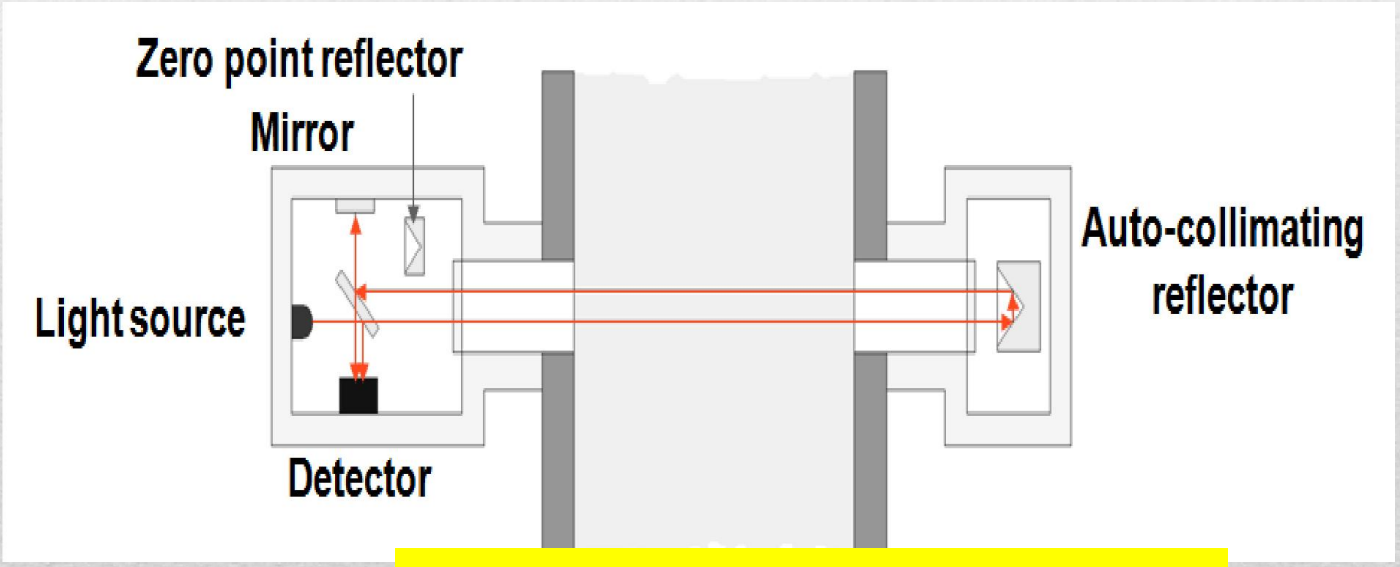
a = mean projected area of particle

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

Transmittance / Opacity

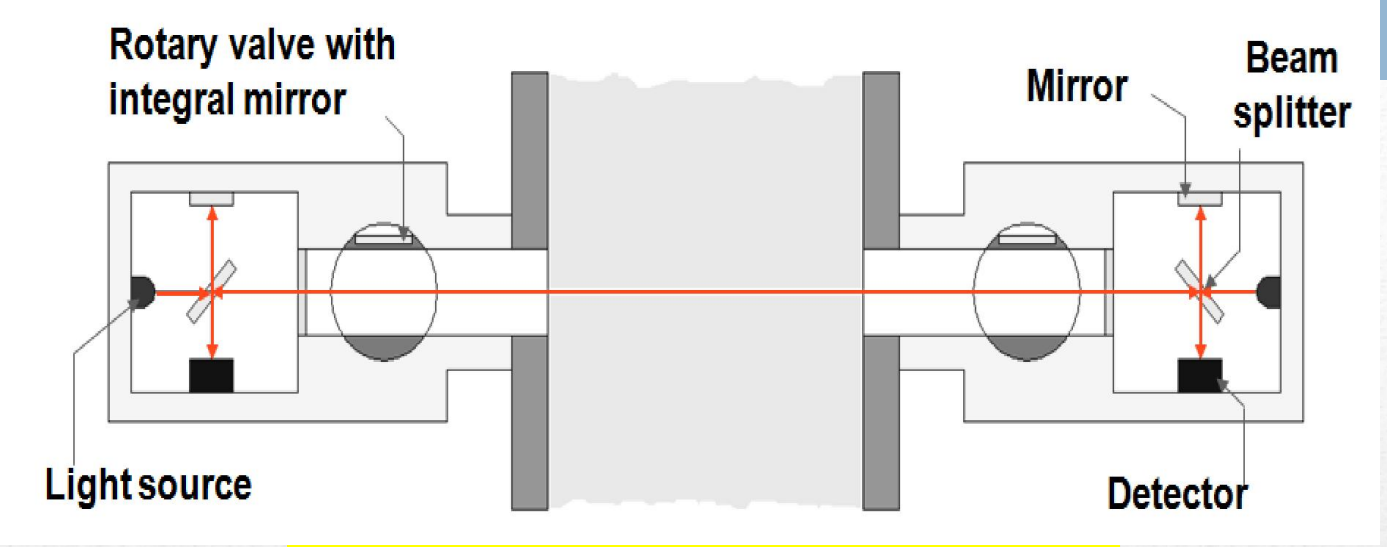


Single pass transmissometer

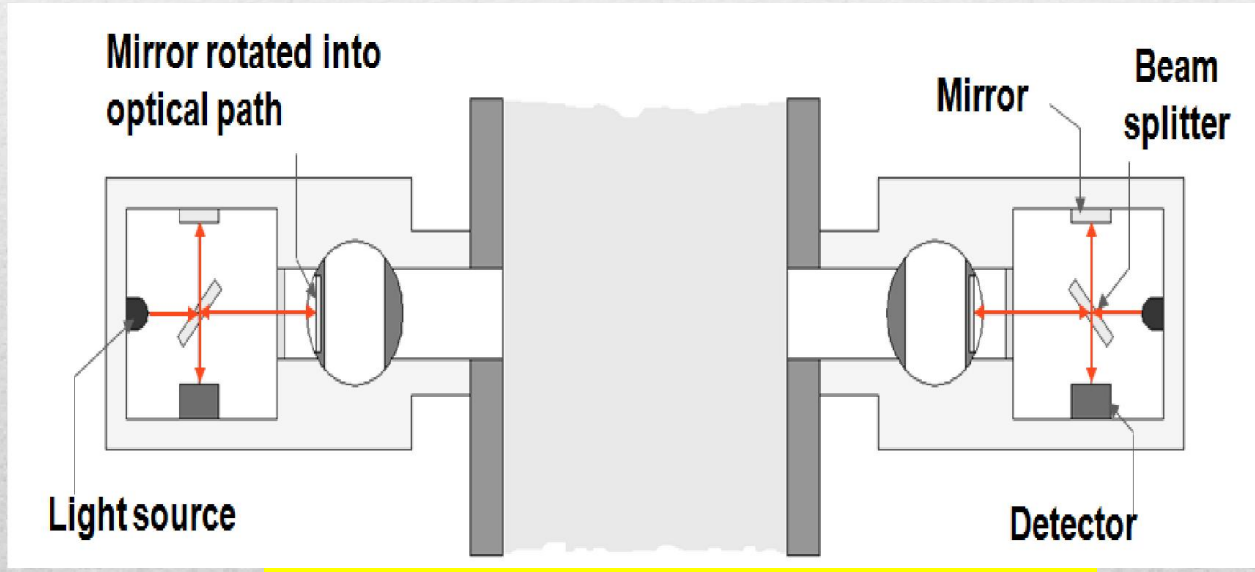


Double pass transmissometer

Types of Transmissometer



Dual beam (measurement)



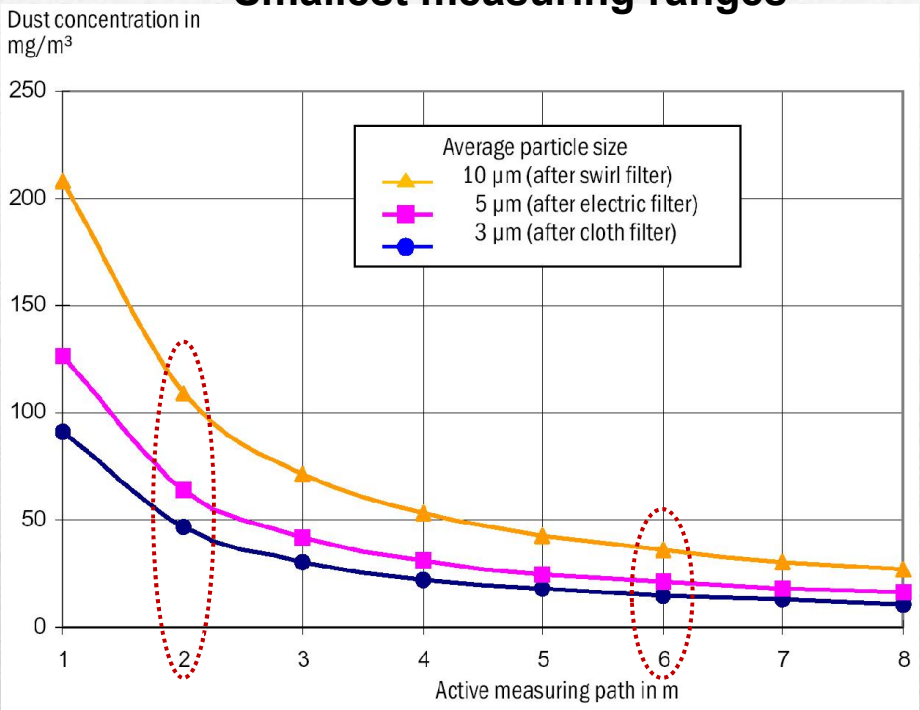
Dual beam (contamination check)

Types of Transmissometer

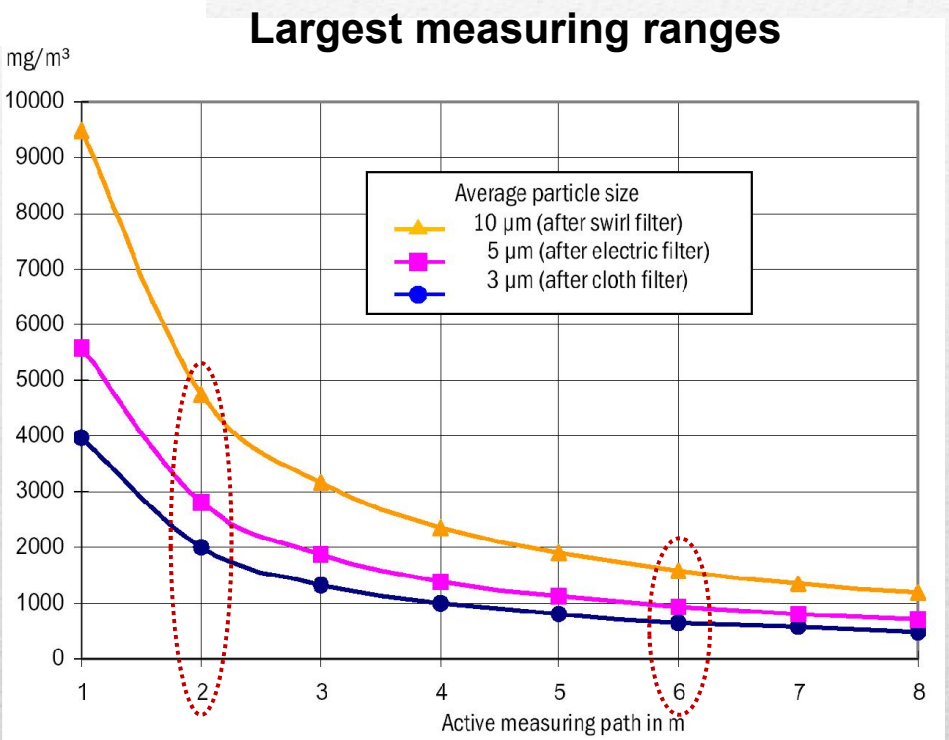
Relationship between

- path length
- particle size
- dust concentration

Smallest measuring ranges



Largest measuring ranges



To measure low concentrations → a long measuring path is required

Measuring Limits – Transmission / Opacity

- **Suitable for medium to high concentration**. At low concentrations (<10mg/Nm3), the reduction in the light beam caused by the particles is indistinguishable from the zero drift.

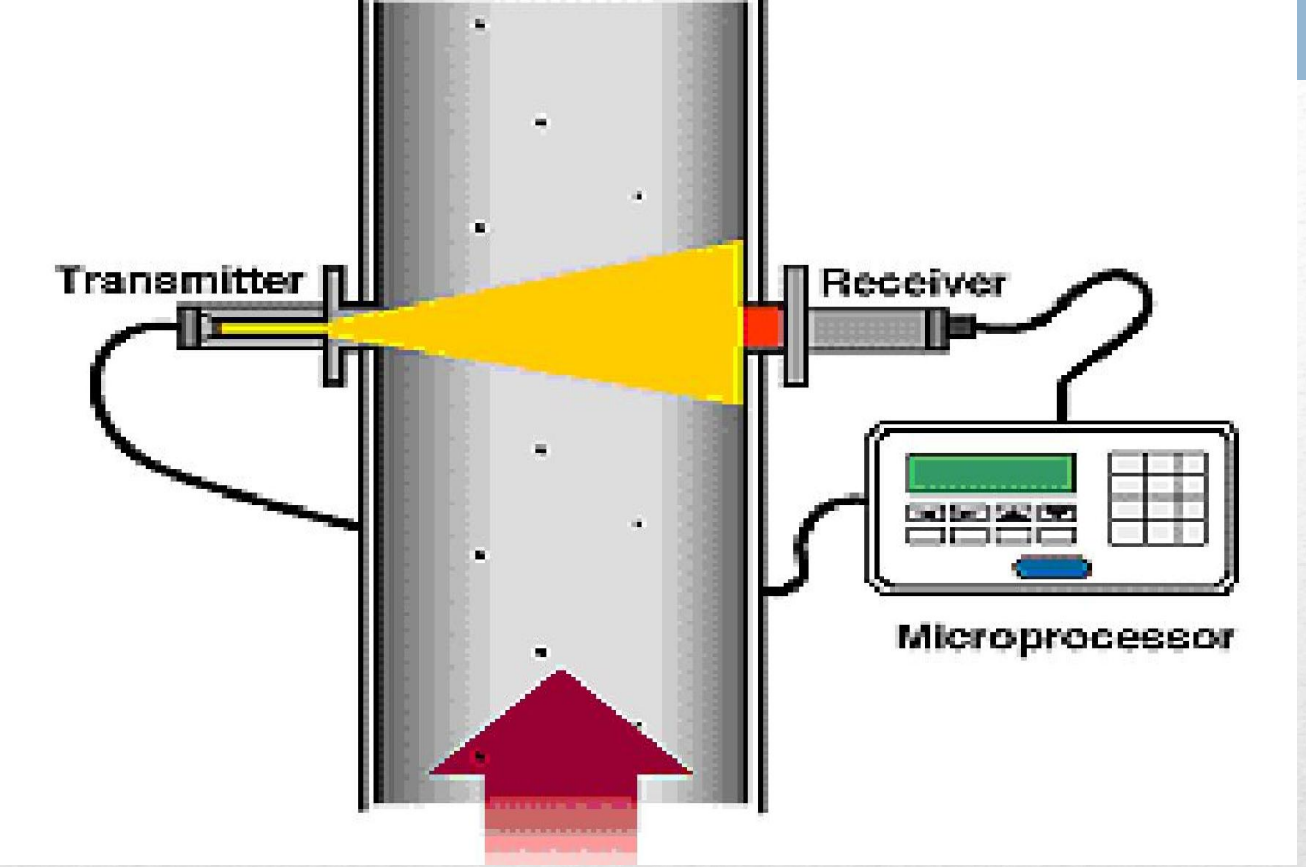
- The attenuation of light is sensitive to dust contamination on the lens surfaces.

- Systems without retro-reflectors (i.e. single pass) are sensitive to misalignment between the transmitter and receiver.

- Not suitable for stacks with flue gas below dew point or containing water droplets from wet collectors.

- Calibration and response from instrument changes with
  - ✓ Particle type and refractive index
  - ✓ Particle colour
  - ✓ Particle size and shape

Opacity meter- Limitations

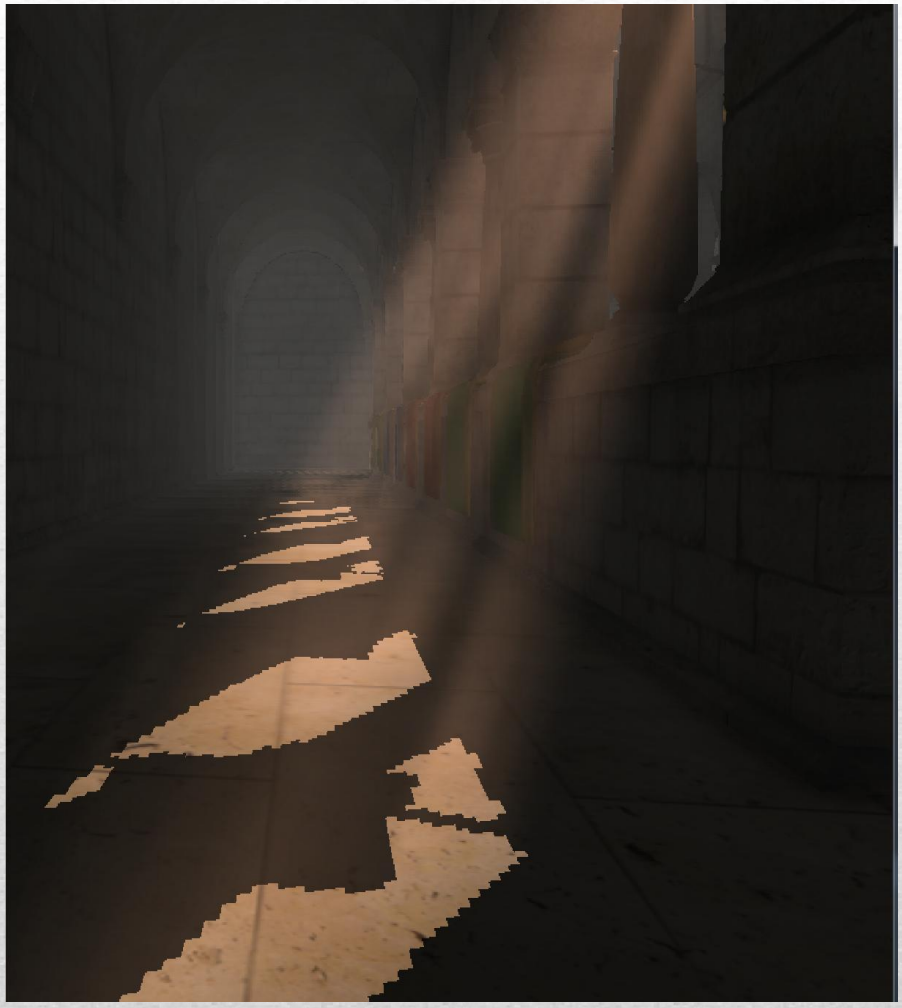


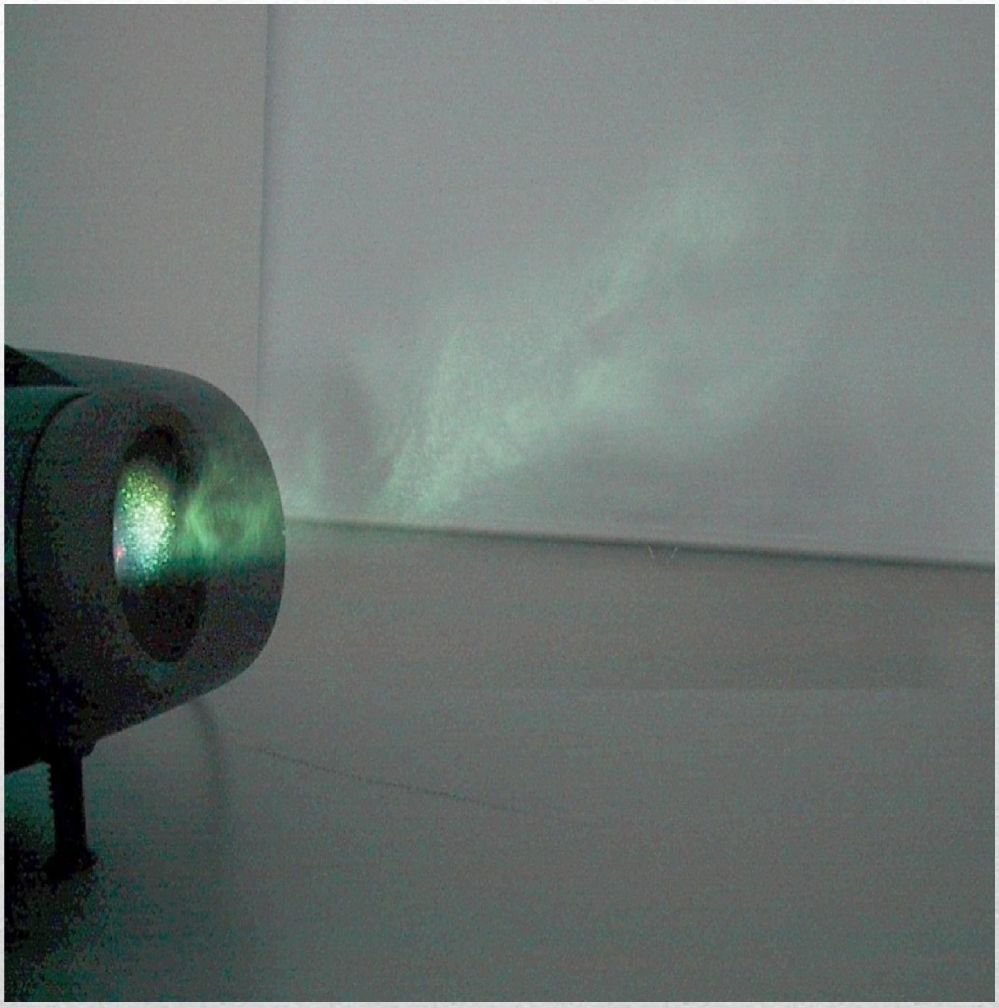
- A variation of transmissometer
- Based on Flicker of light while dust Particles pass the beam
- Dust particles passing through the light beam cause the receiver to detect a modulating signal. The ratio of the fluctuations in the received light (scintillation) to the average light intensity at the detector is used to produce a signal proportional to changes in particulate concentration.

Optical scintillation

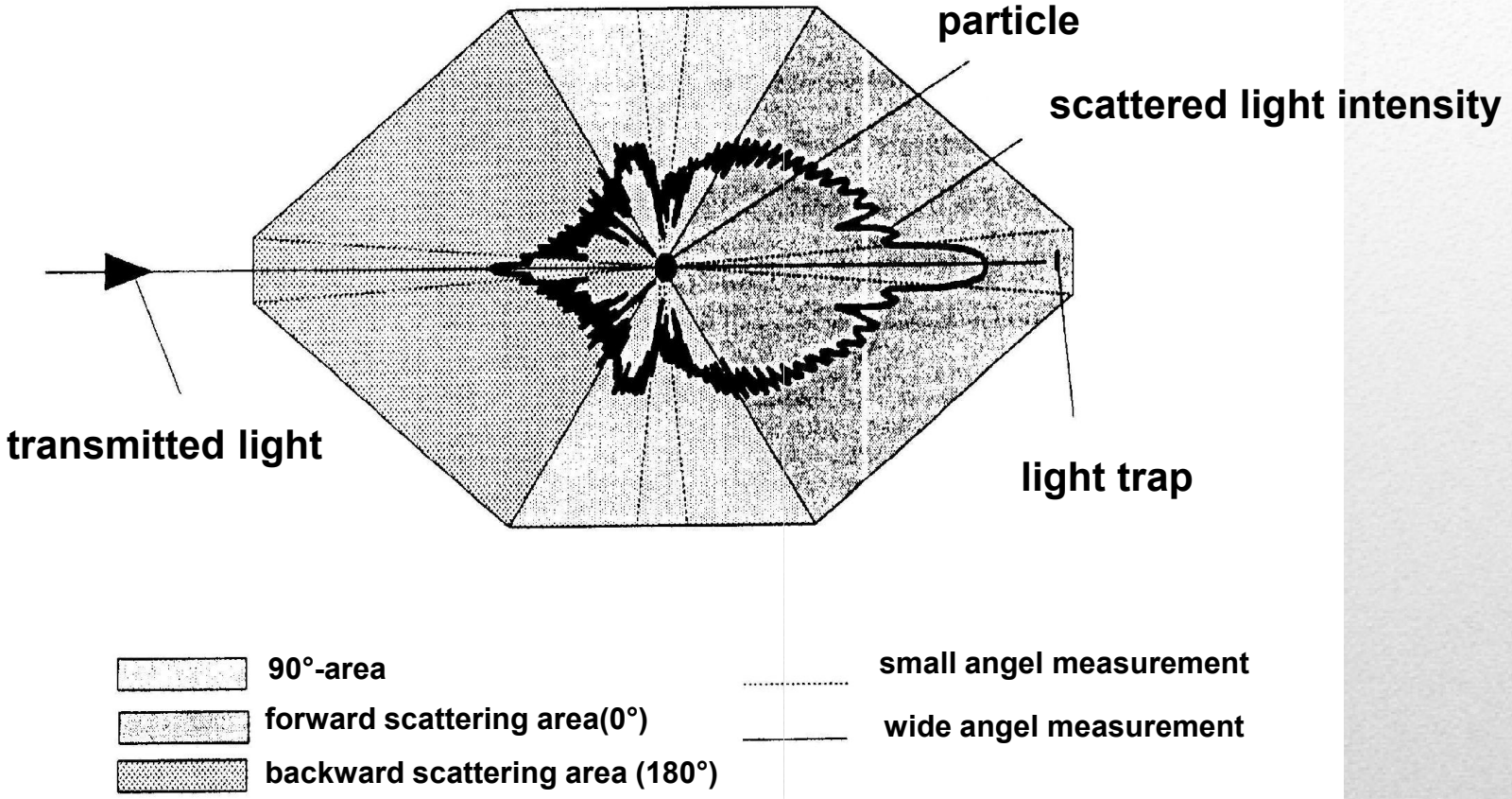
- Liquid droplets or vapour cause erroneous readings due to refraction / reflection of the light beam by the moisture.
- Not suitable for PM levels below the resolution limits of opacity instruments use to offsets created by heat haze.
- Aadversely affected by particle size, density, shape change.
- The cleaning of receiver is an issue.

Opacity meter- Limitations

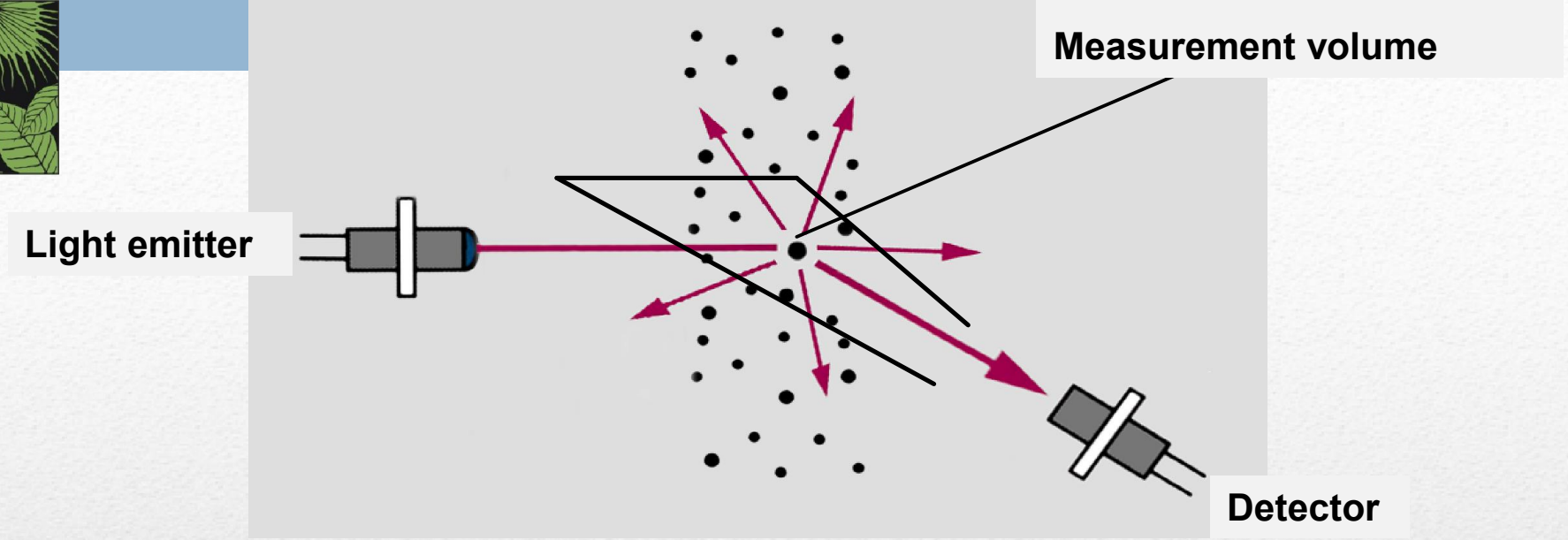




Scatter Light



Different Regions of Scattered Light

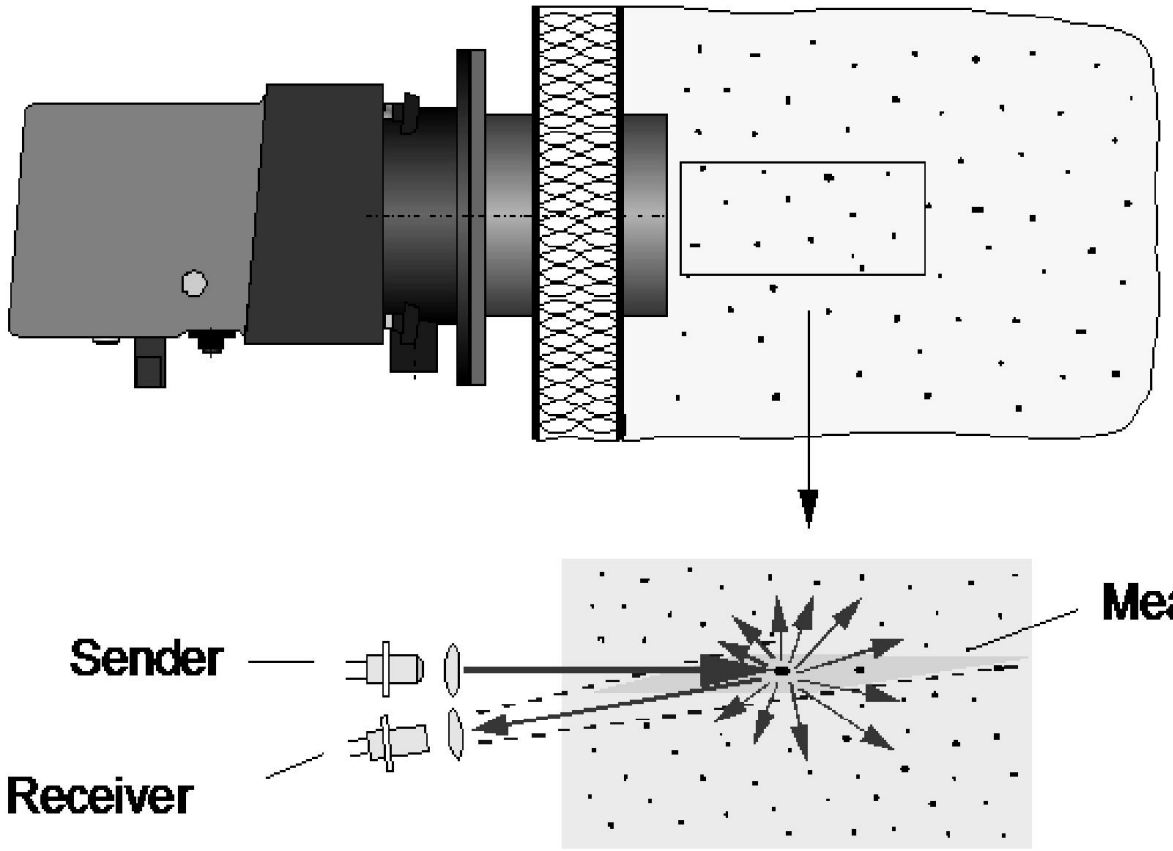


It has better sensitivity than back scatter devices. Suitable for low to medium conc.

Limitations

- Small scattered light intensity requires high measurement accuracy and occurring at small angles to the incidence, it is very important to shield the receiver properly from directly transmitted light.
- Air purges are required for optical surfaces, although compensation for dust accumulation can be made by separately measuring changes in directly transmitted light.

Forward Scatter Light

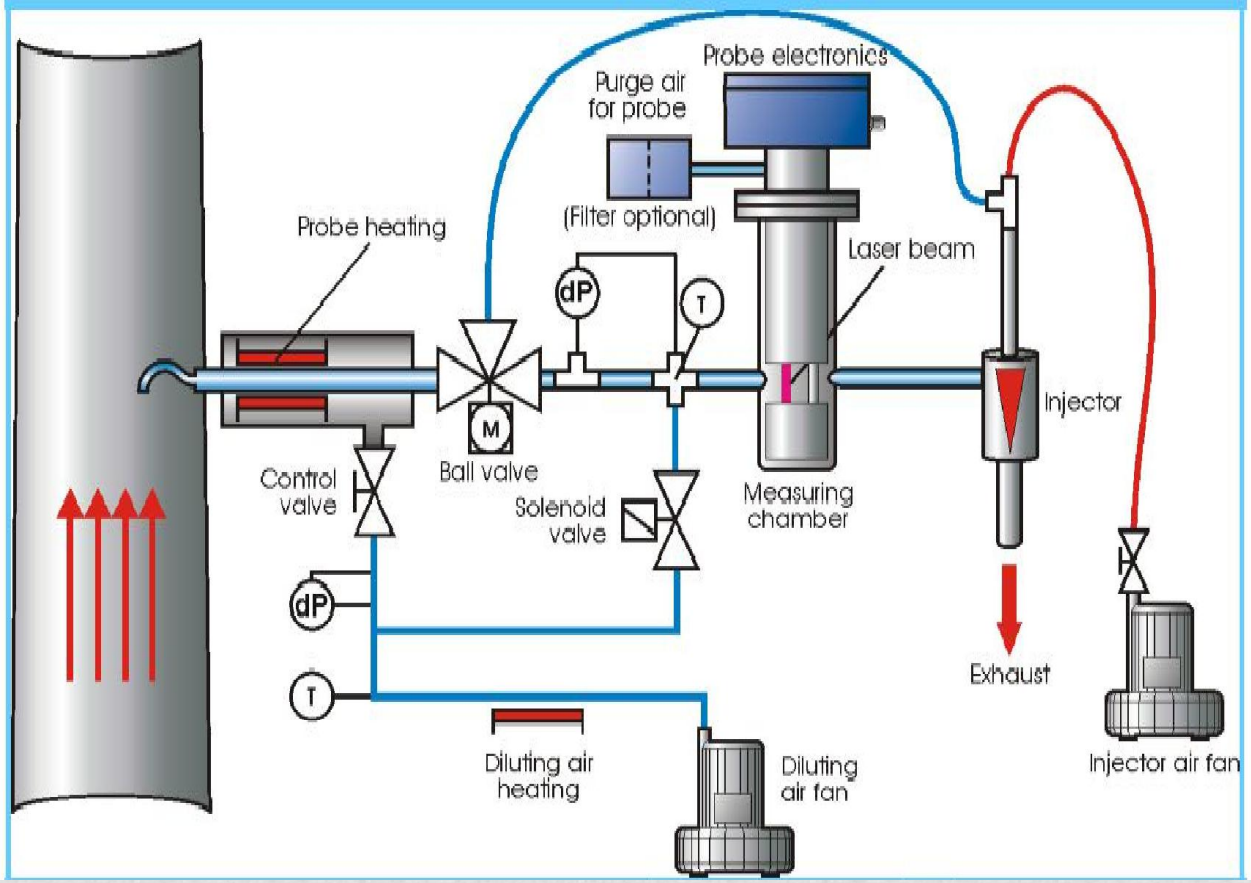


Suitable for high to medium conc.

Limitations

- Calibration is affected by changes in particle size and type of particle. Response reduces by 20% from peak if particle size changes from 0.8- 0.7μm.
- More sensitive to changes in particle composition and refractive index
- Water droplets affect the reading of In-situ instrument.

Backward Scatter Light



Extractive versions are designed for wet flue gas applications and are required for liquid droplets.

Infrared light gives better response than visible light in this instrument.

Works best after a bag filter or multi-stage APC

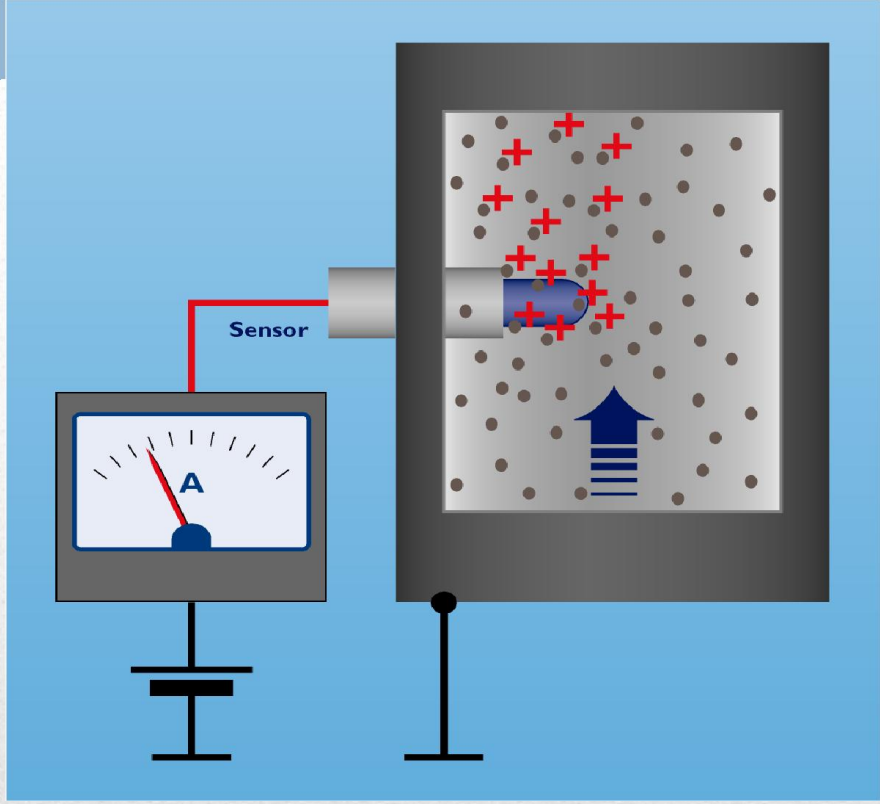
Limitations

- Low cost, low maintenance but high installation cost.
- Sensitive to low PM concentration.
- Performance is adversely affected by particle size, density and shape .

Extractive Light Scatter

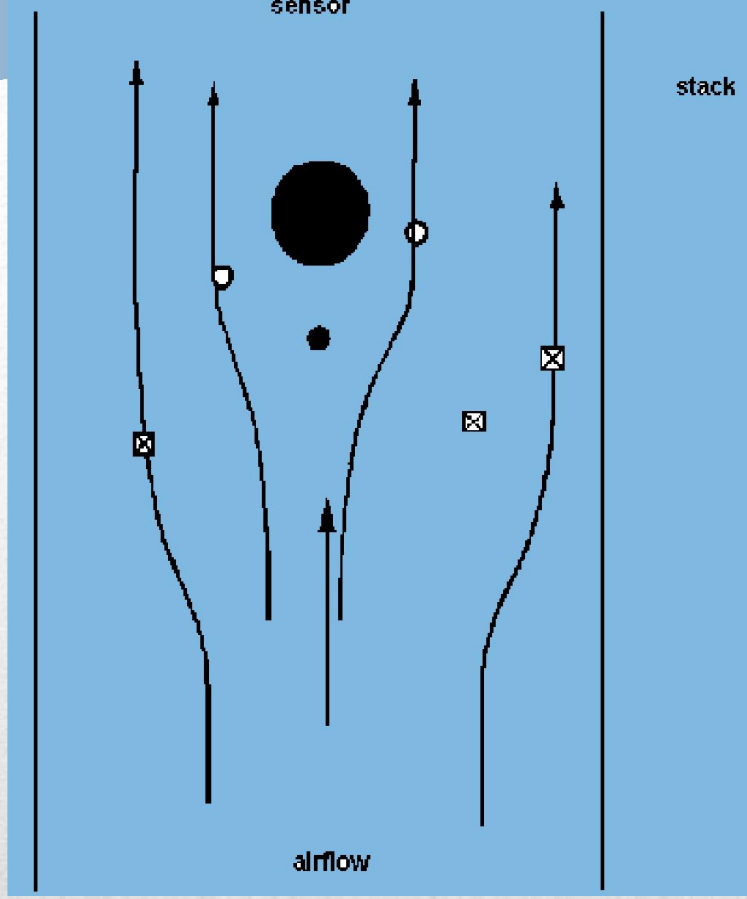
Colliding particles exchange their electrical charge with the measuring electrode.

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"



- A rod length of approximately half the stack size is used to ensure representative measurement.
- Amplification of the small Triboelectric signal (10 Pico amps) is usually performed in the sensor head to maximize the instrument signal.
- The insulator at the base of the sensor rod must be kept clean to avoid false signals from ground loops and stack currents.

Triboflow



Particles produce a AC charge movement by charge induction. Charge on the particle transfer charge in the probe as it passes.

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

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)

Electrodynamic

Limitations

- 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

Tribo Flow & Electrodynamic

- 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

Beta Attenuation

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

Industries/Applications	Process conditions	Typical solution	Comments
Incinerators	0-10mg/m^3 (bagfilters after dry scrubbing)	Light scatter or Probe electrification	Cost effective solution for highly abated processes (below 1 mg/m^3)
Cement kilns	0-10 mg/m^3 (with incineration) 0-50 mg/m^3 (other)	Light scatter Opacity/ dynamic opacity	Plant networked solution extends to mill applications
Coal fired power plant	0-50 mg/m^3 (new plant) 0-150 mg/m^3 (old plant) 0-20 mg/m^3 (wet FGD)	Back or forward scatter Opacity/ Back scatter Extractive Beta or Scatter	Solution depends on dust levels
Small boilers	0-200 mg/m^3 (ESP or no controls)	Opacity/Back scatter	High dust may use opacity or back scatter
Gas turbines	<1 mg/m^3	Forward scatter	
Pulp and paper	0-50 mg/m^3 High humidity	Electrodynamic or opacity	Insulated Electrodynamic probe allows instrument to discriminate between water vapour and particulate
Refineries	0-50 mg/m^3 (Ex gas zone)	Opacity or light scatter or Electrodynamic	Category 1 device approved according to IECX

Suitability of PM- CEMS (CSE's Technical Guidance Manual)

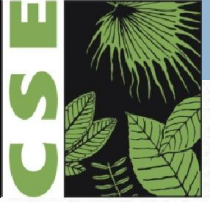
Measurement Technology		Stack Diameter (m)	Concentration mg/m³		APC device	Min. certification. range	Dry	Humid	Wet	Velocity Dependant
			Min	Max						
Probe Electrification	Electrodynamic	0.1 -3 (6m with multiple probes)	< 0.1	250	Bag, Cyclone, Drier,	0 to7.5mg/m3 (QAL1 to EN-15267-3)	√	√	x	Not in 8 - 18m/s range
	AC Tribo	0.1 - 3	< 1	250	Bag, Cyclone	0 - 15mg/m3	√	x	x	Yes
	Tribo	0.1-3	< 1	250	Bag, Cyclone	qualitative bag leak	√	x	x	Yes
Transmissometry	Dynamic Opacity / Scintilation	0.5 - 10	10 10 (5m stack) 25 (2m stack)	1000	Cyclone, ESP, None	0- 150mg/m3	√	x	x	No
	Opacity/ Extinction	1 - 15	10 (at 5m) 50 (at 1m)	1000	Bag, Cyclone, ESP, None	0- 50mg/m3	√	x	x	No
		0.5-12	< 30	1000	ESP, None	None	√	x	x	No
In-situ Light Scatter	Scattered Light (Fwd)	1 - 3	< 0.1	300	Bag, ESP, None	0-15mg/m3	√	x	x	No
	Scattered Light (Back)	2 - 10	<0.5	500	Bag , ESP, None	0-7.5mg/m3	√	x	x	No
Extractive light scatter		0.5 - 10	0.1	100	Wet collector (wet FGD)		√	√	√	N/A
Extractive Beta		0.5 -10	0.5	< 150	Wet collector (wet FGD)		√	√	√	N/A

Suitability of PM- CEMS (CSE's Technical Guidance Manual)

Range of instrument

- ✓ Certified determination range
- ✓ 2.5 times of emission limit or
- ✓ 125% of maximum concentration recorded by Reference sampling during calibration of CEMS, whichever is higher

Range of PM CEMS equipment



Installation

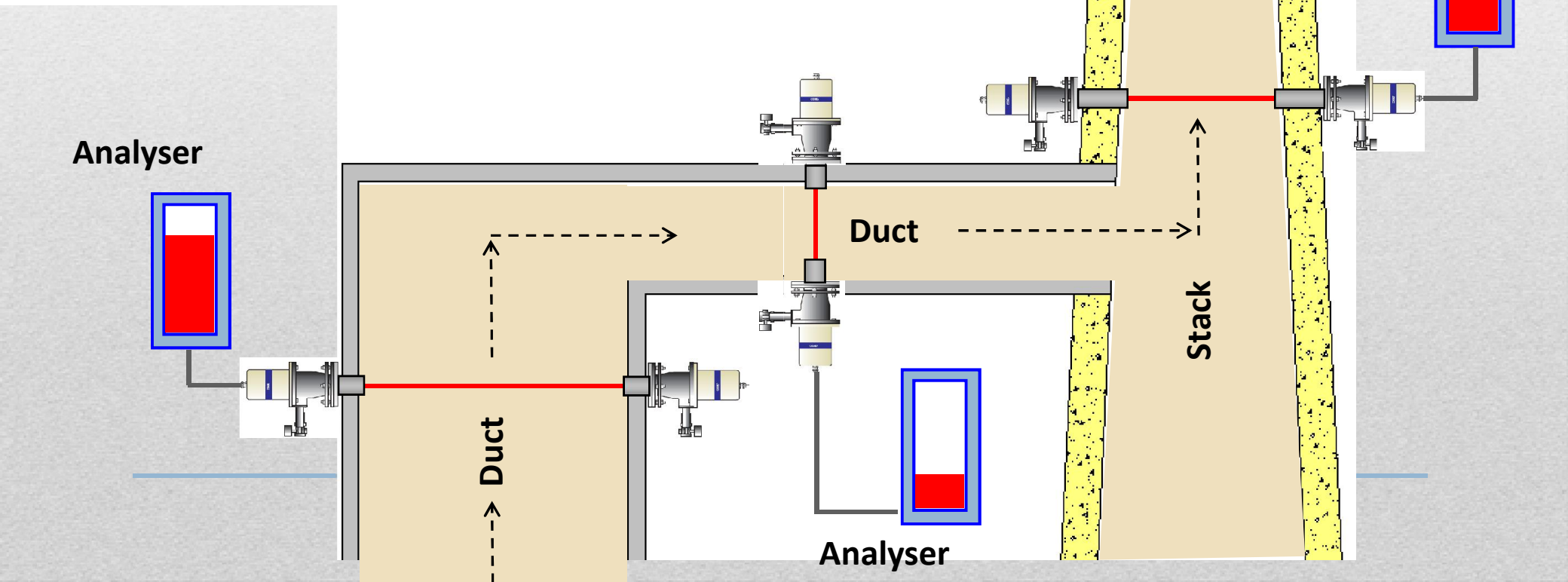
Location of installation ?

- ✓ In stacks or ducts? If not possible, then in duct.
- ✓ Location of device in stacks- 8D from down and 2D from top
- ✓ In rare cases- 2D and ½ D
- ✓ 500mm below manual sampling port- ensuring no disturbance during calibration
  - Probe type at 90 deg angle
  - In horizontal plane
  - Protruding downward with suction system in flow direction

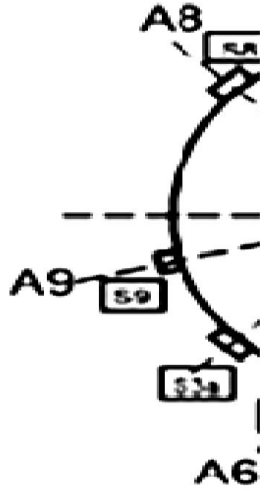
Where to install CEMS ?

Where to install CEMS ?

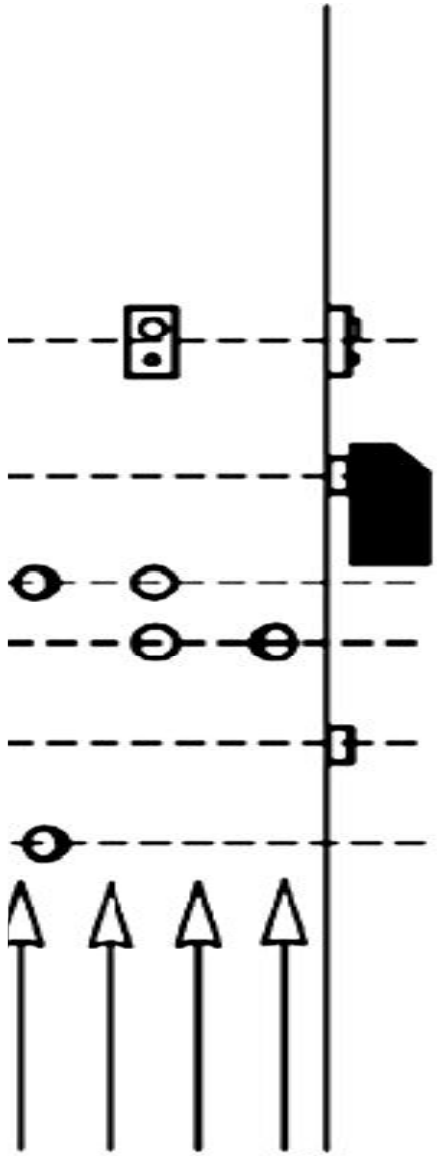
- ✓ Only process stacks/ducts or all stacks/ducts ? Some industries have around 70 process stacks while number of all stacks may reach around 300
- ✓ Stacks for which pollution norms shall be met
- ✓ Construction of stacks should adhere the provision- Emission Regulation-III of CPCB (COINDS/20/1984-85)



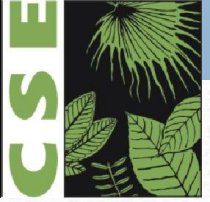
a)



a	Top view
b	Front view
A	Measurement lin
S	Measurement po
S 2,5	1,2,5,7 Referencemeth
S 3	3,3a PM CEM
S 4	CEM for S02, NO
S 6	CEM for HCl, tot
S 8	8,8a Volume flow met
S 9	Temperature mo
S a	9a Pressure monito



Positioning of the monitors



Thank You