

Calibration of Light Scatter PM-CEMs to Satisfy PS-11 on Wet Stacks in Coal Fired EGUs

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Overview of Particulate Monitoring Experiences on Wet FGD EGU Sources

- Drivers for PM monitoring of Electric Generating Units
- MATS Rule PM compliance options for wet FGD sources
- Optical PM CEM for wet FGD (PCME STACK 181WS)
- Typical wet FGD EGU plant configuration
- FGD effect on particle size
- Experiences with generating PS-11 correlations on extractive optical PM CEMS on US EGU wet FGD plants
- Possible alternatives to PS-11 correlation testing
- Summary and conclusions

Regulatory Drivers for PM Monitoring of EGU Sources

- Consent decrees with federal, state or local regulators for compliance with particulate emission limits
- Compliance Assurance Monitoring to fulfill Clean Air Act (CAA) Title V requirements
- In the case of wet FGD EGU stacks, relief from state and local opacity limits and associated reporting, since wet FGD are also particulate removal devices
- Compliance with particulate emission limits in the Mercury Air Toxics Standards (MATS) rule
 - PM limit for existing bituminous coal fired EGU's
 - 0.03 lbs/mmBTU (26 mg/Am³ at wet basis CO₂ of 11%, a stack temperature of 130 degrees F)

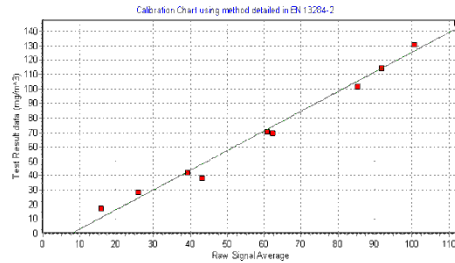
MATS PM Compliance Options for Wet FGD Sources

- Quarterly reference method testing using metals or filterable particulate mass methods
- Installation and certification of a PM CEMS according to 40CFR60 Appendix B PS-11 and quality assurance as per Appendix F Procedure 2
- Installation and operation of a PM CPMS (Particulate Mass Continuous Parametric Monitoring System) and determination of an operating limit

PS-11 & Procedure 2 Approach

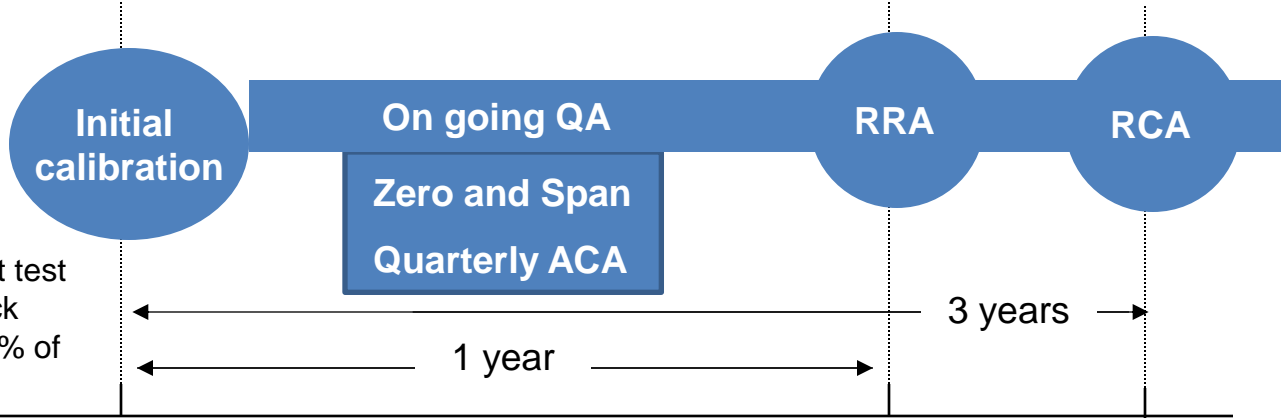
Note that due to Feb 2014 change to PS-11, Calibration Drift is now assessed versus **Range** (previously was versus Upscale Reference).

PS-11 Correlation Test



RRA:
(Relative Response Audit)
3 Run Calibration check

RCA:
(Relative Correlation Audit)
12 Run Calibration check



Time →

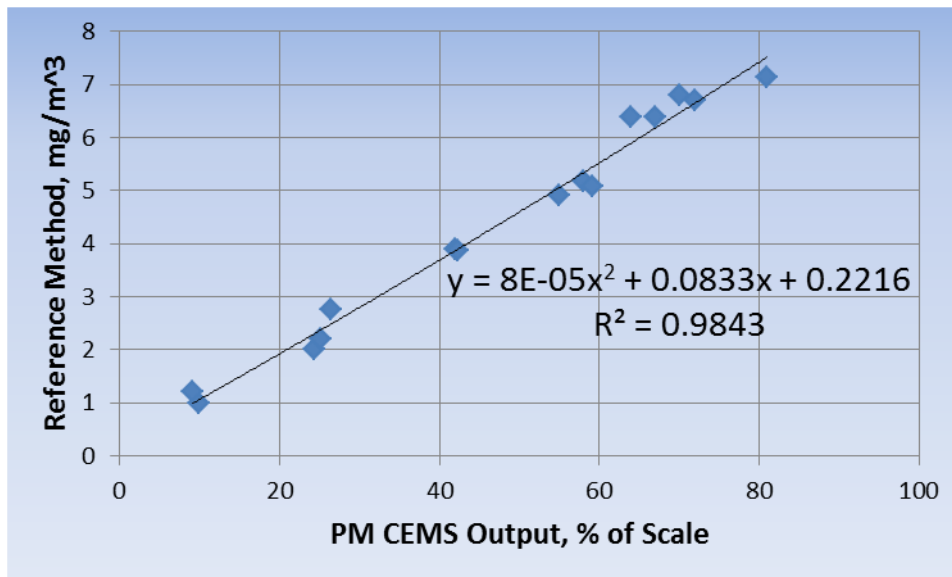
← PS-11 →

← Procedure 2 →

PS-11 Correlation Test

- Minimum of 15 runs in 3 bins (0 to 50%, 25% to 75%, 50% to 100% of maximum RM value of PM). Achieving high PM levels is often a problem.
 - Wet scrubber and bag house sources w/o bypass have difficulty elevating emissions
 - Post control device injection of PM ash collected by controls is often used (spiking)
 - PS-11 does allow use of zero point data from the PM CEMS in lieu of the 3 bins
- Acceptance criteria
 - Correlation Coefficient ≤ 0.85
 - Confidence Coefficient $\leq 10\%$ of emission limit
 - Tolerance Interval $\leq 25\%$ of emission limit

X = PM CEMS, %	Y = RM, mg/m ³
10	1
9.2	1.2
24.3	2
25.2	2.21

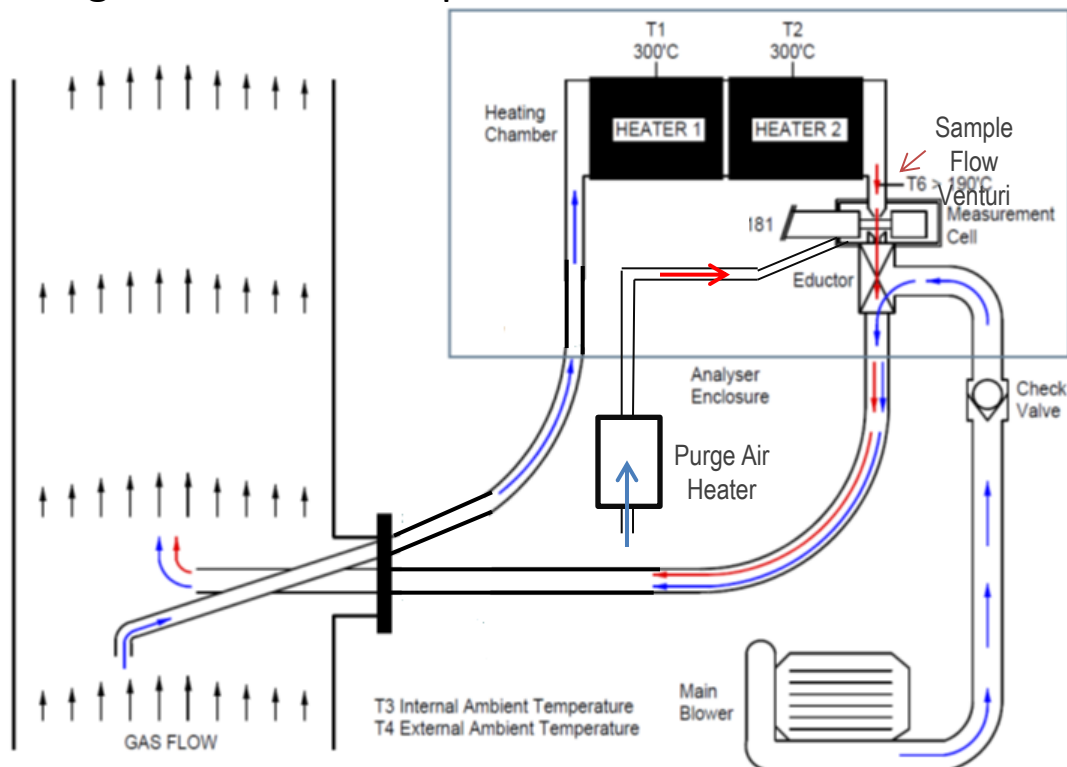


Model Types
Linear
2 nd Order Polynomial
Logarithmic
Exponential
Power

STACK 181WS PM CEM / CPMS

Measurement Concept

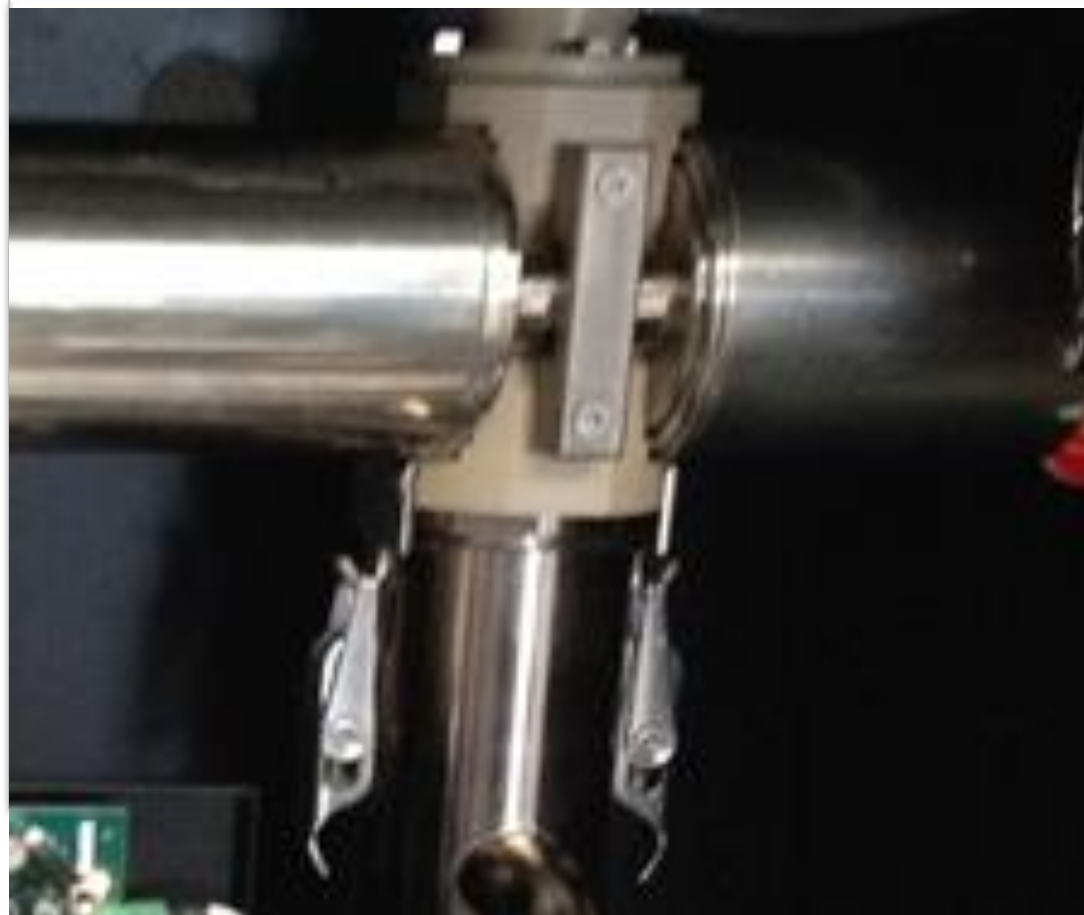
1. Extract wet flue gas at appropriate velocity (can sample at fixed or variable velocity)
2. Change liquid content into gas phase
3. Measure dust concentration with light scatter technique
4. Return sample back to stack



STACK 181WS Improvements

- Purged Sample Chamber (PSC)

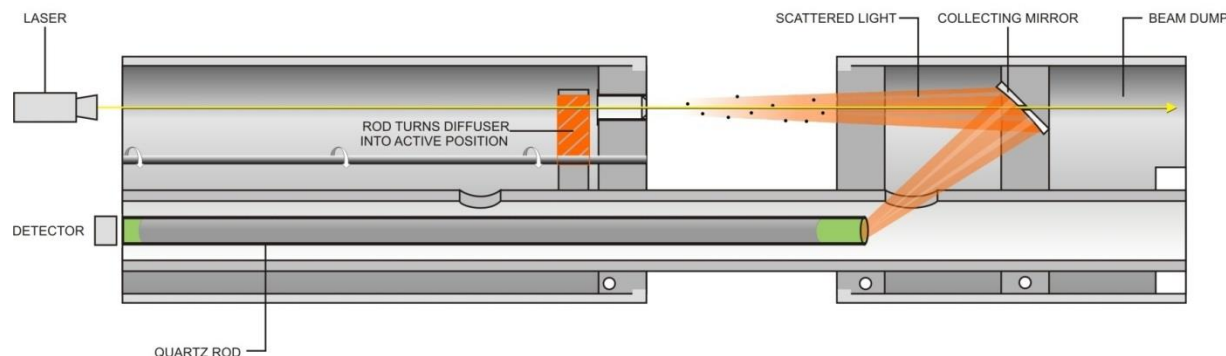
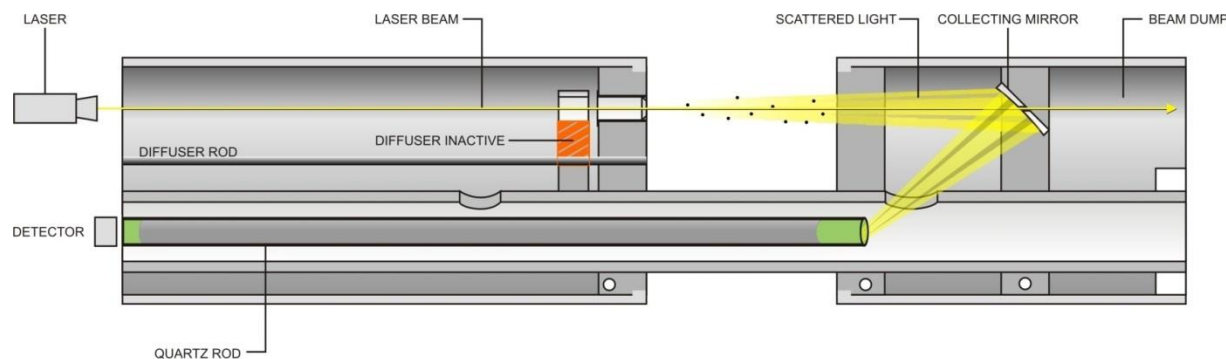
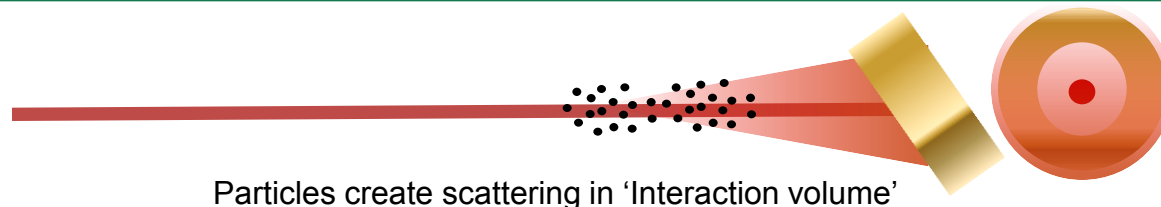
- Improves maintenance interval, reduces cost of ownership by
 - Reducing sample chamber dead spaces where contamination can accumulate
 - Heating purge air preventing formation of condensation on optics
- Currently installed at several US Electrical Utility stacks with excellent results



181 ProScatter™

Forward Scatter Technology

- Conical mirror improves light collection by gathering full cone of scattered light.
- Narrow forward scatter angle minimizes effect of changing particle size.
- While the calibration is still sensitive to changes in particle size, ProScatter has reduced sensitivity compared to designs using angles further from angle of incidence.
- Span check is provided by introducing a scatter body in light path.



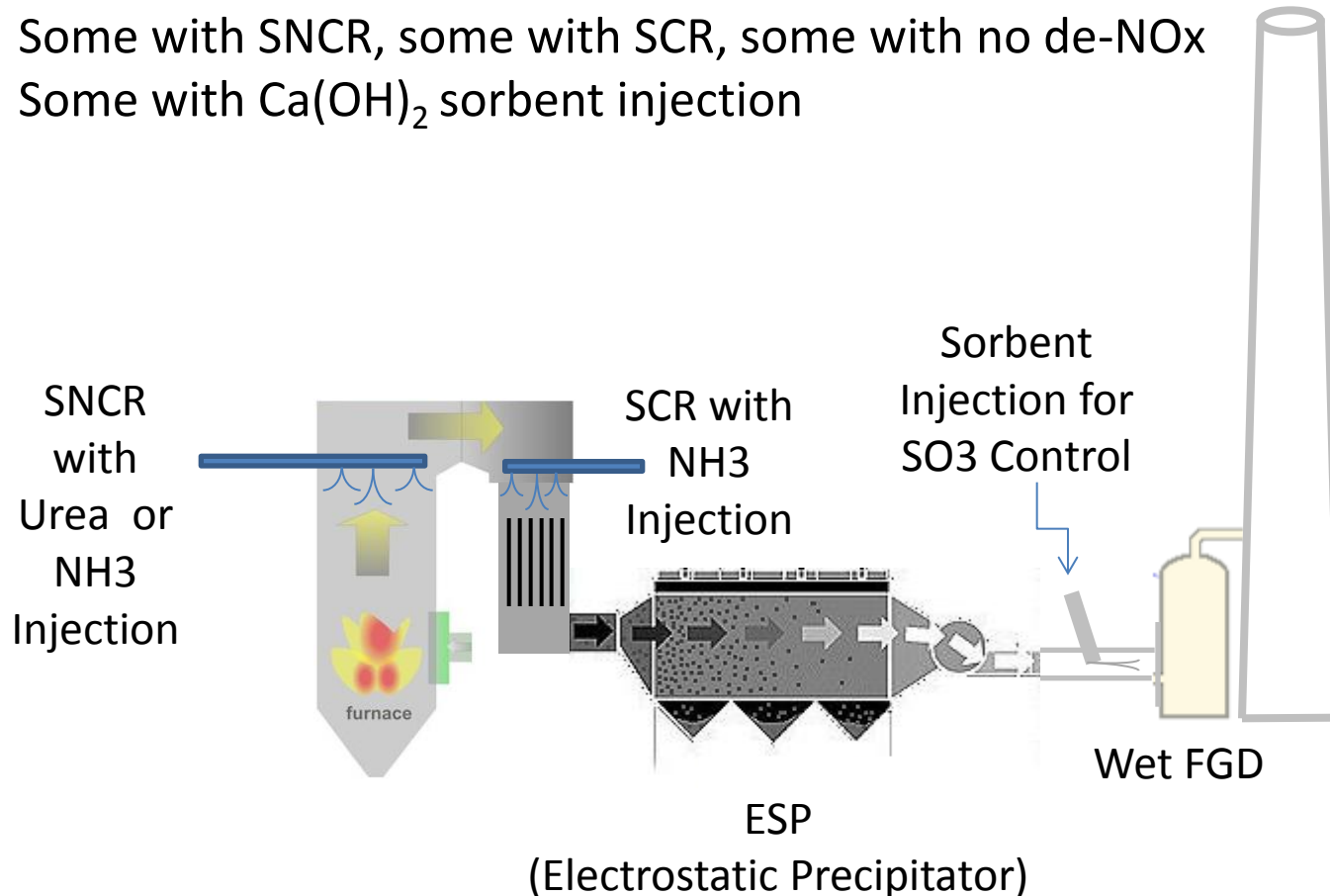
Audit Filters for ACA Test

- Audit filters can be inserted in optical path of STACK 181WS sensor without removing the sensor from sample chamber.
- These audit filters create a controlled amount of light scatter that corresponds to a known particulate reading from the sensor.
- Audit filters can be used as quarterly audit materials for the Absolute Correlation Audit requirements in Appendix F Procedure 2.



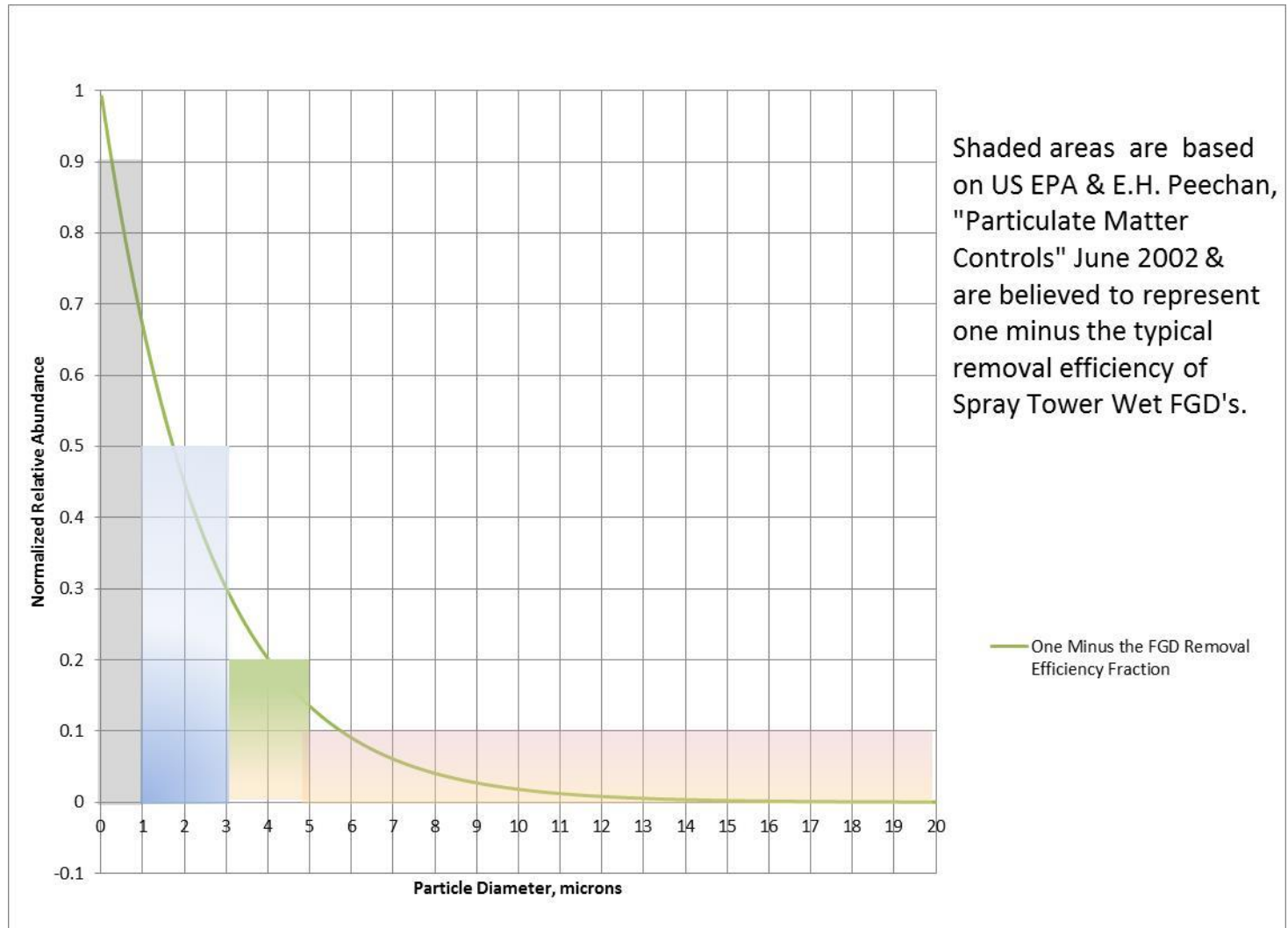
EGU Wet FGD Plant Abatement Processes

- PM CEM's have been installed on many US EGU wet stacks after various abatement processes
 - Wet FGD and ESP with occasional bag house in place of ESP
 - Some with SNCR, some with SCR, some with no de-NO_x
 - Some with Ca(OH)₂ sorbent injection



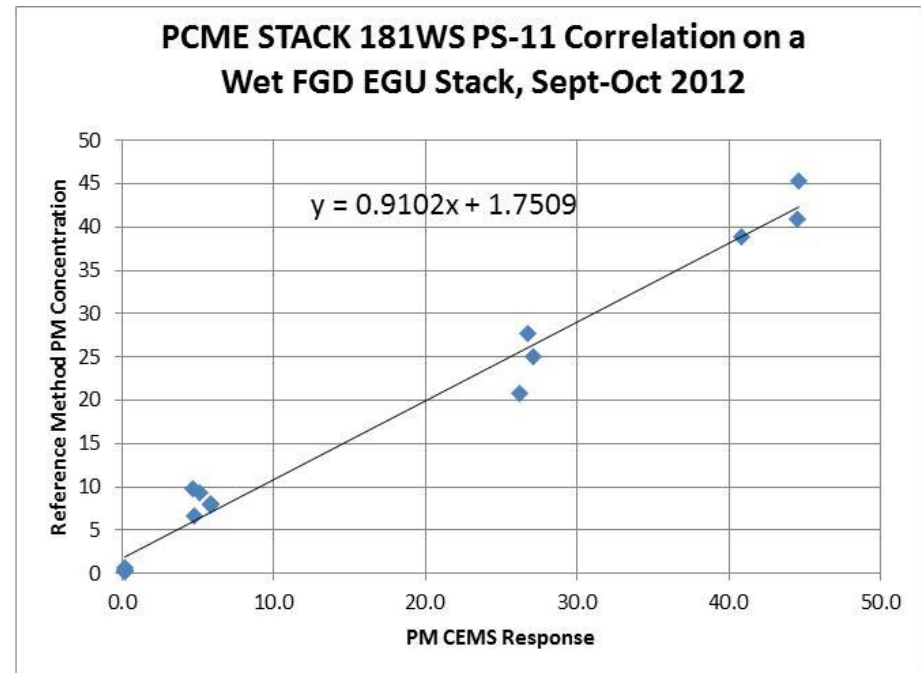
Effect of Wet FGD on Particle Size

- Wet Spray Tower FGD's (common in US EGU's) generally remove large, high mass particles very well but are not efficient at removing small particles.



One STACK 181WS PS-11 Correlation Test

- Plant configuration:
 - Bituminous coal fuel
 - Precipitator
 - Wet FGD
 - No SCR, SNCR, SO3 control
- PS-11 correlation test passed with MATS rule limits



Model	Correlation coefficient	≥ 0.85 ?	Confidence interval %	$\leq 10\%$?	Tolerance interval %	$\leq 25\%$?	Does model meet all criteria?
Linear (best model)	0.989	Yes	7.30%	Yes	23.0%	Yes	Yes
Polynomial	0.988	Yes	9.30%	Yes	24.7%	Yes	Yes
Logarithmic	0.852	Yes	25.75%	No	81.2%	No	No
Exponential	0.769	No	24.99%	No	146.8%	No	No
Power	0.980	Yes	7.32%	Yes	24.8%	Yes	Yes

Two STACK 181WS PS-11 Correlation Tests

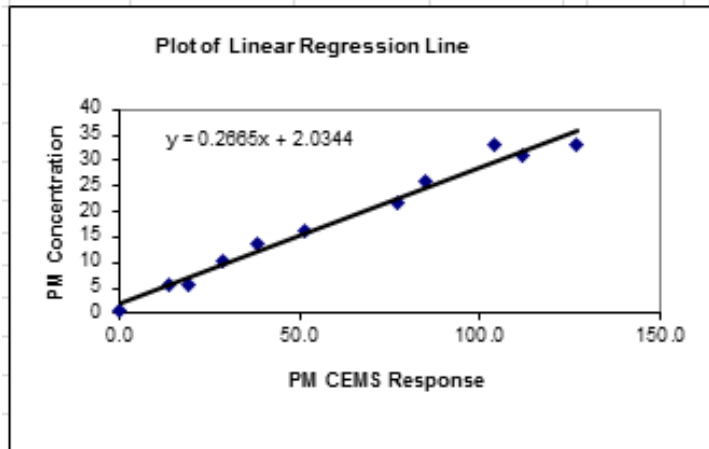
- Upscale particulate achieved by detuning plant (removing precipitator banks, turning off FGD pumps)
- Reference was MATS Method 5 (160° C filter temperature)

Correlation equation: $y = 2.034 + 0.266 x$

Summary of Acceptance Criteria for PS-11

Criterion	Actual	Allowable	Acceptable?
Correlation coefficient	0.987	≥ 0.85	yes
Confidence interval	6.35%	$\leq 10\%$	yes
Tolerance interval	18.3%	$\leq 25\%$	yes

* Indicates correlation coefficient is undefined.

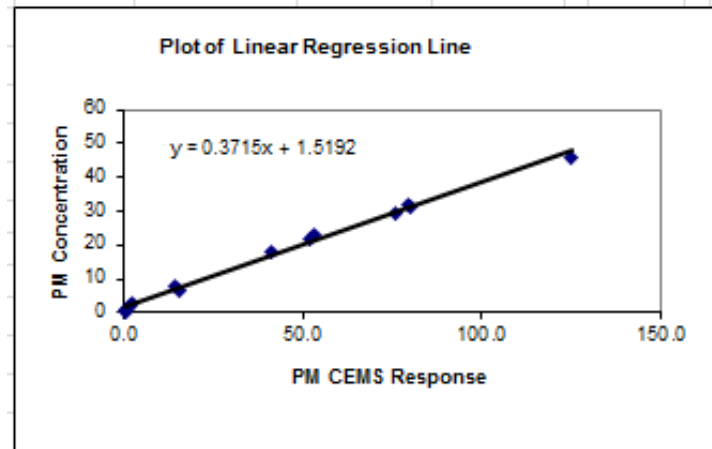


Correlation equation: $y = 1.519 + 0.371 x$

Summary of Acceptance Criteria for PS-11

Criterion	Actual	Allowable	Acceptable?
Correlation coefficient	0.997	≥ 0.85	yes
Confidence interval	3.57%	$\leq 10\%$	yes
Tolerance interval	11.3%	$\leq 25\%$	yes

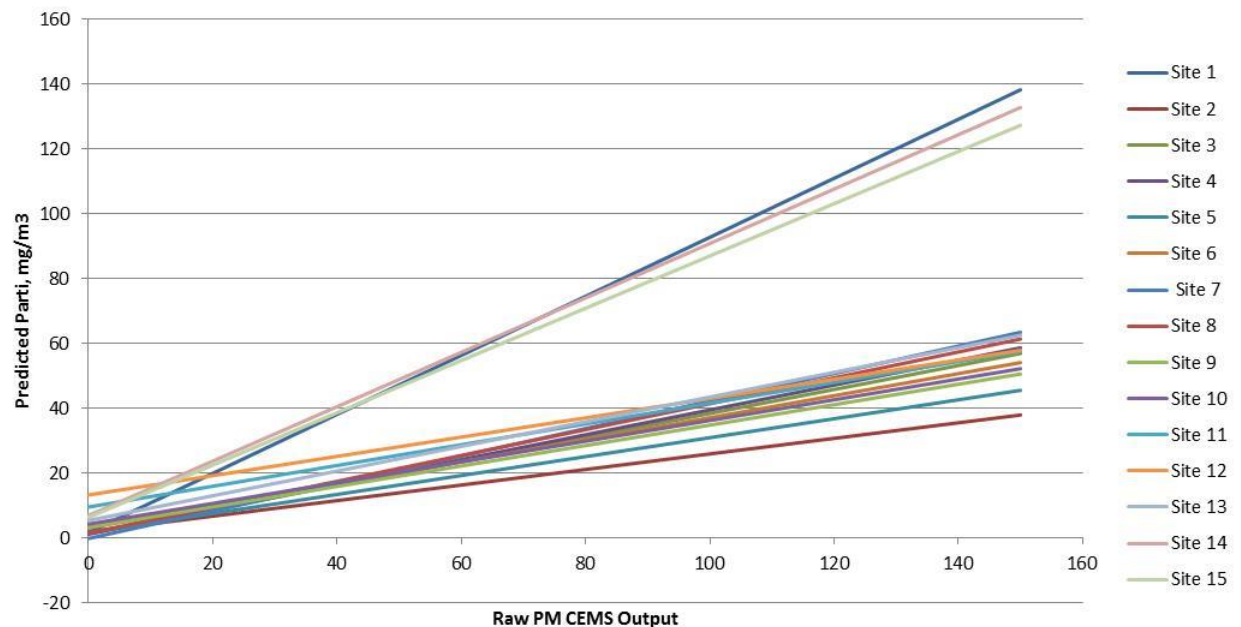
* Indicates correlation coefficient is undefined.



Variability in PS-11 Correlation Test Slopes at Fifteen STACK 181WS Sites

PS-11 Correlation Curve Coefficients															
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12	Site 13	Site 14	Site 15
b0	1.751	1.945	1.416	1.211	1.758	3.11	-0.146	1.528	3.30	4.29	9.59	13.30	5.43	6.95	6.41
b1	0.910	0.24	0.37	0.383	0.292	0.34	0.424	0.399	0.315	0.32	0.32	0.30	0.38	0.84	0.81
b2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

**PCME STACK 181WS PS-11 Correlation Test Slopes from US EGU
Wet FGD Sources, Circa 2012 to 2014**



- Plant configurations
 - All had Wet FGD & Precipitator; many other differences
- Slopes clustered in two groups
 - 0.24 to 0.42
 - 0.81 to 0.91
- Why the difference?
 - May be due to particle size dissimilarity from various but constant plant configurations

Possible Alternatives to PS-11 Correlation Testing for PM CEMS Calibration

- **PM CPMS** (PM Continuous Parametric Monitoring System)
 - Popular in PC MACT but more restrictive implementation for existing EGU sources has not gained favor in power industry
 - Existing EGU's must use highest PM CPMS 1 hour average from 3 run performance test as Operating Limit instead of (as in PC MACT or for new EGU) interpolating up to 75% of emission limit
- **Quantitative Aerosol Generator (QAG)**
 - NIST traceable aerosol generator that injects known particle size distribution and mass into PM CEMS
 - Currently under test by Cooper Environmental & EPRI in coordination with various PM CEMS vendors

Summary

- Optical PM CEMS such as PCME STACK 181WS can be applied to wet FDG stacks for meeting environmental compliance requirements from
 - Consent decrees with federal, state or local regulators
 - CAA Title V CAM plans
 - MATS rule PM limits
- PM CEMS may also allow wet FGD EGU to gain relief from inlet opacity reporting requirements if local and state regulatory authorities are agreeable to the idea.
- PM CPMS relieves source from difficulty of elevating PM levels for PS-11 correlation test but Operating Limit determination for existing EGU sources is more restrictive than with MACT's for other industries
- Work with other PS-11 alternatives like the QAG is ongoing but not an option for EGU sources yet

PCME's background in PM monitoring

- Specialist supplier of PM monitors (30,000 to industrial processes across 6 continents)
- Core technologies
 - Light scatter
 - Electrodynamic
 - Scintillation
- Recently expanded US based service and support capability

