DUST MEASUREMENT TECHNOLOGIES

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DUST MEASUREMENT TECHNOLOGIES

AGENDA

- Understanding dust
- SICK AG
- Why measure dust emissions?
- Legislation & Limit Values
- Dust Measurement Technologies
  - Transmission
  - Scattered light
  - Tribo-electric
  - Beta-radiation
  - Gravimetric measurement
- Calibration
Dust consists of fine, solid particles of matter suspended in air or gas.

- It's everywhere in our everyday life!

**Differentiation by**

- Organic (bee pollen, bacteria, fungal spores...)
- Inorganic (stone dust, mineral fibers, ...)
- Particulate size, shape, color...
- Cosmic....

**Dust in context of continuous emission monitoring (CEM)**

- Dust is particulate matter, which is suspended in solid form at the actual stack temperature.
- Dust is particulate matter, which is collected at the temperature of the sampling probe.
Bad air quality was reported to King Charles 2nd to be problematic in London 1661

Approx. 1700 the impact of dust to Baker's asthma disease was reported

Approx. 1879 first successful particle „measurement“ was achieved.

Developments in 19th and early 20th were concentrated on workplace measurements, since dust related lung diseases became a serious problem.

As an example for early work place measurement Zeiss Konimeter approx. 1950

...
„We certainly don´t need more technology. What we need is better and more proper technology.“

Dr. Erwin Sick (1909 – 1988), German inventor and entrepreneur
Erwin Sick took care for environment long before there was a huge public interest

He was a pioneer in technology and „Technology for humans….“

First patent 1958 – first double beam transmissiometer (Smoke density measurement) „Vorrichtung zur Rauchüberwachung“, DBP. 1117318, 1958;

SICK was a REAL company with green focus long before this was common sense
SICK – worldwide one of the leading manufacturers of sensors and sensor solutions for industrial applications.

- 70 Years of experience. Founded 1946.
- 7,417 Employees worldwide
- 88 Countries with SICK presence: More than 50 subsidiaries and participations as well as numerous specialized agencies
- 1,267 Million euros Group sales in the fiscal year 2015
- 40,000 Products and thus widest product and technology portfolio in the sensor industry
- 3,000 Patents and thus leading in developing innovative sensor solutions
Anthropogenic dust emissions:

- Industrial processes
- Electricity generation (combustion)
- Traffic
- Agriculture
- Construction activities
- Households
- Slash-and-burn farming

Effects:

- Health problems (allergic reactions, pneumonia and asthmatic attacks)
- Limited visibility & road safety
- Decrease crop productivity
Influences on dust measurements:

- Duct / Pipe diameter: from small (0.25 m) to large (12 m and more)
- Dust concentration: from low (< 1 mg/m³) to high (10 g/m³ and more)
- Gas composition: from ambient air to aggressive gases
- Gas temp. and moisture: from low (ambient temp.) to very high (600 °C +), above (dry) or below dew point (wet)
- Particle properties: size, form, color, material density, specific characteristics (e.g. sticky)
- Environmental conditions: ambient temperature, air composition (e.g. salty, fine dust)
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LEGISLATION AND DUST LIMIT VALUES

- **European Regulations**
  - EN 14181
    Stationary source emissions - Quality assurance of automated measuring systems
  - EN 15267
    CEN standard for testing and certifying automated measuring systems (AMS)
  - EN 13284
    Stationary source emissions - Determination of low range mass concentration of dust

- **German Regulations**
  - Bundes-Immissionsschutzgesetz (BImschG)
    German law on protection against harmful environmental influences
  - Bundes-Immissionsschutzverordnungen (e.g. 17. BImschV, 30. BlmSchV)
    Specific regulations for small and medium particle emission sources EN 14181
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LEGISLATION AND DUST LIMIT VALUES

Some examples:

- **Germany** (13./17. BlmSchV – large combustion plants & waste incineration)
  
  - Solid fuels: 10 mg/m³ - 20 mg/m³
  - Liquid fuels: 10 mg/m³ - 20 mg/m³
  - Gaseous fuels: 5 mg/m³ - 10 mg/m³
  - Waste incinerators: 5 mg/m³ (daily average); 20 mg/m³ (½ hr. average)
  - Cement plants: 10 mg/m³ (daily average); 30 mg/m³ (½ hr. average)
  - Waste gasification plants: 10 mg/m³ (daily average); 20 mg/m³ (½ hr. average)

- **India** (Environment (Protection) Amendment Rules):
  
  - Thermal Power plants: 100 mg/m³ (inst. <2013); 50 mg/m³ (2013-2016); 30 mg/m³ (2017+)

- **China** (GB13223-2011):
  
  - Coal fired power plants: 20 mg/m³ - 200 mg/m³
  - Oil fired power plants: 20 mg/m³ - 30 mg/m³
  - Gas fired power plants: 5 mg/m³ - 10 mg/m³
Continuous dust measuring technologies

- Transmission
- Scattered light
- Tribo-Electric

Semi-continuous dust measuring technologies

- Beta-Radiation

Discontinuous dust measuring technologies

- Gravimetric measurement

- For CEMS according to local regulation
- Bag filter/electrostatic precipitator efficiency meas.
Transmission principle

- Measuring of the amount of light received as a fraction of the amount of light emitted in an optical cross stack monitoring.
- Opacity is the %-age of light lost
- Transmission is the %-age of light received
- Calculation of the dust concentration (for high dust concentrations)
- In-situ measurement
Transmission principle
Transmission principle
Transmission principle
Typical Applications
- Mainly for medium to high dust concentrations
- Emission and process monitoring

Strengths
- Representative measurement (cross-stack)
- Little maintenance effort
- Automatic self-check functions for control of stability of the measurement signal
- Contamination compensation functions
- Independent of gas velocity, moisture content of the particles and operating conditions of the separator

Weaknesses
- Two-sided installation means higher investment and installation effort
- Physical detection limits for low dust concentrations in small stacks
- Purge air necessary
- **Scattered light (forward)**
  - Radiation of the dust loaded measuring volume with visible laser light (wavelength approx. 655 nm);
  - Receiver is on the transmitter side (for low to medium dust concentrations)
Scattered light (forward)

- High sensitivity
  - Very low dust concentrations can be measured independent of path length

Everyday situations
DUST MEASUREMENT TECHNOLOGIES

- **Scattered light (backward)**
  - Radiation of the dust loaded measuring volume with visible laser light (wavelength approx. 655 nm);
  - Sender/Receiver unit (for low to medium dust concentrations)
DUST MEASUREMENT TECHNOLOGIES
SCATTERING LIGHT: STRENGTHS AND WEAKNESSES

- **Typical Applications**
  - For very low to medium dust concentrations
  - For emission monitoring
  - Qualitative and quantitative process monitoring

- **Strengths**
  - Well suited for low dust concentrations
  - One-sided installation (Back scattered, Probe version)
  - Wide application range
  - Automatic function checks available
  - Contamination compensation functions
  - Independent of gas velocity, moisture content of the particles, operating conditions of the separator and contamination of the probe-well suited for low dust concentrations

- **Weaknesses**
  - Purge air necessary
DUST MEASUREMENT TECHNOLOGIES

Tribo-electric

- Particles, which collide with the probe or fly past, transfer their charge to the measuring electrode
  - Physical effects: friction & induction
- Charge exchange is proportional to dust concentration through application specific calibration factor
- Measurement is influenced by:
  - Gas velocity,
  - Electrical charge and moisture content of particles,
  - Operating conditions of the separator,
  - Contamination of the probe
TRIBO ELECTRIC: STRENGTHS AND WEAKNESSES

- **Typical Applications**
  - Qualitative and quantitative process monitoring
  - Simple monitoring tasks (bag filter leakage)
    ➔ Not suited for CEM, only simple dust measurement

- **Strengths**
  - One-sided installation
  - Cost-Effective (no purge air necessary)

- **Weaknesses**
  - Measurement depends on gas velocity, moisture content of the particles, operating conditions of the separator and contamination of the probe ➔ very limited use
  - No automatic function tests with zero- and span-value. Only with standard reference method ➔ unreliable measurements can not be detected during normal operation, only by work-intensive manual linearity check
  - The probe needs to be cleaned very often as it get less sensitive with more contamination ➔ short maintenance intervals and hence high cost-of-ownership
**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
DUST MEASUREMENT TECHNOLOGIES
BETA-RADIATION: STRENGTHS AND WEAKNESSES

- **Typical Applications**
  - Low to high dust concentrations
  - For emission monitoring in dry and wet gas

- **Strengths**
  - Output directly in mg/m³ without calibration (but for representative network measurement, e.g. for emissions monitoring, calibration is necessary)
  - Suited for gases above and below dew point

- **Weaknesses**
  - Single Point Measurement → Needs to be calibrated as well for CEM
  - Discontinuous measurement → Measurement only every ten minutes!
  - High investment costs (Approx. 60.000 – 80.000 €)
  - High spare part consumption, especially filter paper (cost intensive)
  - High maintenance effort
  - Beta-Radiation source requires qualified staff (with certificate)
DUST MEASUREMENT TECHNOLOGIES
CALIBRATION

- Why is a calibration on site needed?
  - Dust concentrations cannot be measured in a direct way.
  - The measurement signal is influenced by:
    - Number of particles,
    - Particle properties (size, structure, color)
    - Material density
  - Calibration is strictly required for exact dust measurements using optical, electro-dynamic or tribo-electric monitors

- European Standards:
  - EN 14181: Stationary source emissions - Quality assurance of automated measuring systems (AMS)
    - QAL2: Calibration and validation of the automated measuring system
    - QAL3: Ongoing quality assurance during operation
  - EN 13284-1: Determination of low range mass concentration of dust
    Part 1: Manual gravimetric method
DUST MEASUREMENT TECHNOLOGIES

CALIBRATION

- Determination of the relationship between the mA signal of the automated measurement system and the real dust concentration in the stack in mg/m³
- Calculation of a regression function (quadratic or linear formula) and implementation in a measurement computer or dust monitor

At least 15 measurements at different plant operation conditions (e.g. full load, half load)
Isokinetic extraction of a partial gas volume

Collection of the dust particles, contained in the extracted gas volume on/in a filter element

Weighing the filter element before and after the dust collection

Determination of the relationship between dust content in mg and extracted volume in m³

Measurement of the gas velocity and gas temperature in the stack for normalization of the results (calculation of mg/m³ in standard conditions)

Requirements:

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

1. Weighing of the collector before gravimetric measurement = \( m_{\text{bare}} \)

2. Drying of the collectors

3. Gravimetric measurement

4. Drying of the collectors

5. Weighing of the collector after gravimetric measurement = \( m_{\text{brutto}} \)

6. Interpretation of the data
DUST MEASUREMENT TECHNOLOGIES
SICK AG - DUST MEASUREMENT PRODUCT PORTFOLIO

DUSTHUNTER SP
Scattered light forward (probe)

DUSTHUNTER SB
Scattered light backward

DUSTHUNTER SF
Scattered light forward (cross-stack)

DUSTHUNTER T
Transmission

DUSTHUNTER C
Transmission + scattered light forward

FWE200
Scattered light forward (extractive)

GRAVIMAT
Gravimetric measurement
MANY THANKS FOR YOUR ATTENTION.

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