

# **Field Evaluation of a Total Mercury Continuous Emissions Monitor at a U.S. Department of Energy Mixed Waste Incinerator**

**99-60**

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## **ABSTRACT**

In conjunction with proposed Maximum Achievable Control Technology (MACT) standards for hazardous waste combustors, extended duration testing sponsored by the U.S. Department of Energy (DOE) and the Environmental Protection Agency (EPA) of three mercury continuous emissions monitors (CEMs) was conducted in the 1996-97 timeframe at a commercial cement kiln burning hazardous wastes at Holly Hill, South Carolina. The emission characteristics of the kiln, specifically the combination of high particulate matter, moisture, and acid gases, were believed to have contributed to the failure of the tested CEMs. The MERCEM mercury analyzer for stack gases manufactured by Perkin Elmer and represented by Aldora Technologies was selected for further evaluation on a DOE mixed waste incinerator at Oak Ridge, Tennessee, expected to present less adverse conditions. The overall scope of the evaluation was carried out over a two-month period from September through October 1998. Not only was the performance of the MERCEM evaluated according to proposed EPA Performance Specification 12 but also were alternative methods of calibration with reference concentrations of mercury and a qualitative assessment of long-term endurance under wet stack conditions.

## **INTRODUCTION**

### **Background**

The U.S. Environmental Protection Agency (EPA) proposed revised regulations for the burning of hazardous wastes in incinerators and boilers and industrial furnaces on April 19, 1996.(1) The proposed regulations outlined the eventual requirement of advanced continuous emissions monitors (CEMs) for some hazardous air pollutants (HAPs) or surrogates for HAPs and encouraged the use of CEMs for other HAPs or HAP surrogates. In support of these monitoring

requirements, the EPA and the U.S. Department of Energy (DOE) formed a joint program to identify and test commercially available CEMs to meet the proposed requirements. As result of a request for proposals, an extended duration test of three total mercury CEMs was conducted at a commercial hazardous waste burning cement kiln at Holly Hill, South Carolina, in 1996-97 timeframe.(2) It is believed that failure of the CEMs was due to emission characteristics of the kiln, specifically the combination of high particulate matter, moisture, and acid gases.(3) It became expected that a DOE mixed waste incinerator would present less adverse conditions and thus allow a total mercury CEM to operate successfully. The MERCEM manufactured by Perkin Elmer and represented by Aldora Technologies was selected for that further evaluation at the DOE Toxic Substances Control Act (TSCA) Incinerator located at the East Tennessee Technology Park (ETTP), formerly K-25 Site, in Oak Ridge, Tennessee.

## **Project Objectives**

The objectives of the evaluation were the following:

- Evaluate performance of the MERCEM continuous emissions monitoring system
- Evaluate methods of calibration with reference concentrations of mercury
- Assess qualitatively the long-term endurance of the MERCEM under wet stack conditions of a mixed waste incinerator

## **Project Overview**

A technical approach and scope were developed to meet the project objectives within budgetary and time constraints. Site modifications to accommodate proposed testing were determined to be minimal with logistics and services to support the project readily available.

Performance testing was designed to address elements of EPA Draft Performance Specification 12 (PS12) (4), specifically:

- Calibration error test
- 7-day calibration and zero drift test
- Relative accuracy test
- Interference test

The overall scope of the project was carried out over approximately a two-month period from September through October 1998. Perkin Elmer supplied a newly factory conditioned MERCEM system. It was installed, commissioned, and underwent a calibration error test, 7-day calibration and zero drift test, and relative accuracy test with comparison to reference method measurements. The initial testing was repeated after four weeks of instrument operation and data collection under normal incinerator operating conditions with interference response testing also conducted as part of the second set of performance tests.

## **Project Organization**

The project was funded by the DOE Office of Science and Technology Characterization, Monitoring and Sensor Technology (CMST) Crosscutting Program and the DOE Mixed Waste Focus Area (MWFA).

The TSCA Incinerator is owned by DOE and managed by Bechtel Jacobs Company LLC for DOE under contract DE-AC05-98OR22700, effective April 1, 1998. Lockheed Martin Energy Systems, Inc., is the DOE prime contractor that formerly managed the incinerator and currently manages the Oak Ridge Y-12 Plant under contract DE-AC05-84OR21400.

The following organizations participated in the project:

- Lockheed Martin Energy Systems, Inc. (Oak Ridge, Tennessee)
- Bechtel Jacobs Company LLC (Oak Ridge, Tennessee)
- Aldora Technologies (Hartsdale, New York)
- Perkin Elmer, Environmental & Process Control Division (Meersburg, Germany)
- Spectra Gases (Alpha, New Jersey)

## **DESCRIPTION OF HOST FACILITY AND MERCEM**

### **General Facility Description**

The TSCA Incinerator is the only operational incinerator in the United States that can process hazardous and radioactively contaminated polychlorinated biphenyl (PCB) waste. It consists of a rotary kiln and a secondary combustion chamber (SCC) as well as liquid and solid feed, off-gas, and kiln ash removal systems and tanks and sumps for management of feeds and liquid effluents. Organic liquid, aqueous, and solid wastes can be fed into the rotary kiln. Only high-heat organic liquid wastes are permitted to the SCC. The rotary kiln and SCC each have an auxiliary burner that utilizes natural gas to control incineration temperatures. The off-gas cleaning system consists of a fully saturated quench chamber, venturi scrubber, packed bed scrubber, two ionizing wet scrubbers (IWS) in series, an induced draft fan, and 100-ft high stack. Both mercury stack emissions and mercury feed rate to the incinerator rate are currently restricted to 0.48 pounds per day.

### **MERCER Description**

The MERCER is designed to measure total mercury emissions from hazardous waste combustors. A gas sample is extracted from the stack through a probe with a coarse inlet filter at a constant sample rate (not isokinetically) of 17 liters per minute (L/min) and transported to the analyzer through a Teflon lined probe and sample system heated to 185°C. At the analyzer, a small portion of the sample flow (about 0.5 L/min) enters a reactor in which ionic mercury is reduced to elemental mercury by a stannous chloride solution. The sample gas containing vapor phase elemental mercury is separated from the liquid and enters an amalgamation unit. In the amalgamation unit, mercury is collected on a gold and platinum trap. At the end of the collection time period, the trap is purged with nitrogen and a photometric baseline is established. Then the trap is heated driving off the mercury, which is measured by atomic absorption spectrometry.

The sensitivity of the instrument can be varied by changing the collection time, which is about 10 seconds for a 0-100 micrograms per dry standard cubic meter ( $\mu\text{g}/\text{dscm}$ ) measuring range. The entire cycle time is about 3 minutes. Since the flow through the photometer consists of only nitrogen and elemental mercury, optical interferences are eliminated. Finally, the remaining flue gas sample is dried and the volume flow rate measured so that instrument output can be reported on a dry basis. The reagents used in the analyzer are stored in the CEM enclosure and pumped continuously into the reactors. Replenishment of reagents and removal of waste solutions are required about every three months. The MERCEM uses an internal chiller to maintain the required instrument temperature. The MERCEM has been published as an aptitude-tested instrument in Germany by the TUV Rheinland Sicherheit und Umweltschutz GmbH.

## **Sampling Locations**

The TSCA Incinerator stack is 53.75 inches inside diameter and has two stack platforms used for sampling and monitoring emissions from the air pollution control system. Both are accessible by ladders from the ground. The lower platform is approximately 30 feet from the ground. One port at this location is dedicated to a probe that extracts stack gas analyzed for CO, CO<sub>2</sub>, and O<sub>2</sub> by facility CEMs. Other ports at this level are used for experimental CEM testing and compliance testing for gaseous pollutants. The upper platform is approximately 50 feet from ground level and contains ports for continuous radionuclide and metals sampling systems, reference methods requiring particulate sampling traverses, and experimental CEM testing. Ports on the upper platform meet ideal regulatory sampling location requirements for particulate traverses at least eight equivalent duct diameters downstream and more than two upstream from any flow disturbance. Ports on the lower platform are four equivalent diameters downstream of the fan discharge. The sampling probe for the MERCEM analyzer was installed in a port on the lower sampling platform. A heated sample line approximately 100 feet long transported the gas sample to the analyzer in a laboratory trailer on the ground. The probe of the reference method sampling train was co-located with the MERCEM probe and remained fixed (i.e., not traversed).

## **TECHNICAL APPROACH**

### **Test Planning and Execution**

In addition to determining the sampling locations and equipment layout and the site support and logistical considerations of the project, radiological control, health and safety, and incinerator feed operation were addressed during test planning and execution.

A unique concern associated with testing any type of equipment that comes in contact with TSCA Incinerator process streams is that of radiological contamination. The TSCA Incinerator thermally treats low-level radioactively contaminated hazardous waste containing PCBs and is categorized as a "radiological facility" per DOE guidelines. The radiological activity level of air emissions is low because the radiological activity in feed material is low and most of the radiological activity in the off-gas stream is associated with particulate matter removed by the air pollution control system. Deposition of radioactive contamination removable by cleaning has been noted on external surfaces of equipment installed in the stack. To ensure that the MERCEM left the TSCA Incinerator site in a radiologically clean state, health physics (HP) technicians directly surveyed the stack probe and filter. In addition the sample line was rinsed

with nitric acid, and the rinse solution was sampled and analyzed for total activity. The condensate removed from the gas processed by the analyzer was sampled and analyzed for total activity. As deemed necessary by HP technicians, tubing connections inside the analyzer cabinet were disconnected to survey analyzer internal surfaces. Other radiological contamination control measures included return of that portion of the stack gas not processed for analysis back to the stack, filtering the exhaust of the processed gas sample, and return of liquid condensates to a sump for treatment.

Ensuring the health and safety of individuals participating in the project was of utmost importance and of top priority during test planning. The project was conducted following the guidelines embodied by the DOE Integrated Safety Management Program. All activities were planned in advance allowing all participants a chance to voice any concern or suggestion for improving the safety of an activity. All personnel participating in the test were required to meet training requirements based on their level of participation and the work activities required of them.

Normal incinerator operation during testing was planned with actual waste streams containing mercury with no additional spiking. MERCEM performance data were obtained while incinerating liquids only as well as both liquids and bulk solids.

## **Performance Testing**

Performance testing was based on PS12. Available data on mercury emissions from the TSCA Incinerator suggested most of the mercury to be in vapor phase. A performance evaluation addressing speciated mercury was determined to be beyond the scope of resources available to the project. Additionally, EPA Method 101A (5) was selected as an alternate approved and cost-effective reference method compared with either Method 101B (6) for speciated mercury or Method 29 (7) for metals including mercury.

### ***Preliminary Reference Method Testing***

Although the MERCEM system was calibrated at the factory, the need was considered to conduct an initial series of reference method tests to develop a site-specific response factor to adjust MERCEM output readings before any measurements to determine relative accuracy. Such a measure was recognized to have merit particularly in cases in which reference materials are unavailable or unreliable. However, due to the short-term schedule of the project, no preliminary reference method testing was performed.

### ***Calibration Error Test***

Calibration error (CE) is the difference between the concentration indicated by the CEM and the known concentration generated by a calibration source when the entire system, including the sampling interface, is challenged. PS12 prescribes that the CEM be challenged three non-consecutive times at each measurement point and that the responses be recorded. The measurement levels are specified as a zero level (0-20% of the emission limit), mid-level (40-60% of the emission limit, and high-level (80-120% of the emission limit). According to PS12, calibration error is to be assessed using standards for both mercury and mercuric chloride. For this project, the CE challenge test was performed only at a high-level concentration in range of an assumed emission limit for total mercury. CE was assessed only for elemental mercury.

The calibration error in percent at each measurement point is calculated by

$$CE = \left| \frac{d}{R_v} \right| \times 100$$

where:

d = difference,

$R_v$  = reference concentration value.

According to PS12, the mean difference between the indicated CEM concentration and the reference concentration value at all test levels shall be no greater than  $\pm 15\%$  of the reference concentration at each level.

### ***Interference Response Test***

Interference response testing is prescribed by PS12 during the CE test at the high concentration level. After the CE measurements are made, the interference test gases are substituted for a portion of the nitrogen dilution gas flow. The response of the CEM is recorded and compared three times alternately to that with the mercury challenge alone. Each interference gas is introduced singly. The interference test gases are injected into the sampling system in a manner to undergo all the conditioning of an actual sample. The prescribed interference test gas concentrations are:  $500 \pm 50$  ppm carbon monoxide,  $10 \pm 1$  percent carbon dioxide,  $20.9 \pm 1$  percent oxygen,  $500 \pm 50$  ppm sulfur dioxide,  $250 \pm 25$  ppm nitrogen dioxide,  $50 \pm 5$  ppm hydrogen chloride,  $10 \pm 1$  ppm chlorine, and  $25 \pm 5$  percent water vapor.

Interference response testing was performed near the end of the project by blending interference gases at a 1:1 ratio with mercury vapor calibration gas.

Percent interference is calculated by

$$I = \left| \frac{d}{R_{HL}} \right| \times 100$$

where:

d = difference,

$R_{HL}$  = value of the high-level calibration standard.

According to PS-12, the sum of the interferences shall be less than 10% of the emission limit value.

### ***Calibration and Zero Drift Test***

Calibration drift (CD) is defined as the difference in CEM output readings from the established reference value after a stated period of operation during which no maintenance, repair, or

adjustment took place. Zero drift (ZD) is similarly defined for zero input. PS12 is designed to allow calibration of CEMs by use of a calibration standard that challenges the pollutant analyzer part of the CEM and as much of the whole system as possible, but not necessarily the entire system and the sampling interface.

CD and ZD were evaluated daily for a seven-day period. ZD was determined by exposing the CEM to zero gas. CD was evaluated by challenging the CEM with elemental mercury only.

Calibration drift in percent is calculated by

$$CD = \frac{R_{CEM} - R_v}{R_v} \times 100$$

where:

$R_{CEM}$  = the CEM response,

$R_v$  = the reference value of the high-level calibration standard.

Zero drift in percent is calculated by

$$ZD = \frac{R_{CEM} - R_v}{R_{EM}} \times 100$$

where:

$R_{EM}$  = the emission limit value.

According to PS12, the CEM calibration shall not drift or deviate from the reference value of the calibration standard by more than 2% of the reference value, and the zero point shall not drift by more than 2% of the emission standard.

The April 19, 1996, EPA proposal provided for an emission standard for mercury of 50  $\mu\text{g}/\text{dscm}$  corrected to 7% oxygen. A subsequent notice of data availability and request for comment on May 2, 1997, changed the proposed emission limit for mercury to 40  $\mu\text{g}/\text{dscm}$  corrected to 7% oxygen.(8) An emission standard of 100  $\mu\text{g}/\text{dscm}$  has been assumed for purposes of evaluating data from this field test.

### ***Relative Accuracy Test***

Relative accuracy (RA) is defined in PS12 as the absolute mean difference between the pollutant concentration determined by the CEM and the value determined by the reference method (RM) plus the 2.5 percent error confidence coefficient of a series of tests with that result then divided by the mean of the RM tests or the applicable emission limit.

Relative accuracy in percent is calculated by

$$RA = \frac{|MD| + |CC|}{RM_{avg}} \times 100$$

and

$$CC = t_{0.975} \times \frac{SD}{\sqrt{n}}$$

where:

RA = relative accuracy,

|MD| = absolute mean difference between the CEM and RM values,

|CC| = 2.5% error confidence coefficient (one-tailed),

RM<sub>avg</sub> = average of the RM data set or the value of the emission standard,

SD = standard deviation of the differences between the CEM and RM values,

t<sub>0.975</sub> = t statistic (2.306 for nine runs),

n = number of sample pairs.

The RA test was conducted by comparing simultaneous MERCEM and RM measurements. The selected RM was EPA Method 101A. The RM measurements were performed with a sampling probe co-located with the MERCEM probe at a fixed point (i.e., not traversed). Nine one-hour runs were conducted during each performance test period with a target gas sample volume for each of 30 dry standard cubic feet. During each run, a gas sample was obtained for measurement of oxygen and carbon dioxide by classical Orsat analysis. The runs were scheduled during a consistent set of operating conditions for the incinerator to the extent possible. No additional waste feed characterization was performed beyond that required for operation under applicable regulatory permits and approvals.

In EPA Method 101A, particulate and gaseous mercury emissions are withdrawn isokinetically from the source and collected in acidic potassium permanganate (KMnO<sub>4</sub>) solution. During sample analysis, the mercury collected (in the mercuric form) is reduced to elemental mercury, which is then aerated from the solution into an optical cell and measured by atomic absorption spectrophotometry. For this project, the sampling nozzle and the probe liner were constructed from quartz glass and the optional filter was omitted. Glassware preparation followed the cleaning procedure of EPA Method 29. The liquid impingers of the sampling train were recovered along with a rinses of the sampling train glassware with fresh acidic permanganate solution and deionized water. Remaining deposits were recovered by rinsing with 8 normal hydrochloric acid, which was analyzed separately for mercury.

The results for both the MERCEM and the reference method were corrected to 7% oxygen using Orsat data from the reference method.

## **Operational Testing**

A four-week operational test period between relative accuracy tests during which the MERCEM would remain installed and collecting data was planned to provide a qualitative assessment of long-term operational issues.

## **Mercury Vapor Calibration Gas**

Spectra Gases supplied cylinders of elemental mercury calibration gas. Aldora Technologies also furnished an elemental mercury permeation tube calibration device controlled by an isothermal bath with nominal range of 0-300  $\mu\text{g}/\text{m}^3$ . Two of the initially prepared cylinders were sent to Energy and Environmental Research Center of University of North Dakota, in Grand Forks, North Dakota, for verification prior to use in the field at Oak Ridge. The measurements for each cylinder were made in duplicate using a full-scale EPA Method 101A and a Semtech mercury analyzer (a CEM). All of the cylinders supplied by Spectra Gases as well as output from the permeation tube device were sampled by Lockheed Martin technicians after the second relative accuracy test using a modified train, minus the probe and filter, with midjet impingers arranged in the same configuration as Method 101A. This modified impinger train configuration was previously used during the joint EPA/DOE demonstration.(9)

## **RESULTS**

### **Test Schedule**

The MERCEM arrived at the host facility on September 8, 1998. After a period of analyzer commissioning, optimization, and fine-tuning, the first relative accuracy test was conducted on September 16 and 17 coincident with initiation of calibration error and 7-day calibration and zero drift testing. A four-week operational test period proceeded without continuous on-site support by Aldora and Perkin Elmer personnel until the week of October 19. A second relative accuracy test was performed on October 22 and 23, along with interference response testing and a second calibration error and 7-day calibration and zero drift test during the timeframe. The field activities concluded shortly thereafter with attempts to verify the mercury vapor calibration reference materials by sampling and analysis and with decontamination, decommissioning, and shipment of the MERCEM from the host facility.

### **MERCEM Installation and Commissioning**

A major issue that arose during installation and commissioning was the potential for transient spikes of mercury to be released into the flue gas during the feeding of bulk solids in discrete charges introduced by the ram feeder system for the rotary kiln. Although the feed operating conditions were within hourly and daily limits established in regulatory approvals, the temporarily elevated stack concentrations on occasion over-ranged the MERCEM and required manual intervention for recovery and resumption of reliable unattended operation. A decision was made to operate only with liquid waste during the first relative accuracy test and to leave the MERCEM in standby when feeding solids containing more than 1  $\mu\text{g}/\text{g}$  of mercury during the four weeks before the second relative accuracy test.

## **Initial Performance Test Results**

### ***Calibration Error, Calibration Drift and Zero Drift Tests***

The interpretation of calibration error test results was made complicated by uncertainty in reference values for mercury calibration gas. Except for that uncertainty, the results appeared sufficiently consistent to reveal no other issue in assessing performance against PS12 guidelines. Likewise, the interpretation of calibration drift results was complicated by uncertainty in reference values for mercury calibration gas. The interpretation of zero drift results was complicated by uncertainty in a final emission limit value that may be proposed by EPA.

### ***Relative Accuracy Test***

During the first relative accuracy test, the incinerator was operated only with liquid wastes being fed to the secondary and aqueous waste feed systems. An analysis of the waste feeds is presented in Table 1, and operating conditions for the incinerator are summarized in Table 2 as an average and range of the average values for each run.

Results from the first relative accuracy test are summarized in Table 3.

For the first relative accuracy test, the MERCEM demonstrated a relative accuracy of 20% compared to the reference method.

## **Operational Test Results**

Operational test results will be discussed more completely in a subsequent project completion report. There were significant periods during which bulk solids being fed to the incinerator were greater than the conservatively established control point of 1  $\mu\text{g/g}$  of mercury and the MERCEM was placed in standby.

## **Second Performance Test Results**

### ***Interference Response Test***

According to PS12, percent interference is calculated as a difference in response while measuring a reference concentration with and without the interference gas present relative to a reference value. With uncertainty in establishing a reference value, it may be as valid to redefine percent interference more simply as a percent change in response while measuring a level of mercury not intentionally varied. This approach is consistent with reporting of data from the EPA demonstration.(10) Interference response testing results are summarized in Table 4.

### ***Calibration Error, Calibration Drift and Zero Drift Tests***

Again interpretation of results was made complicated by uncertainty in reference material values and in the final emission limit that might be proposed by EPA. The calibration error tests did confirm the integrity of the entire sampling system with zero gas deviations about 2  $\mu\text{g/m}^3$  and other measurements in range of 2% of the nominally prepared reference concentrations.

### ***Relative Accuracy Test***

During the second relative accuracy test, the incinerator was operated with both organic liquid waste and bulk solids fed to the rotary kiln. An analysis of waste feeds is presented in Table 5 and operating conditions for the incinerator are summarized in Table 6 again as an average and

range of the average values for each run.

Results from the first relative accuracy test are summarized in Table 7.

For the second relative accuracy test, the MERCEM demonstrated a relative accuracy of 339% compared to the reference method. The emission standard for mercury would have to be as high as 173  $\mu\text{g}/\text{dscm}$  before the relative accuracy would meet the alternative 10% based on the emission standard defined in PS12.

An evaluation of the feed and operating data revealed that the MERCEM results were in close agreement with emission calculations assuming 100% partitioning of mercury in feeds to the stack gas. The results could indicate a potential bias of the reference method at low concentrations or merely be a coincidence from assignment of discrete values to parameter measurements with underlying uncertainty.

### **Mercury Vapor Calibration Gas Verification**

Results of the mercury calibration gas verification are presented in Table 8. The results indicate a variation in measurements performed at different times and potential sampling and analytical difficulties with the modified midjet impinger train. A final analysis of the cylinders by Energy and Environmental Research Center was pending.

## **CONCLUSIONS**

The MERCEM exhibited potential at a mixed waste incinerator to meet requirements proposed in draft PS12 under conditions of operation with liquid feeds only at stack mercury concentrations in range of proposed MACT standards. Reliable performance under conditions of incinerating solids was not demonstrated for the operating conditions and configuration of the host facility. The reliability of available reference materials, particularly mercury calibration gas in cylinders, was not adequately demonstrated to support without further evaluation their incorporation into routine procedures performed by operating facility personnel. It was possible to conduct the demonstration at a facility incinerating radioactively contaminated wastes and to release the equipment for later unrestricted use elsewhere.

## **REFERENCES**

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**Table 1.** Waste feed analysis for first relative accuracy test

Parameter	Units	SCC organic liquid	Aqueous feed
Density	g/mL	0.899	1.05
Viscosity	cP	27.1	1.45
Heating value	Btu/lb	14256	172
Ash content	wt %	0.556	3.87
Organic chlorine	wt %	0.892	0.376
Organic fluorine	wt %	0.0861	0.0618
Sulfur	wt %	0.126	0.317
Mercury	µg/g	2.70	1.79

**Table 2.** Incinerator process parameters during first relative accuracy test

Parameter	Units	Average	Minimum	Maximum
Kiln temperature	°F	1853	1835	1907
SCC temperature	°F	2237	2235	2238
Aqueous waste feed rate	lb/h	343	318	351
SCC waste feed rate	lb/h	319	301	340
Quench temperature	°F	184	184	185
Combustion (stack) gas velocity	ft/s	17.5	16.7	18.3
Stack gas CO CEM	ppmv	3	3	4
Stack gas O <sub>2</sub> CEM	vol %	8.5	8.1	8.6
Stack gas CO <sub>2</sub> CEM	vol %	6.9	6.8	7.1

**Table 3.** First relative accuracy test results

<b>Run No.</b>	<b>RM 101A (ng/dscm)</b>	<b>MERCEM (ng/dscm)</b>		<b>Difference (ng/dscm)</b>
1	59.1	64.6		5.5
2	46.9	53.0		6.1
3	51.5	54.6		3.1
4	61.2	69.0		7.8
5	63.4	70.6		7.2
6	62.0	70.5		8.5
7	49.1	60.2		11.1
8	48.0	60.1		12.1
9	66.8	82.6		15.8
<b>Statistical analysis</b>				
n	9	9	n	9
Mean	56.44444	65.02222	MD	8.577778
SD	7.55763	9.265093	SD	3.857712
			CC	2.965302
			MD  + CC	11.54308
			t	2.306006
			%RA	20.45034

**Table 4.** Interference response test results

Carrier gas	MERCEM response (ng/m <sup>3</sup> )	Difference (ng/m <sup>3</sup> )	Difference (%)	Percent change (absolute)
N <sub>2</sub> /CO <sub>2</sub>	44.4/44.5	0.1	0.225	0.225
N <sub>2</sub> /CO	44.4/44.2	-0.2	-0.450	0.450
N <sub>2</sub> /O <sub>2</sub>	44.4/44.2	-0.2	-0.450	0.450
N <sub>2</sub> /SO <sub>2</sub>	44.4/44.3	-0.1	-0.225	0.225
N <sub>2</sub> /NO <sub>2</sub>	45.4/45.7	0.3	0.661	0.661
N <sub>2</sub> /Cl <sub>2</sub>	45.4/44.9	-0.5	-1.101	1.101
N <sub>2</sub> /HCl	45.4/44.4	-1.0	-2.203	2.203
N <sub>2</sub> /H <sub>2</sub> O	46.4/47.2	0.8	1.724	1.724
Total response				7.040

**Table 5.** Waste feed analysis for second relative accuracy test

Parameter	Units	PCC organic liquid	Bulk solids
Density	g/mL	0.964	0.733
Viscosity	cP	2.73	not applicable
Heating value	Btu/lb	7759	4179
Ash content	wt %	1.50	64.3
Organic chlorine	wt %	0.0096	0.019
Organic fluorine	wt %	0.299	0.012
Sulfur	wt %	0.0416	0.274
Mercury	μg/g	0.985	0.471

**Table 6.** Incinerator process parameters during second relative accuracy test

<b>Parameter</b>	<b>Units</b>	<b>Average</b>	<b>Minimum</b>	<b>Maximum</b>
Kiln temperature	°F	1860	1837	1918
SCC temperature	°F	2224	2221	2232
PCC organic waste feed rate	lb/h	405	297	515
Bulk solids waste feed rate	lb/h	96	78	159
Quench temperature	°F	185	185	185
Combustion (stack) gas velocity	ft/s	19.3	17.6	20.2
Stack gas CO CEM	ppmv	29	0	88
Stack gas O <sub>2</sub> CEM	vol %	8.6	7.8	9.0
Stack gas CO <sub>2</sub> CEM	vol %	7.1	6.7	7.6

**Table 7.** Second relative accuracy test results

<b>Run No.</b>	<b>RM 101A (ng/dscm)</b>	<b>MERCEM (ng/dscm)</b>		<b>Difference (ng/dscm)</b>
1	6.7	24.3		17.6
2	9.8	22.0		12.2
3	4.5	20.4		15.9
4	2.8	19.2		16.4
5	5.7	20.7		15.0
6	3.6	19.9		16.3
7	1.9	19.9		18.0
8	4.4	21.5		17.1
9	6.4	20.5		14.1
<b>Statistical analysis</b>				
n	9	9	n	9
Mean	5.088889	20.93333	MD	15.84444
SD	2.380359	1.519046	SD	1.832424
			CC	1.408527
			MD  + CC	17.25297
			t	2.306006
			%RA	339.0322

**Table 8.** Mercury calibration gas reference materials and analyses

<b>Cylinder</b>	<b>Date</b>	<b>Method</b>	<b>Mercury concentration (ng/m<sup>3</sup>)</b>
CC90843 (8.87 ppbv)	08/28/98	101A	88.5
CC90843 (8.87 ppbv)	08/31/98	101A	65.1
CC90843 (8.87 ppbv)	08/31/98	Semtech CEM	72.2
CC90843 (8.87 ppbv)	10/28/98	midget 101A	39.3
CC90848 (8.87 ppbv)	10/28/98	midget 101A	60.6
CC90913 (5.7 ppbv)	08/28/98	101A	52.5
CC90913 (5.7 ppbv)	08/31/98	101A	44.2
CC90913 (5.7 ppbv)	08/31/98	Semtech CEM	47.1
CC90913 (5.7 ppbv)	10/28/98	midget 101A	60.7
CC94785 (30 ppbv)	10/28/98	midget 101A	210.8
Permeation tube device	10/22/98	midget 101A	48.2