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PM CEMS: PS11 and Field Experience

CEMTEK User Group Seminar

September 28-29, 2016

Agenda

- Brief History of PM CEMS
  - Usage
  - Technology Overview
- Overview of PS-11 and CPMS
  - PS-11
  - PM CPMS
- Field Experience
- Lessons Learned
- Success Stories
- Questions

PM CEMs: Technology and History

PM CEM History

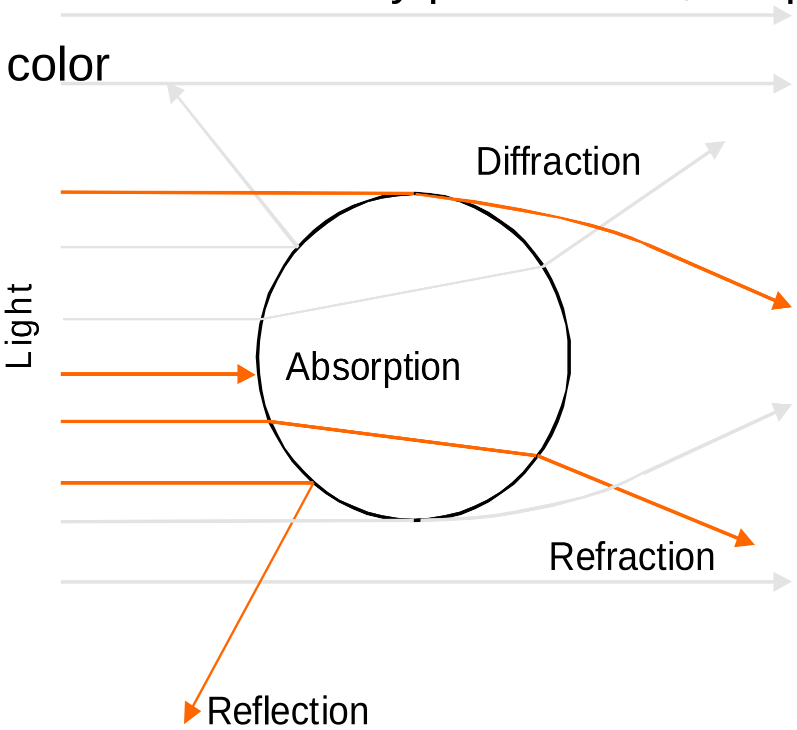
- Optical devices have been used for the determination of PM since the 1950's.
  - Opacity
- Opacity monitors are good for PM levels above 5% opacity.
  - Based on visible emissions
  - Human eye can only detect > 5%
- The EU has been using scatter light and other PM techniques for nearly 20 years.
  - More sensitive to lower PM levels
- PM CEMs started to be used in the US in the mid-2000's
  - Consent Decrees
  - Mainly large coal-fired Power Boilers
- Today:
  - Over 300 PM CEM's installed and certified to PS-11 in the US
    - Beta Gauge and scatter light.

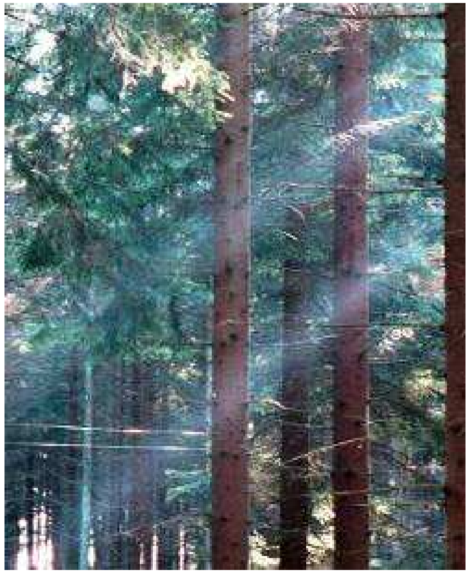
Technology - Beta Gauge

- Beta-Attenuation
  - Beta radiation measured through dust laden tape
  - Nuclear source
- Dilution-Extractive
- Dry or Wet stack applications
- Batch Sampling
  - 716sec / cycle - 4 measurements / hour
- Sample umbilical up to 150 ft.
  - May require shelter
- Several PS-11 Installations

Technology – Scatter Light

- Optical principle
- When light hits the particle, it is scattered
- Relation between the scattered light intensity and dust concentration
- Results affected by particle size, shape and color





Technology – Forward Scatter Light

- Forward - Light Scatter
- -Less sensitive to particle size changes

- Over isokinetic Sampling
  - No flow measurement input needed

- Wet and dry stacks
- Integrated zero and span for daily QA/QC
- Single sided installation

Technology - Backward Scatter Light

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- Backward - Light Scatter
  - More effected by particle size
- In-situ
  - Single sided installation
- Dry stack only
- Few known PS-11 Installations
- Limited to one penetration Depth
  - Can not do traverse large annular space

Technology – Forward vs. Backward Scatter

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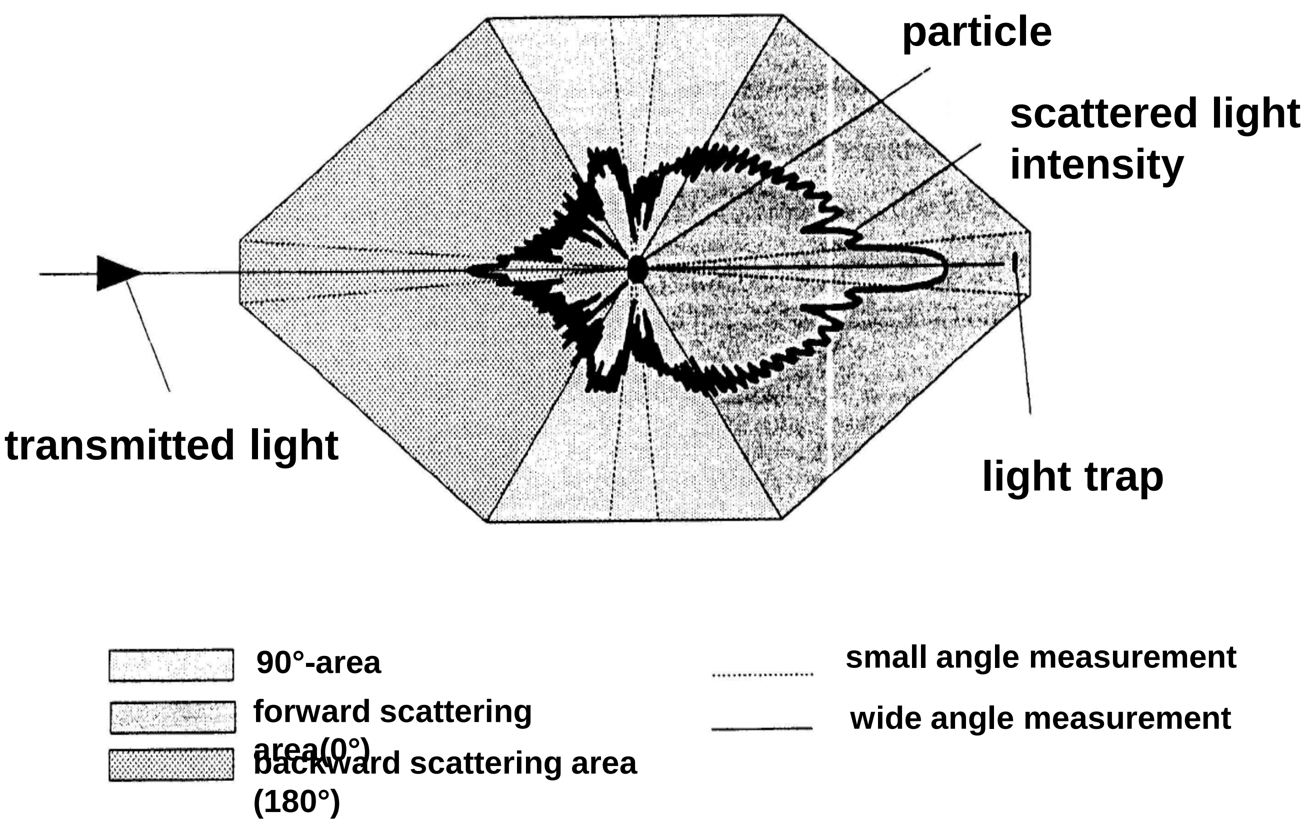

"Fortschritt-Berichte VDI" Reihe 8, Nr. 773, Düsseldorf: VDI Verlag 1999

Technology – Forward vs. Backward Scatter

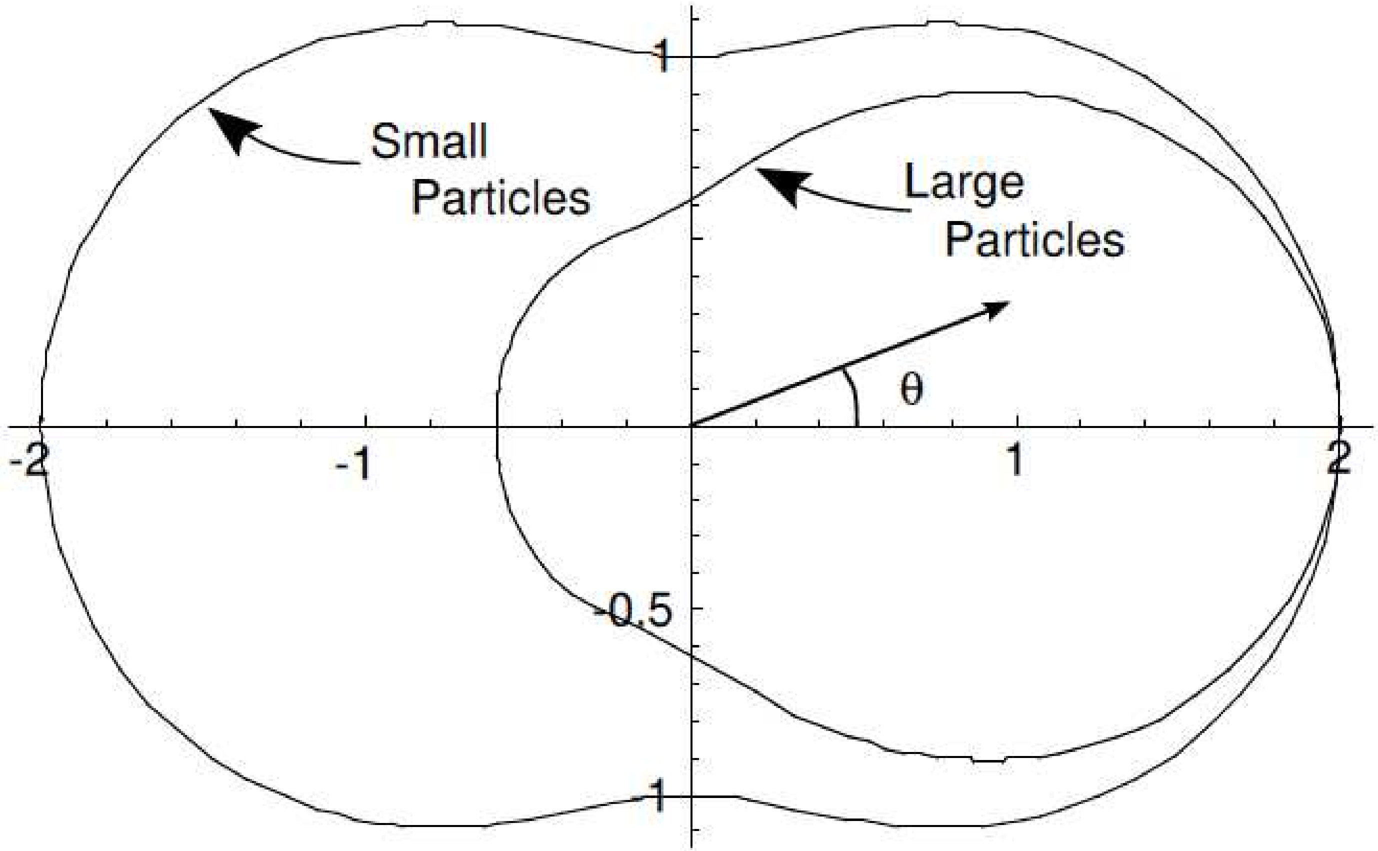

Figure 7.7: Scattering diagrams for both small particles and large particles.

Typical Particle Size Distribution

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MALVERN INSTRUMENTS MASTERSIZER

Result: Histogram Report

Sample Details

Sample ID: Sample A
Sample File [redacted]
Sample Path: R:\MALVER~1\
Sample Notes: Particle Technology Labs
Carrier: Water
Analyst: JK
Particle Technology Labs

Run Number: 5
Record Number: 34

Product Type
Sample A
PTL ID: 12345

Measured:
Analysed: Fri Jan 28 2011 11:45AM
Result Source: Averaged

System Details

Range Lens: 300RF mm
Presentation: 3OJD
Analysis Model: Polydisperse
Modifications: None

Beam Length: 2.40 mm
[Particle R.I. = (1.5295, 1.0000); Dispersant R.I. = 1.3300]

Sampler:

Obscuration: 12.8 %
Residual: 0.812 %

Result Statistics

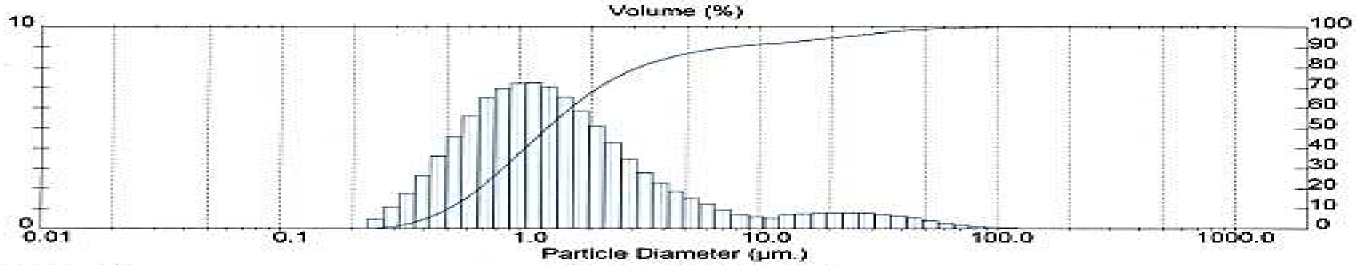
Distribution Type: Volume
Mean Diameters:
D [4, 3] = 4.06 um

Concentration = 0.0016 %Vol
D (v, 0.1) = 0.50 um
D [3, 2] = 1.06 um

Density = 1.000 g / cub. cm
D (v, 0.5) = 1.30 um
Span = 5.144E+00

Specific S.A. = 5.6842 sq. m / g
D (v, 0.9) = 7.21 um
Uniformity = 2.523E+00

Size (um)	Volume Under %	Size (um)	Volume Under %	Size (um)	Volume Under %	Size (um)	Volume Under %
0.055	0.00	0.635	17.52	7.31	90.09	84.15	99.84
0.061	0.00	0.700	21.39	8.06	90.63	92.79	99.91
0.067	0.00	0.772	25.59	8.89	91.10	102.3	99.95
0.074	0.00	0.851	29.96	9.80	91.51	112.8	99.99
0.082	0.00	0.938	34.47	10.81	91.86	124.4	100.00
0.090	0.00	1.03	39.10	11.91	92.19	137.2	100.00
0.099	0.00	1.14	43.75	13.14	92.61	151.3	100.00
0.109	0.00	1.26	48.37	14.49	93.10	166.8	100.00
0.121	0.00	1.39	52.87	15.97	93.58	183.9	100.00
0.133	0.00	1.53	57.20	17.62	94.07	202.8	100.00
0.147	0.00	1.69	61.30	19.42	94.57	223.6	100.00
0.162	0.00	1.86	65.12	21.42	95.08	246.6	100.00
0.178	0.00	2.05	68.64	23.62	95.59	271.9	100.00
0.196	0.00	2.26	71.84	26.04	96.11	299.8	100.00
0.217	0.00	2.49	74.70	28.72	96.61	330.6	100.00
0.239	0.04	2.75	77.23	31.66	97.10	364.6	100.00
0.263	0.36	3.03	79.43	34.92	97.57	402.0	100.00
0.290	0.96	3.34	81.34	38.50	98.01	443.3	100.00
0.320	1.77	3.69	83.00	42.45	98.40	488.8	100.00
0.353	2.89	4.07	84.46	46.81	98.75	539.0	100.00
0.389	4.34	4.48	85.74	51.62	99.04	594.3	100.00
0.429	6.18	4.94	86.87	56.92	99.29	655.4	100.00
0.473	8.42	5.45	87.85	62.76	99.48	722.7	100.00
0.522	11.05	6.01	88.71	69.21	99.64	796.9	100.00
0.576	14.06	6.63	89.45	76.32	99.76	878.7	100.00



Malvern Instruments Ltd.
Malvern, UK
Tel:=+[44] (0)1684-892456 Fax:+[44] (0)1684-892789

Mastersizer S long bed Ver. 2.18
Serial Number:

31 Mar 11 08:59

PS-11 vs PM CPMS

PS-11 vs. PM CPMS

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PS-11

Initial Correlation Audit (ICA) Testing

- Pass the 7-day drift test

- PS-11 Correlation requirements
  - Conduct at least 15 reference method tests at 3 particulate mass concentrations that represent the range of unit operation – de-tune ESP to achieve higher mass loadings

  - Correlation coefficient must be >/= 0.85

  - 95% confidence interval half range must be within 10% of PM emission limit

  - Tolerance interval half range must have 95% confidence that 75% of all possible values are within 25% of the PM emission limit

PS-11 vs. PM CPMS

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Response Correlation Audit (RCA) Testing

PS-11

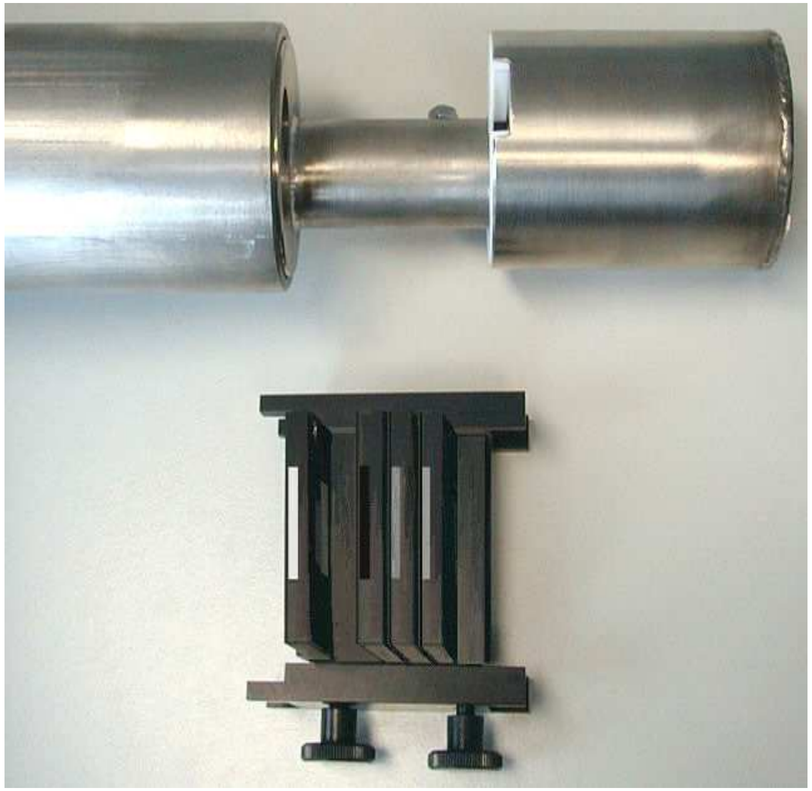
- Verify curve stability over time (every 3 years)
- Requirements
  - Conduct at least 12 reference method tests at 3 particulate mass concentrations
  - Each of the 12 runs must be less than or equal to the highest value obtained during the PS-11 testing
  - Must have 9 out of 12 inside the range of values used to create the correlation curve
  - 75% of the 12 data points must fall within two parallel lines that represent +/- 25% of the equivalent emission limit from the correlation curve

PS-11 vs. PM CPMS

Absolute Correlation Audit Testing

PS-11

- Required to be done quarterly (i.e., linearity)
- Requirements
  - Challenge the monitor 3 times at 3 audit points (i.e., 0-20%, 40-60%, 70-100%)
- Successful, if each
  - reference audit value is ≤ 10% and the equivalent emission standard ≤ 7.5%



PS-11 vs. PM CPMS

PM CPMS

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- PM emissions cam be continuously monitored using the CPMS.
  - Use an annual Method 5 gravimetric test to show compliance and compare it to the un-correlated PM CEM's output.
    - Minimum 3 runs – done annually
  - Un-correlated PM CEM output then becomes the "parametric operating limit" for the next year.
    - < 75% of the limit can use 75% as their operating limit
    - > 75% of the limit must use the average of the Method 5 testing as their limit.
  - If a source exceeds that sites specific parametric operating limit, it must conduct corrective action including performing a Method 5 or 5I performance test within 45 days.
  - If the source exceeds that parametric limit four times in a calendar year, the source is presumed to be in violation of the PM missions standard itself, subject to rebuttal by the source

- PM CEM's devices are to be used, not opacity or tribo-flow devices as they are less sensitive.

PC MACT – Scaling

- The “problem” with PM CPMS
  - Setting a limit at normal operating conditions not ideal
  - Penalizes low emitting sources
  - Still would be advisable to perform annual testing at elevated PM levels
    - Is this allowable?
- The “solution”
  - Scaling to 75%
  - Method 5 Results < 75% of the Emission Limit
  - 2 Point scaling of the emission limit
  - Forcing the curve through zero
  - Does this eliminate the need to test at elevated PM levels?

PM CPMS

PC MACT – Scaling

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PM CPMS

$$O_L = I_z + \frac{0.75(E_L)}{R}$$

- Q_L: Operating / Compliance Limit
- I_Z: PM CPMS Instruments @ Zero PM (Milliamps)
- E_L: Emissions Limit
- R: Ratio of the emissions limit per PM CEMS output during the performance test

PC MACT – Scaling

PM CPMS

$$R = \frac{(E_a)}{(I_a - I_z)}$$

- R: Ratio of the emissions limit per PM CEMS output during the performance test
-
- E_a: Average Emissions Results for the 3 compliance test runs
- I_a: Average PM CPMS output from the 3 compliance test runs
- I_Z: PM CPMS Instruments @ Zero PM (Milliamps)

PC MACT – Scaling

- Field Study of 3 PM CEM in coal fired power plants
  - Still limited data from cement plants, but for the purpose of discussion, the results can be correlated across processes.

- Nearly 6 month of raw hourly data

- Computed 30 Day rolling average for:

  - Maximum 1 hour average

  - Average results of 3 test runs

  - Scaling to 75% for new units

  - Scaling to 75% for existing units.

PM CPMS

PC MACT – Scaling

Approach Used	CPMS-1		CPMS-2		CPMS-3	
	Exceedences	Time	Exceedences	Time	Exceedences	Time
Maximum	59	42%	35	25%	32	23%
Average	71	51%	38	27%	67	48%
75% - New	18	13%	0	0%	32	23%
75% - Existing	0	0%	0	0%	0	0%

- Field study was for PS-11 applications
- PS-11 correlation was conducted on for all units
- Never exceeded PM limit, per PS-11 correlation.

PC MACT – Scaling

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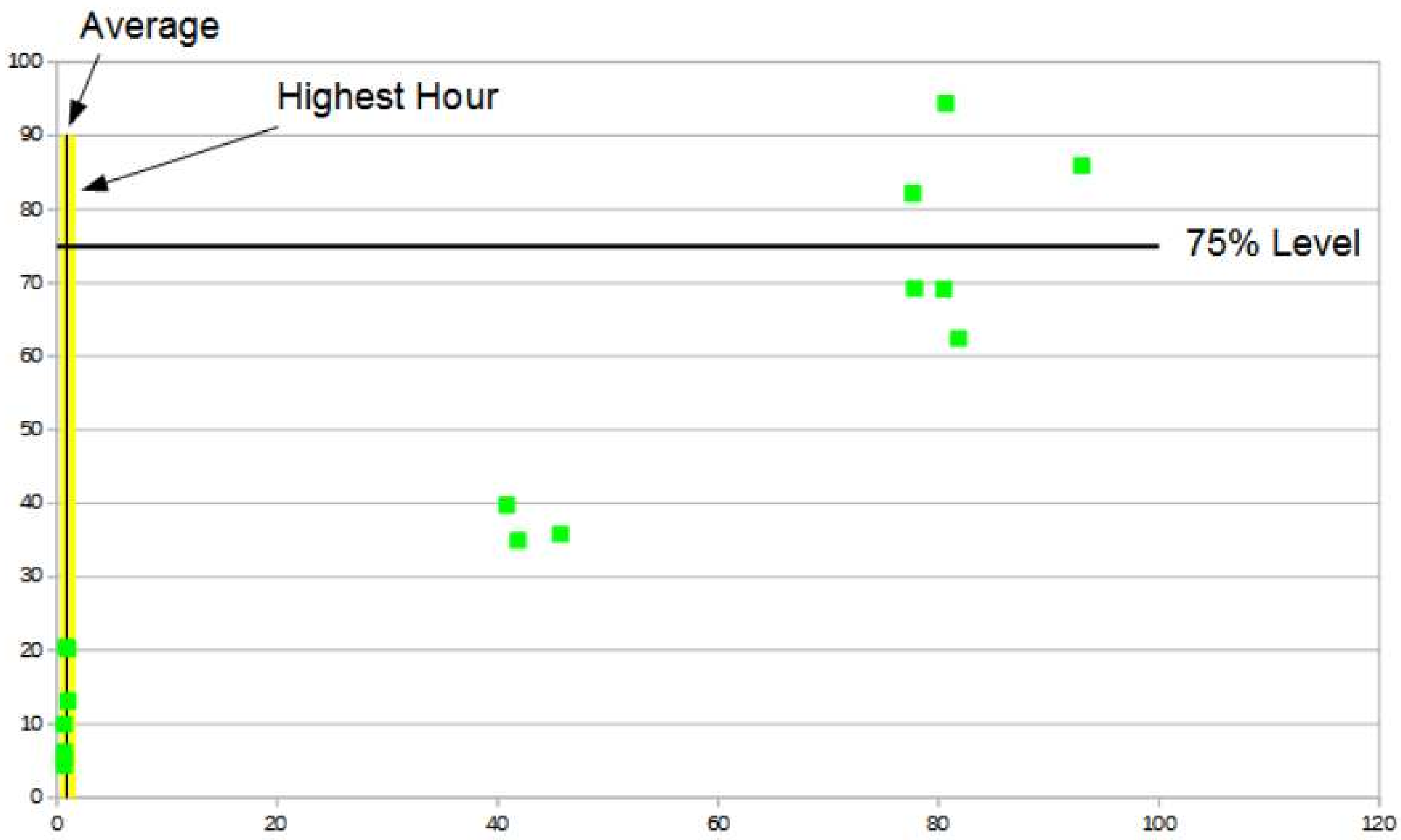
- Things to consider for PM CPMS

PM CPMS

  - PM CPMS is concentration only
    - Actually output is mA (4-20) and not easily correlated to an actual PM concentration
  - PS-11 is Mass Rate
  - Hardware is the same as PM CEM
  - New Limit is established every year.
  - Does “best practice” with CPMS eliminate the need to test at elevated PM levels?
  - Integration with DAS is critical for accurate data transfer
    - Digital vs. Analog

Look at more data



Another look at the data

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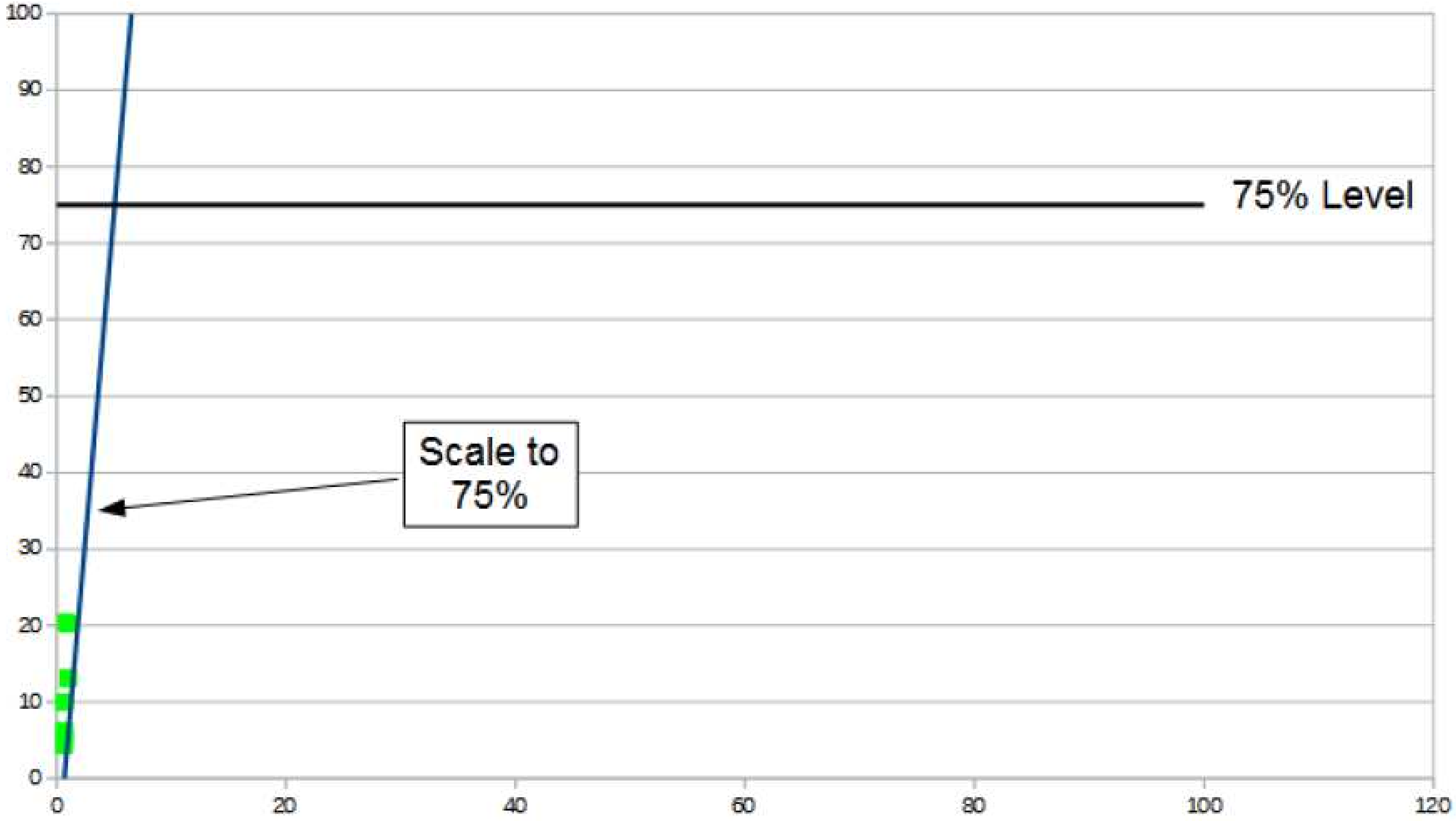
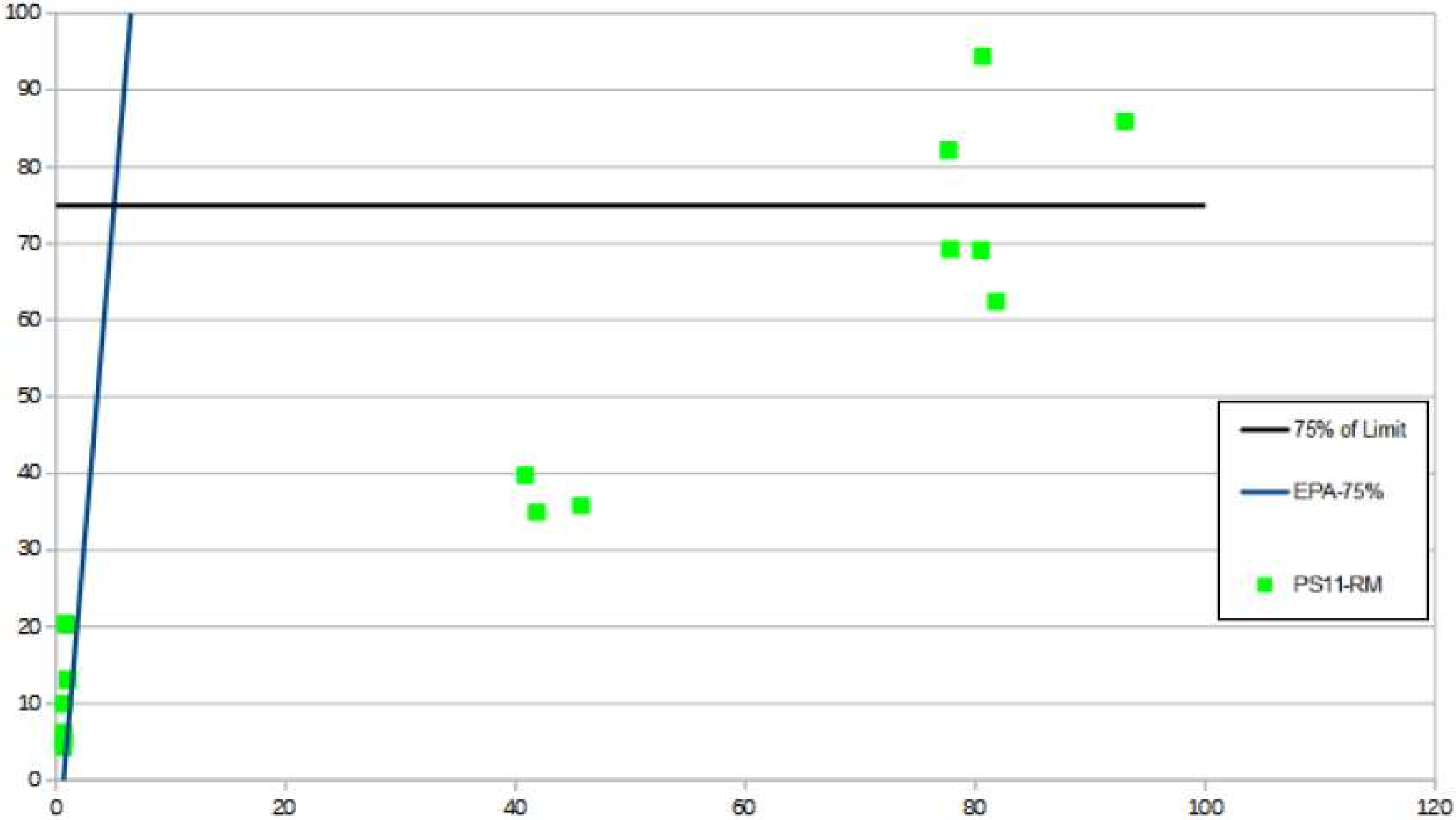
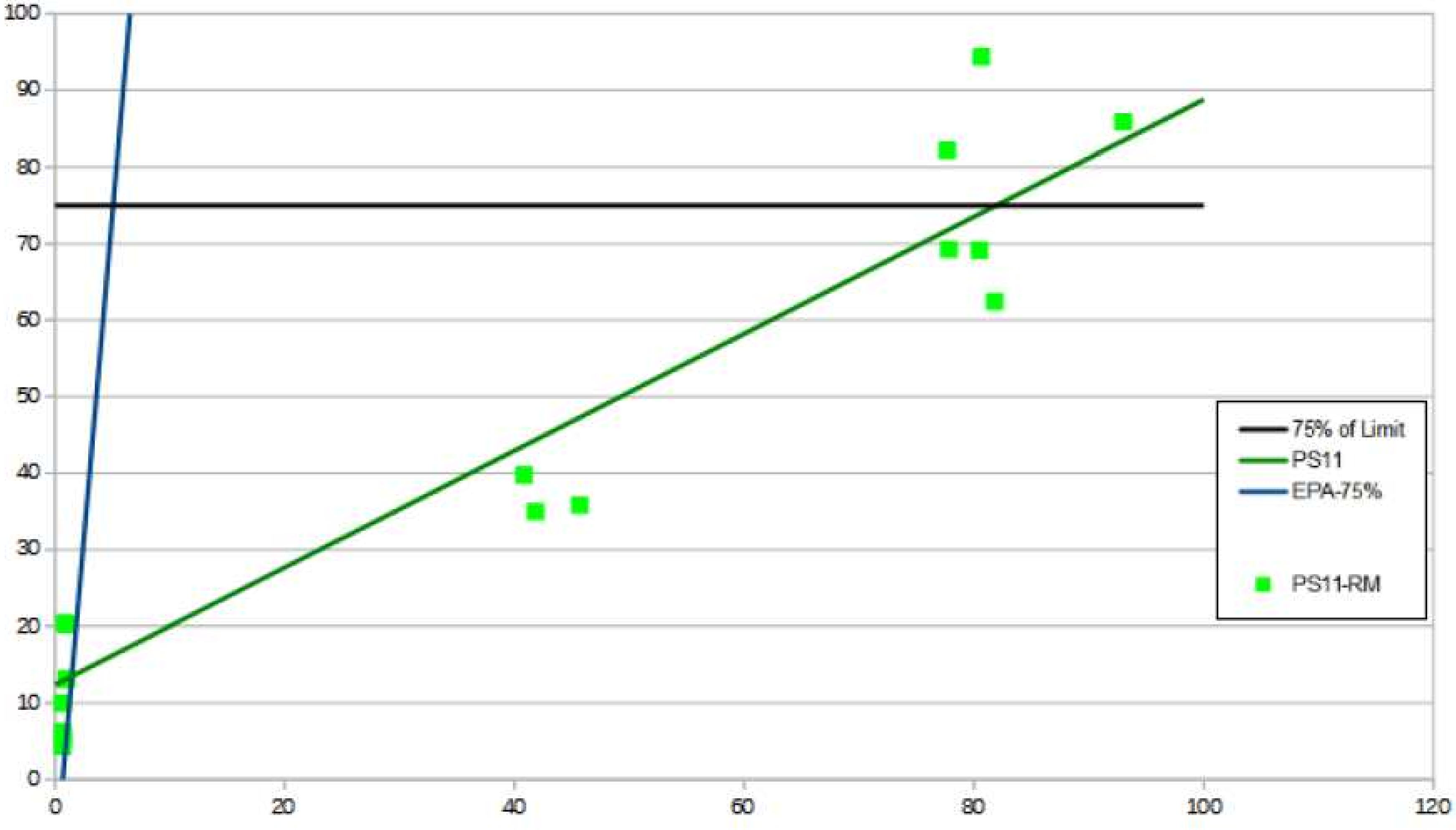


The rest of the data

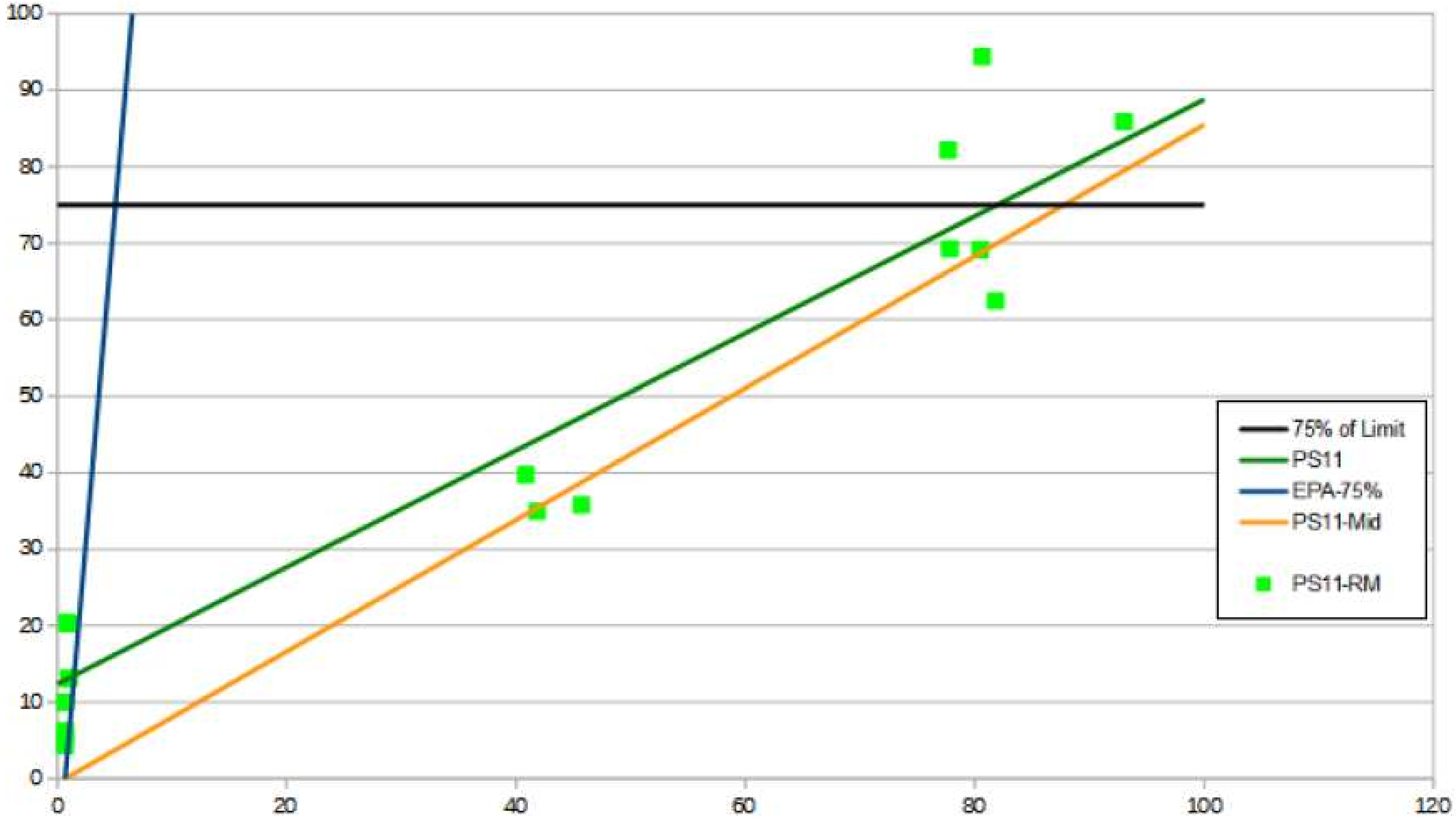


PS-11 Curve

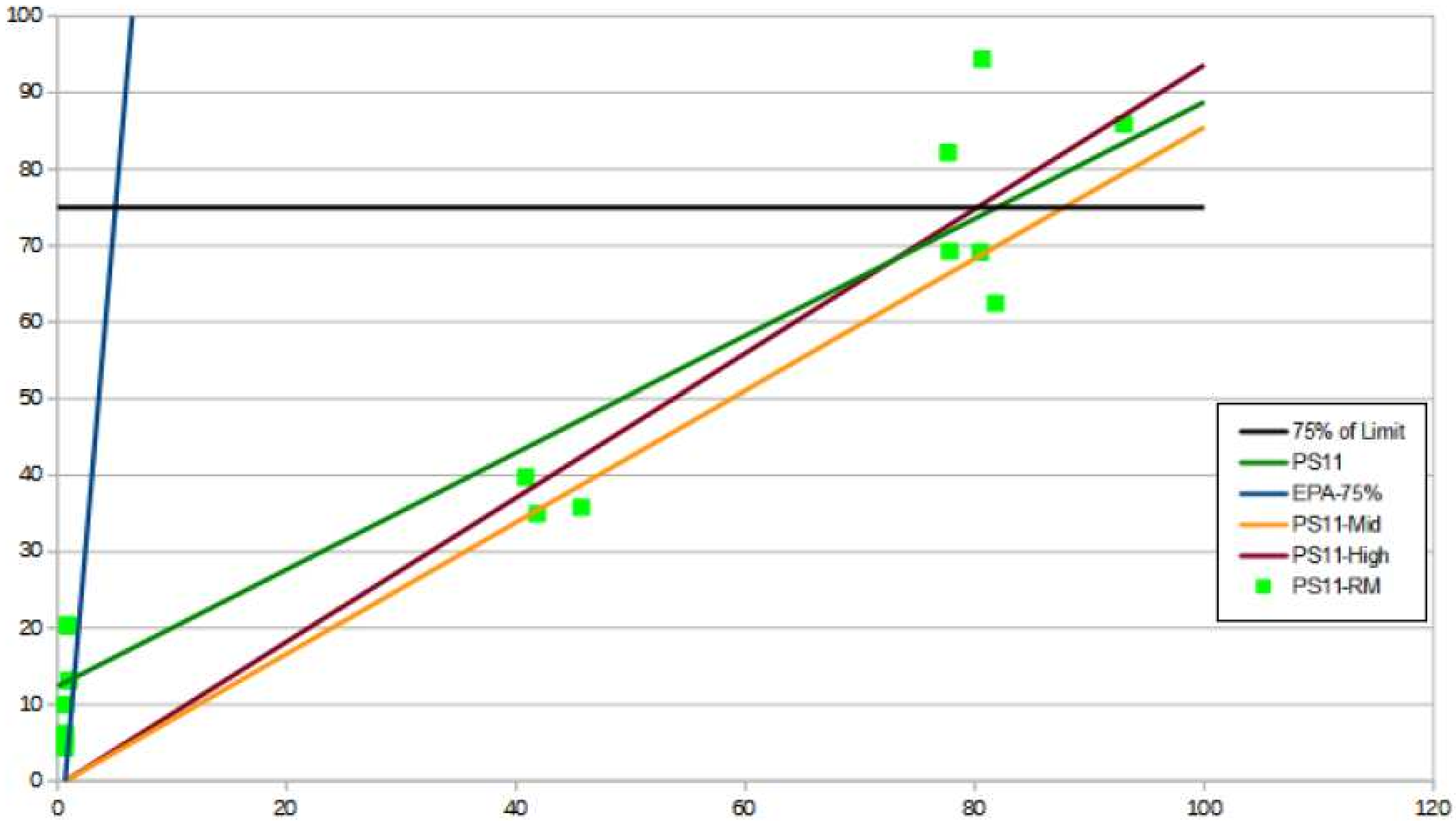


100
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
75% of Limit
PS11
EPA-75%
PS11-RM

Scale to PS-11 Midpoints



Scale to PS-11 High Points



PM CEM – Lessons Learned

Lessons Learned

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- Extremely low PM is great for compliance
- Higher PM is better for setting limits, especially when using the scaling option
- Lower levels can also run into the MDL of EPA Method 5/5i
  - Greater uncertainty
  - Longer run times may be required
- Are you allowed to elevate during your testing?
- Can PM limit setting runs be a separate condition?

Lessons Learned

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- Upscale dust loads may put you out of compliance with your permit. Early discussions with the local regulator on your test plan is advised.

- Testing should be done by well known, established test companies.

- Mistakes can be made, so it’s important to watch and question things when necessary.

- Take time to work with the PM CEM and see how it responds to process changes in order to develop a good test plan.
  - Reliable response to known changes.

- Take every process condition into account.
  - Bypass conditions, raw mill, etc.

Lessons Learned

- The "Baghouse Issue":
  - Difficult to vary dust loading with baghouse.
  - Varying your process conditions has little effect on output dust level of the baghouse.
  - Older bags become more efficient at removing particulate.
  - Options?
    - Bypass baghouse?
    - Remove bag?
    - PM Spiking?

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Field Issues and Success Stories

What to look for

- Fiberglass Stack or annular space means corrosion possible
  - Special materials of construction may be needed
  - Purged cabinet for the blower may be needed
- If the metal inside the stack is corroded, the analyzer will corrode
  - Will need fresh air purge on the system
- How does the plant operate?
- Where will the monitor be mounted…. Outdoors? In a shelter?
- How many ducts feed the stack?
  - This must be considered in the test plan.
- What type of APC equipment does the customer have?
  - Baghouse
  - ESP
  - Scrubber??

What to look for

- Example of a bad stack environment – This is after a few months in a stack annulus with SO_2 leakage.

Sticky Particulate

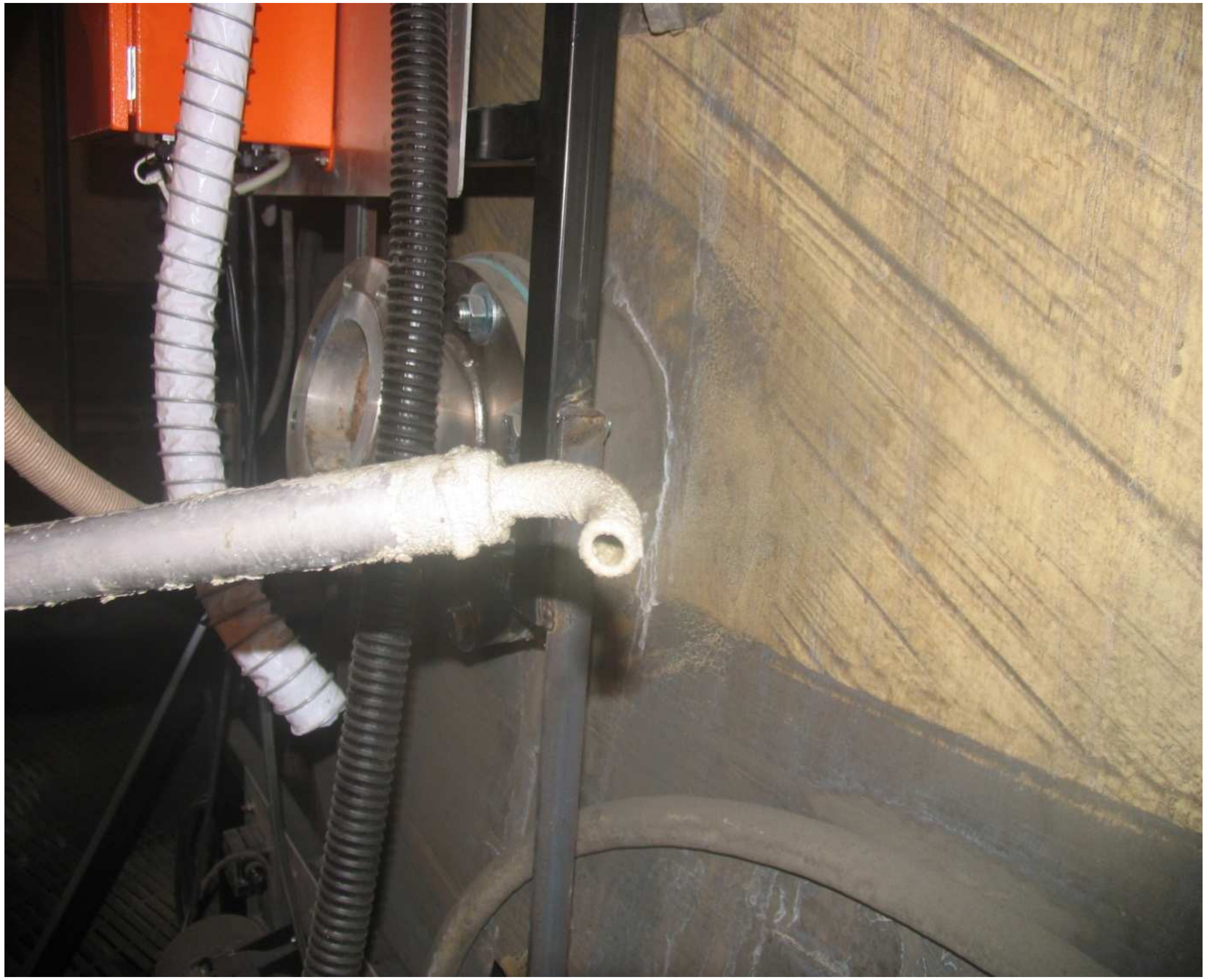
- Depending on the type of APC and its operation, Particulate Matter (PM) can be sticky

- Type 1 – "Concrete like" sticky ash usually sticks to the stack probe
  - Requires the probe to be cleaned every 1 to 2 weeks

- Type 2 – "Black Tar like" sticky ash builds up on the stack probe
  - Requires the probe, Nozzle 21, and sometime the eductor to be cleaned every 1 to 4 weeks.

Sticky Particulate

- Example of Type 1 – Concrete like sticky ash



Sticky Particulate

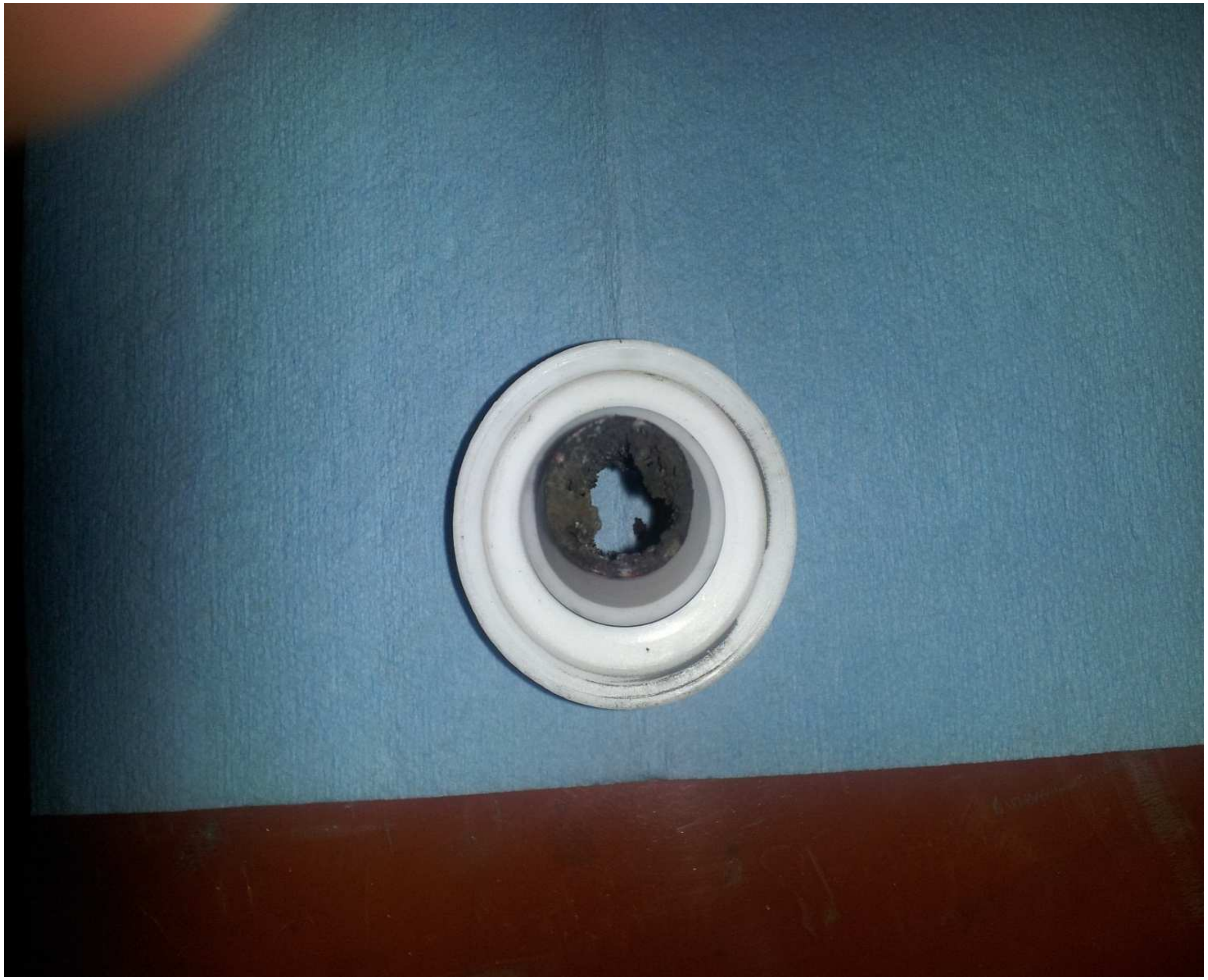
- Example of Type 2 – Black Tar sticky ash at the Probe outlet

Sticky Particulate

- Example of Type 2 – Black Rock Tar at Nozzle 21

Sticky Particulate

- Example of Type 2 – Black Rock Tar at Eductor



Success Stories

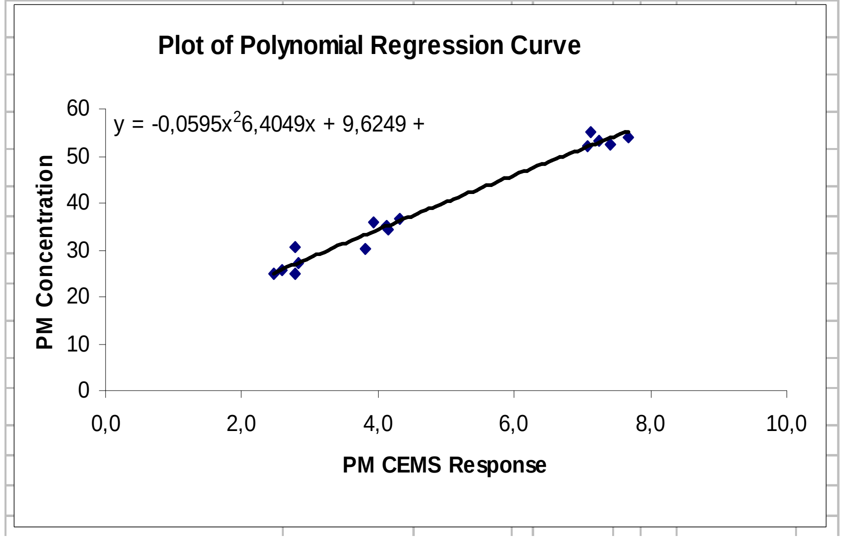
Summary of Acceptance Criteria for PS-11

Criterion	Actual	Allowable	Acceptable?
Correlation coefficient	0,988	≥ 0.85	yes
Confidence interval	2,44%	≤ 10%	yes
Tolerance interval	5,3%	≤ 25%	yes

* Indicates correlation coefficient is undefined.

Check for Correlation Curve Minimum/Maximum

Correlation curve minimum point	NA
Minimum allowable x value	NA
Is correlation curve minimum < minimum x value?	NA
Correlation curve maximum point	53,8
Extrapolation limit for x (125% of maximum x value)	9,6
Is correlation curve maximum > extrapolation limit?	yes



Success Stories

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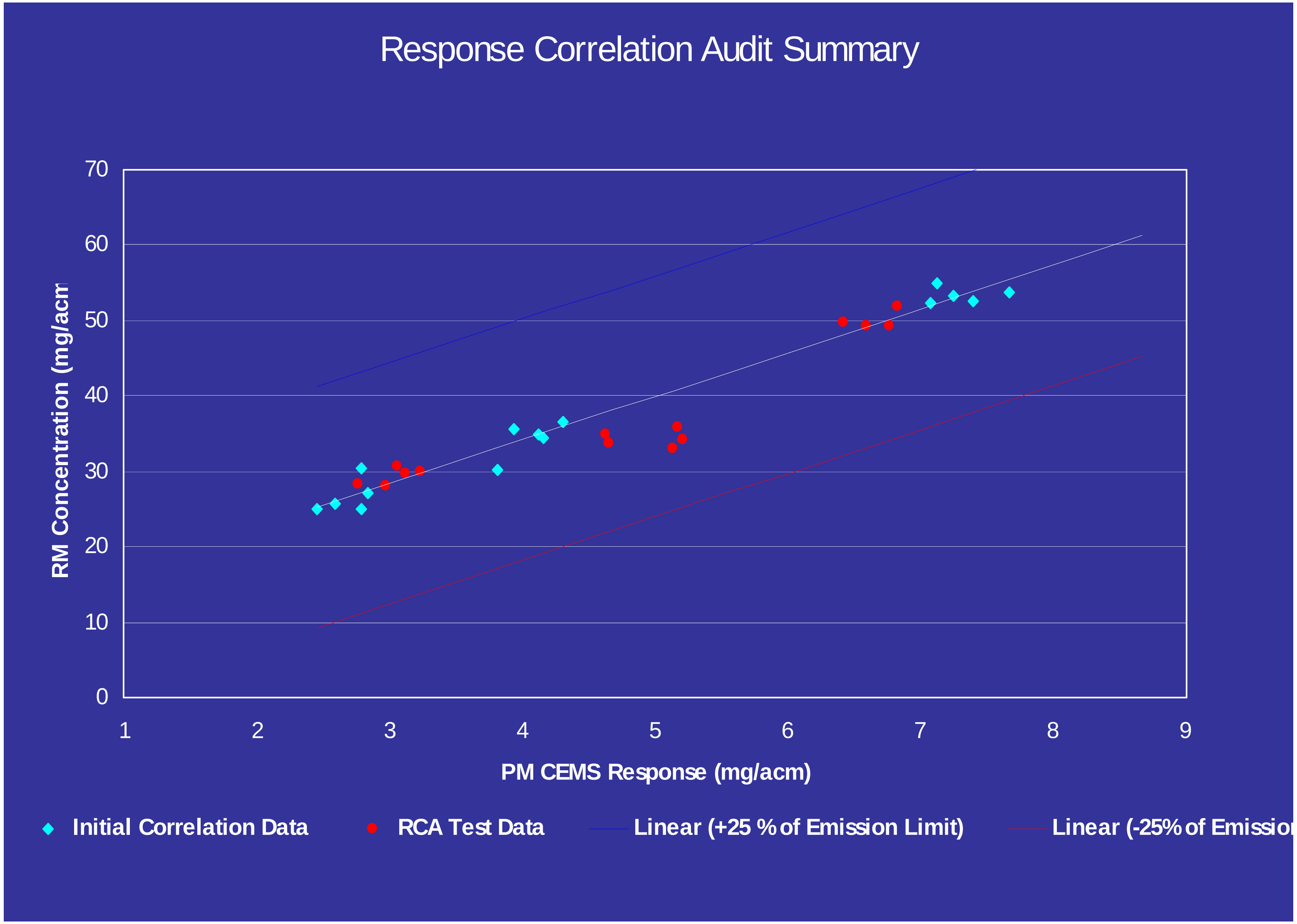
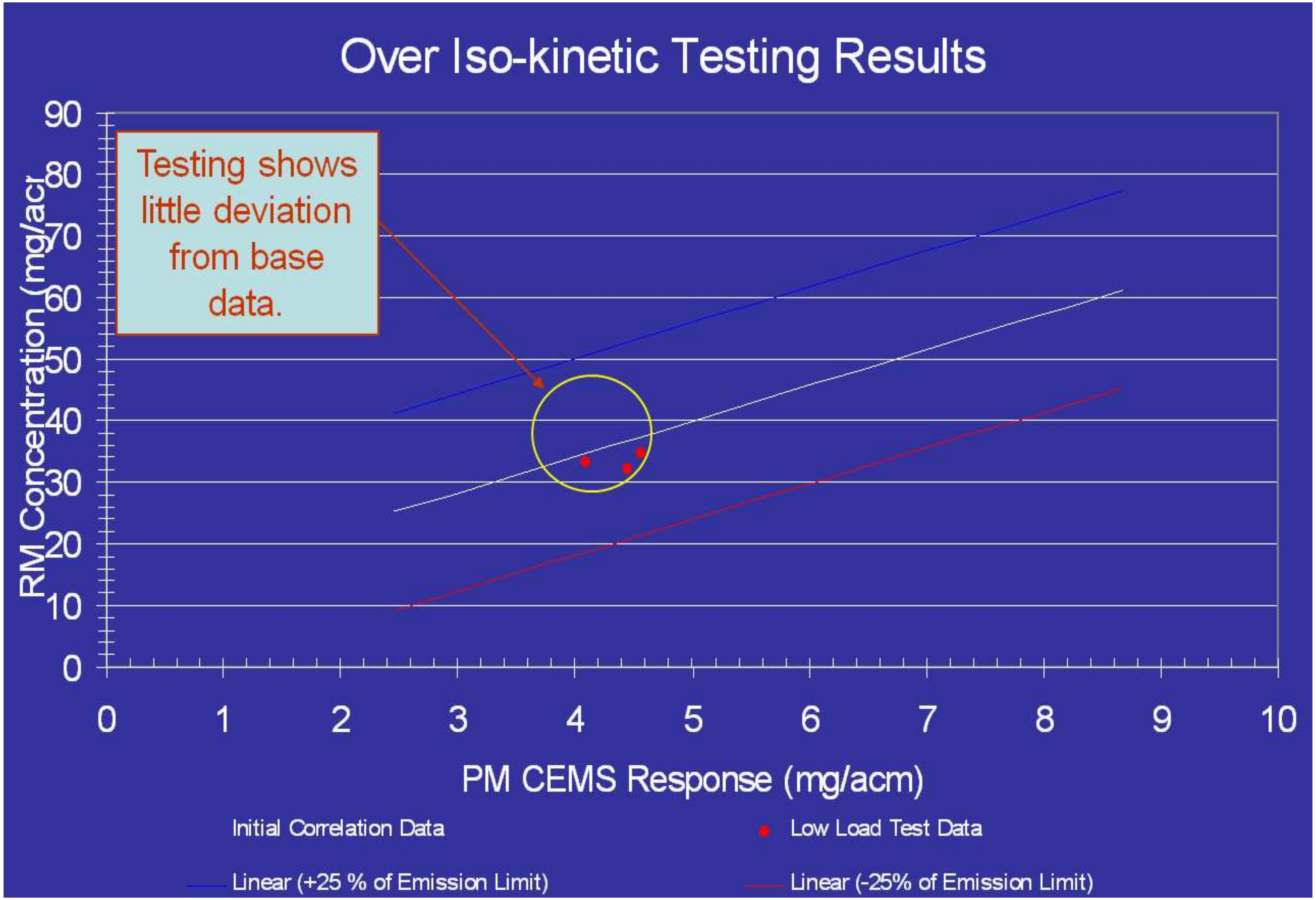


Success Stories



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Absolute Correlation Audit Testing Results

Date	Reference Filter	Reference Value (%)	Response Value (%)	Absolute Difference (%)
January	1	0.00	0.0	0.0
	2	37.9	37.8	0.1
	3	55.3	56.2	0.9
	4	92.6	92.8	0.2
April	1	0.00	0.0	0.0
	2	37.9	37.1	0.8
	3	55.3	56.0	0.7
	4	92.6	93.1	0.5
June	1	0.00	0.0	0.0
	2	37.9	37.9	0.0
	3	55.3	55.6	0.3
	4	92.6	93.2	0.6

Conclusions

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- PM CPMS can be a reliable way to determine compliance with PC MACT
  - Devices are extremely repeatable and sensitive to changes in PM levels
- As with any device, proper planning and maintenance are keys to success
  - Elevated PM during testing?
  - Routine maintenance and QA/QC is similar to that of an opacity monitor
- There is a lot of experience in the US in using, certifying and maintaining these types of devices.
  - Look for equipment, DAS and testing vendors with experience w/ PS-11 and/or PM CPMS testing and certification.
- The earlier you can install and "play" with the equipment, the more prepared you will be for the compliance date

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Questions?

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