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Introduction to the Xact 640 Multi-Metals Continuous Emissions Monitor

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Presentation Outline

- Xact 640 – Introduction to Operation and Capabilities
- XRF Accuracy – Comparison to Reference Methods
- Stack Specific Comparison Studies
- Quality Assurance Features
- Conditions where the instrument has been used

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Xact 640 Operation and Capabilities

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Xact CEMS Summary

- Based on X-ray Fluorescence (XRF)
- Utilizes reactive filter tape and chemical dopant to capture vapor phase and particulate phase metals
- Able to measure up to 19 metals simultaneously

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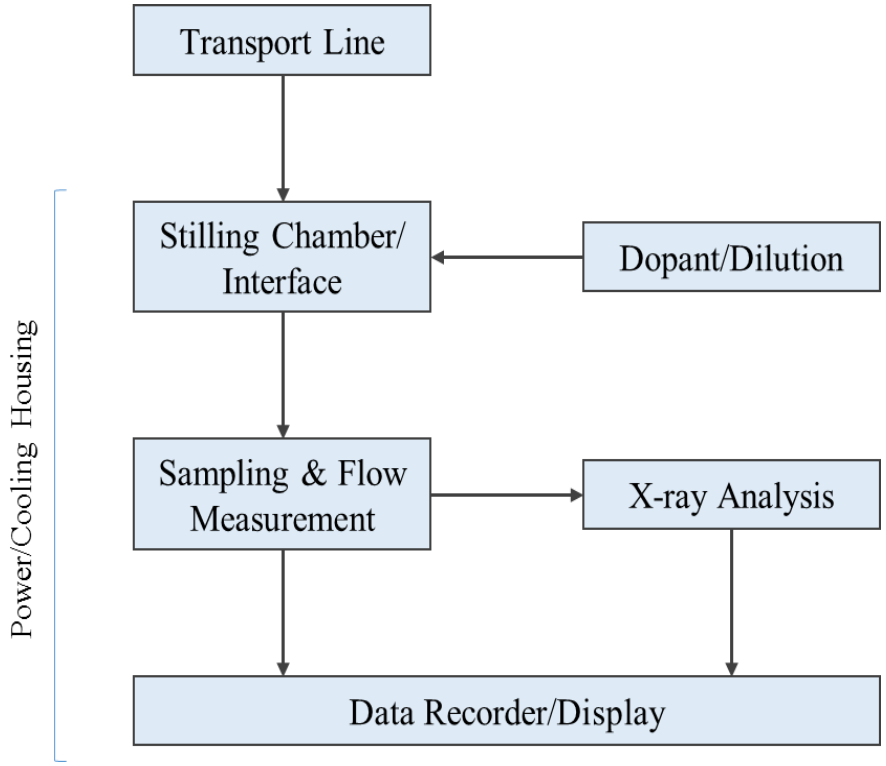
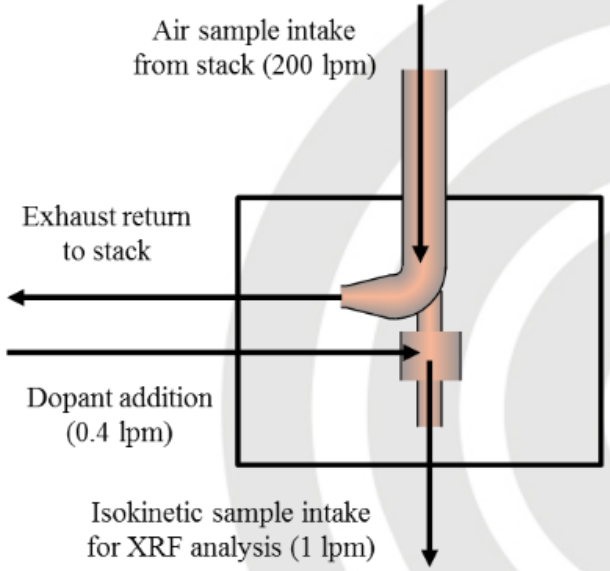
Xact CEMS Overall Operation





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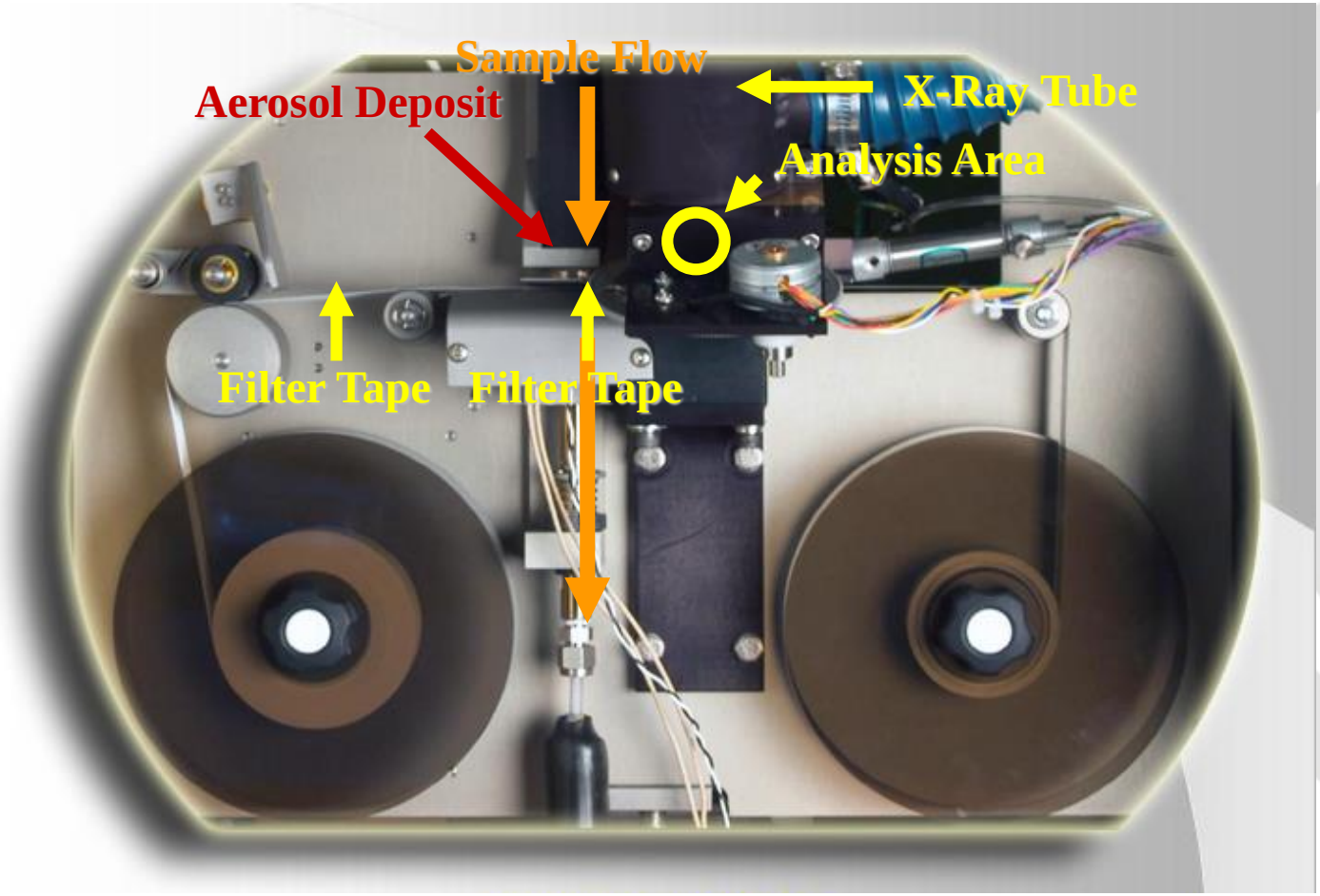
Xact Sampling and Analysis



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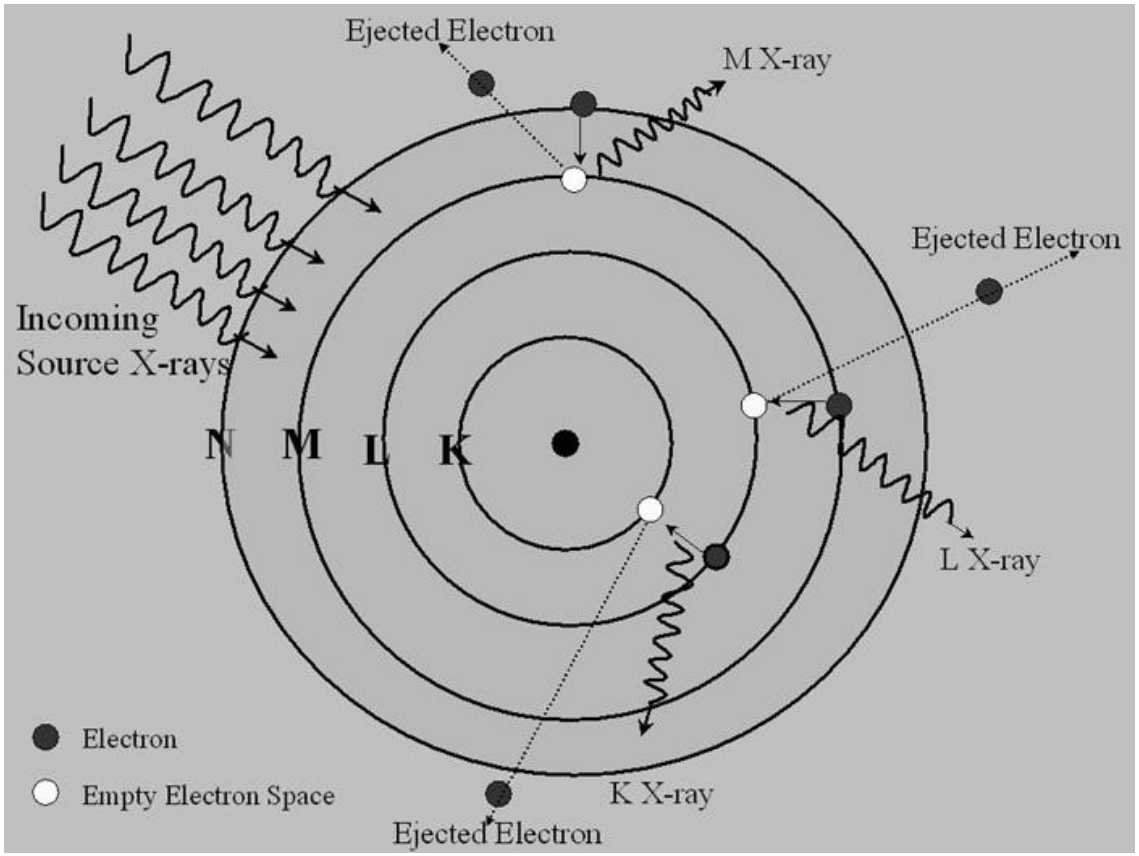
XRF Theory



- Incoming X-rays eject an inner shell electron
- Electrons from higher shells fill the vacancy
- This process releases energy in the form of fluorescing X-rays
- Energy is characteristic of each element
- Intensity or brightness is related to the mass of each element

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Strengths of XRF

- XRF utilizes inner shell electron transitions so the response is not dependent on what the element is chemically bound to
- Can measure a wide range of elements simultaneously
- XRF is non-destructive – so samples can be reanalyzed later

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Strengths of XRF

- XRF is very stable – calibrations can last for years
- XRF response is linear over the a wide concentration range (over 5 orders of magnitude) – this means no additional standards required depending on concentration range

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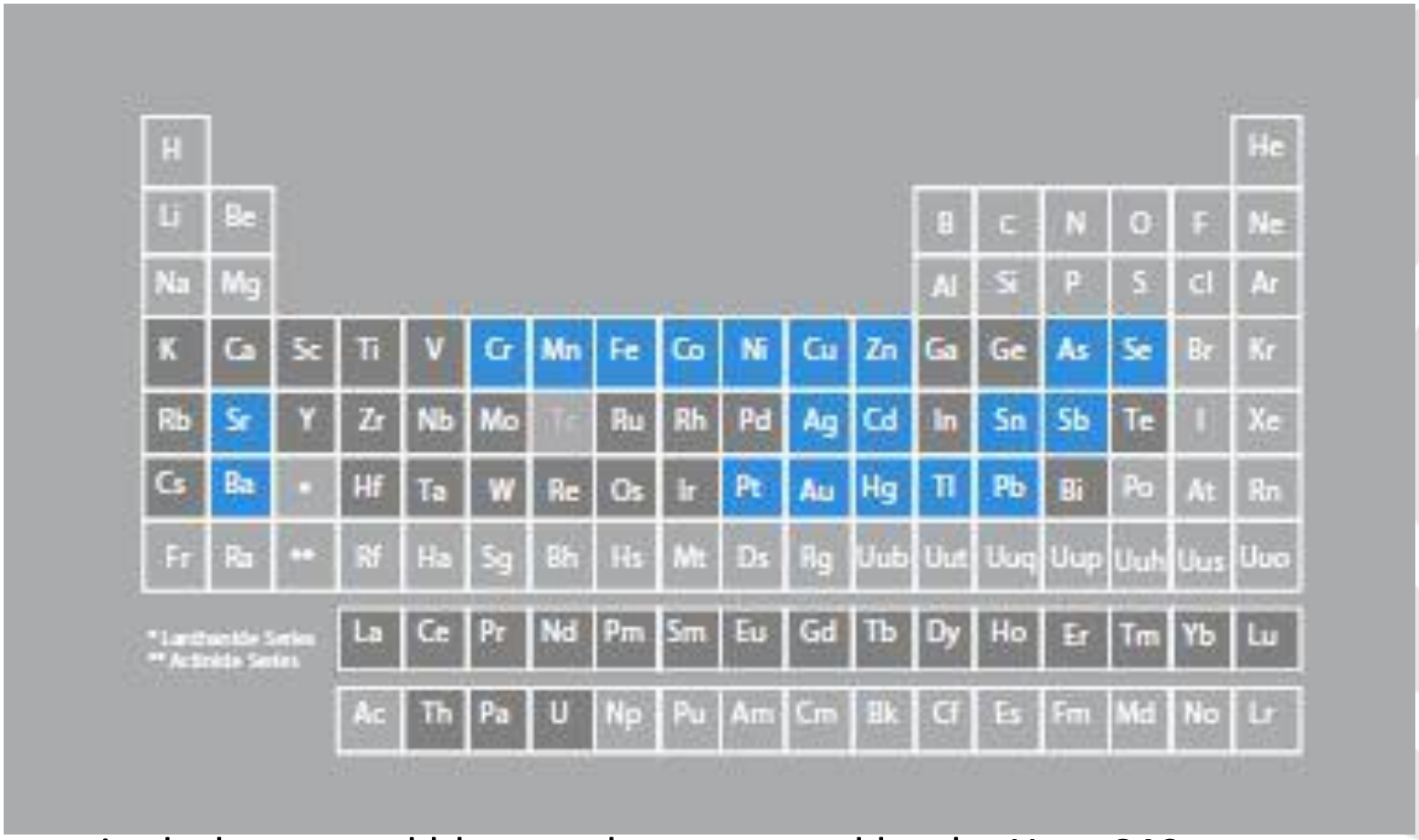
Elements that can be Measured with the Xact



- Elements in dark grey and blue can be measured by the Xact 640
- Detection limits determined for elements in blue

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Xact 640 Detection Limits

Minimum Detection Limits (µg/dscm)
Sampling Time (min)

Element	Atomic Number	15	30	60	120
Cr	24	0.14	0.05	0.018	0.006
Mn	25	0.14	0.05	0.018	0.006
Fe	26	0.38	0.13	0.048	0.017
Co	27	0.16	0.06	0.020	0.007
Ni	28	0.11	0.04	0.014	0.005
Cu	29	0.13	0.05	0.017	0.006
Zn	30	0.12	0.04	0.014	0.005
Ga	31	0.05	0.02	0.007	0.002
Ge	32	0.06	0.02	0.008	0.003
As	33	0.06	0.02	0.007	0.003
Se	34	0.07	0.02	0.009	0.003
Ag	47	2.17	0.77	0.271	0.096
Cd	48	2.88	1.02	0.360	0.127
In	49	3.39	1.20	0.424	0.150
Sn	50	3.74	1.32	0.467	0.165
Sb	51	0.33	0.12	0.042	0.015
Ba	56	0.47	0.17	0.059	0.021
Hg	80	0.09	0.03	0.012	0.004
Tl	81	0.09	0.03	0.012	0.004
Pb	82	0.11	0.04	0.014	0.005
Bi	83	0.12	0.04	0.015	0.005

Interference Free, 1 Sigma

- Detection Limit is a function of sampling time
- The longer the sampling time the better the detection limit
- For 1 hour sampling the detection limit for all elements is less than 1 µg/m^3

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Operational Experience

(Types of facilities where the Xact 640 has been used)

- Facility Type
  - Hazardous Waste Incinerator
  - Secondary lead smelter
  - Demilitarization Incinerator
  - Test Furnace
  - Coal Fired Power Plant
  - Coal Fired Boiler
- Fuel Type
  - Coal
  - Natural gas
  - Diesel Fuel
  - Biomass

➢ Control Technologies
- Baghouse
- ESP
- Powder Activated Carbon Injection
- Brominated Carbon
- Wet Flue Gas Desulfurization
- Wet Electrostatic Precipitator
- Upstream of all controls

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Sampling Experience

The Xact 640 has been used in a wide variety of sampling conditions including those listed below

Source Type	Fuel	Controls	Stack Temp (F)	Moisture	PM (mg/m3)	HCl (ppm)	NO2 Dry (ppm)	SO2 Dry (ppm)
Hazardous Waste Incinerator	Natural Gas	ESP and Wet Scrubber	170 F	9%	8-16	10	110	ND
Demil Incinerator	Diesel Fuel	Baghouse	500	5%	10	50	1200	10
Pilot Scale Coal Combustor	Bituminous	ESP and Wet FGD	120	15-20%	160	ND	70	20-35
Coal Fired Power Plant	Sub-Bituminous	ESP	300	10	275	ND	200	225
Coal Fired Power Plant	PRB and Bituminous	ESP and Wet FGD	150	Saturated	3-5	ND	ND	ND

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Accuracy of XRF – Ambient Xact Studies

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Ambient Xact

- Over 200 installations of the ambient Xact globally
- Used by Environmental Agencies (e.g. U.S EPA, Environment Canada), Universities (e.g. (King's College, U of Massachusetts) and Industry
- Widely used within China by EMC's and researchers
- Accuracy of the ambient Xact has been extensively evaluated against reference methods in peer-reviewed literature
- Next slides show results from U.S. EPA ETV and King's College London Study
- Xact 640 uses the same XRF system and processing software as the ambient Xact – only the sampling system is different

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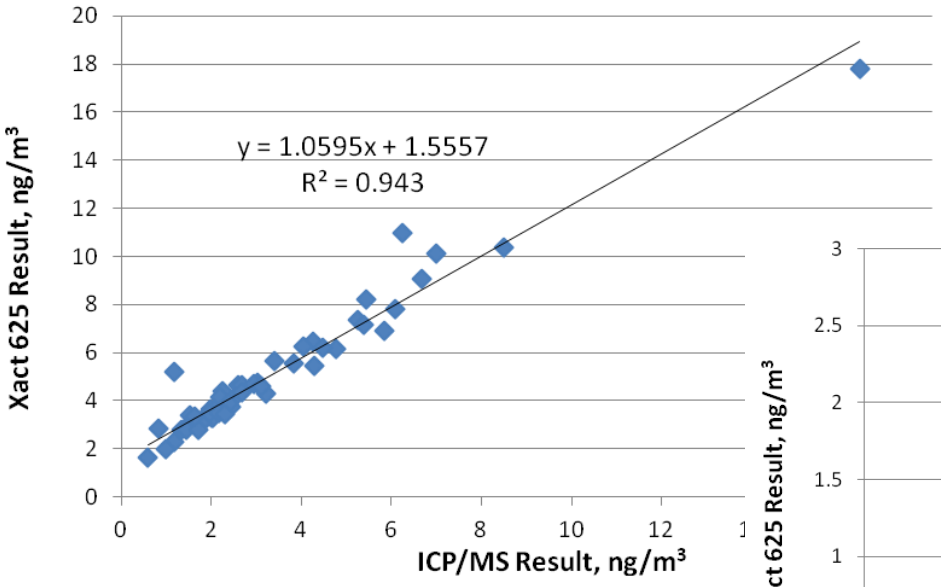
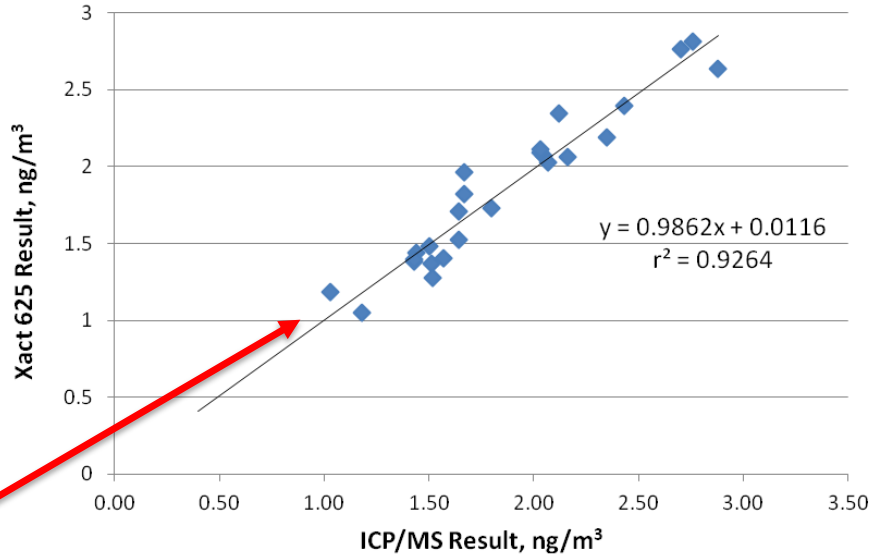
EPA ETV Accuracy Data



Lead (Pb)



Selenium (Se)

Accuracy Demonstrated Down to 1 ng/m³

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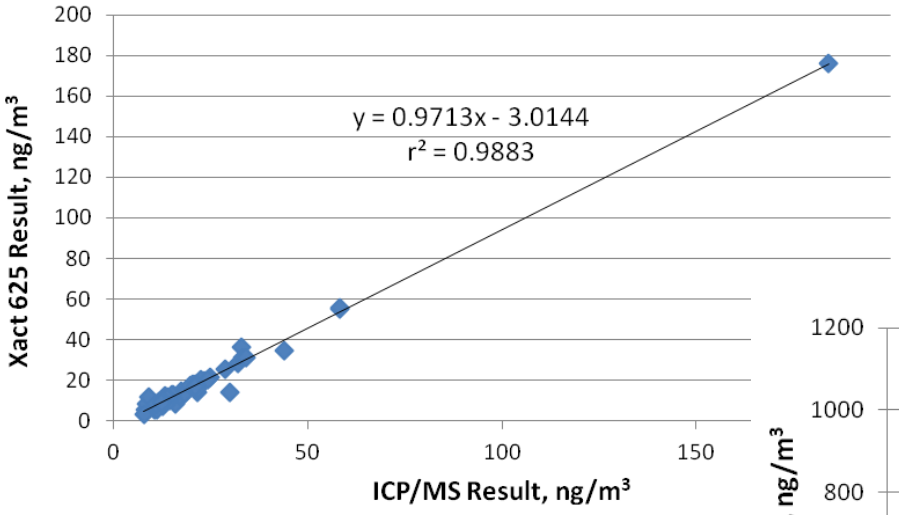
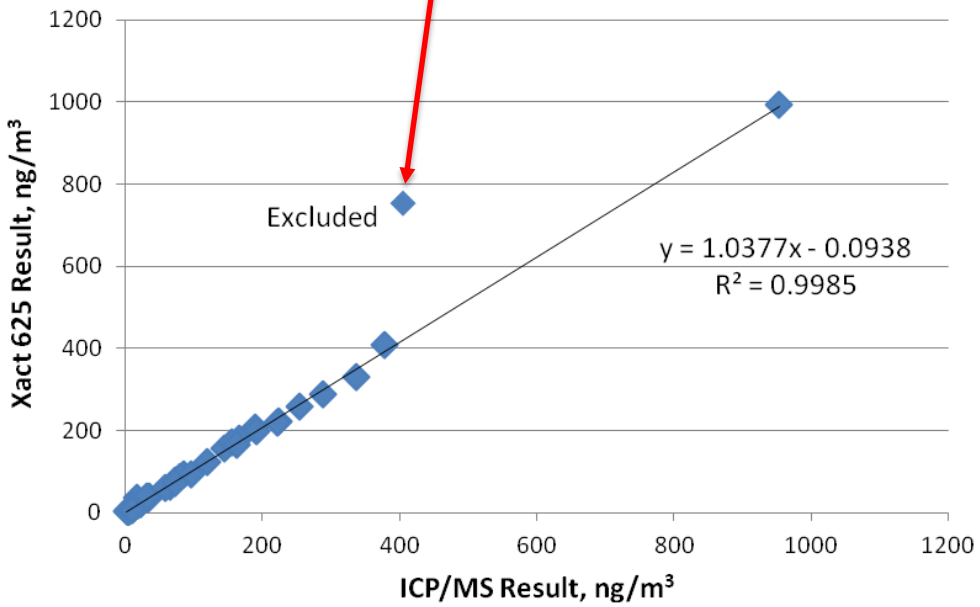
EPA ETV Accuracy Data



Zinc (Zn)

Excluded because Xact® did not sample for 24 hours



Manganese (Mn)

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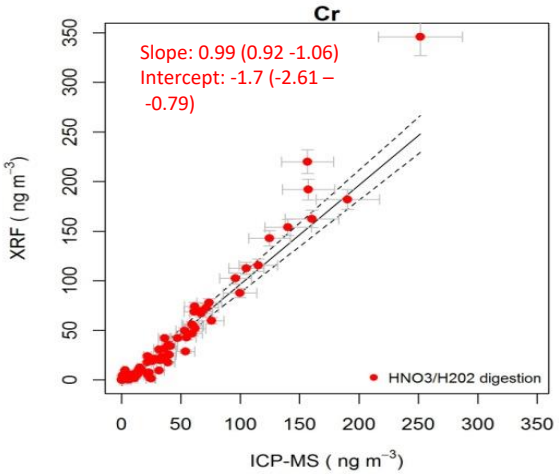
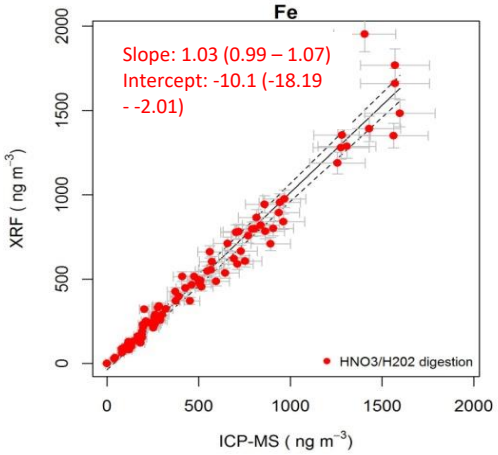
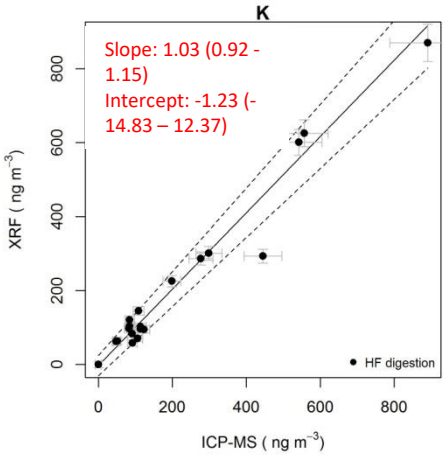
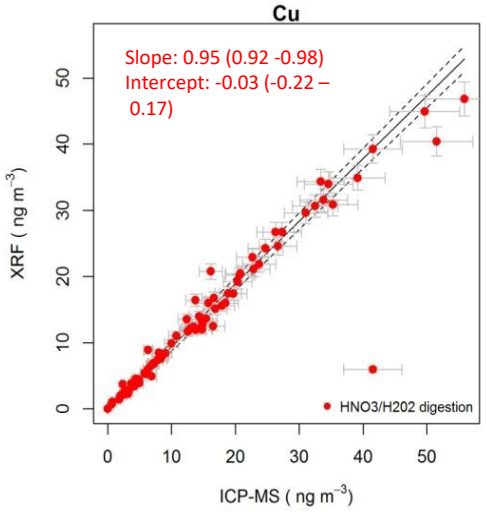
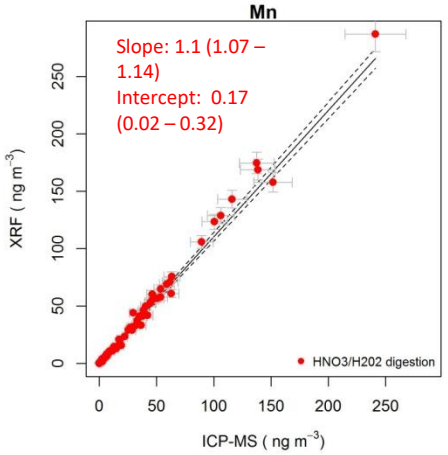
London Study











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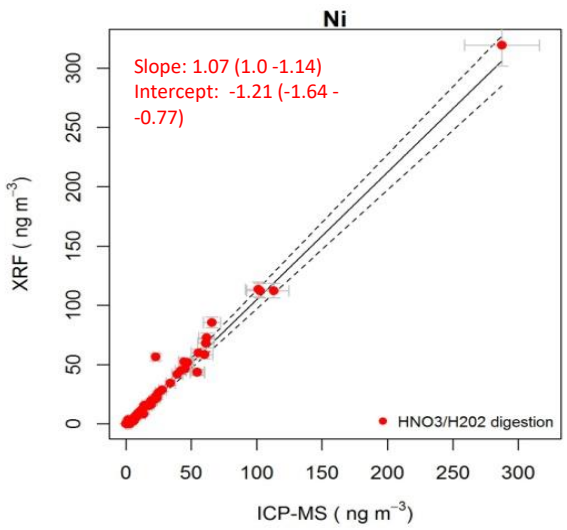
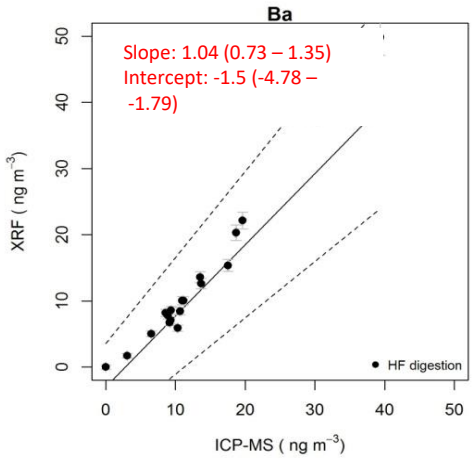
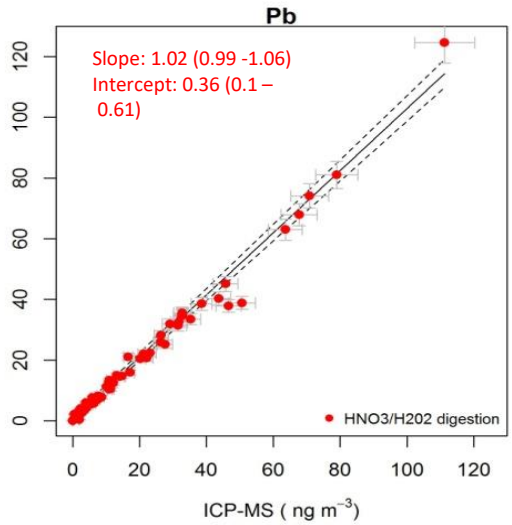
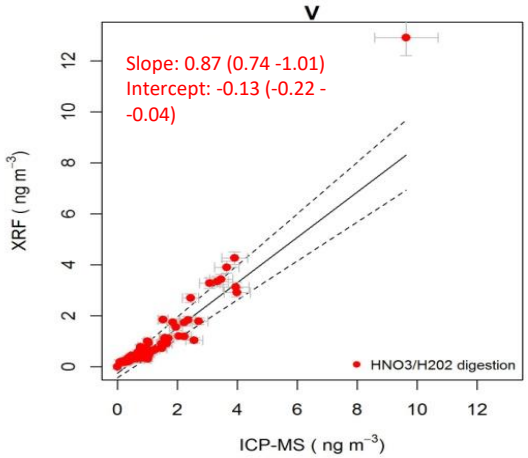
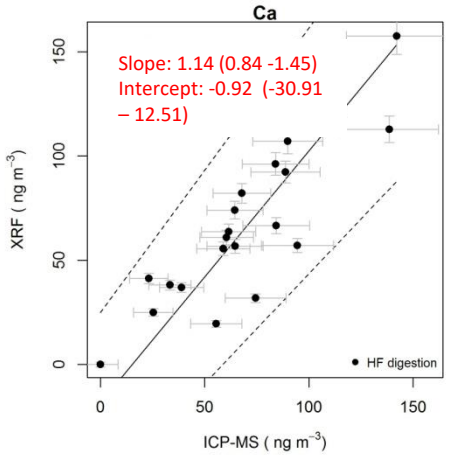
London Study

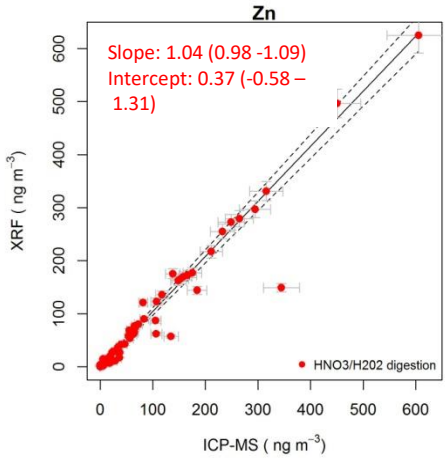












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Xact 640 Accuracy Studies

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Example Stack Sampling Experiences with the Xact

- Method 301 validation
- Mercury measurement at coal fired power plants
- Lead and Arsenic Measurement at a Secondary Battery Recycler

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Method 301 Validation

- Method 301 is the procedure by which new stack measurement methods are evaluated for **accuracy** and **precision**
- At Eli Lilly's Tippecanoe Laboratories Hazardous Waste Incinerator
- Xact evaluated using a reference aerosol of 5 metals (As, Cd, Cr, Pb, Hg) at three concentration levels
- Reference aerosol generated using the Quantitative Aerosol Generator (QAG)
- QAG itself was Method 301 validated, and PM version of QAG has been extensively validated with EPRI support
- M301 Validation of the Xact summarized in the Journal of the Air and Waste management Association

Yanca, C. A., Barth, D. C., Petterson, K. A., Nakanishi, M. P.,Johnssen, B. E., Lamber, R. H., Bivins, D. G. *Validation of Three New Methods for Determination of Metal Emissions Using a Modified Environmental Protection Agency Method 301;* J. Air and Waste Management Association 56, 1733-1742

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Quantitative Aerosol Generator (QAG)

Aerosol Concentration Traceable to NIST Standards

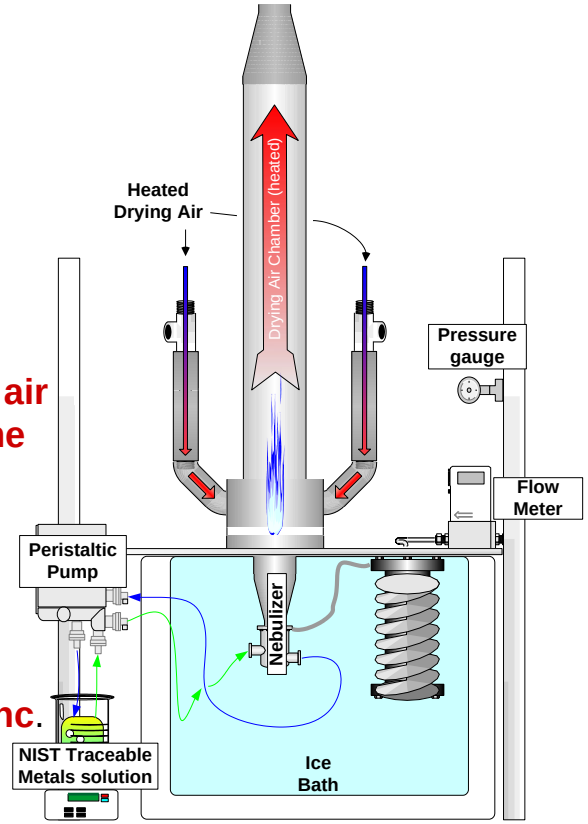
$$C_i^Q = (RTC)/V$$

Time

Carrier air volume

Metal Sol. conc.

Solution loss rate



Aerosol Types

-Metals

-PM

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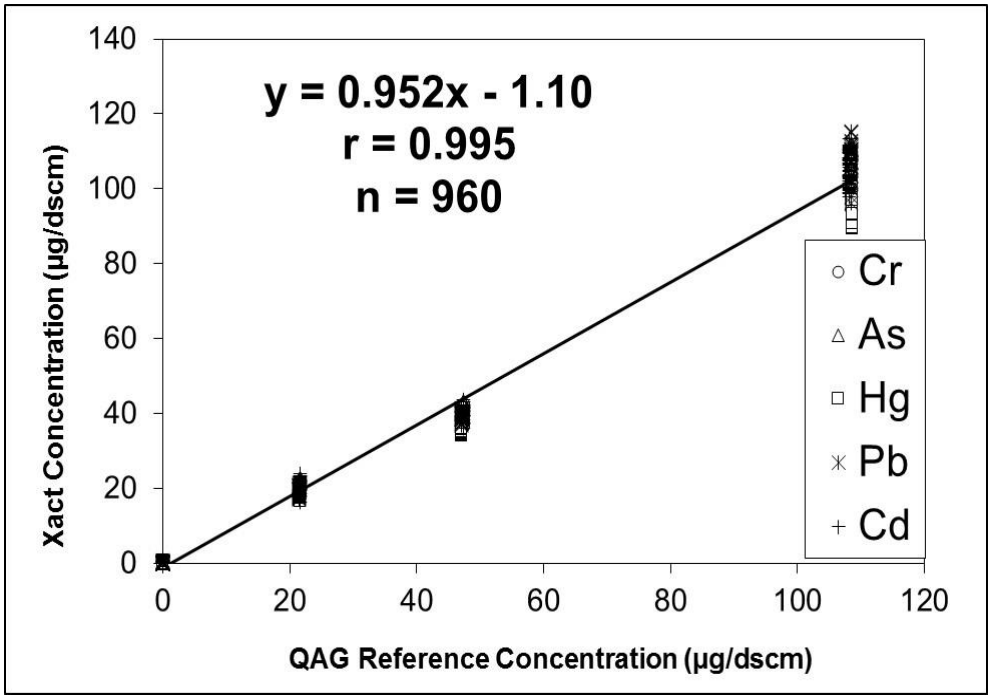
Method 301 Testing Results - Linearity



- Passed M301 requirements for slope, intercept and correlation coefficient
- All data included

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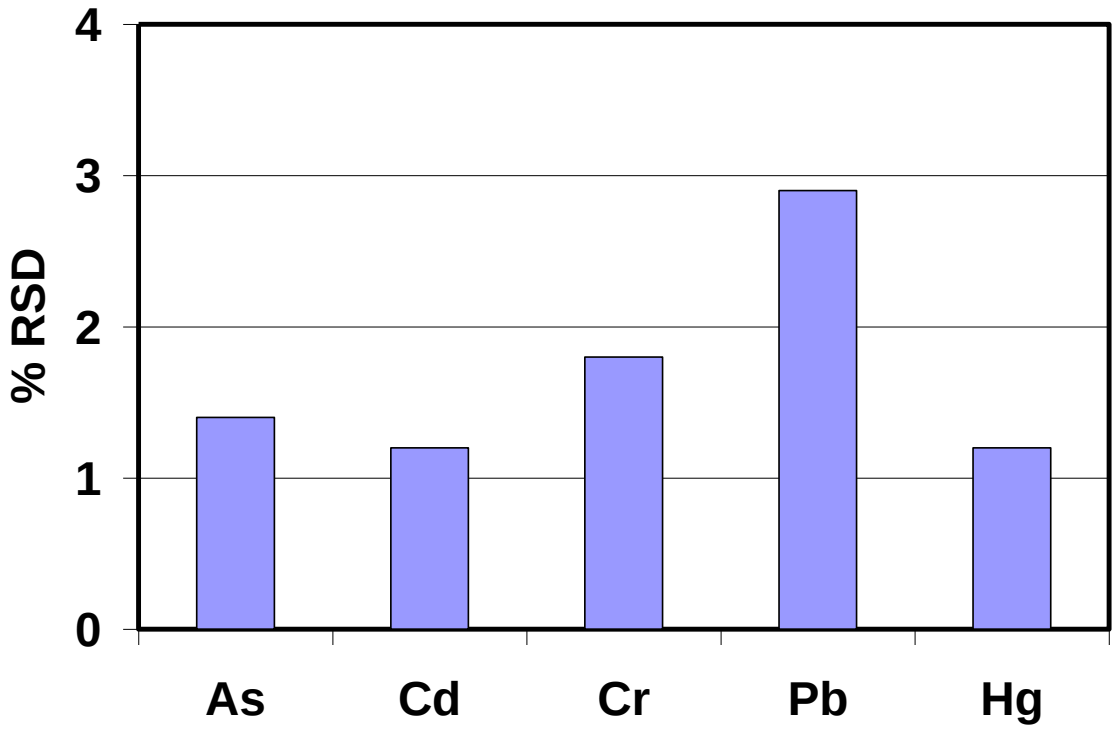
Method 301 Testing Results - Precision



- Required <10% relative standard deviation
- Easily met M301 precision requirement

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Mercury Measurement on a Coal Fired Power Plant – Study 1

- 585 MW coal fired power plant
- Downstream of electrostatic precipitator
- Measurement of stack concentrations of Hg
- Comparison with Method 30B and an on-site operating Thermo Mercury Freedom Unit
- Xact was installed and operating within 2 days

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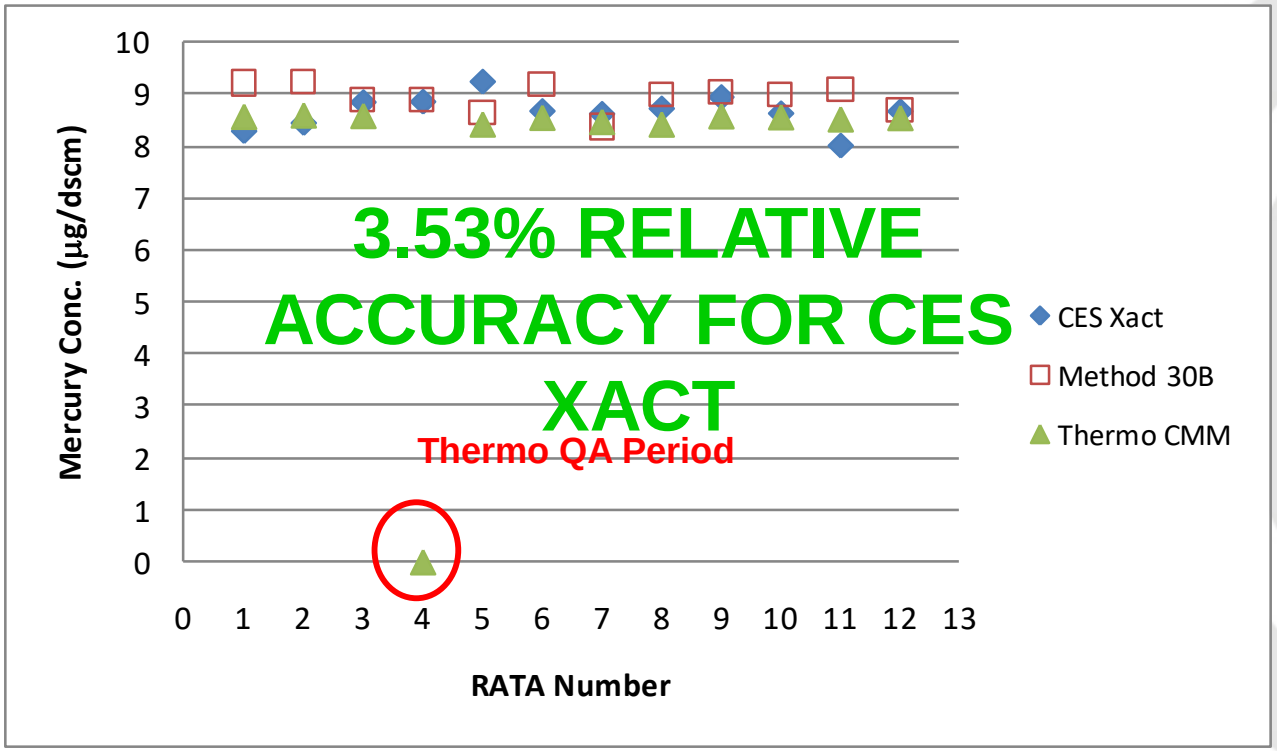
Hg Measurement on a Coal Fired Power Plant



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Mercury Measurement on a Coal Fired Power Plant – Study 2

- 750 MW source burning Lignite/PRB blend (60/40 and 80/20) equipped with ESP and Wet FGD controls
- Mercury control strategy testing- Brominated Powder Activated Carbon and EMO (separately and in combination)
- Sampling done downstream of a single ESP module
- Side by side sampling with speciated Method 30B at various times each day
- Xact measured Hg, Br, As, Se, and Pb – gas phase and very small particulate
- Test length – about 2 weeks

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Mercury Measurement on a Coal Fired Power Plant – Study 2

Fuel Conditions	Time	Hg Controls	Method 30B Hg (µg/dscm)	Xact Hg (µg/dscm)	Percent Difference
60% Lignite 40% PRB	10/3/2012 11:45	Baseline	24.57	22.59	-8.1%
	10/3/2012 14:45	EMO Only	14.85	15.33	3.2%
	10/3/2012 16:45	EMO Only	16.30	15.83	-2.9%
	10/5/2012 12:15	EMO & PAC	9.25	10.09	9.0%
	10/5/2012 16:15	EMO & PAC	11.52	12.74	10.6%
	10/5/2012 17:45	EMO & PAC	4.05	5.88	45.2%
	10/6/2012 10:45	Baseline	24.03	24.55	2.2%
	10/6/2012 13:45	EMO & PAC	11.14	12.34	10.8%
	10/6/2012 15:45	EMO & PAC	5.74	7.97	38.8%
	10/6/2012 18:45	EMO & PAC	13.92	15.72	13.0%
80% Lignite 20 % PRB	10/9/2012 10:15	Baseline	28.14	25.07	-10.9%
	10/9/2012 12:15	PAC Only	19.01	19.26	1.3%
	10/9/2012 16:15	PAC Only	7.00	7.34	4.9%
	10/10/2012 10:30	Baseline	23.19	23.98	3.4%
	10/10/2012 13:45	EMO Only	18.73	20.22	8.0%
	10/10/2012 16:45	EMO Only	20.10	22.10	10.0%
	10/10/2012 19:45	EMO Only	18.60	22.10	18.8%
	10/10/2012 9:00	Baseline	21.57	18.69	-13.4%
	10/11/2012 9:00	Baseline	24.00	23.53	-1.9%
	10/11/2012 10:45	EMO Only	20.52	18.90	-7.9%
	10/11/2012 11:30	EMO Only	21.38	19.55	-8.6%
Average Percent Difference Baseline Conditions					**-4.8%**
Average Percent Difference with Hg Control					**7.6%**
Overall Average Percent Difference					**6.0%**

- Results show good agreement between the Xact 640 and the reference method (Method 30B)
- Average percent difference of 6%

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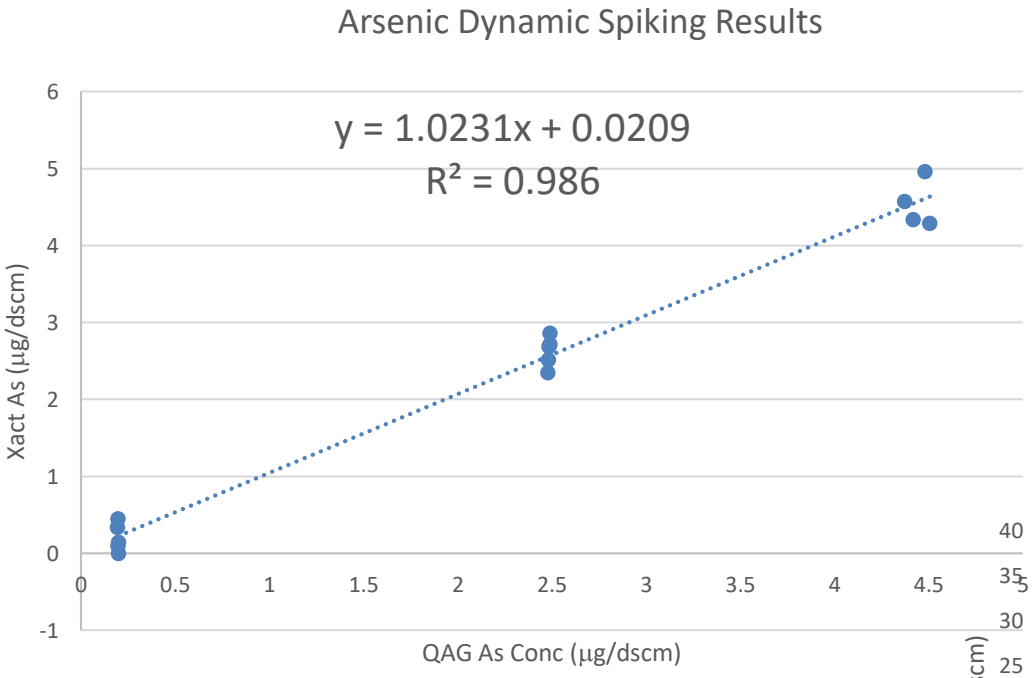
Secondary Lead Smelter

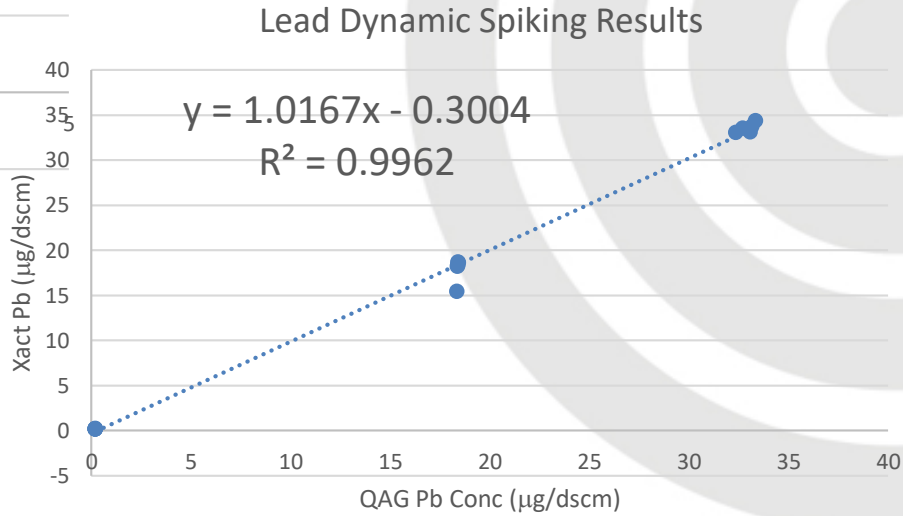
- 10 month demonstration at a secondary lead smelter
- Measuring Arsenic and Lead
- Measurement accuracies tested down to concentrations as low as 0.2 μg/dscm
- Comparisons to manual reference method
- Following the test the Xact 640 was approved by the Air Quality Monitoring District as part of the facility's risk reduction plan
- Currently operates at the facility with better than 95% uptime

Comparison to QAG



As Test Results

Study shows excellent agreement between the Xact and the reference aerosol



Pb Test Results

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Quality Assurance

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Xact Operation at a Hazardous Waste Incinerator

- Xact operated as a compliance instrument for five plus years at Eli Lilly Tippecanoe Laboratories
- Xact incorporated into Eli Lilly's Alternative Monitoring Plan
- Evonik Degussa purchased facility
- Evonik successfully used the Xact to do CPT performance test in 2010 in lieu of using Method 29
- Xact met initial and on-going performance criteria

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Initial and On-going Performance Criteria for the Xact

Test Category	Test	Test Requirements	Test Criteria
Seven Day Stability (Automatic, Daily)	Zero Drift	Monitor Zero standard for 7 consecutive days	< 20%
	Upscale Drift	Monitor upscale standard for 7 consecutive days	<15%
	Flow Drift	Monitor Flow drift for 7 consecutive days	< 20%
Calibration Check (Quarterly)	XRF Calibration Drift	Check a standard for each compliance element measured	< 10%
	Flow Calibration Drift	Compare sample flow meter to NIST Traceable meter	< 10%
Accuracy (Annually)	Linearity RATA (Dynamic Spiking)	3 concentration levels Spike into transport line as close to probe as possible	Slope = 0.80 to 1.20 R > 0.90 Intercept < 20% of emission limit

These are the criteria that the Xact had to meet during its operation at Eli Lilly

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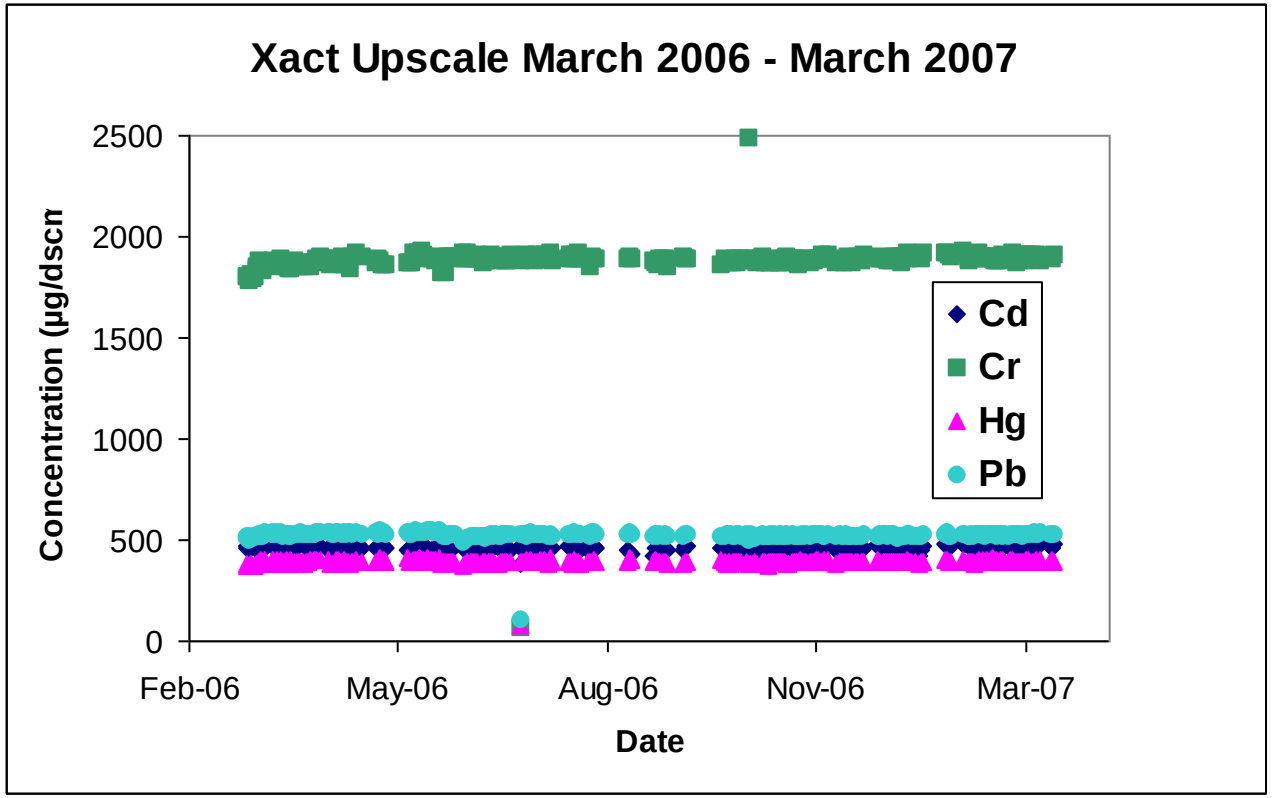
Xact Daily Upscale Results for a Year



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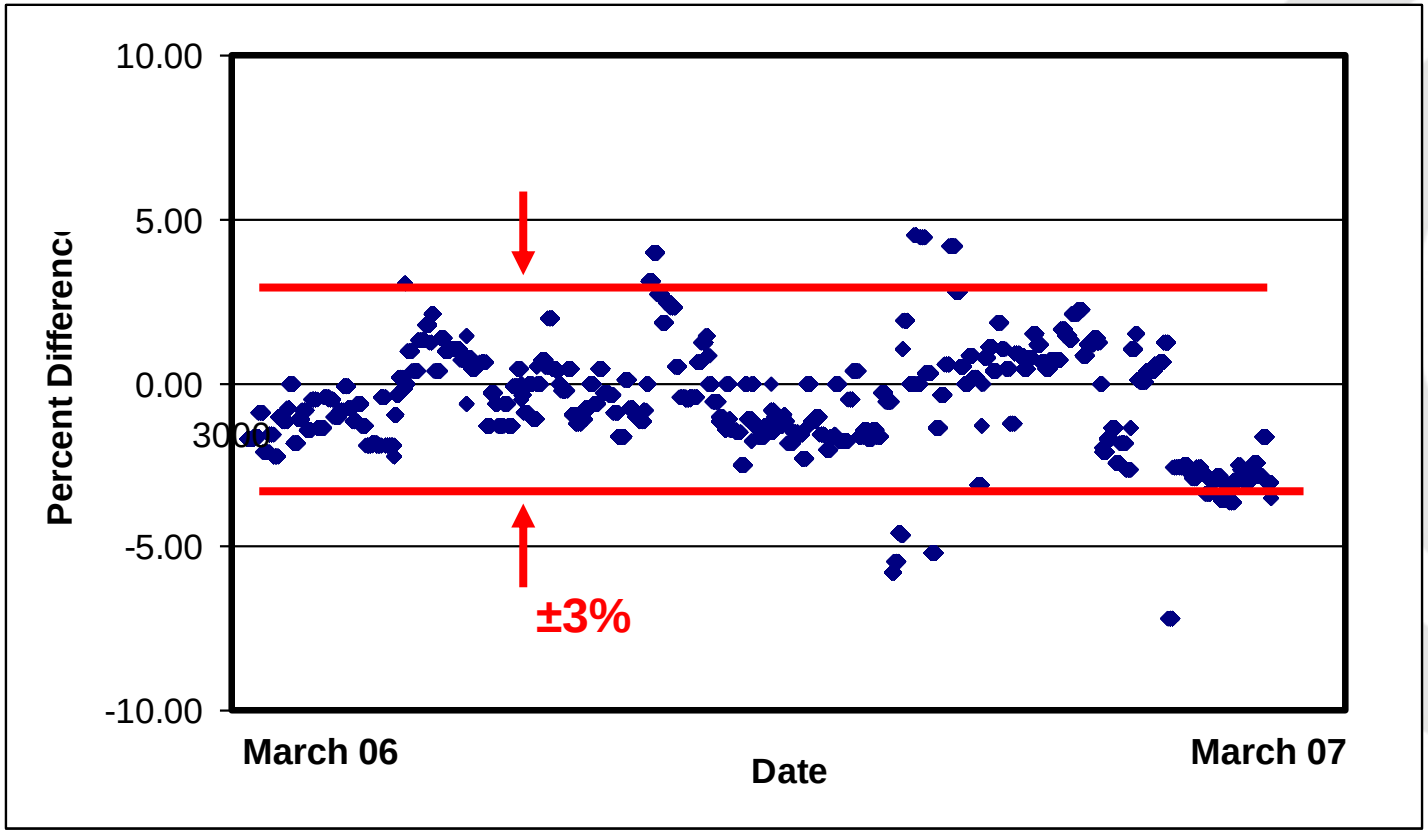
Daily Flow QA/QC Check Percent Difference



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Xact Long Term QA Data – Quarterly Audits

Audit Year	Quarter	Audit Date	Flow Error	XRF Audit Error				
				Cr	As	Cd	Hg	Pb
2007	1	3/1/2007	3.04%	1.46%	2.18%	2.84%	1.75%	2.34%
	2	5/25/2007	3.13%	3.32%	0.13%	4.23%	2.60%	2.96%
	3	8/29/2007	0.68%	-3.74%	2.18%	-4.13%	2.36%	2.76%
	4	12/26/2007	1.42%	6.50%	0.36%	7.36%	4.18%	0.40%
2008	1	2/15/2008	NA	0.22%	0.11%	1.20%	-0.99%	0.87%
	2	3/17/2008	1.07%	1.93%	0.66%	1.82%	2.16%	2.34%
	3	5/20/2008	0.53%	2.96%	2.61%	3.30%	2.53%	0.68%
	4	10/20/2008	1.37%	1.77%	0.72%	1.48%	0.56%	1.06%
2009	1	1/7/2009	2.10%	0.60%	2.94%	1.52%	3.45%	0.46%
	2	5/6/2009	3.67%	1.49%	4.09%	1.07%	1.78%	0.30%
	3	7/9/2009	0.84%	2.00%	5.43%	2.78%	0.72%	0.22%
	4	NA	NA	NA	NA	NA	NA	NA
2010	1	1/12/2010	NA	1.60%	5.13%	0.45%	0.71%	2.11%
	2	4/25/2010	NA	1.61%	5.92%	1.12%	4.00%	0.96%
	3	7/13/2010	1.68%	-3.47%	-0.92%	-2.82%	-2.42%	-2.11%
	4	12/10/2010	NA	2.00%	0.82%	2.70%	1.83%	2.91%
AVE			**1.77%**	**1.35%**	**2.16%**	**1.66%**	**1.68%**	**1.22%**

NA - Data Not Available

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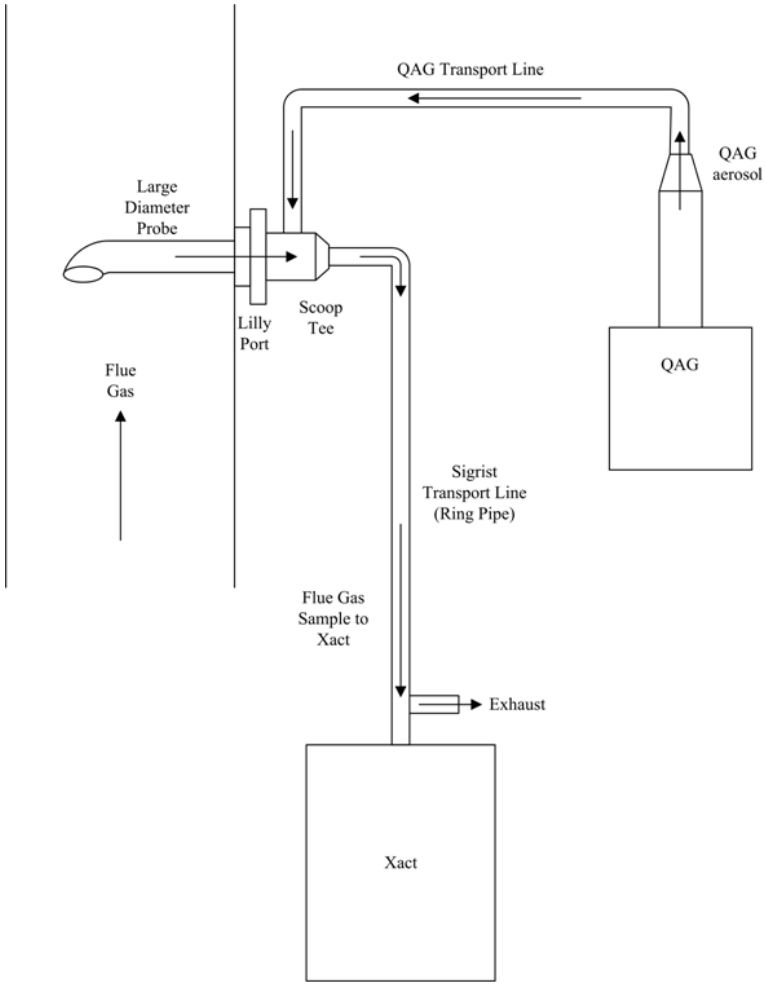
Schematic of Dynamic Spiking for Annual RATA



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Annual RATA Results

Year	Slope					
	Cr	As	Cd	Hg	Pb	Average
2006	0.83	0.90	0.85	0.82	0.85	0.85
2006 (Quarterly)	0.91	0.77	0.95	0.92	0.93	0.89
2007	0.84	0.82	0.88	0.84	0.81	0.84
2008	0.96	0.71	0.98	0.99	0.97	0.92
2009	0.96	0.99	0.99	1.10	1.00	1.01
2010	0.97	1.06	1.11	1.02	1.04	1.04
Average	**0.91**	**0.87**	**0.96**	**0.95**	**0.93**	**0.93**

Passed All Required Annual and Quarterly Audits During its Operation

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Summary

- Xact 640 is an XRF based Multi Metals CEMS
- Concentrations reported by the Xact 640 are comparable to reference methods (e.g. Method 30B)
- Xact 640 has been accepted by the U.S. EPA and by Air Quality Management Districts for regulatory compliance

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QUESTIONS?

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