mra
measurement registration analysis

International comparison of validation methods for dust concentration measurement

14:00	International comparison of validation methods for dust concentration measurement	Mr. Angelo, M.Sc.E.E., M.B.A. Consulting Engineer,

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Validation of dust monitors can be divided into 2 steps:

1. Validation of a generic dust monitor as an instrument (Type testing).
2. Validation of each individual installation (Commissioning testing).

Not all countries have both;

Europe has both; **USA** has only the last point.

In the short time we have today, we will look at the status and background in Europe and briefly on USA/EPA.

Europa

In **European** the present situation is that a dust monitor installation must:

1. Use a dust monitor type approved and certified according to the standards in EN 15267-serie.
2. Perform a calculation of total uncertainty for its intended installation according to EN 14.188 “QAL1” before installation (should be before purchase?).
3. Perform a initial calibration and uncertainty assessment according to EN 14181 “QAL2” after 1st installation.
4. Perform automatic or manual uncertainty/drift testing regularly according to EN 14181 “QAL3”.
5. Calibration function tested every year according to EN14181 “AST”
6. Renew calibration function and uncertainty assessment according to EN 14181 “QAL2” every 5 years.

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How did Europe develop it's system?

It all started probably in the early 1960's with TÜV testing according to VDI 2066.

VDI 2066 contained both dust monitor calibration guidelines in "Sheet 1" und dust monitor specifications in "Sheet 4".

DK/UDC 502.55(203).057:543.275.3
543.275.3.082.53:535.362:535.341
351.777.078.3:614.71(083.132)

VDI-RICHTLINIEN

Januar 1989
January 1989

VEREIN DEUTSCHER INGENIEURE

Messen von Partikeln
Staubmessung in strömenden Gasen
Bestimmung der Staubbeladung durch kontinuierliches Messen der optischen Transmission

Particulate Matter Measurement
Measurement of Particulate Matter in Flowing Gases
Determination of Dust Load by Continuous Measurement of Optical Transmission

VDI 2066

Blatt 4 / Part 4

Ausg. deutsch/englisch
Issue German/English

Frühere Ausgabe: 5.80 Entwurf, deutsch
Former edition: 5/80 draft, in German only

© Verein Deutscher Ingenieure, Düsseldorf 1989

Der Entwurf dieser Richtlinie wurde mit Ankündigung im Bundesanzeiger einem öffentlichen Einspruchsverfahren unterworfen.
Die deutsche Version dieser Richtlinie ist verbindlich.

The draft of this Guideline has been subject to public scrutiny after announcement in the Bundesanzeiger (Federal Gazette).
No guarantee can be given with the respect to the English translation. — The German version of this Guideline shall be taken as authoritative.

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tion — even for internal use — not permitted

Background in VDI 2066

VDI 2066 Blatt 4 was based upon 2 commercially available transmission monitors the **SICK type RM41** and DURAG type DR280.

It measured extinction (negative logarithm of transmission), and was specified to measure down to full scale E=0.1 with a detection limit of 3%.

This detection limit corresponds to E=0,003 of T=99,3%

It means that 100% emitted light shall be compared to 99,3% received light.

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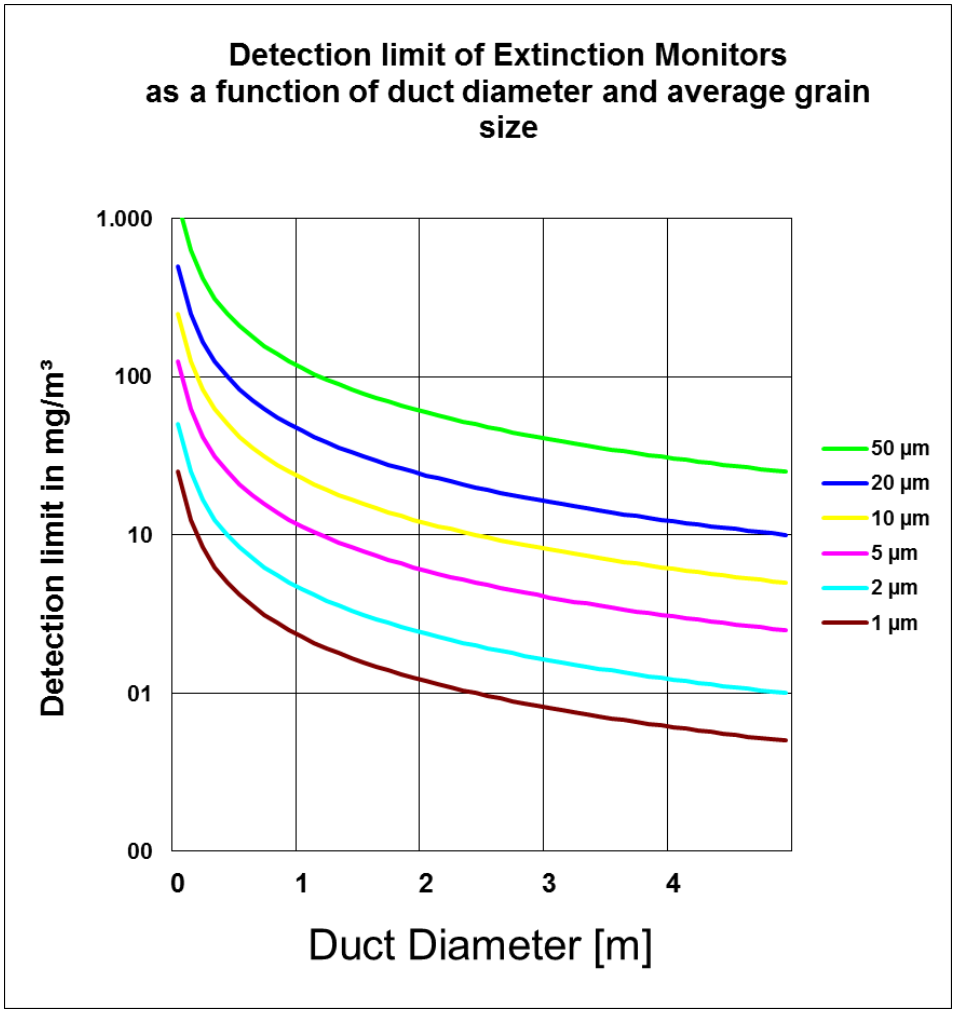
Background in VDI 2066

Using the data from VDI 2066 Blatt 4, the detection limit for ordinary fly ash (with specific mass 2.5) measured by a transmission monitors can be calculated.

For modern filters were these detection limits too high.

It required a shift in technology.



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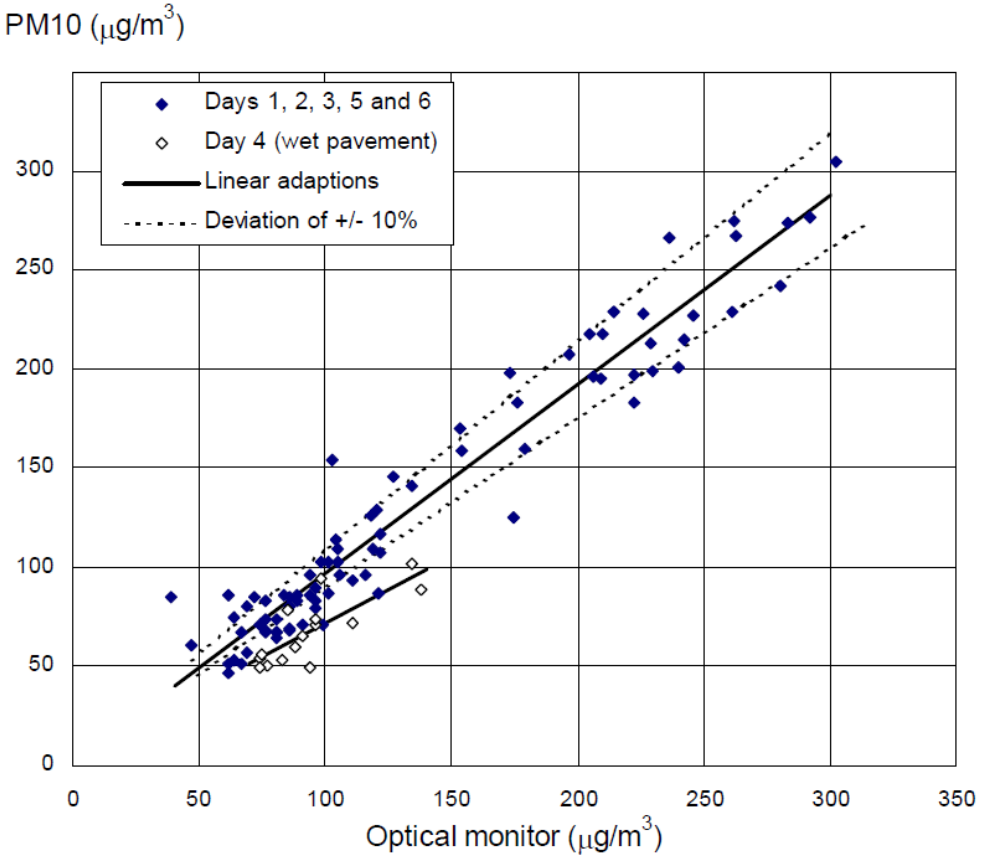
It initiated a new dust monitor technology:

Scatter light.

It was introduced by SICK in the early 1991 with RM100

☺

Probably the most sensitive dust monitor ever commercially available.



Please observe the scale in µg/m³ and not mg/³

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EU Commission is the driving force

In the early 1990's European environmental standardisation started to move on request from the EU Commission.

These standards were initiated in the planning phase for EU Directives for:

Waste Incineration (WID 2000/76) and

Large Combustion Plants (LCP 2001/80),

both today superseded by EU Directive for Industrial Emission (IED 2010/75)

28.12.2000 EN Official Journal of the European Communities L 332/91

27.11.2001 EN Official Journal of the European Communities L 309/1

17.12.2010 EN Official Journal of the European Union L 334/17

DIRECTIVES

DIRECTIVE 2010/75/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 24 November 2010

on industrial emissions (integrated pollution prevention and control)

(Recast)

(Text with EEA relevance)

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,

emissions of volatile organic compounds due to the use of organic solvents in certain activities and installations (?), Directive 2000/76/EC of the European Parliament and of the Council of 4 December 2000 on the incineration of

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EU Commission is the driving force

EU Commission is **ordering** CEN to write the standards;

by placing an order EU Commission is **mandating** the standards.

EU Commission write into the Directives, that existing standards must be used.

EU Commission pays for the validation test

A major difference to ISO standards.

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Dust standard: EN 13.284

Driven by the new dust monitor technology, one of the first European environmental standards developed for stationary sources was EN13284-1 and -2 for dust monitoring.

(This standard is right now under revision)

It has 2 parts:

1. How to make a proper manual gravimetric measurement at low concentrations.
   (~ VDI2066 Blatt 1)
2. How to calibrate a dust monitor at low concentrations.
   (~ VDI2066 Blatt 4)

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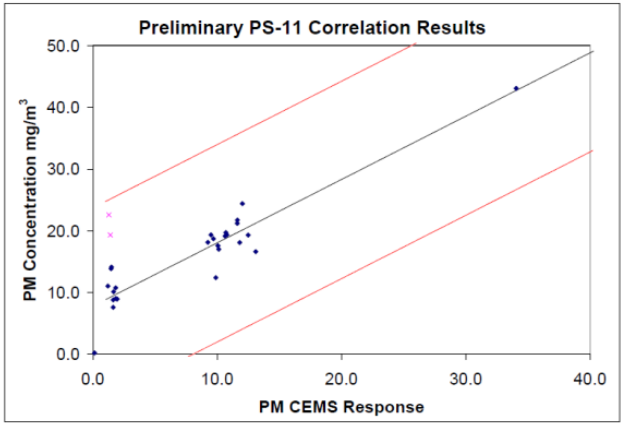
Semi volatiles : EN 13.284-2

With this standard did Europe taken another way, than USA/EPA in the treatment of "Semi volatiles" or "Condensables" like NH_4Cl or $(NH_4)_2SO_4$

- EPA Method 202 states that condensable particulate matter (CPM) shall be measured as PM.

- EN13.284-2 is focussed upon calibrating what the dust monitor sees:
  - If they has particle form, where the monitor is, it must be measured by the gravimetric method.
  - If they has gas form, where the monitor is, it must not be measured by the gravimetric method.



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QA/QC : EN 14.181

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In the years 1999-2004 was EN 14181 developed, dealing with QA/QC of monitors.

One of the major (and widely underestimated) news was the so called QAL1 procedure:

> The obligation to estimated the total measurement uncertainty of a projected monitor before it is even bought.

It is based upon EN/ISO 14.956, which is a purely mathematical standard.

When EN14181 was published, it missed input data for the instruments.

Certification : EN 15.267

This standard, developed in the years 2002-2008, should secure, that instruments used for reporting to the EU Regulation **was of a minimum quality through type testing and QA/QC requirements on instrument manufacturers based upon ISO 9001:2000.**

This standard also gave input to QAL1 calculation:

1. the instruments intrinsic uncertainty and
2. introduced so-called “influence parameters”

Item 2 is allowing the plant owner to estimate the total uncertainty from the instrument itself and from uncontrolled outside influences, like temperature, air pressure, variations in voltage, etc.

TÜV/MCERT - EN 15.267-3

EN 15267-3 prescribes a European (International) type test of instruments, resulting in

1. a test report containing the most important measurement range and uncertainty data for the instrument and
2. a certificate certifying, that all subsequent instruments are manufactured with proper QA/QC.

This testing has traditionally been done by TÜV with reference to VDI standards, but during 1980's and 1990's, UK manufacturers realized that instruments with a TÜV certificate had an increasing marketing advantage outside Europe, and consequently UK formed its own MCERT-scheme.

In the early 2000's did TÜV and MCERT sign an agreement to honour each others tests.

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USA

In **USA**, the present situation is that EPA has for many years concentrated on opacity, i.e. how visible is the plume of smoke to the public.

These instruments were transmissiometers (like RM41), but “calibration” was done subjectively, i.e. by inspectors according to Method 9.

The instruments however were very carefully defined in PS01 for opacity above 10% and by ASTM 6215 from 1998 for opacity below 10%.

	ASTM D 6215 - 1998	CPS-001
Specification	**Requirements**	**Requirements**
Spectral response	Peak and mean spectral response between 500 and 600 nm; less than 10% of peak response below 400 nm and above 700 nm	LED light source
Angle of view Angle of projection	=<4º for all radiation above 2,5% of peak radiation	Lightbeam must allow for small thermal and wind movements
Sensitivity to voltage variations	±1,0% opacity for ±10% of nominal voltage supply change; or as specified.	±0,2% opacity for ±10% of nominal voltage supply change; or as specified.
Thermal stability	<±2,0% opacity change per 40ºF (22K) over spec. Operation range	<±0,3% opacity change per 40ºF (22K) over spec. Operation range
Sensitivity to ambient light	<±2,0% opacity change from sunrise to sunset with at least 1 h above 900 W/m² radiation level.	<±0,2% opacity change from sunrise to sunset with at least 1 h above 900 W/m² radiation level. Flanges and tubes painted white.
External audit filter access	Required	Required
External zero-device optional	Repeatability <±1,0% opacity	Repeatability <±1,0% opacity
Automated calibration checks	Check of all active analyser optics with power or curvature all active electronic circuitry including light source and photodetector assembly, and electro- or electromechanical systems used during normal measurement operation.	
Zero check divice (simulated)	Check by 90% to 190% of "clear path received energy"	
Upscale calibration check (CEN: Span point check)	Check from 10% opacity to the highest opacity used in the calibration check.	
Status indicators	To be specified by manufacturer, but note 21 in §6.10 suggests alarms for "lamp failure", "purge air failure", "excessive zero or span point fault" and "excessive contamination compensation"	
Path length correction factor security	To be specified by manufacturer which of the 3 methods are used.	
Measurement output resolution	<0,5% opacity from -5% to 50% opacity	<0,1% opacity from -4% to 20% opacity
Measurement and recording frequency	=< 10 s sampling and analyzing time. Calculate averages from at least 6 samples per minute	
Response time	=< 10 s to 95% of end value	
Calibration error	=<3% opacity for: absolute value of mean difference plus 95% confidence coefficient for each of the 3 terst filters	=<0,3% opacity for: absolute value of mean difference plus 95% confidence coefficient for each of the 3 terst filters
Optical alignment indicator (Uniformity of light beam and detector)	Clear indication of misalignment at or before the point, where opacity changes ±2% due to misalignment, as system is misaligned both linearly and rotationally in horisontal and vertical planes.	Clear indication of misalignment at or before the point, where opacity changes ±0,5% due to misalignment, as system is misaligned both linearly and rotationally in horisontal and vertical planes.
Calibration device repeatability	=<1,5% opacity	

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USA – EPA validation.

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In mid-1990's EPA accepted calibration of dust monitors in concentration as mg/m^3 with PS -011

- PS-011 is a major change in EPA philosophy and a break through for the European way of thinking
- PS-011 is in philosophy very close to EN14181, but terminology and structure is very different.
- Major difference is that EN-standards are written as a tight structured "law text" with explanatory notes, while EPA text is often structured as question and answers.

9.2 How do I know if I have acceptable QC procedures for my PM CEMS? Your QC procedures are inadequate or your PM CEMS is incapable of providing quality data if you fail two consecutive QC audits (*i.e.*, out-of-control conditions resulting from the annual audits, quarterly audits, or daily checks). Therefore, if you fail the

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USA – EPA validation.

EPA accepted calibration of dust monitors with PS -011

PS-011 is emphasising the need for non-linear calibration curves, due to the particle size problem, and allows:

1. Linear calibration curves $y=ax+b$
2. Logarithmic calibration curves $y=e^{ax+b}+c$
3. Polynomial calibration curves $y=\ldots dx^3+cx^2+bx+a$
4. Power calibration curves $Y=a^x+b$

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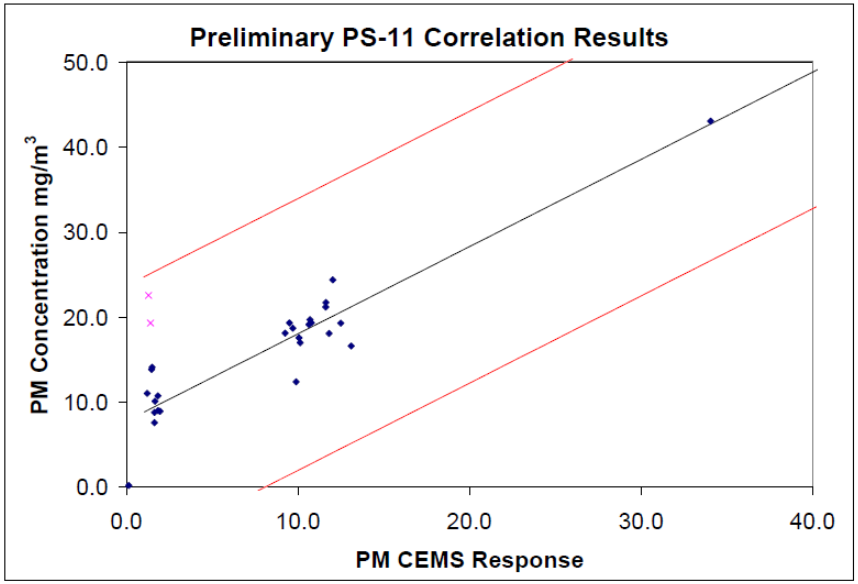
USA – EPA validation.

- EPA has no specifications on calibrated dust-monitors.
- EPA-rules allow you to install anything in the stack, as long as it can be calibrated according to PS-011.

- EPA-rule CPS-202 specify that condensables must be counted as particles, and consequently be included in the calibration curve; this is different from EN13284-2.
- This is from Killen Power Station, Kentucky, USA, and the condensables were $(NH_4)_2SO_4$



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USA – EPA validation.

USA – EPA has a serie of test and control requirements similar to EN14181, all specified in *40 CFR Part 60 Amendments to Standards of Performance for New Stationary Sources; Monitoring Requirements; Final Rule:*

3.1 **"Absolute Correlation Audit (ACA)"** means an evaluation of your PM CEMS response to a series of referencestandards covering the full measurement range of the instrument (e.g., 4 mA to 20 mA)

~ EN 14181 QAL3

3.2 "**Correlation Range**" means the range of PM CEMS responses used in the complete set of correlation test data

~ EN 14181 valid calibration range

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USA – EPA validation.

USA – EPA has a serie of test and control requirements similar to EN14181, all specified in *40 CFR Part 60 Amendments to Standards of Performance for New Stationary Sources; Monitoring Requirements; Final Rule:*

3.3 … The PM CEMS correlation is **expressed in the same units as the PM concentration** measured by your PM CEMS (e.g., mg/acm).

Same requirement as in EN 14181

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USA – EPA validation.

USA – EPA has a serie of test and control requirements similar to EN14181, all specified in *40 CFR Part 60 Amendments to Standards of Performance for New Stationary Sources; Monitoring Requirements; Final Rule:*

3.5 ‘‘**Response Correlation Audit (RCA)**’’ means the series of tests specified in section 10.3(8) of this procedure that you conduct to ensure the continued validity of your PM CEMS correlation.

~ EN 14181 QAL2

3.6 ‘‘**Relative Response Audit (RRA)**’’ means the brief series of tests specified in section 10.3(6) of this procedure that you conduct between consecutive RCAs to ensure the continued validity of your PM CEMS correlation.

~ EN 14181 AST

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USA – EPA validation.

USA – EPA has a series of test and control requirements similar to EN14181, all specified in *40 CFR Part 60 Amendments to Standards of Performance for New Stationary Sources; Monitoring Requirements; Final Rule:*

3.7 ‘‘**Sample Volume Audit (SVA)**’’ means an evaluation of your PM CEMS measurement of sample volume if your PM CEMS determines PM concentration based on a measure of PM mass in an extracted sample volume and an independent determination of sample volume.

This is **not specifically covered en EN14181**, because it is considered part of the QAL2/AST.

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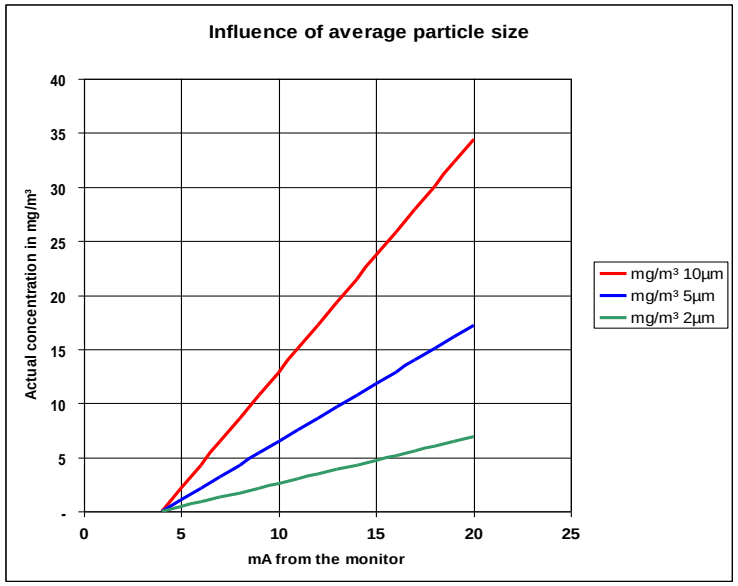
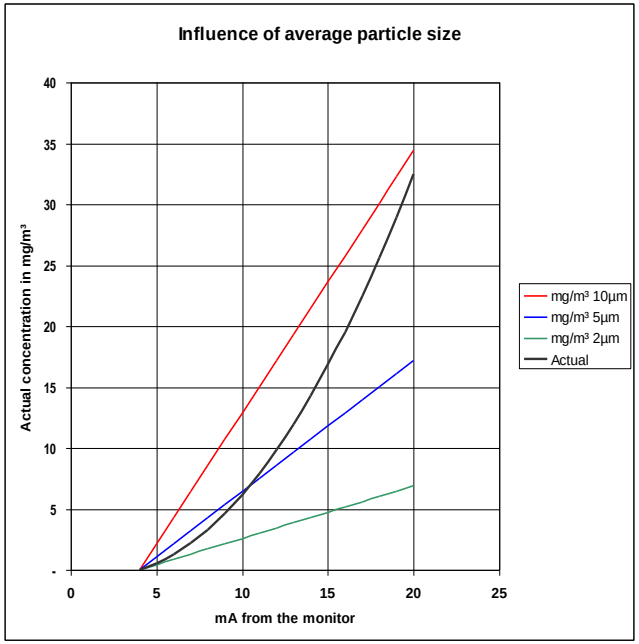
A step child : Particle size.

This is another problem, which is <u>not clearly dealt with</u> in the standards is the influence from average particle size.





This means that the requirement from EN 14.181 for a linear calibration line <u>is not always possible.</u>
Dealt with in EN 13.284-2 and in EPA PS-011 which allows non-linear calibration functions

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Summery

Europa – EU requirements:

1. Opacity hardly used in Europe.
2. QA/QC requirements on manufacturers of Dust Monitors.
3. Type testing and certification of Dust monitors.
4. Mandatory pre-installation uncertainty budget, QAL1.
5. Mandatory initial QAL2 calibration with maximum data scatter.

USA - EPA

1. Opacity still used. Method 9 with inspector control.
2. No such requirements
3. No such requirements.
4. No such requirements.
5. Response Correlation Audit (RCA) mandatory PS-11/CPS202 with maximum data scatter and requirements to R^2.

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Summery

Europa – EU requirements:

1. Mandatory on-going QA procedure – EN 14181 QAL3 manual or automatic at maintenance intervals.
2. Mandatory yearly calibration checks – EN14181 AST
3. Semi volatiles only counts as particles, if they are in solid form at the monitoring point.

USA - EPA

1. Absolute Correlation Audit (ACA) each quarter, at the frequency specified in the applicable regulation or facility operating permit.
2. Relative Response Audit (RRA), at the frequency specified in the applicable regulation or facility operating permit.
3. Condensables are always counted as particulate matter

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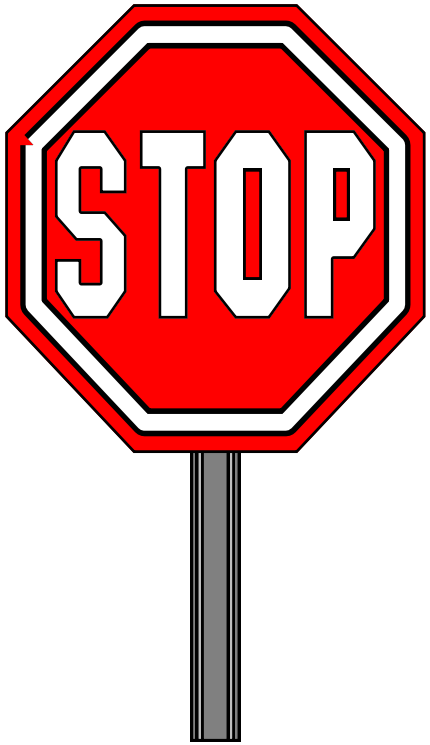

We covered validation of instruments and validation of measurements in Europe and USA.

Questions?

14:00	International comparison of validation methods for dust concentration measurement	Mr. Angelo, M.Sc.E.E., M.B.A. Consulting Engineer,