NETL Mercury Control Technology Conference,
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Energy Research Center

Field Experience with Mercury Monitors: Dry Stack

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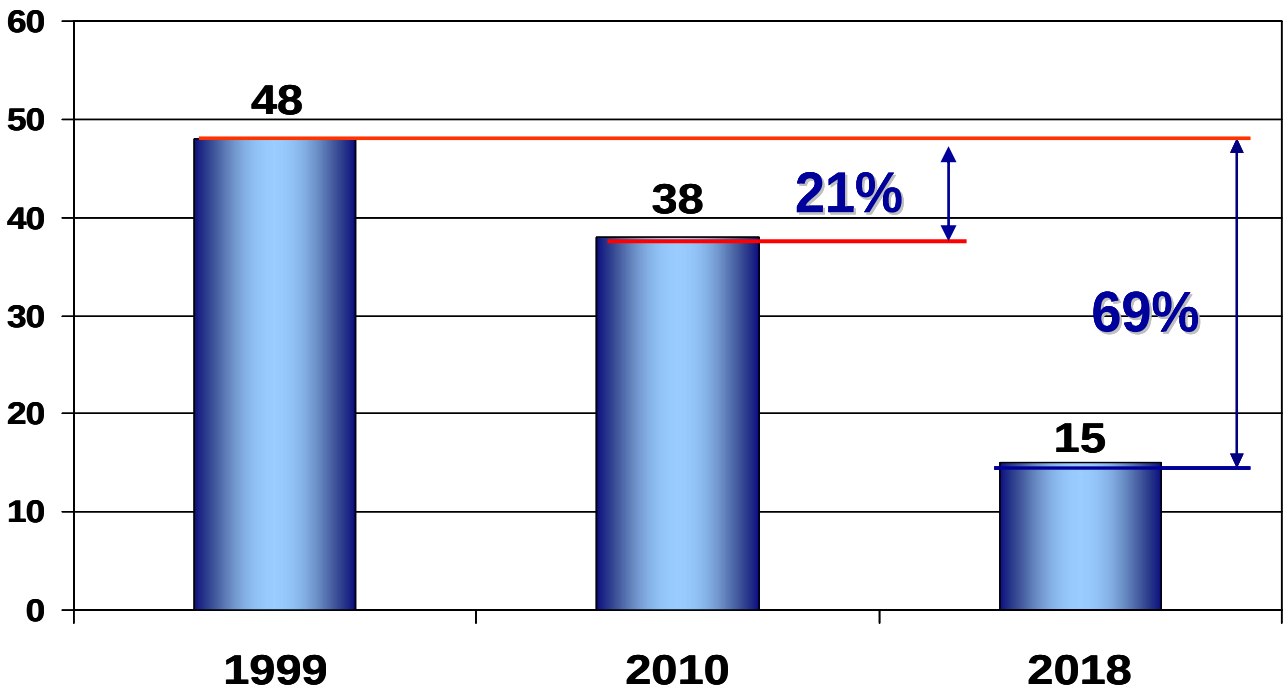
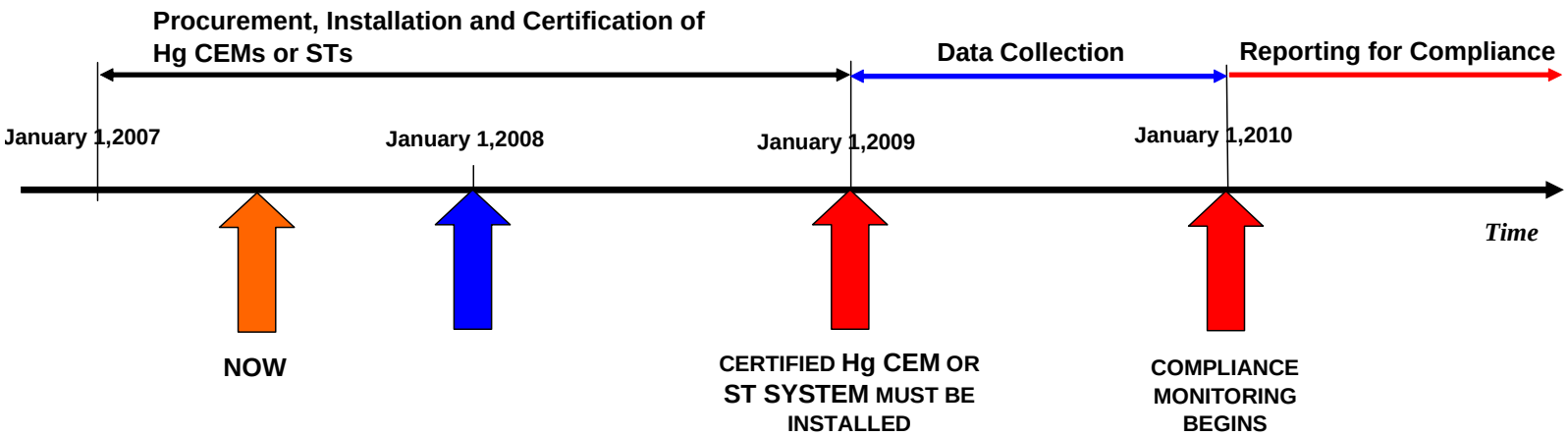
Introduction

- *On March 15th, 2005, U.S. EPA issued **Clean Air Mercury Rules** (CAMR), which mandate national Hg reductions from coal-fired power plants through a "Cap and Trade" Program:*
  - ***21 percent in 2010 (Phase I)***
  - ***69 percent by 2018 (Phase II).***



Introduction, Continued

- **Compliance Timeline:**
  - **January 1st, 2009**: Certified continuous Hg monitors (Hg CEMs) or Sorbent Traps (STs) need to be installed to monitor Hg emissions from stationary sources where annual Hg emissions exceed 29 pounds of Hg.
- Following certification, a certified Hg CEM should collect 12 months of Hg emissions data.
  - **January 1st, 2010**: Start reporting Hg emissions for compliance monitoring.



Armstrong Project Objectives

- *Field-test mercury monitors*
- *Compare against Reference Method, **RM** (ASTM D6784-02 Ontario Hydro Method (OHM)).*
  - *Wet chemistry method*
  - *Manpower intensive*
  - *The only RM available at the time.*
- *Field-test Sorbent Traps and compare against OHM.*
- *Field-test Instrumental Reference Method (IRM).*
  - *First field test of IRM (Method 30A).*
- *Compare Reference Methods for Hg measurement developed in the U.S. and EU.*
  - *Is there a bias in Hg emissions measured in the U.S. and EU?*
- *Compare Reference Methods for heavy metals, $PM_{2.5}$, and PM_{10} developed in the U.S. and EU.*

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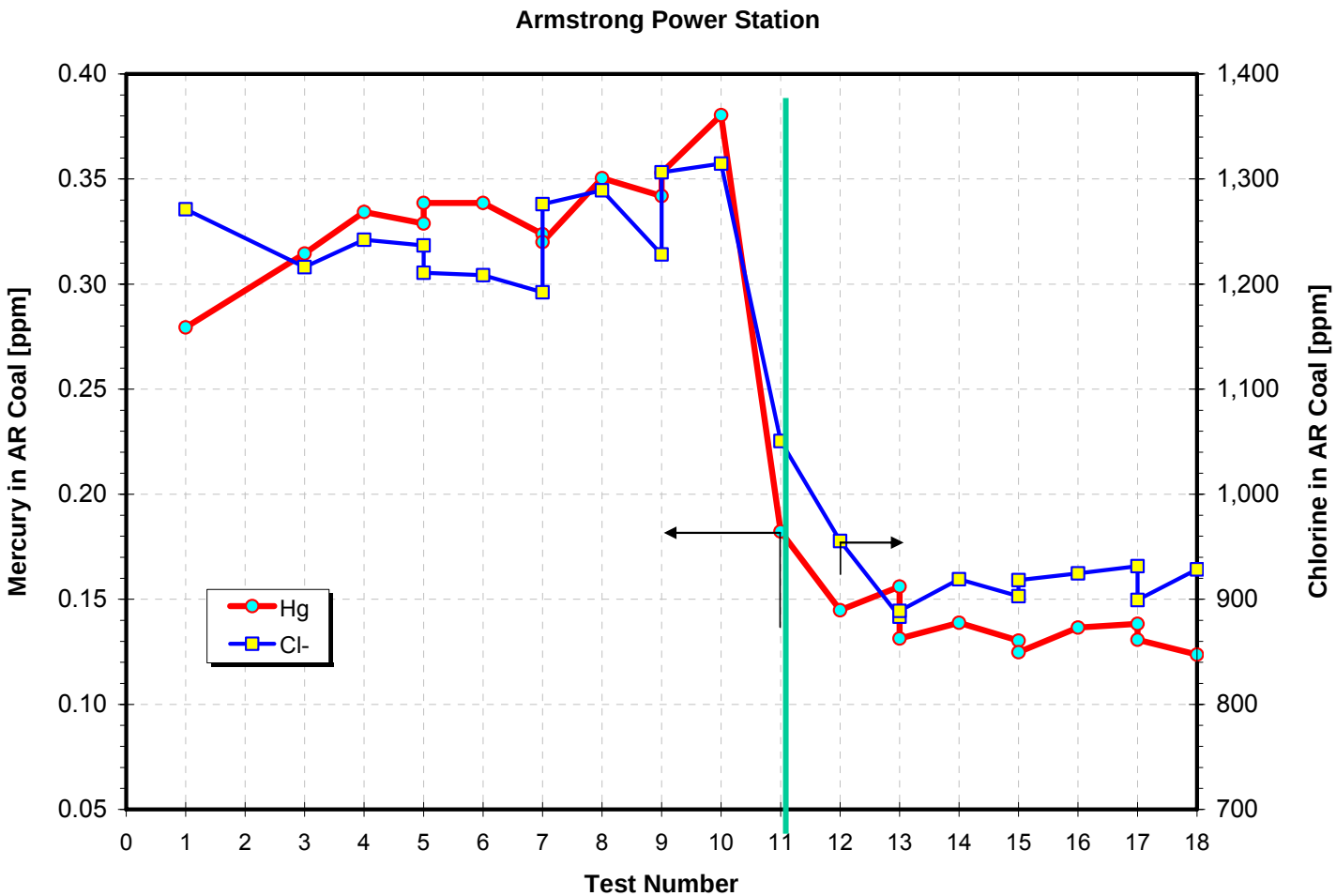
Technical Approach

- *Side-by-side comparison of continuous and semi-continuous **Hg CEMs** to the Reference Method (OHM) under field conditions.*
  - *RM testing performed by Western Kentucky University (WKU) using **2 paired OHM sampling trains**.*
  - *Impinger samples analyzed on site by using the WKU mobile chemical analysis laboratory.*
    - *Results available next morning.*
  - ***Host Unit:** Armstrong Generating Station.*
    - *Two wall-fired units; each rated at approximately 190 MW_{gross}.*
    - *Dry stack, low opacity*

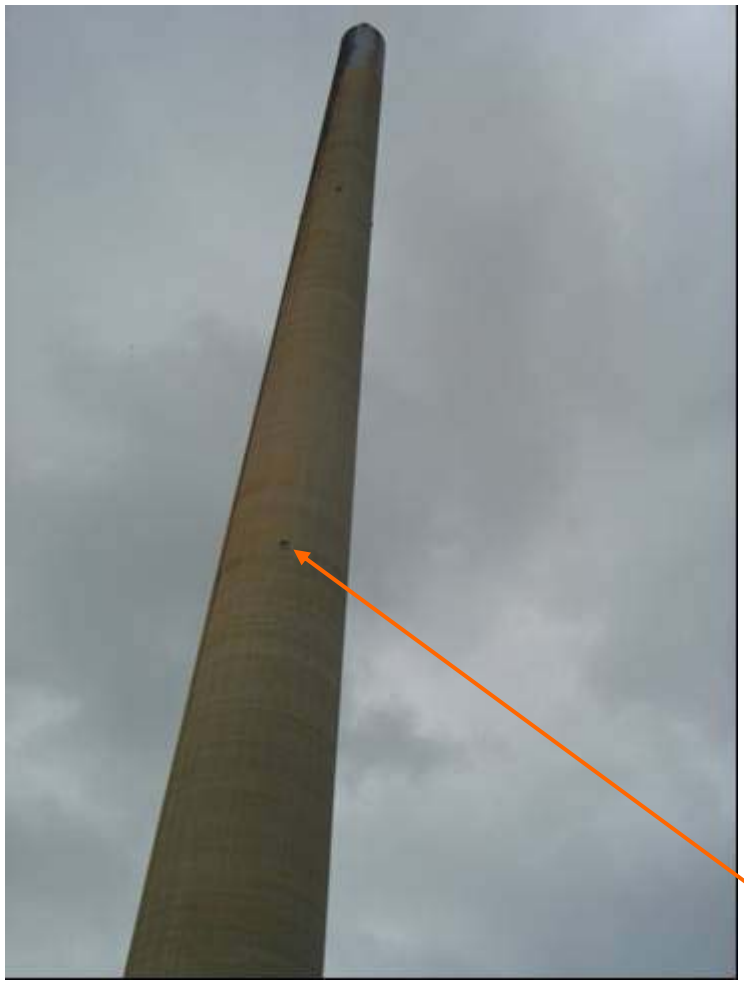
Test Method	Standard	Comment	No. of Tests
OHM	ASTM D6784-02	US Reference Method	72
EU	EN-13211	EU Reference Method	36
Sorbent Trap	Appendix K	New Reference Method	186

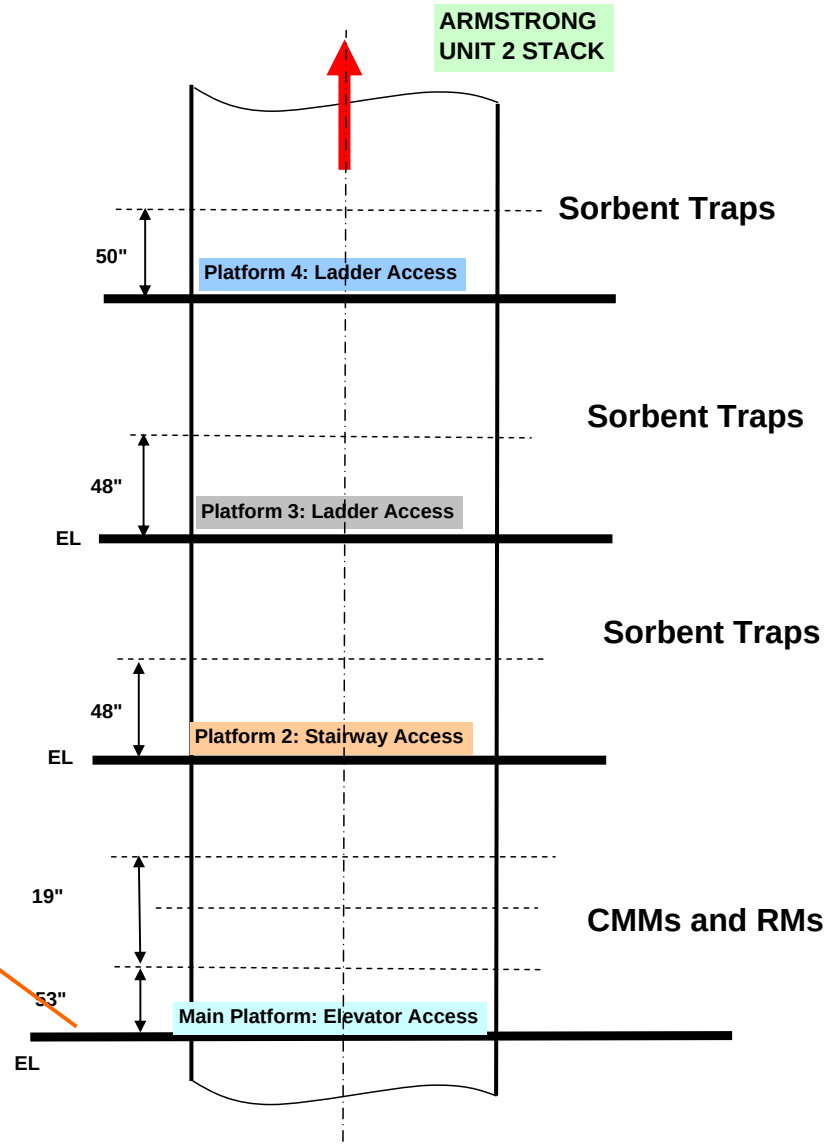
Variation in Coal Properties

- *Coal with high and variable Hg content.*
- *Coal with low and constant Hg content.*



Host Unit: Stack

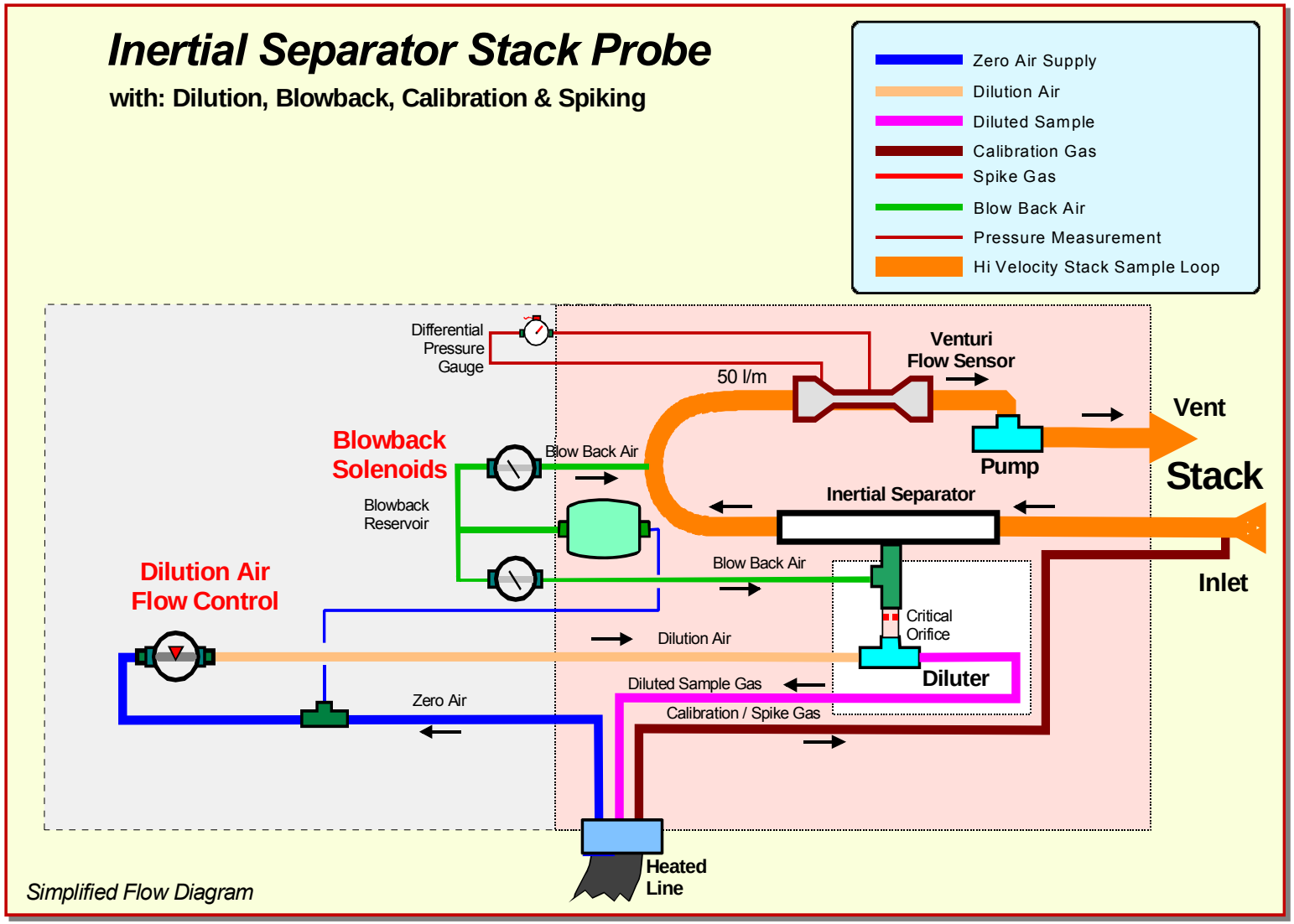




Mercury Measurement Issues

- **Hg CEM technology → Opposite from Hg control technology**
  - Three forms of mercury:
    - Elemental
    - Oxidized (ionic)
    - Particulate-bound: attached to particulate matter (flyash)
- Flyash can adsorb or oxidize elemental mercury
  - Minimize flue gas contact with flyash
    - Remove flyash from sampled flue gas (inertial filter) → **Opposite from sorbent injection**
      - Particulate-bound Hg not measured by CEMs
- No condensation → Opposite from FGD
  - Dilution and heated lines (to avoid ionic Hg loss)
  - Wet stacks: Special challenges
    - Oxidized mercury likely to be associated with water droplets and not captured in isokinetic sampling

Sampling Probe



Hg Monitors Tested at Armstrong

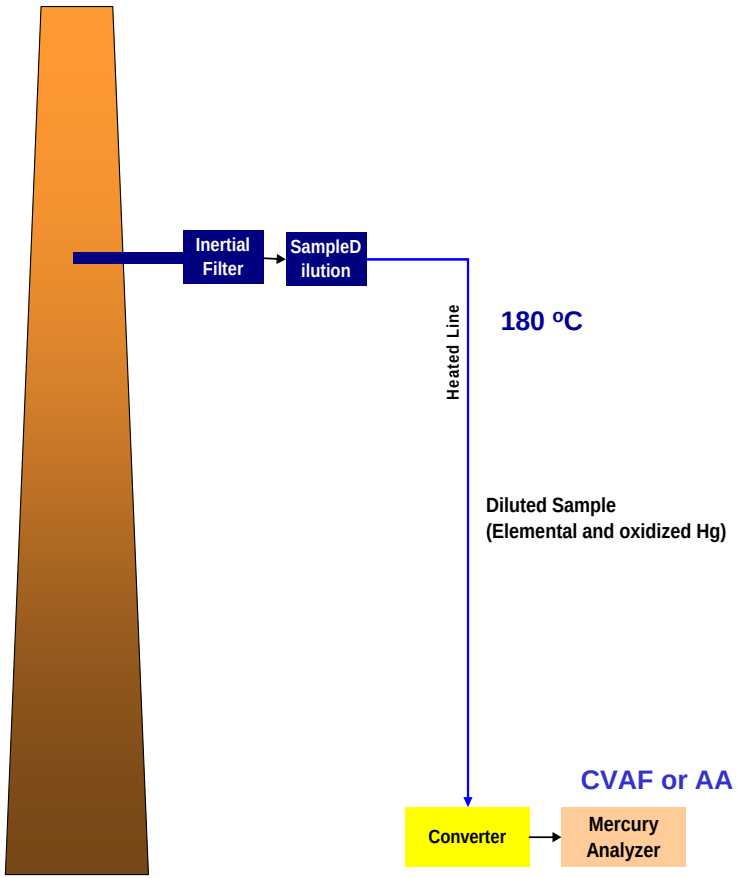
- *Three continuous and one semi-continuous Hg monitors tested at Armstrong.*
- *Measurement principles and features:*
  - *Conversion performed at the probe*
  - *Conversion performed at the ground*

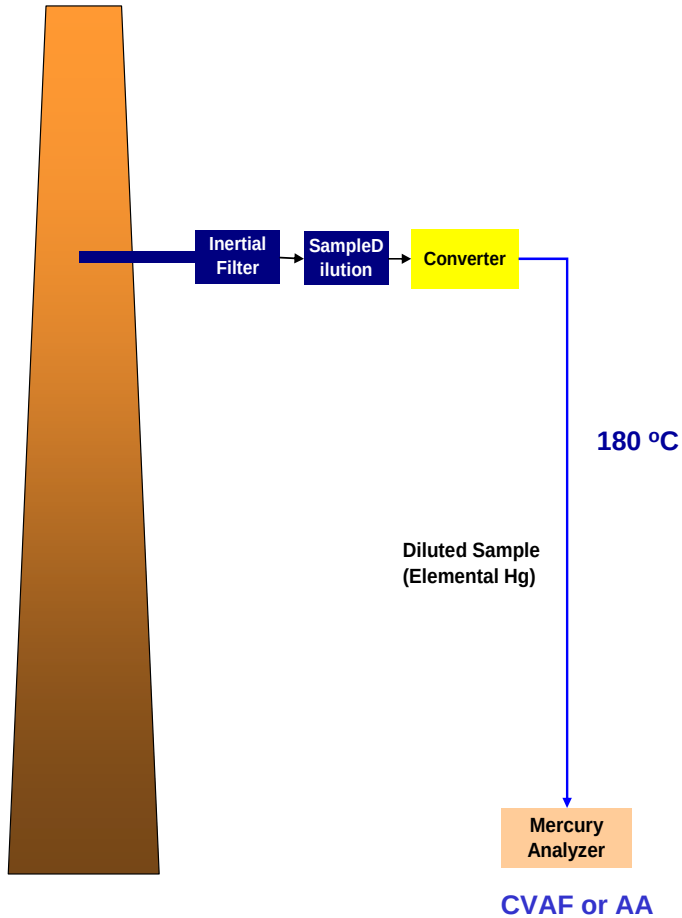
Manufacturer	Monitor Location	Sample Extraction Probe	Sample Treatment	Measurement Principle
A	Ground	■ Inertial, dilution probe ■ 450 ft heated umbilical line	Thermal conversion at the ground	CVAFS with gold preconcentration
B	Ground	■ Inertial, dilution probe ■ 450 ft umbilical line	Thermal conversion at the probe	CVAFS without gold preconcentration
C	Ground	■ Inertial, dilution probe ■ 400 ft heated umbilical line	Dry thermal conversion at the ground	CVAFS with two gold traps
D	CEM Platform	■ Probe with heated filter, dilution and thermal conversion ■ Short heated umbilical line	Thermal conversion performed at the probe	AA with Zeeman background correction, no gold preconcentration

Manufacturer A = Tekran, Manufacturer B = Thermo Electron
Manufacturer C = GE-PSA, Manufacturer D = Ohio Lumex

Sample Treatment: Hg CEMs

sCEM: Hg analyzer located at the stack.

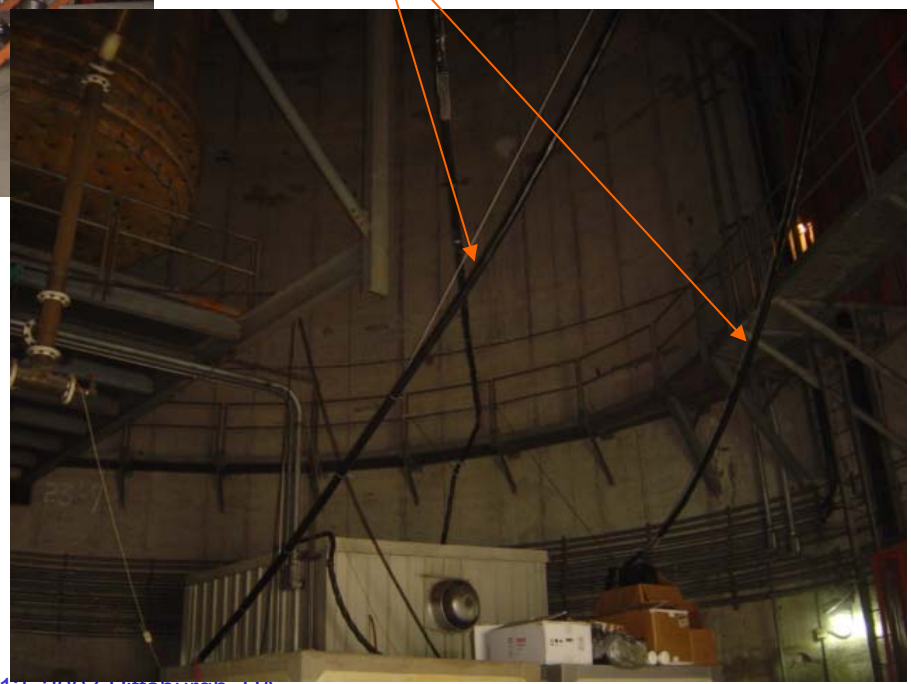




CEM Shelters and Sample Lines

Power requirements:
42 Amps @ 240 VAC/line

Heated Sample Lines
(450 ft long), 180 °C



2 CEM shelters located
at base of the stack:
Tekran, Thermo Electron, GE-PSA.

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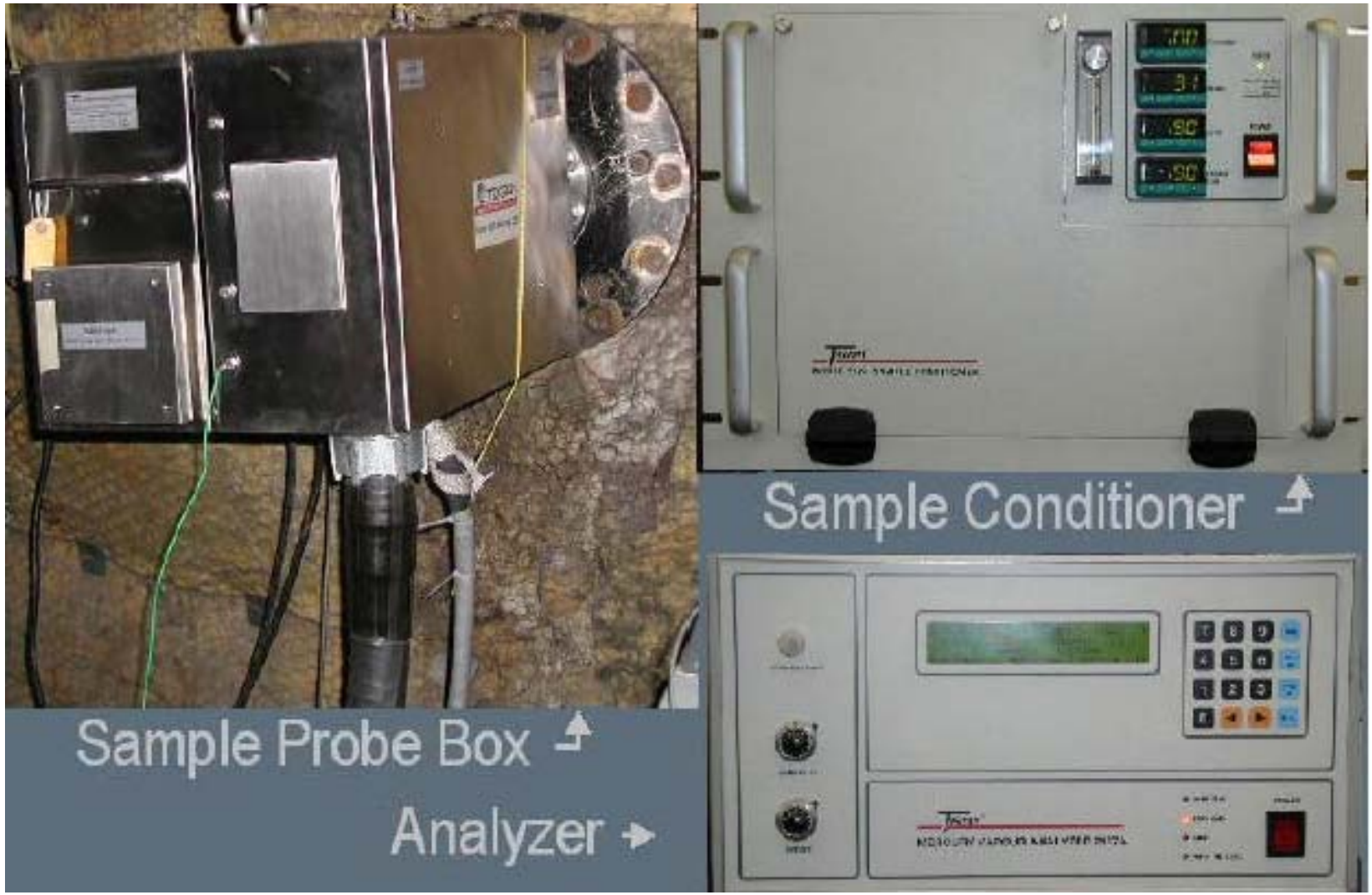
Hg CEMs

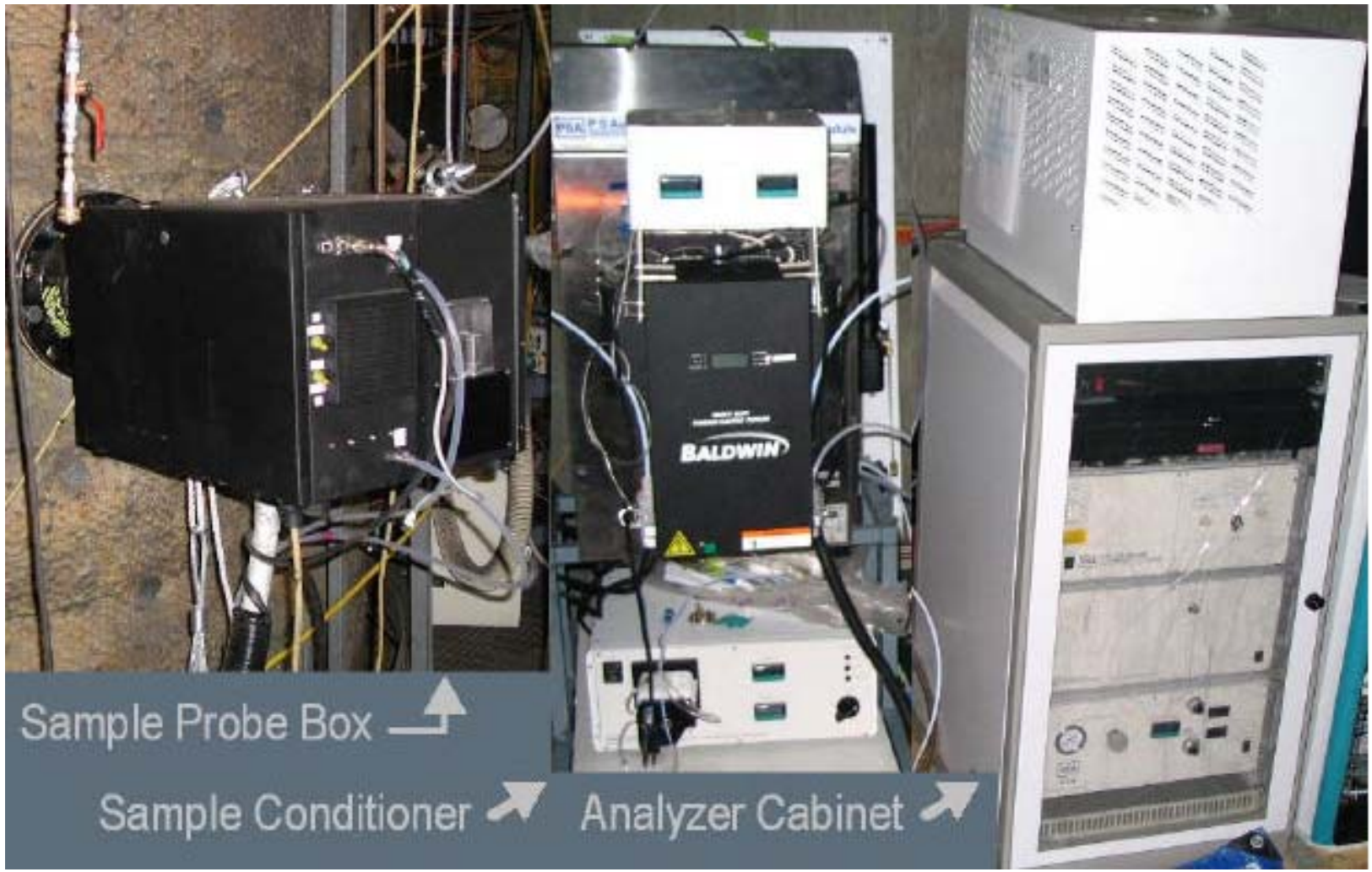
Figure 3-15: Thermo Electron and Tekran CMMs Located in CEM Shelters at Armstrong

Tekran Series 3300 System



Thermo Electron Mercury Freedom System

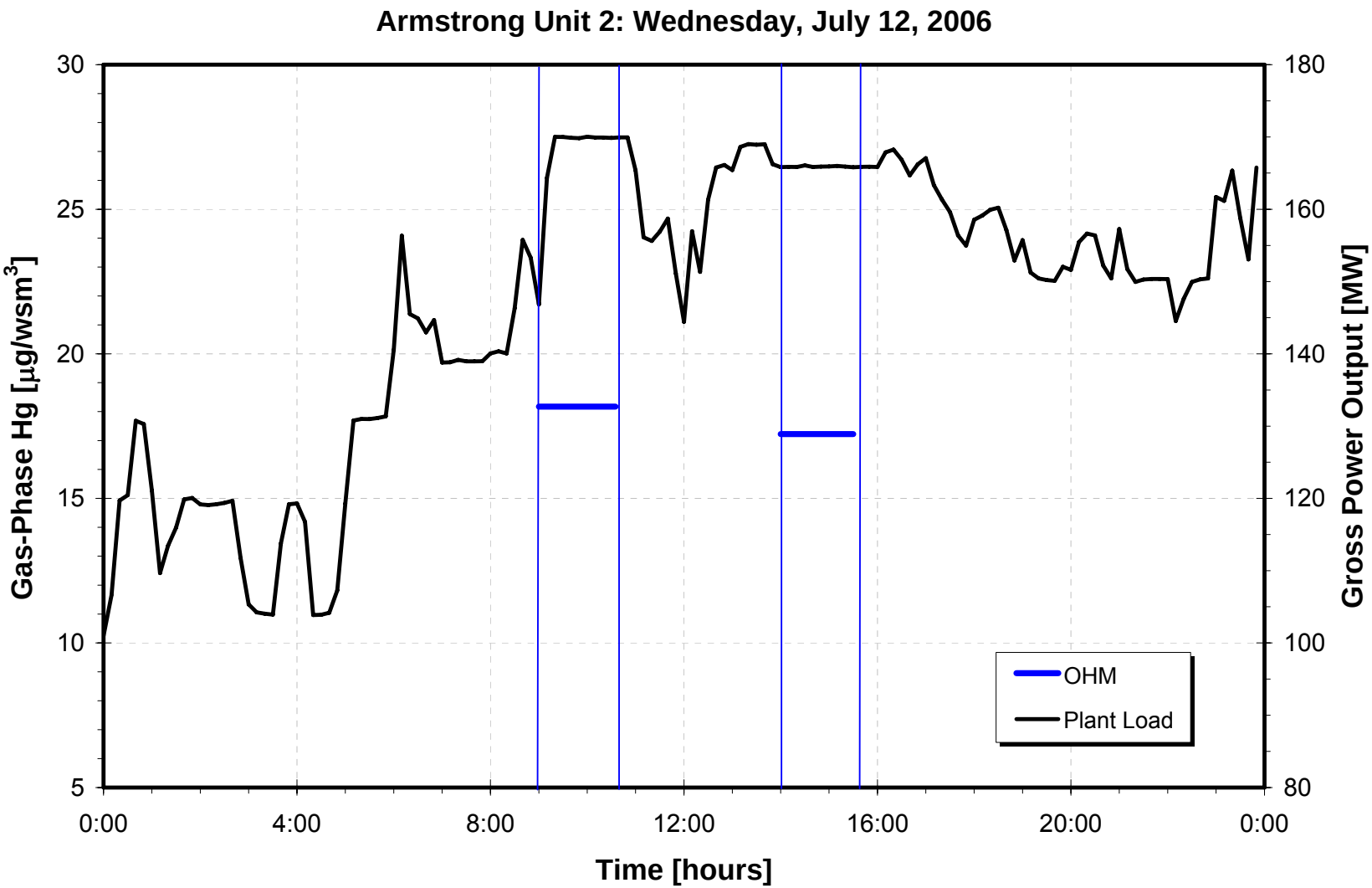
GE-PSA System



Ohio Lumex Semi-continuous System

Typical Hg CEM Results

Manufacturer A = Tekran, Manufacturer B = Thermo Electron
Manufacturer C = GE-PSA, Manufacturer D = Ohio Lumex



Typical Hg CEM Results

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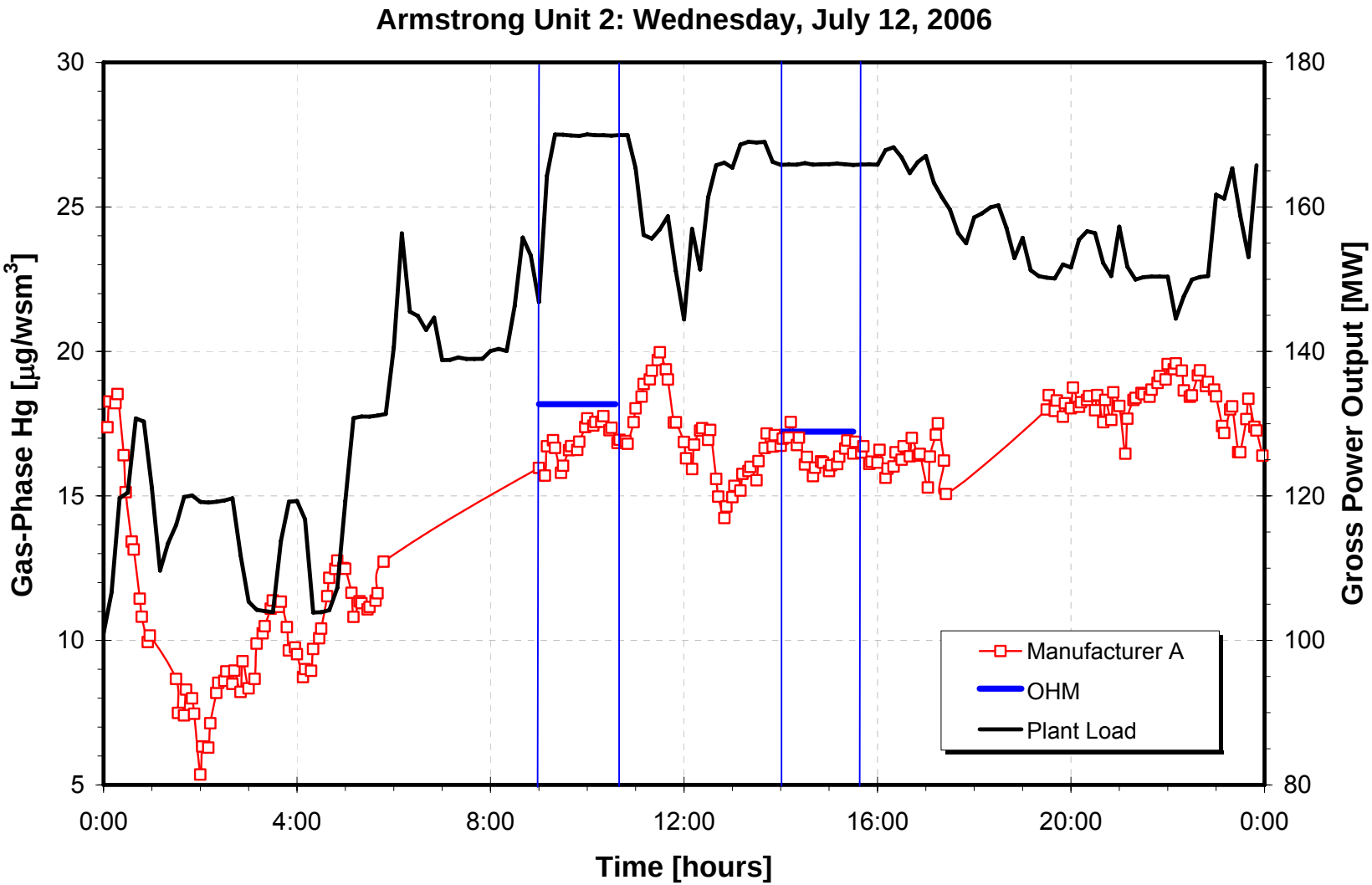

Typical Hg CEM Results

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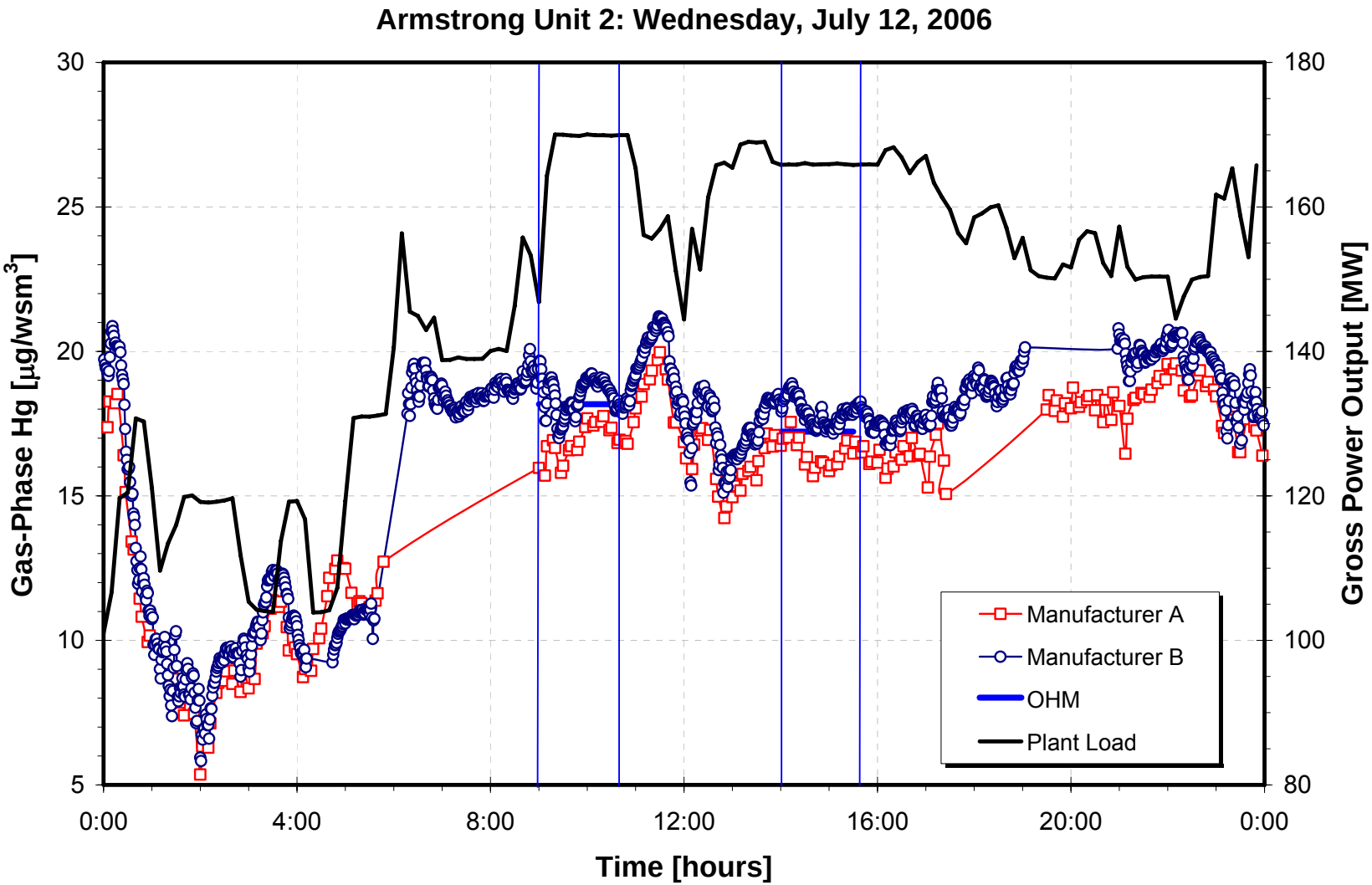

Typical Hg CEM Results

Manufacturer A = Tekran, Manufacturer B = Thermo Electron
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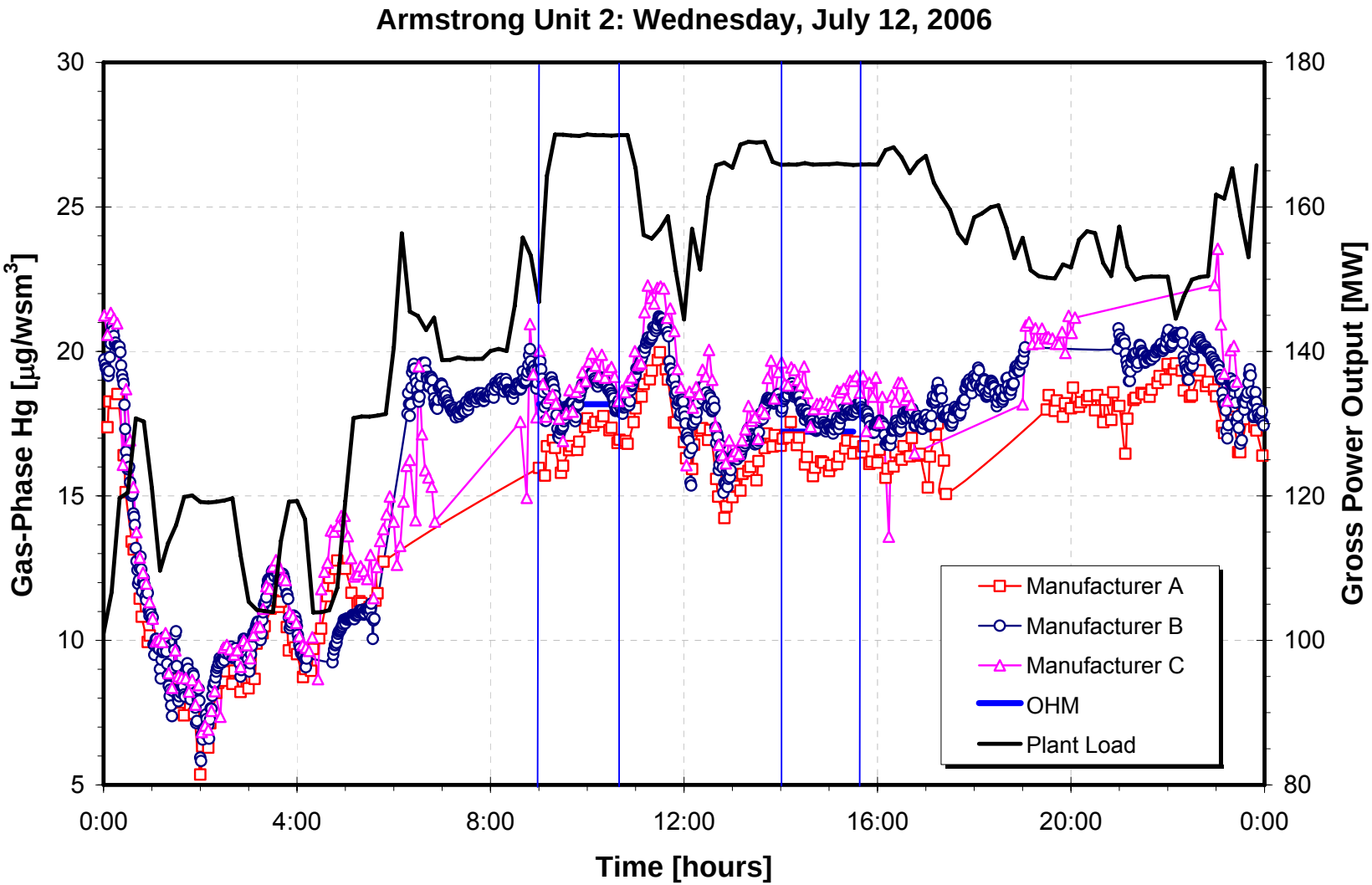

Typical Hg CEM Results

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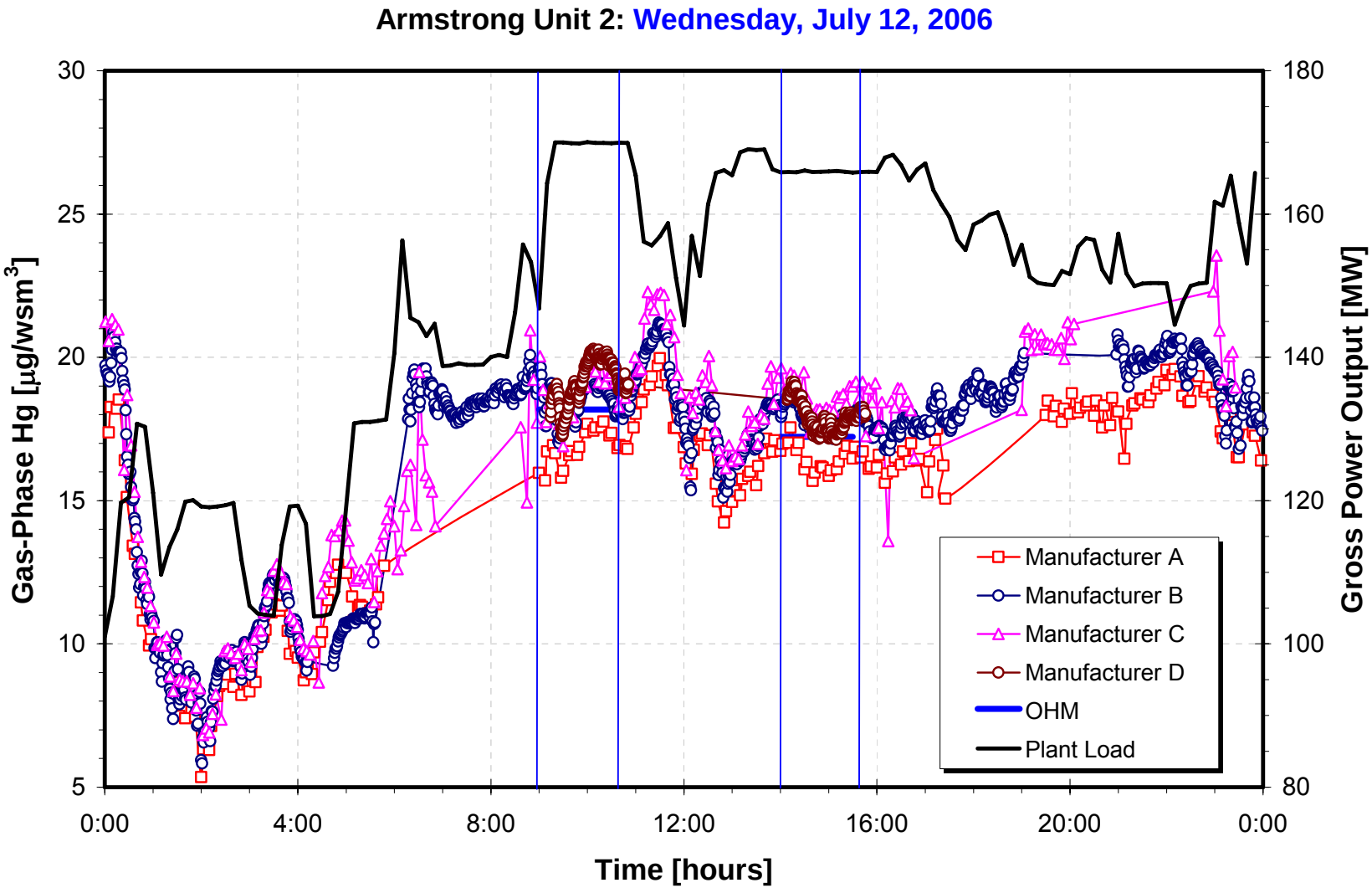
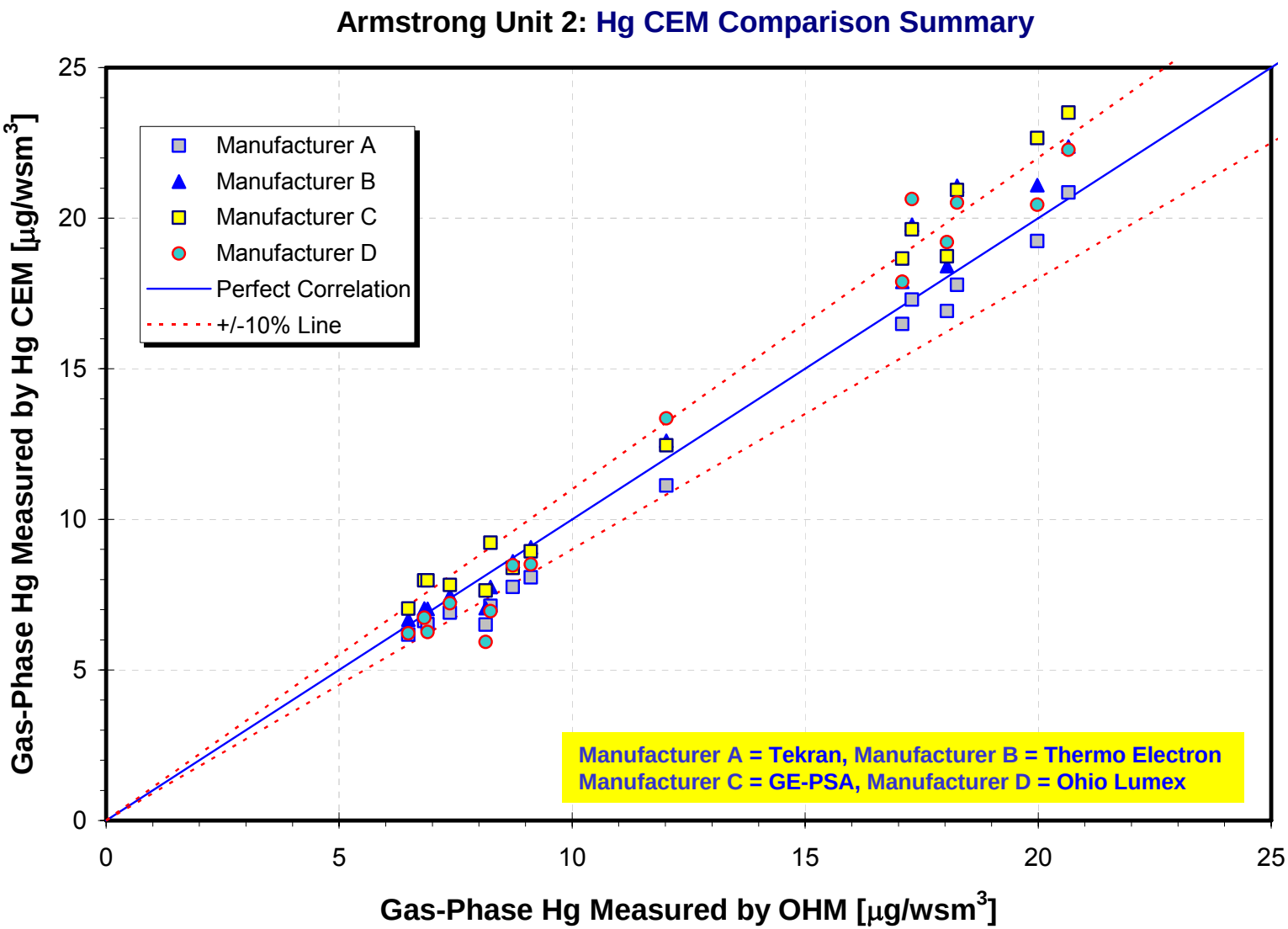
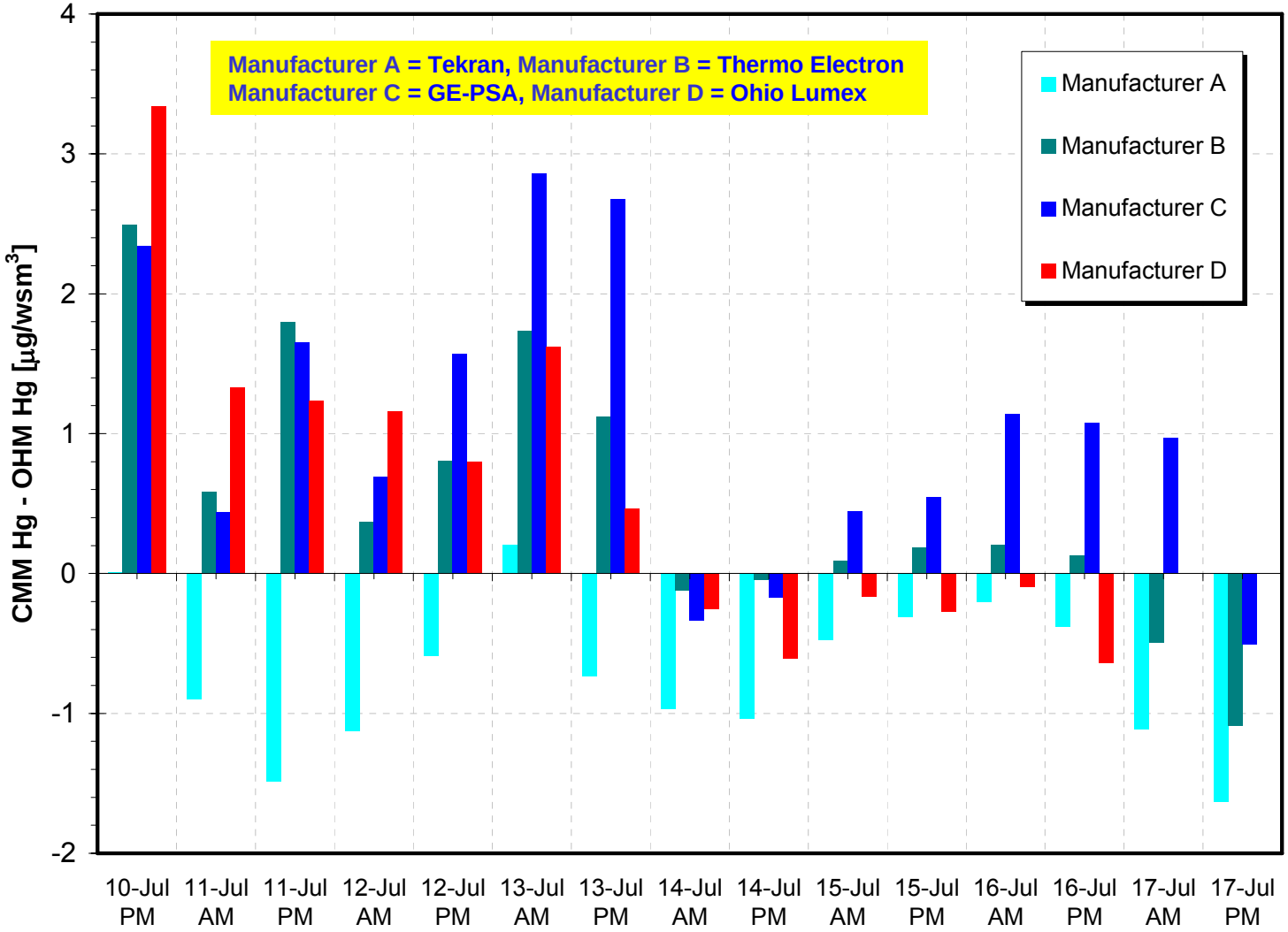


Hg CEM vs. OHM Comparison



Hg CEM vs. OHM Comparison



Results: Accuracy

Parameter	Units	High-Hg Coal		Low-Hg Coal		Test Average	
Manufacturer A		CEM	OHM	CEM	OHM	CEM	OHM
Average Hg	$\mu g/wsm^3$	17.1	17.7	7.0	7.8	11.9	12.4
Bias Error	%	-3.1		-10.4		-4.2	
Manufacturer B		CEM	OHM	CEM	OHM	CEM	OHM
Average Hg	$\mu g/wsm^3$	19.0	17.7	7.6	7.8	13.1	12.4
Bias Error	%	7.8		-2.3		6.2	
Manufacturer C		CEM	OHM	CEM	OHM	CEM	OHM
Average Hg	$\mu g/wsm^3$	19.5	17.7	8.1	7.8	13.7	12.4
Bias Error	%	10.5		4.6		10.5	
Manufacturer D		CEM	OHM	CEM	OHM	CEM	OHM
Average Hg	$\mu g/wsm^3$	19.2	17.7	7.0	7.8	13.1	12.4
Bias Error	%	8.7		-9.4		6.2	

$$B = (Hg_{CEM}/Hg_{OHM} - 1) \times 100\%$$

Manufacturer A = Tekran
Manufacturer B = Thermo Electron
Manufacturer C = GE-PSA
Manufacturer D = Ohio Lumex

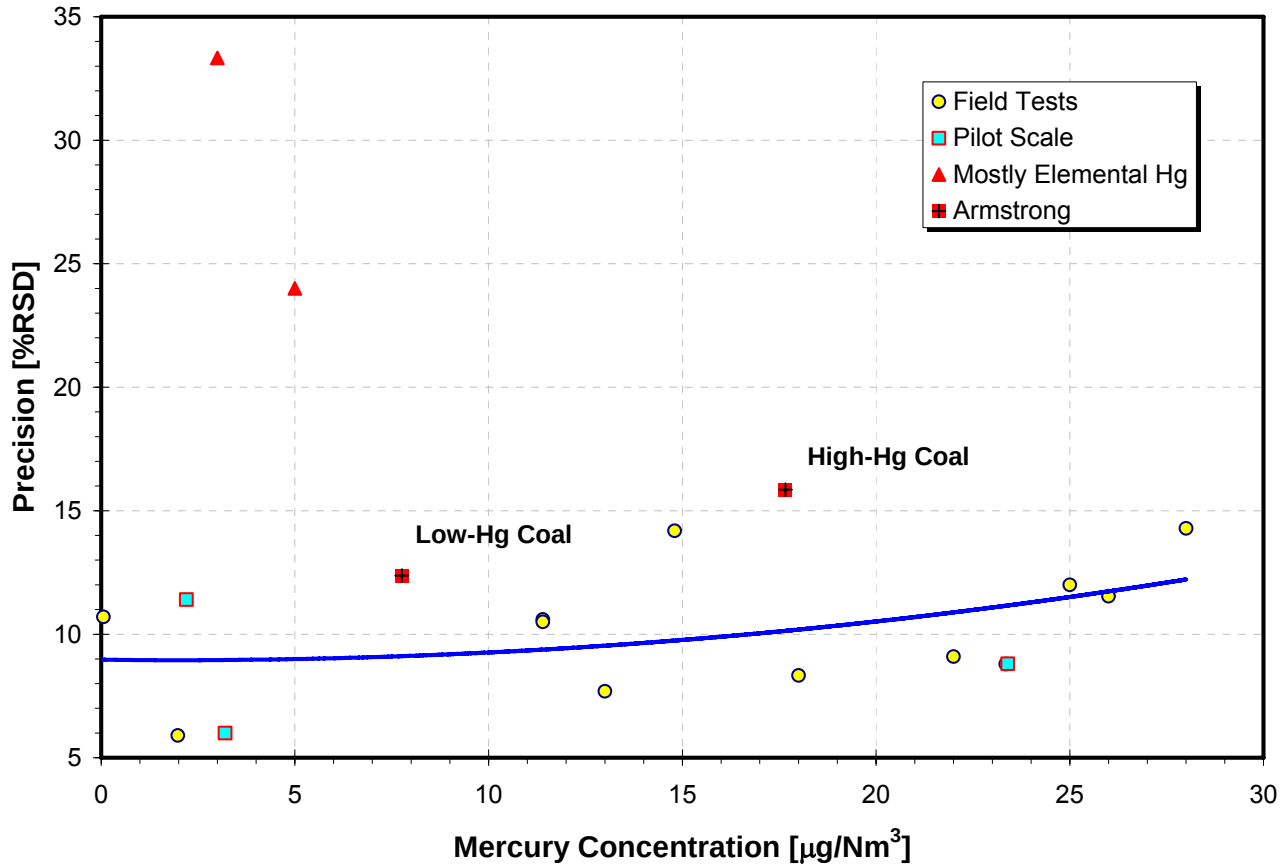
Results: Precision (Relative)

Parameter	Units	High-Hg Coal		Low-Hg Coal	
Manufacturer A		Hg CEM	OHM	Hg CEM	OHM
Average Hg	$\mu g/wsm^3$	17.1	17.7	7.0	7.8
RSD	%	± 17.8	± 16.5	± 9.5	± 14.1
95% RCI	%	± 16.4	± 6.4	± 7.9	± 5.0
Manufacturer B		Hg CEM	OHM	Hg CEM	OHM
Average Hg	$\mu g/wsm^3$	19.0	17.7	7.6	7.8
RSD	%	± 17.0	± 16.5	± 11.2	± 14.1
95% RCI	%	± 15.8	± 6.4	± 9.3	± 5.0
Manufacturer C		Hg CEM	OHM	Hg CEM	OHM
Average Hg	$\mu g/wsm^3$	19.5	17.7	8.1	7.8
RSD	%	± 18.6	± 16.5	± 8.7	± 14.1
95% RCI	%	± 17.2	± 6.4	± 7.3	± 5.0
Manufacturer D		Hg CEM	OHM	Hg CEM	OHM
Average Hg	$\mu g/wsm^3$	19.2	17.7	7.0	7.8
RSD	%	± 15.1	± 16.5	± 14.1	± 14.1
95% RCI	%	± 14.0	± 6.4	± 11.8	± 5.0

- *All mercury monitors performed well.*
- *Precision was similar.*
  - *Relative precision (RCI) for the high-Hg coal was ± 16 %.*
  - *Relative precision (RCI) for the low-Hg coal was ± 9 %.*
  - *Better precision for the low-Hg coal is attributed to constant Hg content of the low-Hg coal and variable Hg-content of the high-Hg coal.*

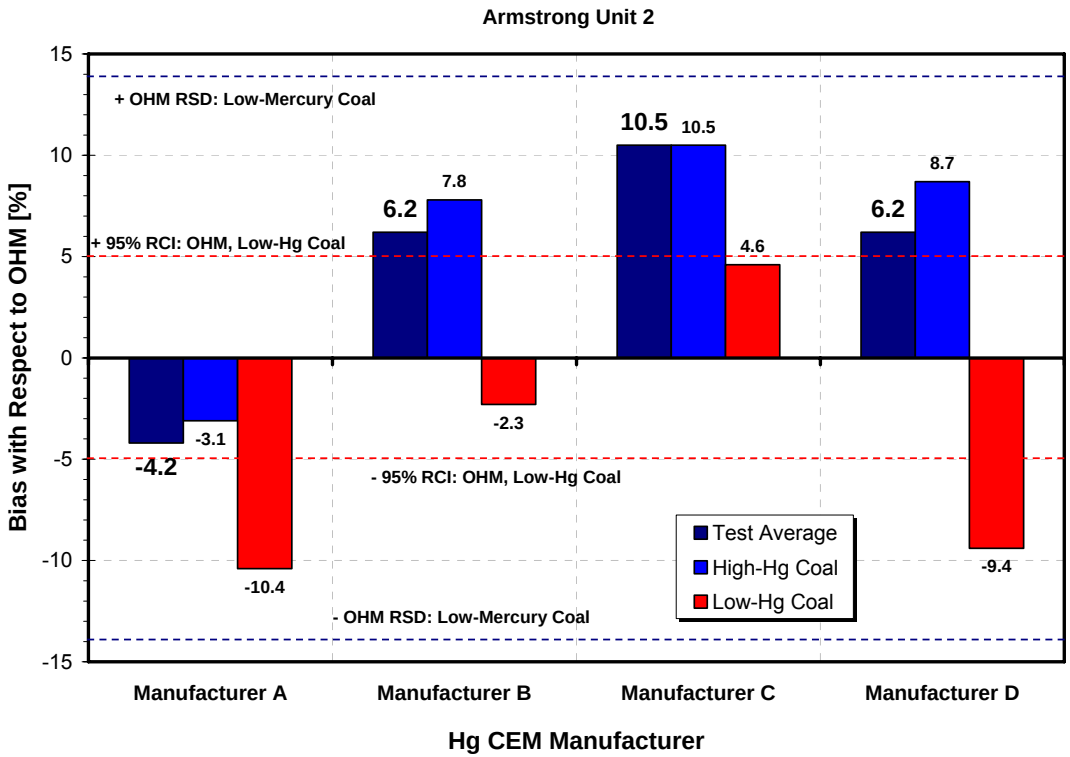
Manufacturer A = Tekran
Manufacturer B = Thermo Electron
Manufacturer C = GE-PSA
Manufacturer D = Ohio Lumex

Precision of the Reference Method



Data Set	Average Hg^T	Standard Deviation	Relative Standard Error, RSE	95% Confidence Interval
	μg/wsm^3	μg/wsm^3	%	μg/wsm^3
High-Hg coal	17.7	2.9	16.5	± 1.1
Low-Hg coal	7.8	1.1	14.1	± 0.4

Statistical Significance of Bias



Manufacturer A = Tekran
Manufacturer B = Thermo Electron
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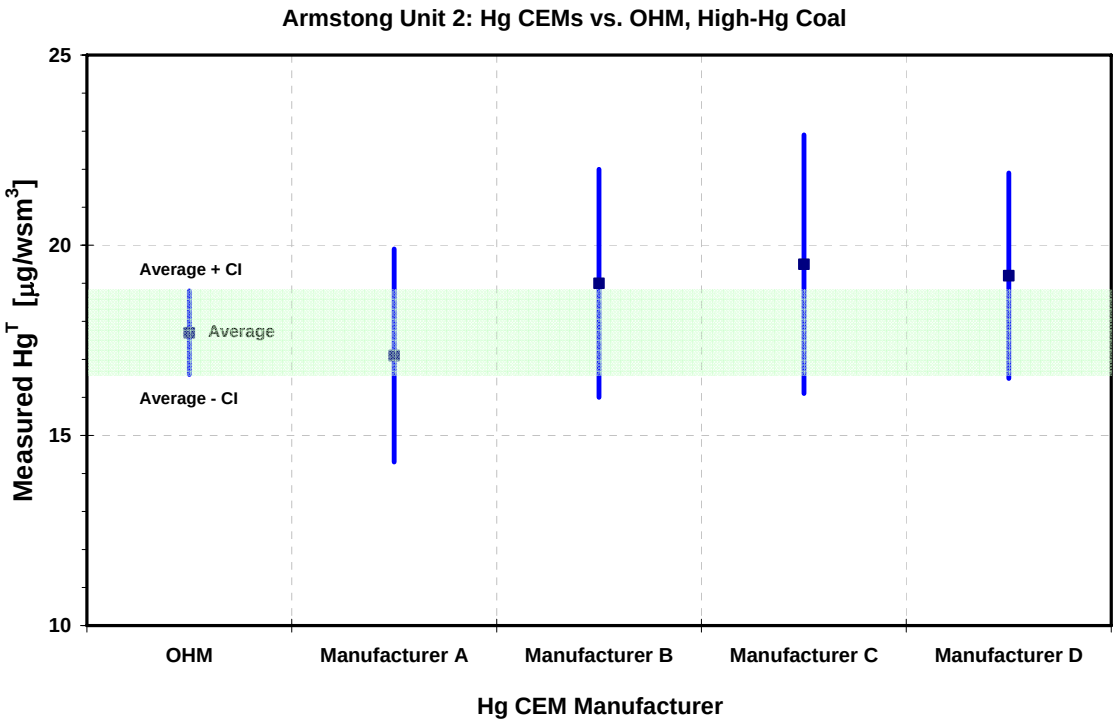
	High-Hg Coal			Low-Hg Coal		
Criterion	**RSD**	**RCI**	**Hg_{avg} ± CI**	**RSD**	**RCI**	**Hg_{avg} ± CI**
Hg CEM	%	%	$\mu g/wsm^3$	%	%	$\mu g/wsm^3$
Manufacturer A	NO	NO	NO	NO	YES	YES
Manufacturer B	NO	YES	NO	NO	NO	NO
Manufacturer C	NO	YES	YES	NO	NO	NO
Manufacturer D	NO	YES	YES	NO	YES	YES

Statistical Significance of Bias



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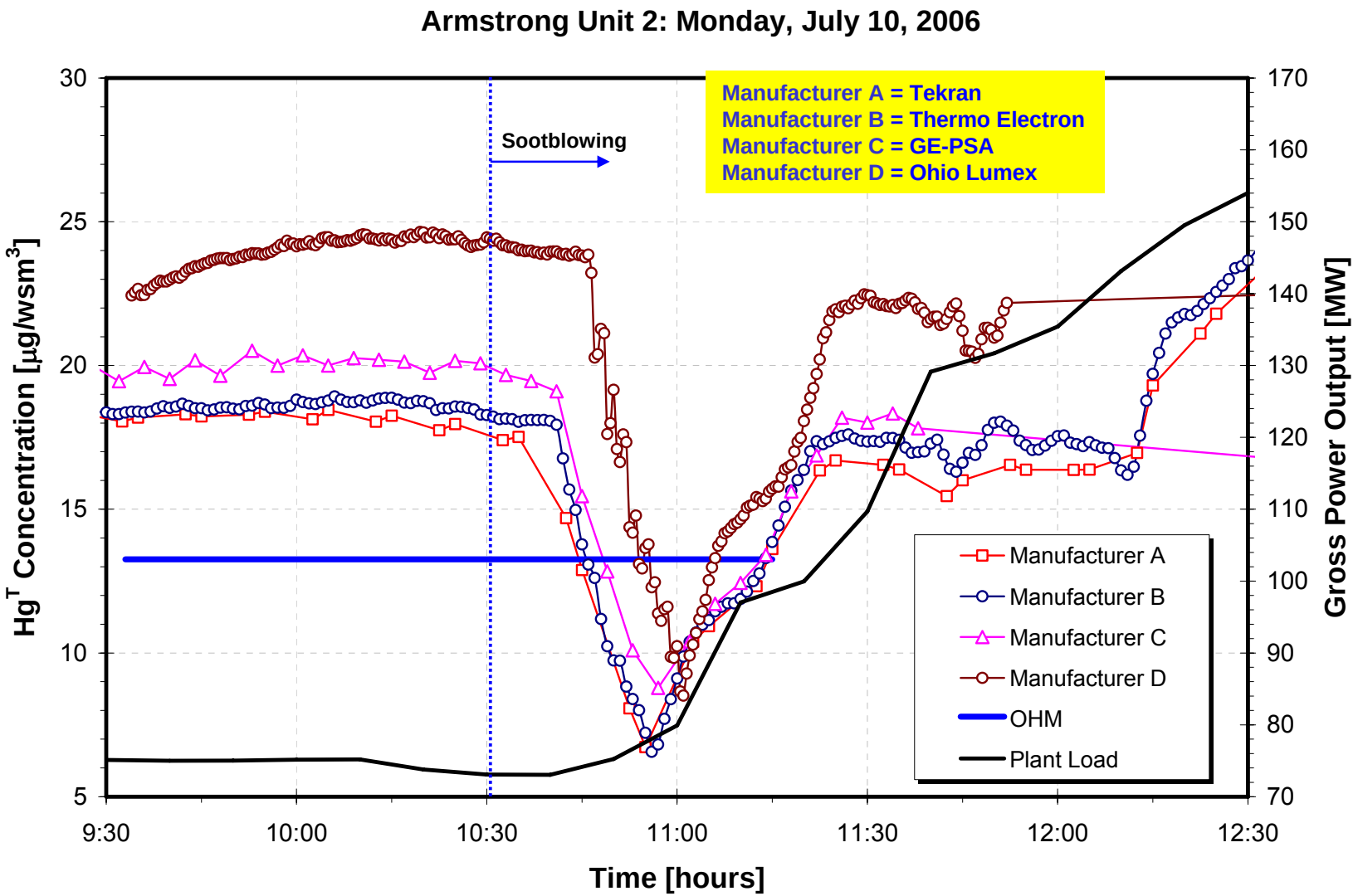
	High-Hg Coal			Low-Hg Coal		
Criterion	**RSD**	**RCI**	**Hg_{avg} ± CI**	**RSD**	**RCI**	**Hg_{avg} ± CI**
Hg CEM	%	%	µg/wsm^3	%	%	µg/wsm^3
Manufacturer A	NO	NO	NO	NO	YES	YES
Manufacturer B	NO	YES	NO	NO	NO	NO
Manufacturer C	NO	YES	YES	NO	NO	NO
Manufacturer D	NO	YES	YES	NO	YES	YES

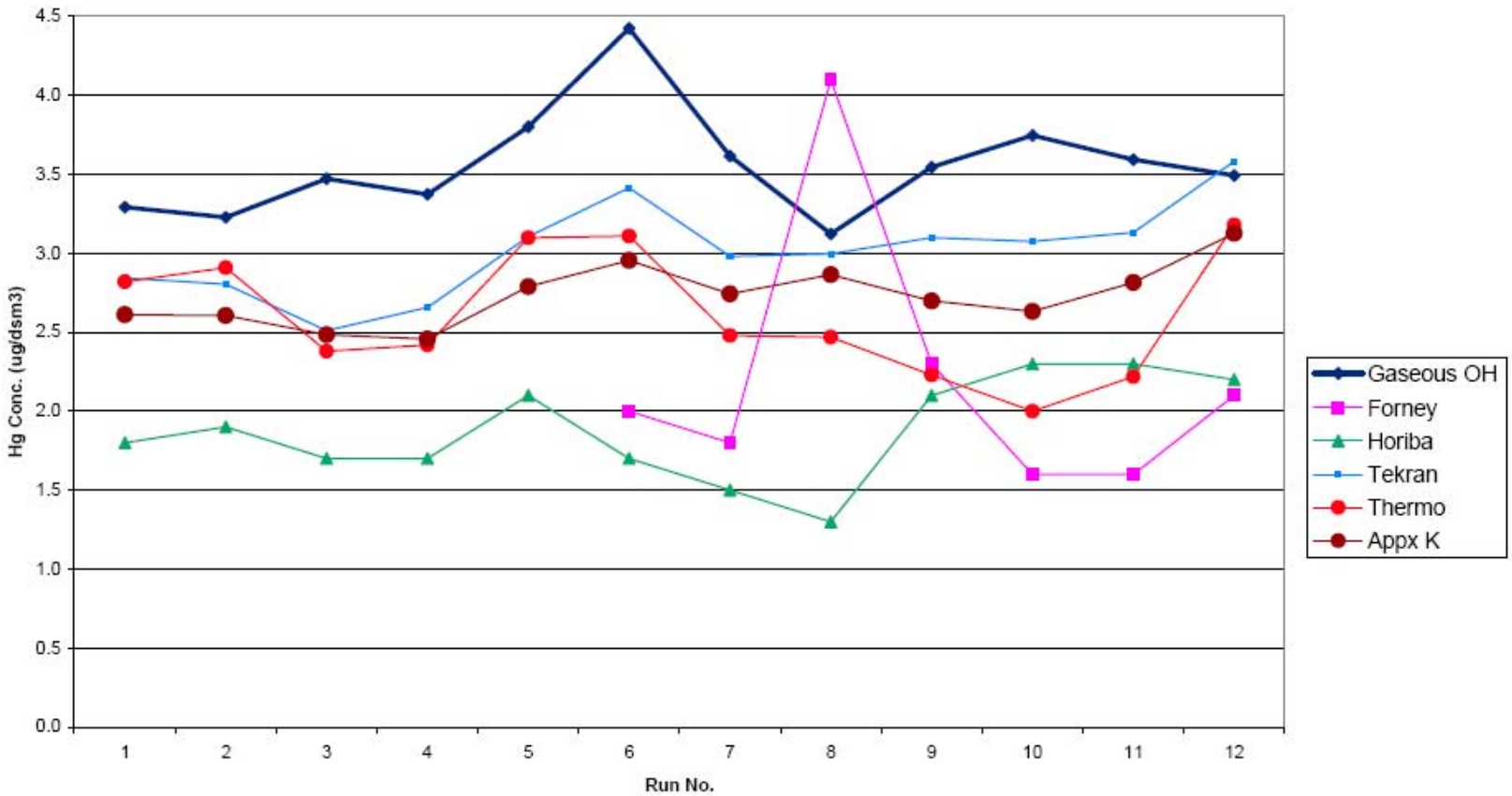
Effect of Sootblowing



Conclusions: Hg CEMs

- *Four Hg monitors were tested at Armstrong.*
  - *All Hg monitors performed well, having similar precision.*
  - *Better precision was obtained for the low-Hg coal, compared to high-Hg coal.*
    - *Constant Hg content of the low-Hg coal.*
    - *Variable Hg-content of the high-Hg coal.*
- *Statistical criteria were used to determine significance of bias with respect to the RM (OHM).*
  - *Not all calculated bias values are statistically significant.*
- *Sootblowing interferes with Hg measurement.*
  - *For obtaining good quality repeatable Hg measurements required for RATA, it is crucial that sootblowers are not activated during the test.*

Wet Stack*



*Trimble County project (MRI): Phase 1

Mercury RATAs

- *Compare CEM to approved Reference Method.*
- *Available Reference Methods:*
  - *Ontario Hydro (wet chemistry)*
  - *EPA Method 30A (IRM)*
    - *Performance-based*
    - *Hardware needs further development*
  - *EPA Method 30B*
    - *Manual method*
    - *Simple*
- *Stack stratification test (traverse)*
  - *Deferred until January 1, 2009*

Questions?

For more information or for a copy of the presentation contact:

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Test survivors

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