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Mercury Lamp

Drum-Top Crusher

Study

Mercury Lamp Drum-Top Crusher Study

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ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienists
ANOVA	Analysis of Variance
cc/min	Cubic Centimeters per Minute
DTC	Drum Top Crusher
EFT	Extended Field Test
EFTS	Extended Field Test Study
EPA	Environmental Protection Agency
EPSI	Earth Protection Services, Inc.
Hg	Mercury
LOEL	Lowest Observed Effect Level
MCE	Mixed Cellulose Ester
mg	Milligrams
mg/m^3	Milligrams per Cubic Meter
min	Minutes
mm	Millimeters
NA	Not Applicable
ND	Not Detected
NIOSH	National Institute for Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
PEL	Permissible Exposure Limit
PPE	Personal Protective Equipment
PVS	Performance Validation Study
RCRA	Resource Conservation and Recovery Act
REL	Recommended Exposure Limit
RfC	Reference Concentration
TLV	Threshold Limit Value
TSDF	Treatment, Storage, and Disposal Facility
TWA	Time Weighted Average
µg	Microgram

1. EXECUTIVE SUMMARY

The increasingly wide-spread use of energy-efficient, fluorescent lamps has had tremendous environmental benefits. However, mercury, a toxic chemical, is an essential component of fluorescent lamps. When lamps are broken, whether during storage, transport, disposal, or crushing, a substantial portion of the mercury contained in the lamp is released as mercury vapor. If the mercury vapor is not controlled or contained, it could be readily inhaled by anyone in the area and be hazardous to the health of those exposed individuals. Additionally, mercury released from broken lamps is persistent in the environment, where it can be chemically transformed to methylmercury, which is more toxic than elemental mercury and which bioaccumulates up the food chain.

When lamps are disposed of in a landfill, rather than recycled, a substantial percentage of the lamps are broken and virtually all of the mercury contained in the lamps is released into the environment. In addition, lamps may be broken during collection, shipping, or handling. Therefore, in order to protect human health and the environment, the Environmental Protection Agency (EPA) strongly encourages the safe handling and recycling of fluorescent lamps.

Lamp recycling can be done either by sending whole, boxed lamps to a recycler or by using a drum top crusher (DTC) device at the point where lamps are removed from service. DTC devices are designed to fit on the top of a 55 gallon drum in order to prevent the release of mercury vapors while crushing the fluorescent lamps into the drum below. These devices are used to reduce the volume of waste lamps so as to improve storage and handling and reduce shipping costs associated with fluorescent lamp recycling. Each method of recycling has potential benefits and draw-backs. This report examines DTC devices only and does not address whole lamp recycling or disposal of lamps.

As part of ongoing efforts to encourage safe management of mercury-containing equipment and fluorescent lamps, EPA conducted the Mercury Lamp Drum-Top Crusher Study (the Study). The objective of the Study was to evaluate the ability of four DTC devices to contain the mercury released from crushed lamps in terms of preventing worker exposure to adverse levels of airborne mercury resulting from the operation of these devices. The scope of the Study did not include evaluating other lamp handling methods or comparing other lamp handling methods to the use of DTC devices. This report presents the findings of the Study; the purpose of this report is not to endorse or discourage the use of DTC devices.

1.1 Study Overview

The original study design called for testing of four DTC devices from four different manufacturers: A, B, C, and D.[1] However, the Manufacturer D device was removed from the Study after two rounds of testing because of its inability to maintain

[1] *The focus of the Study was on DTC devices in general. It was not the intent of the study team to find the "best" manufacturer or to recommend a certain device. The manufacturers that participated in the Study may choose to identify themselves; however, for the purposes of this report, Manufacturer A, B, C, and D will not be identified.*

mercury vapor concentrations below the Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) of 0.1 milligrams per cubic meter (mg/m^3) during device operation (*refer to Section 3.5.3 and Appendix I*). Therefore, the executive summary focuses primarily on the three other DTC devices that completed the entire Study. A large amount of data was collected and analyzed throughout the Study. To fully understand the information gained, this report should be reviewed in its entirety.

Testing of the DTC devices was performed in a confined space, constructed for the Study, at three separate commercial lamp recycling facilities (the AERC Recycling Solutions facility in Ashland, VA, was used twice during the Study). Lamp recycling facilities were used as the sites for the Study to ensure compliance with all state requirements, to take advantage of the availability of spent lamps that were sent to them for recycling, and to facilitate appropriate recycling of the lamps crushed during the Study. The containment structure was used in order to isolate the Study from background mercury present in the facilities due to regular lamp recycling operations (*refer to Sections 4.2 and 6.1 for information about background mercury levels*) and also to test a "worst-case" scenario for the type of environment in which a DTC device may be operated (i.e., a room with low ventilation rates). Operator exposures would be expected to be lower than found in this Study if a DTC device is operated in a room with higher ventilation rates than used in this Study.

Concentrations of mercury in the air were measured using two Jerome Mercury Vapor Analyzers (Jerome analyzers) and using National Institute for Occupational Safety and Health (NIOSH) Analytical Method N6009 and Draft Analytical Method N9103 (*refer to Appendix E*). Surface wipe samples (from the inside of the containment structure), unbroken lamps, and bulk samples of crushed lamps and pollution control media were also collected and analyzed for mercury using procedures described in Appendix E. A number of observations about possible mercury exposure, DTC operation, and operational problems with the devices tested were made based on data collected over a range of conditions, including:

- Operational period - normal crushing
- Operational period - drum changes and filter changes
- Operational period - improper assembly/leakage of seals
- Non-operational period - broken lamps staged for crushing
- Non-operational period - overnight (full, or partially-full, 55-gallon drum)

After the Study was completed, each manufacturer was able to review the results specific to their device. The purpose of this was to make it possible for the manufacturers to consider the results of the Study and make any modifications to their devices based on these results.

In September 2004, EPA prepared a draft report for the Study, and RTI International, under contract to EPA, arranged for an independent review of the draft report, by recognized technical experts. This review was conducted by letter format in a manner consistent with EPA's Office of Research and Development and Science Policy Council *Peer Review Handbook* (December 2000). Many substantive comments

were made by the reviewers. As a result of these comments, EPA extensively revised this report (*refer to Appendix J for the peer review comments and EPA's responses to the comments*).

1.2 Observations

All three of the devices that completed the Study usually maintained mercury levels below the OSHA PEL within the containment structure and in the operator breathing zone, and one device generally maintained mercury levels below the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV) of 0.025 mg/m^3 during normal lamp crushing operations.[2] However, this Study also demonstrated that during operation of a DTC device, under the operating conditions that existed during the Study, the operator can be exposed to levels of mercury above the TLV and the PEL. Specifically:

- Operator exposure only remained below the OSHA PEL and ACGIH TLV values when the three well-designed DTC devices were operated optimally. That is, when a sub-standard device was used, and when the well-designed devices were not performing optimally or were improperly assembled, operator exposures increased above these levels. (Note: In most of the cases of potential mercury exposure experienced in this Study, the operator only realized that the device being used was not effectively containing mercury because a real-time mercury vapor monitor, equipped with an alarm, was used. The exception to this was that when one of the DTC devices was incorrectly assembled and was, therefore, releasing much more mercury than it would have under normal operating conditions, the operator noted white powder coming out of the connection between the feed tube and the main device assembly that was missing a seal.)

- Measurable concentrations of mercury were detected in the air in the lamp recycling facilities (background air sample results ranged from 0.00052 mg/m^3 to 0.044 mg/m^3).

- There is an increased risk of mercury exposure when full drums are replaced with empty ones, an operation inherent in the use of a DTC device. Drum changes typically resulted in short-term excursions above the PEL. These high mercury levels decreased after the drum changes were complete. Several short-duration, high-volume air samples were taken during drum changes to estimate maximum possible worker exposure. Over 70 percent of these samples were above the PEL.

- Performance of DTC devices may change over the lifetime of the device and under varying environmental conditions. Two of the devices showed a significant

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[2] *Throughout this report the ACGIH TLV is used as a point of reference with which the analytical air samples are compared. The TLV is an eight-hour, time-weighted average; however, the analytical air samples generally represent one to three hour sampling periods (refer to Section 3.1 for a description of the analytical air samples and Appendix A, Table 1 for individual sample durations). Sample results that are greater than the TLV should not necessarily be interpreted to indicate that use of one of the DTC devices included in the Study would result in operator exposure above the TLV because exposure would need to be averaged over an eight-hour day and a 40-hour week.*

decrease in their ability to contain mercury after being used to crush eight drums of lamps. (Note that changes in the test environment, such as increased ambient temperature, may have had some affect on device performance.)

- Minor mistakes in assembly of a DTC device can significantly affect its ability to capture mercury. A leak on one device notably raised mercury levels for the samples in the operator's breathing zone and caused mercury concentrations to exceed the PEL for the area sample collected near the leak. The leak was located at one of the seals and was due to improper device assembly.

- Overnight tests, which were performed during non-operational periods, were inconclusive. Further study would be needed to determine whether or not drums containing crushed lamps with the DTC device attached to the top of the drum, but not in operation, would release mercury in quantities that pose a risk.

- Finally, in one test, the operation of the Manufacturer D device resulted in ambient mercury concentrations of 0.89 mg/m^3, nine times the OSHA PEL, even though exclusively low mercury, Alto® lamps, manufactured by Phillips Lighting, were used.[3] The results from this test illustrate that mercury vapor can exceed established levels even if the lamps being crushed in the DTC device (i.e., low-mercury lamps) are not identified as hazardous wastes.

Use of DTC devices allows several hundred crushed lamps to occupy the space that 40 or 50 whole lamps would occupy, thereby reducing storage and shipping costs. This leads to a reduction in recycling costs on a per-lamp basis. Crushing lamps before shipment also has the advantage of allowing the lamps to be shipped to the recycler in a well-sealed, durable container that is unlikely to release substantial amounts of mercury. Shipping whole lamps inevitably leads to some breakage and potential release; with careful handing, the amount of breakage can be reduced.

The DTC devices evaluated as part of this Study all released some mercury when used. The mercury released during DTC device use will create certain new mercury exposure situations. Exposure will be experienced by the DTC device operator and any assistants handling lamps or working directly with the DTC device. Less direct mercury exposures that could be created by DTC device use include anyone working in or visiting buildings in which DTC devices are used. To eliminate these unnecessary indirect mercury exposures, the ventilation of the lamp crushing room would need to be separate from the general building ventilation system, as is done at industrial lamp recycling facilities.

Additional findings regarding the design and operation of DTC devices, and future areas of study, are discussed in Chapter 7.

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[3] *The Alto® lamps typically contain three to five mg of mercury per lamp and are advertised as "TC compliant" by the manufacturer, meaning that the lamps would generally not be classified as hazardous waste when discarded.*

2. SCOPE OF STUDY

2.1 Mercury Fluorescent Lamp Disposal

On May 11, 1995, EPA adopted new streamlined hazardous waste management regulations under the Resource Conservation and Recovery Act (RCRA) governing the collection and management of certain widely generated hazardous wastes termed "universal wastes" (60 FR 25491). The new hazardous waste management regulations were designed to facilitate the environmentally-sound collection and proper management of certain hazardous waste batteries, pesticides, and mercury-containing thermostats. Hazardous waste lamps were added to the federal list of universal wastes on January 6, 2000 (64 FR 36465). On August 5, 2005, the category of mercury-containing thermometers was removed from the federal list, and a broader category, mercury-containing devices, was added to the federal list of universal waste (70 FR 45508).[4] The universal waste regulations are set forth in 40 CFR Part 273.

By introducing flexibility into the storage, transport, and collection of universal hazardous wastes, the universal waste rule seeks to encourage the development of programs to reduce the quantity of hazardous wastes going to municipal solid waste landfills or combustors and to assure that wastes subject to the universal waste system go to appropriate hazardous waste recycling facilities or treatment, storage and disposal facilities (TSDF). Handlers of universal wastes are subject to more flexible standards for storing, transporting, and collecting these wastes than under full Subtitle C regulation. Hazardous waste lamps are regulated as a universal waste in order to encourage lamp recycling, facilitate better lamp management, and improve compliance with the hazardous waste regulations.

2.2 Study Overview

The Study was performed at three different existing, large-scale lamp recycling facilities. Four DTC devices were originally included in the Study, but only three of the devices completed the Study (*refer to Section 3.5.3*). Analytical air samples were collected to quantify mercury concentrations inside the containment structure and operator exposure to mercury, and a Jerome Mercury Vapor Analyzer was employed to provide real-time measurements of ambient mercury vapor concentrations. Additional samples were collected for the Mass Balance Study.

2.2.1 Study Location

The Study was conducted at mercury lamp recycling facilities for a number of reasons. One critical reason was that these facilities are permitted for hazardous waste lamp processing. Because some states require permits for the use of a DTC device, reliance on the facilities' existing permits allowed the Study to be conducted more quickly and inexpensively and was a key factor in the decision to fund and

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[4] *Mercury-containing thermometers are a type of mercury-containing devices, and thus, are still included in the federal list of universal waste under the broader category.*

conduct the Study. The lamp recycling facilities also provided sufficient numbers of fluorescent lamps to complete each phase of the Study, as well as valuable assistance by receiving and storing the DTC devices, providing sufficient space to conduct the Study, and recycling the crushed lamps generated in the course of the Study.

The disadvantage of conducting the Study at lamp recycling facilities was that each facility had existing background concentrations of mercury that could potentially confound study results. The detected background concentrations are presented in Section 4.2, and apparent effects on study results are further discussed in Section 6.1.

In each facility, the office space was segregated from the work area for the industrial lamp crushing activities. However, the facility layout was different at each study location, which affected facility background mercury levels. AERC Ashland had two large bays, one of which housed an industrial lamp crusher while the other bay was used for the Study. A large doorway separating the two bays was kept closed for most of the study duration. This allowed the DTC crushing activities to be isolated from direct mercury emission sources, but fugitive emissions from the industrial recycling operations were present in the bay used for the Study. AERC Melbourne provided an isolated bay for the Study, and the door between this bay and the main bay where AERC operations took place was closed for the duration of the Study. At EPSI Phoenix, the Study was conducted in the same bay as the facility's industrial-size lamp crusher, resulting in somewhat higher mercury background concentrations, as compared to the other test sites (refer to Sections 4.2 and 6.1).

2.2.2 Containment Structure

During the Study, the DTC devices were operated inside a fabricated containment structure. This structure provided a "worst case" environment in which to evaluate the performance of each device by minimizing ventilation and containing mercury emissions in an enclosed space.[5] The structure was also intended to isolate the DTC operations from the background mercury present in the lamp recycling facilities, although it did so only to a limited extent. The containment structure consisted of a frame constructed from ¾ inch PVC tubing and covered with a single layer of four-millimeter (mm) thick polyethylene sheeting on the walls, floor, and ceiling (*refer to Photograph 2. 1, Photograph 2. 2, Photograph 2. 3, and Photograph 2. 4*).[6]

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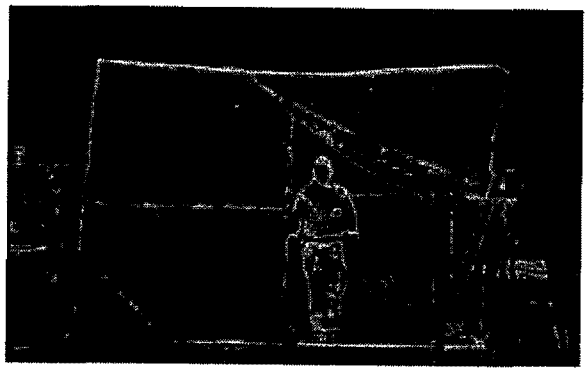
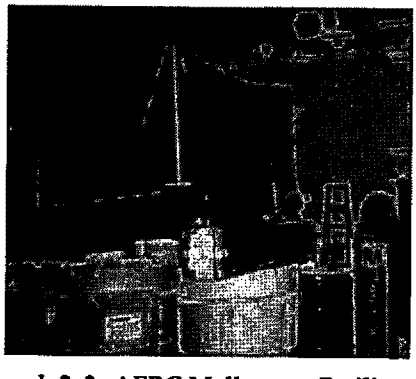
[5] *Operator exposures would be expected to be lower than found in this Study if a DTC device is operated in a room with higher ventilation rates than used in this Study.*

[6] *Mercury has been shown to sorb onto and permeate through polyethylene. Another material, such as vinyl, may have been more appropriate for this Study. During the first set of tests in Ashland, VA, the measurements of the containment structure were 12 feet (ft.) by 12 ft. by 10 ft. high to ensure that there was adequate space to operate each device properly. The containment structure ceiling height was lowered to 8 ft. in Phoenix, AZ, to expedite test set-up. However, three of the devices had feed chutes angled upward, and, as lamps were being fed into the device, they scraped against the ceiling of the containment area. Therefore, containment structures measuring 10 ft. in height were utilized in Melbourne, FL, and the second set of tests in Ashland, VA.*

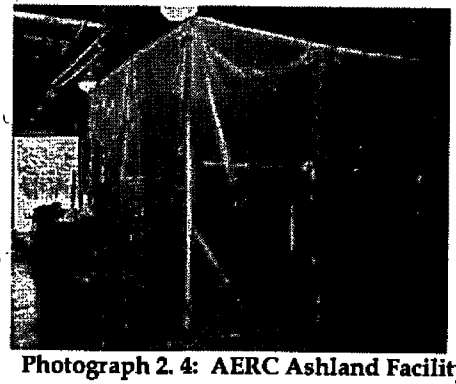
Photograph 2. 1: AERC Ashland Facility – Containment Structure – First Visit



Photograph 2. 2: EPSI Phoenix Facility – Containment Structure



Photograph 2. 3: AERC Melbourne Facility – Containment Structure



Photograph 2. 4: AERC Ashland Facility – Containment Structure – Second Visit

The polyethylene walls, floor, and ceiling were changed before testing each device at each location. The containment structure used a "flap" door to allow entry and exit by the operators. This door, which overlapped the walls, limited the amount of air exchanged between inside and outside the containment structure; however, it was not possible to entirely eliminate air exchanges.

In the initial parts of the Study, the polyethylene was measured and cut inside the facility, next to the containment frame. This was done during Phase I of the Performance Validation Study in Ashland, Virginia and in the first Extended Field

Test in Phoenix, Arizona. However, results from the pre-test wipes of surfaces within the containment structure (taken prior to crushing any bulbs in the DTC device) indicated that mercury was detected on the polyethylene sheeting (*refer to Appendix A, Table 2*). The field team determined that the mercury contamination on the sheeting was most likely attributable to measuring and cutting the polyethylene on the contaminated floor inside the recycling facility, as well as deposition of background airborne mercury from ongoing facility operations. To reduce the potential for contaminating the polyethylene sheeting during construction of the containment structure, staging areas for measuring and cutting the polyethylene sheets were established in the parking lot outside the facility for the second Extended Field Test in Melbourne, Florida and used for all of the remaining tests.

2.2.3 General Procedures

At each stage of the Study, the DTC devices were generally operated in conformance with the manufacturer's operating manual. The only deviation from the operating manual was that more lamps than recommended by one manufacturer (Manufacturer C) were crushed during each round of the Extended Field Test Study.[7] DTC device operations included device assembly and placement on the drum, routine lamp crushing operations, and drum and filter changes. When the DTC device manufacturer representatives were available and on-site, they were allowed to provide further operational instructions specific to their device. In the first phase of the Performance Validation Study, representatives of the four manufacturers were required to be present during the operation of their device. For the remainder of the Study, DTC device representatives were invited to observe, but their presence was not required to include their device in the Study.

Each DTC device was operated according to the following procedure:

1. Construct the containment structure (*described in Section 2.2.2*);
2. Calibrate the Jerome analyzer and take background readings;
3. Equip the operator with required personal protection equipment (PPE), Tyvek® coveralls, respirator, Kevlar® gloves, etc., and personal air samplers;
4. Assemble the DTC device on top of the collection drum inside the containment structure;
5. Ensure that the device is properly assembled and the filter is in place;
6. Collect pre-test wipe samples.
7. Bring spent lamps into the containment structure;

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[7] *The operator's manual for the Manufacture C device specifies that the device should only be used to crush one drum of lamps per eight-hour period in order meet with OSHA safety standards.*

8. Power up the device (runs off of 110-volt, single-phase service) and ensure negative pressure inside the device has been activated;

9. Begin feeding lamps (feed rate during the test was between 30 and 40 bulbs per minute using a two-person crew; for a one-person crew, the rate is expected to be closer to 20 to 25 bulbs per minute).

10. After filling the prescribed number of drums, collect post-test wipe samples from the device and from the walls, ceiling, and floor of the containment structure.

The specific methodologies employed during each of the three studies are discussed in detail in Chapter 3 of this report.

2.2.4 Study Components

The DTC Device Study was divided into three distinct studies.[8] The basic elements of each study are described below.

- Performance Validation (PVS) – sought to (1) quantify ambient mercury vapor concentrations inside the containment structure and personnel exposure during the operation of several DTC devices, and (2) establish initial baseline air concentrations of mercury (Phase I) for comparison to air concentration measurements after DTC devices have processed enough fluorescent lamps to fill approximately eight 55-gallon drums (Phase II).

- Mass Balance Study – sought to estimate the overall capture efficiency of each device by quantifying (1) the total mass of mercury contained in the lamps fed into the DTC device, and (2) the masses of mercury retained in the drum, captured by the DTC device's pollution control equipment, and released into the ambient environment as mercury vapors, aerosols, and particulates containing mercury. Samples for the Mass Balance Study were collected during Phase I of the PVS.

- Extended Field Test Study (EFTS) – sought to quantify and compare ambient mercury concentrations and worker exposure during the operation of the different DTC devices at several different locations, which represented a range of potential operating conditions. The EFTS was designed to evaluate the mercury vapor capture efficiency of each DTC device in a simulated occupational environment, with a focus on assessing the potential for human (operator) exposure to mercury as a result of DTC use. The following tests were performed as additional components to the EFTS.

  - Overnight Test – was conducted during EFT #1, EFT #2, and EFT #3 and sought to quantify the amount of mercury that may escape the DTC device and full drum assembly when the device is not in operation.

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[8] *Because of the exploratory nature of the Study and the desire to maximize data collection while in the field, certain ad hoc changes to the original sampling plan were introduced not always with the ability to pre-define data quality objectives such as sample sizes or acceptable error ranges.*

- "U" Shaped Lamp Test - was conducted during EFT #3 and sought to evaluate airborne mercury levels from two DTC devices, while processing "U" shaped lamps (U-tubes).

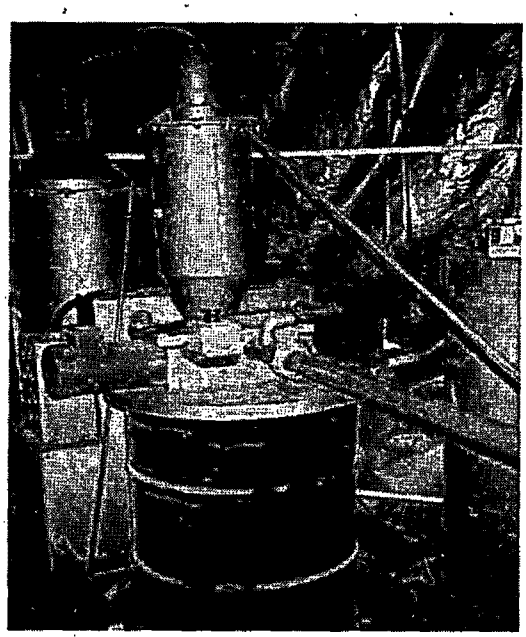
- Box Test - was conducted during EFT #2 and EFT #3 and sought to determine the degree to which shipping boxes containing broken lamps located inside the containment structure contributed to elevated mercury concentrations detected during early phases of the DTC Study.

2.2.5 Equipment

The DTC Device Study evaluated crushers from four different manufacturers:

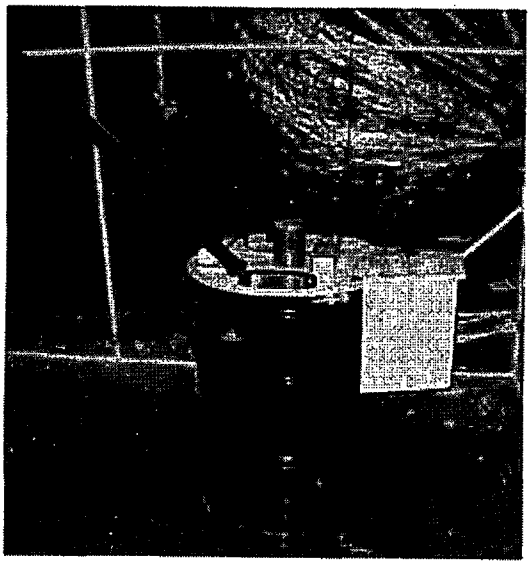
- Manufacturer A *(Photograph 2. 5)*
- Manufacturer B *(Photograph 2. 6)*
- Manufacturer C *(Photograph 2. 7)*
- Manufacturer D *(Photograph 2. 8)*

All manufacturers except Manufacturer A provided new, unused DTC devices for the Study. Manufacturer A provided a prototype machine that was used prior to the Study, but was cleaned and decontaminated by the manufacturer before it was sent for testing in the Study. For reasons that are discussed in Section 3.5.1 of this report, the Manufacturer D device was tested only during Phase I of the PVS and the first round of the EFTS.

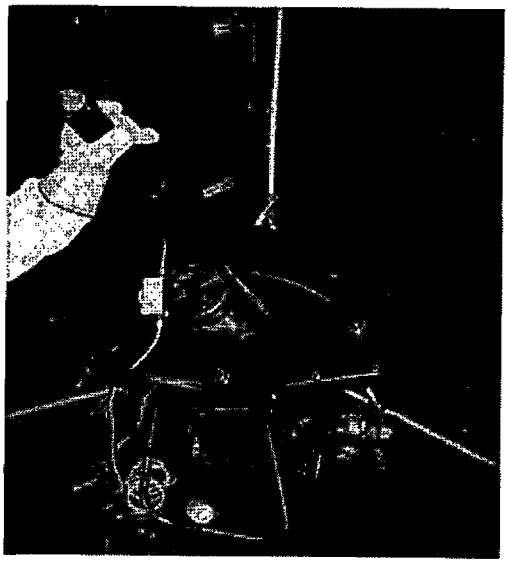


Photograph 2. 5: Manufacturer A Device

Photograph 2. 6: Manufacturer B Device



Photograph 2. 7: Manufacturer C Device



Photograph 2. 8: Manufacturer D Device

Table 2. 1 summarizes the manufacturer information contained in the operating manual that was provided with each machine.

Table 2. 1: DTC Device Equipment Operating Manual Comparison

	Manufacturer A	Manufacturer B	Manufacturer C	Manufacturer D
Filter Maintenance Change Frequency				
Particulate Filter	Change every 100,000 Lamps	Change Every 2,400 Lamps	Change Every Full Drum	Change Every 300 Lamps
HEPA Filter	NA	NA	Change Every 10 Drums	Change Every 10 Particulate Filters or 3,000 Bulbs
Carbon Filter (quantity)	85 lbs	Not Specified (Approx. 13 oz)	22 lbs	Not Specified (Approx. 5 lbs)
Filter Change Frequency	Change After 750,000 Lamps	Change Every 2,400 Lamps. Lamp Counter Shuts Down Motor at Lamp Count of 2,400	No Change Frequency Specified	Change Annually or Every 10,000 Lamps
Operating Manual has Filter Change Instructions or Procedure For:	Particulate and Carbon Filter	Filter Cartridge (Contains Particulate and Carbon)	Particulate and HEPA Filter	Particulate, HEPA and Carbon
Operating Manual has a Log Form to Document Filter Maintenance	No	No	Yes	No
Health and Safety				
Operating Manual Specifies Operational Time Limits	No	No	Do not crush more than one drum per Eight-Hour Shift	No
Operating Manual Requires/Recommends Respirator	Required If indicated by Direct Reading Mercury Vapor Instrument Results	No	No	Required (Half Face Respirator)
Operating Manual Requires/Recommends Safety Glasses	Required	Required	Required	Required

	Manufacturer A	Manufacturer B	Manufacturer C	Manufacturer D
Operating Manual Requires/Recommends Gloves	Recommended	No	Required	Required
Operating Manual Requires/Recommends Hearing Protection	Recommended	No	No	No
Operating Manual Requires/Recommends Coveralls	Required	No	No	No
Operating Manual Requires/Recommends Air Monitoring for Mercury Vapor	Recommended	No	No	No
Operation				
Operating Manual has Equipment Operating Instructions or Procedure	Yes	Yes	Yes	Yes
Operating Manual has Shutdown Instructions or Procedure	Yes	Yes	Yes	Yes
Operating Manual Shutdown Instructions or Procedure Requires use of Vacuum System During Equipment Shutdown	Automatic Operation of Vacuum System Continuously while Device is attached to Drum of Crushed Lamps	Manually Allow Disposer to Run for 2 to 3 Minutes When Finished Using Machine	Automatic Purge for 10 Seconds after Shutdown	NA
Operating Manual has Drum Change Instructions or Procedure	Yes	Yes	No	Yes
Features and Controls				
Device Has a Drum Full Indicator	Yes	No	Yes	No
Device has Automatic Lamp Counter	No	Yes - Shuts Down Motor and provides Audible and Visual Alarm at 800 Count	No	No
Device has Lid Open Indicator/Interlock	Yes Indicator with Interlock to Prevent Motor Start	No	Yes Indicator with Interlock to Prevent Motor Start	No
Device has Programmable Logic Controller (PLC)	Yes	No	No	No
Device has Emergency Stop Switch	Yes - Crushing head will not engage unless negative pressure system is operating	No	Yes	No
Listed Lamp Capacity	400- 500 Lamps (T8 or T12 type)	800 Four-Foot Lamps	NA	1200 Four-Foot Lamps
Mercury Hazard Information				
Operating Manual Contains Mercury Hazard Information and Reference To OSHA Mercury Exposure Limits	Mercury Hazard	NA	Mercury Hazard	Mercury Hazard OSHA
Regulatory Information				

	Manufacturer A	Manufacturer B	Manufacturer C	Manufacturer D
Operating Manual Provides Information on Universal Waste	Yes	No	Yes	Yes
Operating Manual Provides Information on Lamp Recycling	Yes (Minimal)	No	Yes (Comprehensive)	Yes
Operating Manual Identifies Spent Pollution Control Media as Hazardous Waste	Specified for Filter and Carbon	Not Specified	Specified for Spent Particulate and HEPA Filters Only	Specified for Particulate, HEPA, and Carbon Filter
Operating Manual Provides Disposal Instructions for Spent Pollution Control Media	General Instruction	General Instruction	Place in Drum for Disposal with Crushed Lamps	Not Specified
Air Emissions				
Operating Manual Contains a Statement about the Device's Ability to Control Mercury Emissions	Yes "...is equipped with state of the art components to capture mercury vapors generated by crushing lamps to ensure a safe environment surrounding your drum top crusher."	No	Yes "...will remove virtually all airborne powder and mercury vapor (well over 99%)."	Yes "Crushes any length of fluorescent lamp in seconds into fragments while recovering 100% of the hazardous mercury vapors."

2.3 Testing Locations and Study Chronology

The Study was conducted at three locations over approximately five months. Table 2. 2 provides the order in which the devices were tested at each location. The following is a chronology of the DTC Device Study:

- Performance Validation Study, Phase I, AERC Recycling Solutions facility in Ashland, Virginia (AERC Ashland), from February 24, 2003 through February 28, 2003.
- Mass Balance Study, AERC Recycling Solutions facility in Ashland, Virginia (AERC Ashland), from February 24, 2003 through February 28, 2003.
- Extended Field Test Study, Test #1, Earth Protection Services, Inc. (EPSI) facility in Phoenix, Arizona (EPSI Phoenix), from March 24, 2003 through March 28, 2003.
- Extended Field Test Study, Test #2, AERC Recycling Solutions facility in Melbourne, Florida (AERC Melbourne), from April 28, 2003 through May 2, 2003.
- Extended Field Test Study, Test #3, AERC Recycling Solutions facility in Ashland, Virginia, from June 9, 2003 through June 13, 2003.

- Performance Validation Study, Phase II, AERC Recycling Solutions facility in Ashland, Virginia, from June 9, 2003 through June 13, 2003.

Table 2. 2: Order of Device Testing for DTC Device Study

Study	Date	Device
Performance Validation I	2/26/2003	C
	2/27/2003	A
	2/27/2003	D
	2/28/2003	B
Extended Field Test #1	3/24/2003	A
	3/25/2003	B
	3/26/2003	D
	3/27/2003	C
Extended Field Test #2	4/29/2003	B [a]
	4/30/2003	C
	5/1/2003	A
	5/2/2003	B [a]
Extended Field Test #3 & Performance Validation II	6/10/2003	A
	6/11/2003	B
	6/12/2003	C

a The device from Manufacturer B was tested twice during EFT #2. Refer to Section 3.5.1.

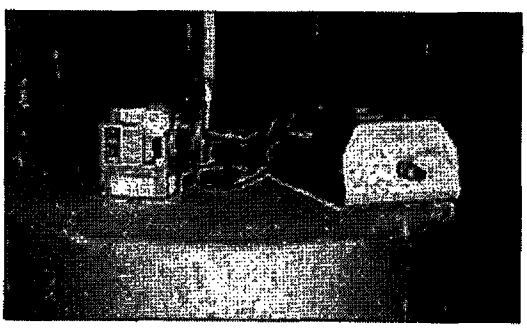
3. DATA COLLECTION METHODOLOGY

This chapter describes the procedures used to collect the various study samples, including descriptions of sampling and analysis methods and sample locations. Airborne mercury was tested using two methods:

- Analytical Air Samples – known quantities of air drawn through collection media designed to capture airborne mercury particulates and mercury vapor over extended periods of time and

- Jerome Analyzer Measurements – direct reading air samples of ambient mercury concentrations using the Jerome Mercury Vapor Analyzer.

Air samples were collected in the operator's breathing zone during normal operation, filter changes and drum changes, and in selected locations within the containment structure. Jerome measurements were taken both inside and outside the containment structure. Photograph 3. 1 shows the air sampling pump and Jerome analyzer inside the containment structure.



Photograph 3. 1: Air Sampling Pumps and Jerome Mercury Vapor Analyzer.

Several additional types of samples were collected for the Mass Balance Study.

- Wipe samples – Wipes of surfaces inside the containment structure were taken to characterize the amount of mercury deposited due to DTC device operation.

- Crushed lamps – Samples were taken out of a full drum after crushing operations (approximately eight inches deep into the drum).

- Pollution control media – Bulk samples were taken of the pollution control media (HEPA filter, pre-filter, and carbon filter) of each DTC device.

- Whole lamps – Samples of the spent, unbroken, Phillips Alto® lamps were taken.

The sample collection methodology, sample analysis, and sampling locations are discussed below. Section 3.1 describes the analytical air samples collected for the Performance Validation Study (PVS), including air samples used in the Mass Balance Study, and the Extended Field Test Study (EFTS). Section 3.2 describes the Jerome

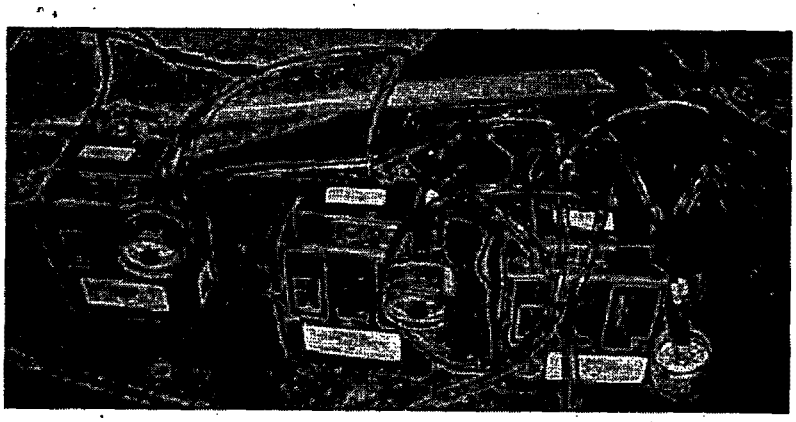
analyzer samples for the PVS and the EFTS. Section 3.3 details the methodology used for collecting the bulk samples used in the Mass Balance Study. Section 3.4 addresses the methodology for measuring surface contamination using wipe samples. Finally, Section 3.5 describes modifications and deviations to the test protocol based on operational difficulties encountered during testing.

3.1 Analytical Air Samples

Personal and area air samples were collected at numerous locations at each facility to support different aspects of the Study. The personal air samples were collected from the operator's breathing zone during operation and during drum changes, and the area samples were collected near the feed tube and the exhaust. Background samples and overnight samples were also collected.

Air samples were collected and analyzed, to measure airborne mercury concentrations in the aerosol and vapor phases, in accordance with the National Institute for Occupational Safety and Health (NIOSH) draft Analytical Method N9103[9] and NIOSH Analytical Method N6009,[10] respectively. The air samples were collected by drawing a known volume of air through two different media specific to the collection of mercury in each phase. A 37mm mixed cellulose ester (MCE) filter was first in line to capture mercury aerosols, and a Hydrar solid sorbent tube was second in line, attached to the MCE filter, to capture mercury vapors. The reporting limit for both the MCE filter and the Hydrar tube is 0.01 µg / sample. This reporting limit is based on the lowest calibration standard analyzed at the laboratory.

Air samples were collected by drawing known volumes of air through the sampling media using Sensidyne GilAir 5RC air sampling pumps equipped with multi-flow adapters (*refer to Photograph* 3. 2).



Photograph 3. 2: Sensidyne Air Sampling Pumps

The Sensidyne pumps were calibrated on site both before and after use, according to the manufacturers' specifications, using the BIOS DC-Lite calibrator as a primary standard. The calibration data are contained in Appendix B. During calibration, the

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[9] *At the time of this Study, Method N9103 (refer to Appendix E) was in draft form. It is undergoing approval by NIOSH.*

[10] *NIOSH Manual of Analytical Methods, 4th ed., Method N6009, Issue 2, 1994. A copy can be found in Appendix E.*

airflow was adjusted in order to establish a known flow rate. The flow rates of the pumps varied depending on sample type. Ranges of pump flow rates are listed below in cubic centimeters per minute (cc/min).

- Background Samples: 136 – 221 cc/min
- On Operator, During Drum Filling: 135 – 212 cc/min
- On Operator, Filter Changes and Drum Changes:[11] 154 – 261 cc/min
- On Operator, Ceiling Samples: 247 – 260 cc/min
- At Exhaust of the Device: 121 – 253 cc/min
- At Feed Tube of the Device: 125 – 210 cc/min
- Overnight Samples: 100 – 163 cc/min

At each facility, three sets of laboratory blanks were prepared at the beginning of each study. Three MCE filters and three Hydrar-sorbent tubes were labeled and placed in storage in the calibration room. Two sets of field blanks were prepared for each day of sampling at each location. Two MCE filters were labeled, the caps were opened and replaced, and the filters were placed into storage in the calibration room. Two Hydrar-sorbent tubes were labeled, the ends of the tubes were broken and capped, and the tubes were placed into storage in the calibration room.

Upon arrival at each study location, two background area samples were collected just outside the containment structure. These samples were collected for a period of time ranging from 3.5 hours to 5 hours before any of the DTC devices were operated. The purpose of these samples was to provide a measure of background conditions inside the lamp recycling facility.

Personal and area air samples were collected within the containment structure for the entire time it took the operator to fill one to two 55-gallon drums with crushed lamps for each DTC device (approximately 60 to 110 minutes). Personal air samples were collected by placing the air pumps on the operator's belt and securing the collection media on the operator's shoulder in order to collect air from within his/her breathing zone (*refer to Photograph 3. 3, Photograph 3. 4, and Photograph 3. 5*). The personal air samples were collected in order to measure the operator's exposure to airborne mercury during different operational activities.

Groups of personal air samples were also collected separately during the filter change and drum change processes for each device, as appropriate. Once the filter change or drum change, which took between two and 10 minutes, had been completed, the operator remained inside the containment structure to allow at least 12 full minutes for sample collection to ensure that the amount of mercury captured in the sample tube was greater than the detection limit (0.01 µg/sample).

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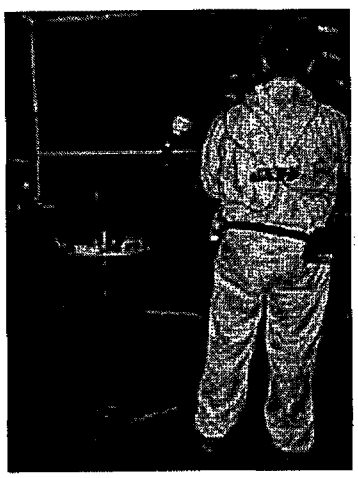
[11] *When a sample is referred to as a "Filter Change Sample," it is a personal air sample taken when the DTC device filter was changed at a time other than during a drum change. This sample is specific to the Manufacturer C and Manufacturer D devices. The Manufacturer A device did not require a filter change during the Study. For the Manufacturer B device, the filter was changed at the same time that the drum was changed, so a separate "Filter Change Sample" was not needed. Personal air samples that were taken when the drum was changed are referred to in this report as "Drum Change Samples."*

Photograph 3. 3: Feeding Bulbs into the Manufacturer A Device

Photograph 3. 4: Feeding Bulbs into the Manufacturer B Device



Photograph 3. 5: Feeding Bulbs into the Manufacturer C Device

During portions of the Study, short-term "ceiling" air samples were taken. The ceiling samples were another set of personal air samples, which were collected to attempt to quantify airborne mercury concentrations at the estimated time of

maximum exposure. Readings taken on the Jerome analyzer indicated that maximum exposure conditions most probably occurred during drum changes. Thus, the ceiling samples were collected during one of the drum changes for each device during PVS-Phase II, EFT #2, and EFT #3. Two samples were collected on the operator's shoulder, in sequence; each ceiling sample was collected for four minutes.

Area samples were collected by placing the air pumps and collection media on elevated surfaces in specified areas (*refer to Photograph 3. 1 and Photograph 3. 7*) to measure the general airborne mercury concentration inside the containment structure. During operation of each device, four area samples were collected in each phase of the PVS, and two area samples were collected in all three parts of the EFTS.

In addition to the area samples collected during the operation of each device, overnight samples were collected as part of the EFTS. The purpose of the overnight samples was to measure the release of mercury when the DTC devices were not operating, thus simulating a realistic field scenario. At the end of each day of the EFTS, each DTC device remained inside the containment structure, attached to a drum containing crushed lamps, once crushing activities for the second drum were completed. Two to three area air samples were then collected for six to 18 hours. At EPSI Phoenix, the overnight samples were collected inside the containment structure, near the device exhaust and device feed tube. During EFT #2 and EFT #3, overnight samples were collected outside of the containment structure in addition to the samples collected at the device exhaust and device feed tube inside the containment structure.

At the end of each day of sampling, the sampling pumps were removed from the containment structure and taken to the calibration room to be post calibrated. The sampling trains were taken apart, and the mixed cellulose filters and Hydrar tubes were immediately capped on both ends. All information regarding sample duration and air pump calibrations were recorded on air sampling data forms at that time (*refer to Appendix B*). The capped samples were then placed in labeled re-sealable plastic bags and kept at the facility.

At the completion of the sampling event at each study location, all analytical air samples were collected, packaged, and shipped via Federal Express to Data Chem Laboratories, Inc. (Data Chem), along with the completed chain-of-custody forms. Data Chem is an American Industrial Hygiene Association accredited laboratory located in Salt Lake City, Utah. Air sampling media were supplied by Data Chem.

The following sections provide details on the sampling protocol used for each stage of the DTC Device Study.

3.1.1 Performance Validation Study

Phase I of the PVS was conducted February 24-28, 2003, at the AERC facility in Ashland, Virginia (AERC Ashland), and it included the DTC devices from all four manufacturers. AERC Ashland was also the site location for Phase II of the PVS. This phase was conducted June 9-13, 2003 and included 3 DTC devices

(Manufacturer A, Manufacturer B, and Manufacturer C). (*Refer to Section 3.5.3 for a discussion of the exclusion of the Manufacturer D device.*)

The PVS was conducted to examine the effectiveness of each device in capturing and retaining mercury vapors and any potential change in effectiveness over time. The Study compared the results among the different devices when new, and after a pre-determined period of operation during which numerous lamps were processed through each device. The analytical air samples collected for PVS-Phase I were also used in the Mass Balance Study to calculate the release of mercury from the devices.

Table 3. 1 lists the air samples collected for the PVS, and the sampling locations are shown in Figure 3. 1.

Table 3. 1: Analytical Air Samples Collected during the Performance Validation Study

	Type of Sample	# of Samples	Approximate Duration (min)
Personal Samples	1 on each shoulder - filling the drum	2	50 - 115
	1 on left shoulder - during drum/filter change	1-2[a, b]	6 - 18
Area Samples	Near device exhaust	2	50 - 115
	Near device feed tube	2	50 - 115

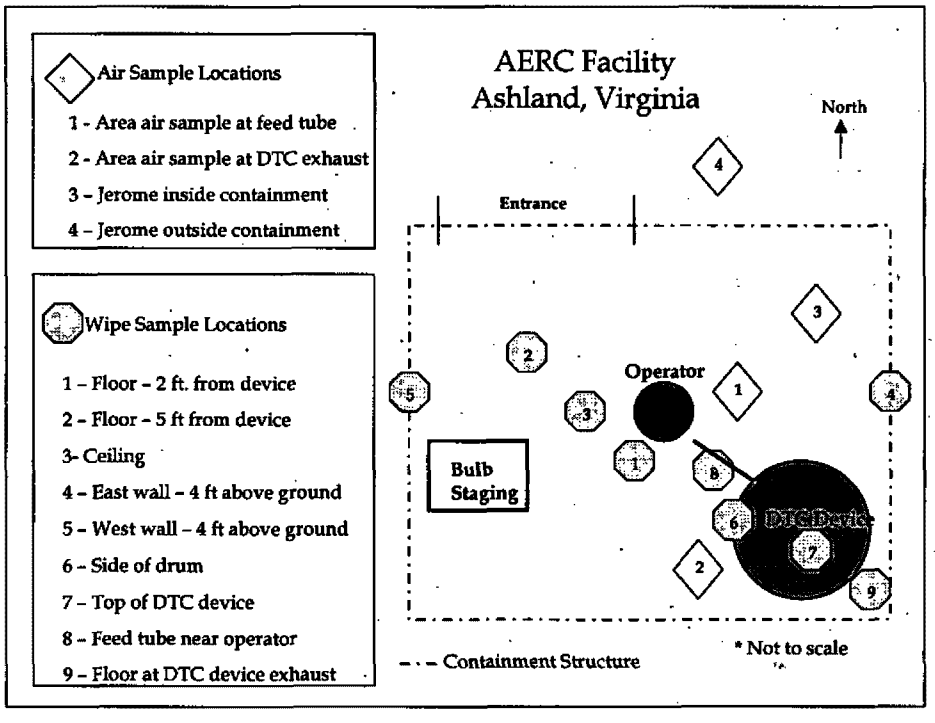
[a] Manufacturer A: 1 Drum Change Sample
Manufacturer B: 1 Drum Change Sample
Manufacturer C: 1 Filter Change Sample, 1 Drum Change Sample
Manufacturer D: 1 Filter Change Sample, 1 Drum Change Sample (only Phase I).

[b] The filter change samples for the Manufacturer C device were taken when the drum was half full (~350 bulbs).

Manufacturer C and Manufacturer D devices required one filter change per drum in addition to the filter changes performed during drum changes. The personal sample on the shoulder of the operator during the filter change for the Manufacturer C device was performed when the drum was half full of fluorescent light bulbs, equivalent to approximately 350 crushed bulbs. This was true for all filter change samples collected for the Manufacturer C device throughout the DTC Device Study.

Due to exposure levels significantly above the OSHA PEL, only 276 bulbs were crushed in the Manufacturer D unit during Phase I of the PVS. The Manufacturer D device was removed from the study after EFT #1 (refer to Section 3.5.3), so the samples listed for this device in Table 3. 1 were only collected during PVS - Phase I.

Figure 3. 1: Sampling Locations for the Performance Validation Study and Extended Field Test #3



3.1.2 Extended Field Test #1

The EFTS was conducted to examine the ongoing performance of each device during extended use and over a range of environmental conditions. EFT #1 was conducted at the EPSI facility in Phoenix, Arizona (EPSI Phoenix), March 24-28, 2003, and it included four DTC devices (Manufacturer A, Manufacturer B, Manufacturer C, and Manufacturer D). Air samples collected during EFT #1 are described in Table 3. 2, and Figure 3. 2 shows the sample collection areas.

Table 3. 2: Air Samples Collected during Extended Field Test #1

	Type of Sample	# of Samples	Approximate Duration (min)
Personal Samples	1 on each shoulder - filling the drum	2	125 - 200
	1 on left shoulder - during drum/filter change	1-3[a, b]	12 - 36
Area Samples	Near device exhaust	1	125 - 200
	Near device feed tube	1	125 - 200
Overnight Samples	Near device exhaust	1	440 - 780
	Near device feed tube	1	420 - 780

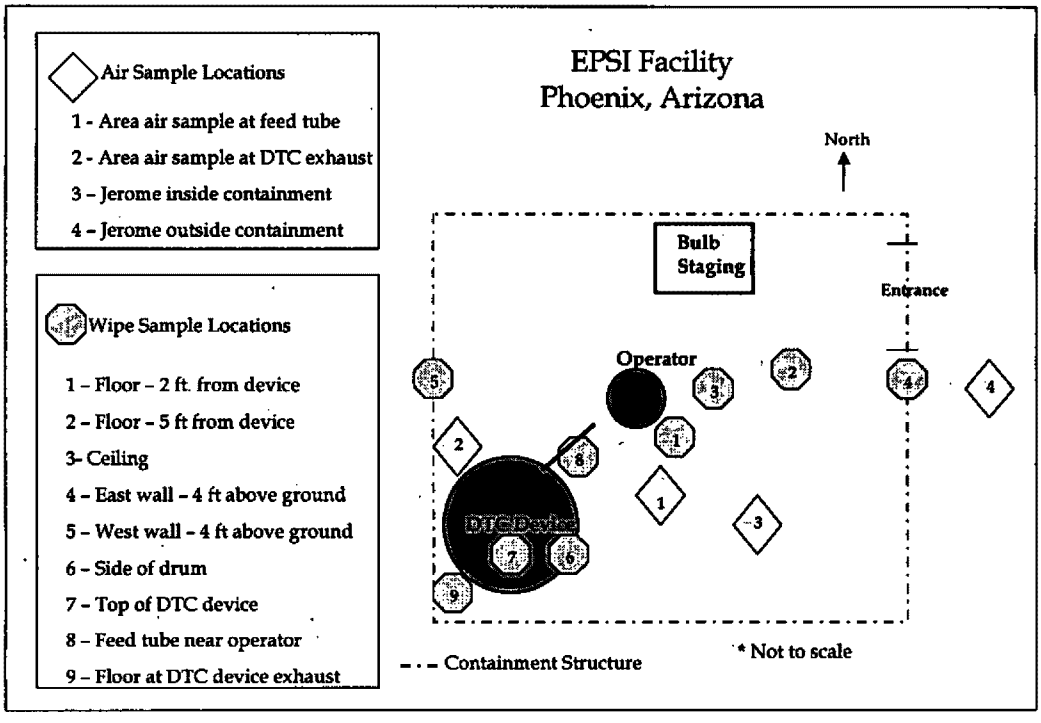
[a] Manufacturer A: 1 Drum Change Sample
Manufacturer B: 2 Drum Change Samples
Manufacturer C: 2 Filter Change Samples, 1 Drum Change Sample
Manufacturer D: NONE

[b] The filter change samples for the Manufacturer C device were taken when the drum was half full (~350 bulbs).

The Manufacturer D device was removed from the Study during Extended Field Test (EFT) #1 because Jerome measurements of mercury vapor concentrations in the

containment structure reached 0.59 mg/m³, nearly six times the OSHA PEL. Further information can be found in Section 3.5.3.

Figure 3. 2: Sampling Locations for Extended Field Test #1



3.1.3 Extended Field Test #2

Air samples were collected during EFT #2 at the AERC facility in Melbourne, Florida (AERC Melbourne), April 28 - May 3, 2003, for three DTC devices (Manufacturer A, Manufacturer B, and Manufacturer C). Short-term ceiling air samples were introduced into the Study during this round of testing. As described above, ceiling samples were air samples collected over a short duration in time in an attempt to quantify airborne concentrations at the estimated time of maximum exposure.

Readings taken on the Jerome analyzer indicated that maximum exposure conditions most probably occurred during drum changes. Drum change sample results from EFT #1 showed that the ambient concentration of mercury is sufficiently high during drum changes such that the samples did not need to be collected for 12 minutes in order to exceed detection limits. Thus, two short-term, personal air samples were collected in sequence during one of the drum changes for each device. The sampling time was four minutes per sample, for a total duration of eight minutes.

Table 3. 3 lists the analytical air samples collected in EFT #2. Sampling locations at the Florida facility are shown in Figure 3. 3.

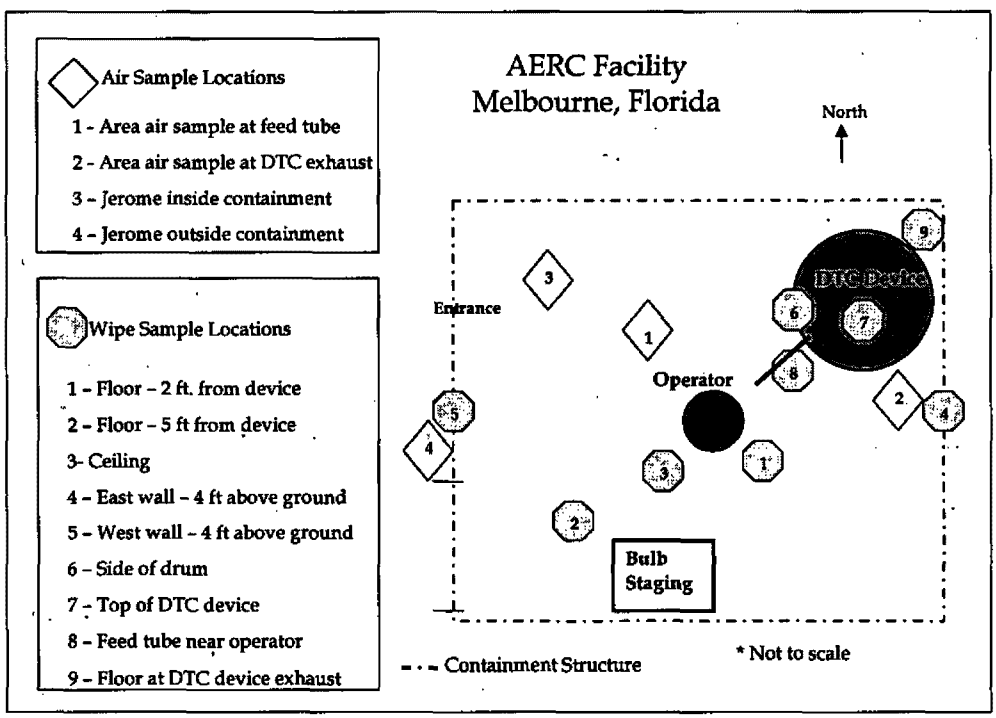
Table 3. 3: Air Samples Collected during Extended Field Test #2 and #3

	Type of Sample	# of Samples	Approximate Duration (min)
Personal Samples	1 on left shoulder - filling both drums, filter changes, drum changes	1	100 - 160
	1 on each shoulder - filling 1st drum	2	60 - 80
	1 on each shoulder - filling 2nd drum	2	40 - 70
	1 on left shoulder - during drum/filter change	2-4[a, b]	12 - 20
Ceiling Samples	1 on shoulder - samples taken in sequence during drum change	2	4
Area Samples	Near device exhaust	1	100 - 160
	Near device feed tube	1	100 - 160
Overnight Samples	Near device exhaust	1	720 - 1080
	Near device feed tube	1	720 - 1080

[a] Manufacturer A: 2 Drum Change Samples
Manufacturer B: 2 Drum Change Samples
Manufacturer C: 2 Filter Change Samples, 2 Drum Change Samples

[b] The filter change samples for the Manufacturer C device were taken when the drum was half full (~350 bulbs).

Figure 3. 3: Sampling Locations for Extended Field Test #2



3.1.3.1 Box Test

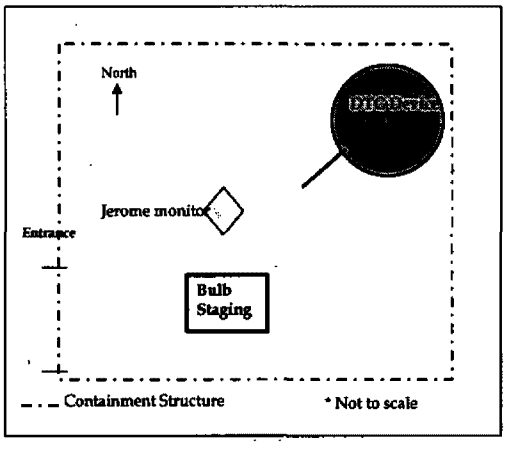
On the first day at AERC Melbourne (EFT #2), the Manufacturer B device was operated and mercury levels were measured. The Jerome analyzer measured airborne mercury levels that exceeded the OSHA PEL: (1) while operating the device to fill the first drum, (2) during the down time taken by the operator after filling and changing out the first drum, and (3) for the first 20 minutes of device operation, while filling the second drum. Because the Manufacturer B Device had previously shown better performance and because mercury levels in the

containment structure had declined during other non-operational periods (i.e., periods during the operator break between drums when devices were not operated), the field team decided to try to evaluate the cause of the high mercury readings.

During Phase I of the PVS and EFT #1 and the beginning of EFT #2, multiple cardboard boxes of fluorescent lamps were brought into the containment structure and kept inside to ensure that the operator had an adequate supply of readily accessible lamps. The field team suspected that the mercury released from the broken lamps in the boxes was contributing to elevated levels inside the containment structure. Based on this concern, testing procedures were revised so that only one box of lamps was kept inside the containment structure.

On April 30 (EFT #2), a test was performed to determine whether the boxes containing broken lamps were contributing to elevated mercury concentrations inside the containment structure (Box Test). Five boxes containing some broken lamps were brought into the containment structure. A Jerome analyzer was also placed inside the containment structure to record the airborne concentrations of mercury. Figure 3. 4 shows the layout of the containment area and sampling locations for the mercury emission test from broken boxed lamps.

Figure 3. 4: Box Test Configuration, AERC Melbourne



At the end of the week, the decision was made to repeat a portion of the Manufacturer B device testing, following the new procedure of bringing only one box at a time into the containment structure. Due to time constraints, the repeat test included only one drum, not two drums as in the first test at this location.

3.1.4 Extended Field Test #3

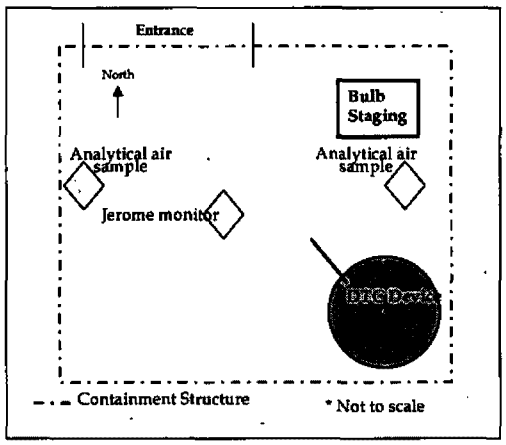
The third EFT was conducted at AERC Ashland, during the same time period as Phase II of the PVS, June 9-13, 2003. Three DTC devices (Manufacturer A, Manufacturer B, and Manufacturer C) were included in this portion of the Study. At the conclusion of EFT #3 for each DTC device, the containment structure polyethylene was replaced with new polyethylene, and Phase II of the PVS for that device began. Table 3. 3 lists the samples collected for EFT #3. Because this test was

conducted at AERC Ashland, the sampling locations are the same for PVS Phase I, PVS Phase II, and EFT #3 (*refer to Figure 3. 1*).

3.1.4.1 Box Test

A Box Test was also conducted at AERC Ashland in a similar manner to the test at AERC Melbourne, with the addition of analytical air samples collected on the east and west sides of the containment structure. Refer to Figure 3. 5 for the containment area layout and sampling areas for the Ashland Box Test. The test was performed at the conclusion of EFT #3 and before the beginning of PVS - Phase II for each device (Manufacturer A, Manufacturer B, and Manufacturer C devices).

Figure 3. 5: Box Test Configuration, AERC Ashland



3.1.4.2 U-Tube Test

The majority of fluorescent lamps processed in the Study were four-foot straight tubes. Although the DTC devices included in the Study were designed to process straight lamps, only two devices (Manufacturer B and Manufacturer C) have attachments that enable them to process "U" shaped fluorescent lamps (U-tubes), as well. At the end of EFT #3 at AERC Ashland, a test was conducted to evaluate airborne mercury levels from the two devices while processing U-tubes. The intent was for both the Manufacturer B and Manufacturer C devices to process enough U-tubes to fill a 55-gallon drum. However, the facility was only able to collect a limited number of U-tubes for the U-tube study. Therefore, the total quantity of U-tubes was divided between the two devices. The Manufacturer B device processed a total of 85 U-tubes, and the Manufacturer C device processed a total of 89 U-tubes.

Table 3. 4 lists the analytical air samples collected during the processing of the U-tubes. Air sample locations correspond to the locations shown in Figure 3. 1; however, there were no wipe samples collected for the U-tube evaluation. Photograph 3. 6 shows the crushing of U-Shaped.

Table 3. 4: Air Samples Collected during U-tube Evaluation

	Type of Sample	# of Samples	Approx. Duration (min)	Air Flow Rate (cc/min)
Personal Samples	1 on each shoulder – filling the drum	2	12 – 14	150
Area Samples	Near device exhaust	1	12 – 14	150
	Near device feed tube	1	12 – 14	150

Photograph 3. 6: Crushing of U-Tubes – Manufacturer C Device

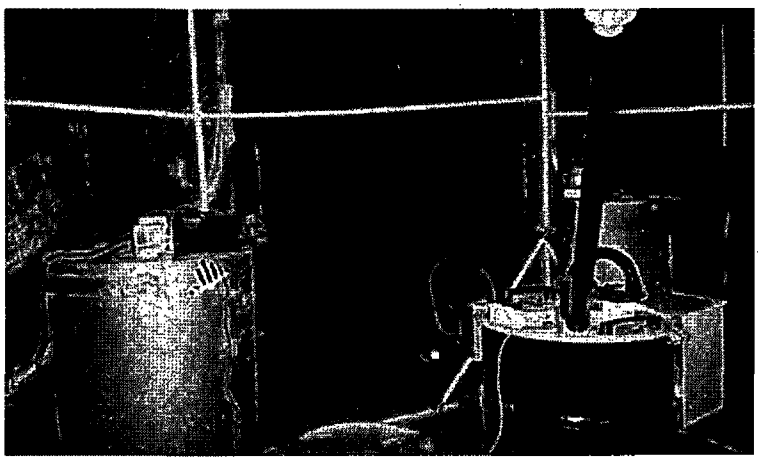
3.2 Jerome Mercury Vapor Analyzer Samples

In addition to measuring mercury concentrations in the air using sampling pumps, two factory-calibrated Jerome Mercury Vapor Analyzers (Model 431-X, Arizona Instrument, LLC) were used to measure real-time mercury concentrations in the ambient air. As shown in Figure 3. 1, Figure 3. 2, and Figure 3. 3, one stationary Jerome analyzer (Jerome #1) remained inside the containment structure (*refer to Photograph 3. 1 and Photograph 3. 7*), while another Jerome analyzer (Jerome #2) was placed outside of the containment structure and brought inside at various times.

Both analyzers were used to identify fluctuations in concentrations while the DTC devices were operated. The Jerome analyzer accurately measures mercury within ± 5% in the sensitivity range of 0.003 to 0.999 mg/m^3 mercury. Both analyzers were equipped with data loggers, to measure and record the mercury concentrations throughout the day. However, due to problems with the data loggers, the analyzers had to be checked manually and the concentrations recorded in field notebooks.

Jerome #2 was specifically utilized to identify emissions at the carbon filter exhaust, leaks around the seals, emissions/releases at the feed tube, varying concentrations within the containment structure, and background conditions outside the containment structure. This information assisted the operators in determining when personal protective equipment (PPE) was necessary. The mercury vapor analyzer alarms were set to activate at 0.05 mg/m^3, to alert the operator of the mercury concentration before the OSHA PEL (0.1 mg/m^3) was approached. The project health and safety plan specified that respiratory protection be used inside the containment structure if mercury levels reached or exceeded 0.05 mg/m^3. It was

common for mercury concentrations to exceed 0.05 mg/m^3 during routine operation; therefore, respiratory protection was employed throughout most of the Study.



Photograph 3. 7: Placement of Air Sampling Pump & Jerome Analyzer in Relation to DTC Device

3.3 Bulk Samples

The Mass Balance Study was intended to account for the fate of the mercury involved in the operation of DTC devices by estimating the total mass of mercury put into the DTC device via crushed lamps and comparing that quantity to the mass of mercury retained by the device plus the mass of mercury released. Samples of unbroken, spent lamps were collected to quantify the average amount of mercury in different types of fluorescent lamps and estimate the total amount of mercury processed by each device. Pollution control media samples and samples of crushed lamps were used in the Mass Balance Study to estimate the amount of mercury retained within the drum and the device assembly for each device.

3.3.1 Unbroken Spent Lamps

During Phase I of the Performance Validation Study (PVS), several unbroken, spent fluorescent lamps were submitted to Data Chem for mercury analysis. Alto® lamps, manufactured by Philips Lighting, were collected and used for this portion of the Study. Specifically, three Alto® T8 lamps, three T12 34-watt lamps, and two Alto® T12 40-watt lamps were obtained from AERC Ashland and analyzed.

Data Chem used a low-temperature drill and acid extraction method to collect the mercury in the lamps, and performed the analysis in accordance with EPA Method 7470. The method used by Data Chem is a non-standardized method based on discussions between Data Chem and Philips Lighting. Philips Lighting shared information with Data Chem on experiments performed to extract mercury from an operating lamp. Data Chem modified the mercury extraction method to extract mercury from a spent lamp rather than an operational lamp *(refer to Appendix E for a description of Data Chem's extraction method)*.

Briefly, the method involved packing the lamps in dry ice for approximately one hour, to chill them and condense the mercury vapors inside. A small hole was then drilled into the end cap, and concentrated nitric acid was introduced into the lamps. The hole was filled with a wax plug and the lamps were agitated for approximately 15 minutes, to allow the mercury to react with the acid. The acid was removed from the lamp and analyzed using EPA Method 7470. The results were used to confirm the amount of mercury reported by Philips Lighting and to calculate the quantities of mercury for the Mass Balance Study.

3.3.2 Pollution Control Media

During Phase I of the PVS, bulk samples of various pollution control media were collected from each DTC device after the operator had filled one drum with lamps. Bulk samples were collected from the filter media prior to removing the device from the containment structure (*refer to Appendix H for detailed procedures for the collection of samples from the pollution control media*).

The bulk samples collected from each of the DTC devices included:

- Three samples of particulates from the particulate pre-filters from the Manufacturer B device, Manufacturer C device, and Manufacturer D device (the Manufacturer A device is not equipped with a particulate pre-filter).
- Three samples of particulates from the HEPA filters from all four devices.
- Three samples of particulates from the carbon filters from all four devices.

Clean filter media were submitted by the manufacturers to Data Chem for quality control (QC) samples. These clean materials were used for blank samples and spike samples so that comparisons could be made to the samples of the used filter media. The samples were analyzed in accordance with EPA Method 7470 and EPA Method 7471A, modified slightly by Data Chem to accommodate materials other than soil or sediment, as outlined in Appendix E.

Before the start of lamp crushing operations, the filters (pre-filter, HEPA filter, and carbon filter) and empty drums were weighed for each device. After the drum was completely full, the drum and filters were re-weighed to determine the amount (by weight) of crushed lamps in the drum or particulate on the filters.

3.3.3 Crushed Lamps

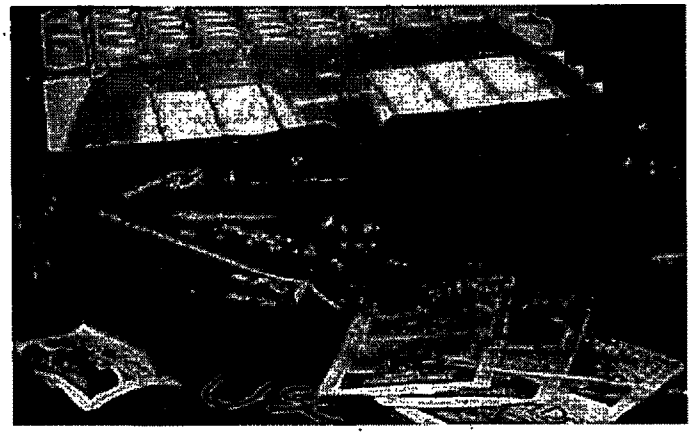
After the samples from the pollution control media were collected, the DTC device was removed from the top of the drum. Three samples of crushed lamps were collected for each device to determine the amount of mercury in a drum of crushed lamps for the Mass Balance Study. Approximately 275 to 300 cubic centimeters (cm^3) of crushed lamps was collected from each drum using dedicated, disposable plastic spoons that had been decontaminated (prior to use) with HgX® in clean water and

allowed to air-dry.[12] The samples were collected from as deep within the drum as possible to minimize the potential for low-biased results due to vaporization or fugitive particulate emissions of mercury. However, due to the density of the crushed lamps, the sampling depth was limited to approximately eight inches. The samples were sealed in sample containers provided by Data Chem Laboratories.

After collection, all the bulk samples (i.e., unbroken spent lamps, pollution control media, and crushed lamps) were packaged and shipped via Federal Express to Data Chem for analysis along with completed chain-of-custody forms that were signed by the personnel who collected the samples.

3.4 Wipe Samples

Surface wipe samples were collected inside the containment structure on numerous surfaces both before and after lamp crushing, as part of the Mass Balance Study. The wipe samples were collected and analyzed in accordance with N9103 for wipe samples (*refer to Appendix E*). Under this procedure, a 100 square centimeter (cm^2) area was wiped using a "Wash N' Dri" towelette (the liquid component of the wipe is 5 to 10 percent ethanol and 80 to 90 percent water), which was placed into a glass vial. Wipe sample supplies were provided by Data Chem (*refer to Photograph 3. 8*).



Photograph 3. 8: Wipe Sample Media

Wipe samples were collected prior to the start of each DTC device operation and again at the conclusion of the DTC device operation. The pre-test and post-test samples were collected in the same general area; however, the post-test wipe samples may not have been collected in the exact location of the pre-test wipe sample (*refer to Figure 3. 1, Figure 3. 2, and Figure 3. 3 for sample collection areas*).

For the testing conducted at AERC Ashland during PVS - Phase I, a set of two pre-test wipe samples and a set of two post-test wipe samples were collected at each of the nine locations shown in Figure 3. 1. The purpose of this activity was to assess the reproducibility of the results. However, although the testing at AERC Ashland indicated, widely divergent values (i.e., orders of magnitude differences), most likely

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[12] *HgX® is a sulfiding and chelating agent that contains sodium thiosulfate and EDTA.*

attributable to the high background level of airborne and surficial mercury contamination, it was not possible to modify the study design to increase the number of replicates of wipe samples at the other locations.

After sampling was complete at each of the study locations, the wipe samples were collected for shipment to Data Chem. Samples were placed in an oversized sturdy box with packing material to fill voids and protect the samples during shipping. The chain-of-custody forms were then signed by the sampling personnel and placed in the box with the samples. Samples were shipped via Federal Express to the laboratory.

3.5 Test Protocol Deviations and Modifications

Due to circumstances encountered in the field, it was not always possible to follow the initial testing protocol. The following sections describe deviations in device operation and modifications to testing procedures, which were mainly associated with difficulties encountered while processing lamps.

3.5.1 Manufacturer B Device

For EFT #1, the vendor provided the operator with a reducer plate to install in the Manufacturer B device at the carbon filter exhaust. The reducer apparently was designed to throttle airflow through the unit, and was installed at EPSI Phoenix per the vendor's instructions. Increased emissions occurred while the DTC device was being tested, apparently as a consequence of the newly installed reducer. After processing the first full drum of crushed lamps, a representative from Manufacturer B was contacted and a decision was made to remove the reducer plate and then to continue the crushing operations for the second drum without the plate.

3.5.2 Manufacturer C Device

For EFT #1 at EPSI Phoenix, the Manufacturer C device experienced some operational difficulties that delayed the start of testing and may have had an effect on the results measured during the operation. After the first lamp was inserted into the feed tube, the motor on the machine stopped. After troubleshooting the problem, the manufacturer found that the machine would start if the start button were depressed for approximately 10 seconds. Depressing the start button for 10 seconds enabled a safety lock operating off a pressure sensor to be disengaged. The operator proceeded to crush lamps, and changed a filter after 350 lamps were crushed. The drum and filter were changed once the first drum was filled with 750 lamps. During crushing operations for the first drum, the operator noted that the feed tube jammed about every 20 bulbs and had to be cleared by sliding a rod down the feed tube.

Due to on-going operational problems and elevated mercury levels, testing of this device was concluded after only 336 bulbs had been crushed in the second drum. The device was returned to the manufacturer to evaluate the cause of the operational difficulties. The manufacture installed a new control panel for the device and then

shipped the machine to Melbourne, Florida for EFT #2.. The device was able to process the required number of lamps during EFT #2, EFT #3, and the PVS.

3.5.3 Manufacturer D Device

During PVS – Phase I, elevated levels of mercury vapor were detected during testing of the Manufacturer D device (*refer to Section 4.4.1.2*). These levels required the temporary suspension of the test to allow the operator to don respiratory protection (after crushing 25-30 fluorescent lamps). The test was permanently suspended (after crushing 276 lamps) at this site because mercury concentrations consistently exceeded the OSHA PEL and continued to increase. The readings on the Jerome analyzer peaked at 0.89 mg/m^3, nearly 9 times the OSHA PEL.

The Manufacturer D device was shipped back to the Manufacturer D facility at the manufacturer's request to evaluate the cause(s) of the elevated ambient mercury measurements. EPA requested that the manufacturer prepare a written report detailing the problem(s) and the cause(s); the report was also required to confirm the adequacy of the repairs, including an analysis for mercury vapor by a qualified industrial hygienist.

The device arrived at EPSI Phoenix (EFT #1) for the next round of testing visibly damaged and modified to the extent that it looked like a different device than the device used for Phase I of the PVS. The overall study design required each DTC device vendor to provide one unit that would be used throughout the entire test. Changing the device design violated the study design. There was also a clearly visible crack in the vacuum assembly, preventing adequate negative pressure when the device was turned on, and some of the carbon from the pollution control media spilled out of device during assembly. Even though only 16 lamps were crushed during testing, the ambient mercury concentration inside the containment structure, measured by the Jerome analyzer, reached 0.406 mg/m^3 mercury, more than four times the PEL.

None of the analytical air samples taken for this device were below the ACGIH TLV. Eight analytical air samples were collected during PVS – Phase I, and only one was below the PEL. Only two of the four samples collected during EFT #1 (when only 16 lamps were crushed) were below the PEL. It was determined that the use of the Manufacturer D device posed a health risk to study personnel, particularly the operator and assistants. After serious consideration, the unit was eliminated from further testing because of the unauthorized modifications and because of continued elevated mercury levels. Further information can be found in Appendix I.

4. RESULTS AND DATA EVALUATION

The overall objective of the DTC Device Study was to gain insights into the abilities of four different DTC devices to capture and contain mercury, while processing fluorescent lamps. A variety of air and other samples were collected for distinct tests that comprise the DTC Study.[13] This chapter presents the data collected for the Performance Validation Study (PVS) and the Extended Field Test Study (EFTS) and evaluates those results against study objectives. The next chapter (Chapter 5) presents and evaluates the data collected for the Mass Balance Study. The objectives for the different studies discussed in this chapter are listed below.

- The PVS was conducted to examine the effectiveness of each device in capturing and retaining mercury vapors and to identify any potential change in effectiveness over time. The study compared the results among the different devices when new and after a pre-determined period of operation during which numerous lamps were processed through each device (Section 4.4).

- The EFTS was conducted to examine the ongoing performance of each device during extended use and over a range of environmental conditions (Section 4.5).

- The Box Tests, conducted as part of the EFTS, were performed as an addendum to the EFTS to determine if the presence of broken lamps inside the containment structure confounded the study results (Section 4.6).

- The Overnight Tests were performed as part of the EFTS to evaluate releases of mercury vapor from DTC devices attached to partially filled drums during non-operational periods (Section 4.7).

- The U-tube Test, conducted as part of the EFTS, examined the performance of two of the devices when processing U-shaped fluorescent lamps (Section 4.8).

4.1 Exposure Evaluation Criteria

The results from the analytical air samples and the Jerome analyzers were compared to published mercury exposure limits to assess the performance of the devices in effectively capturing mercury vapors, while processing fluorescent lamps.

OSHA PEL: The federal Occupational Safety and Health Administration (OSHA) has established a maximum work-place regulatory permissible exposure limit (PEL) for inorganic mercury, which is codified in 29 Code of Federal Regulations (CFR) 1910.1000, Table Z-2. The current mercury exposure limit for workers is 0.1 mg/m^3 (ceiling). This regulatory exposure limit is established as a "ceiling" value in the

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[13] *It is important to note that, out of the 199 analytical air samples collected, only eight mercury aerosol (MCE filter) samples had values above the detection limit, and all blank MCE filter samples were below the detection limit. All of the mercury vapor (Hydrar tube) samples contained levels of mercury above the detection limit. Because the amount of mercury aerosol was not high enough to measure, the air results discussed in this chapter only address the Hydrar tube samples. The results for the MCE filters can be found in Appendix A, Table 1. Future research may be necessary to determine why aerosols were generally not detected (refer to Section 7.4).*

CFR, meaning that exposure to this value is not to be exceeded during any part of the work day, as opposed to a time weighted average (TWA) that calculates average exposure over the entire work shift. [14] However, in a memo dated September 1996, it states that OSHA currently implements the mercury PEL as an eight-hour TWA rather than as a ceiling value.[15]

ACGIH TLV: The other exposure limit that is referenced in this report regarding DTC device performance is a published work-place exposure limit, the threshold limit value (TLV) established by the American Conference of Governmental Industrial Hygienists (ACGIH), which is a professional organization for individuals in the industrial hygiene and occupational health and safety industry. The ACGIH TLV is 0.025 mg/m^3 and is a TWA (eight hours per day, 40 hours per week).[16]

EPA has established an exposure limit (a reference concentration, or RfC) of 3.0×10^{-4} mg/m^3 for the general public for chronic exposure to elemental mercury.[17]

The data from analytical air samples taken in this Study represent average values for the time periods during which the samples were taken; sampling time was generally between one and three hours for the samples taken during device operation (*refer to Appendix A, Table 1 for sample durations*). Sample results that are greater than the TLV value should not necessarily be interpreted to indicate that use of one of the DTC devices included in the Study would result in operator exposure above the TLV because the device may not be used for eight hours per day, 40 hours per week. The analytical air sample results were not normalized to an eight hour workday because DTC device use patterns may vary significantly (e.g., from a few minutes to eight or more hours per day). More information about the actual use patterns of DTC devices and the mercury exposures experienced by workers during non-operational periods would be necessary in order to calculate an eight hour TWA accurately for any specific pattern of use.

4.2 Background Air Samples

Because the Study was being conducted at commercial lamp recycling facilities, which were expected to have ambient mercury concentrations above those in outdoor air, three types of background samples were collected in order to quantify the mercury present at each site before, during, and after device operation.

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[14] *Refer to 29 CFR 1910.1000(b).*

[15] *The PEL for mercury was promulgated as a ceiling value in 1971 (36 FR 10505, May 29, 1971). A memorandum to OSHA compliance personnel was issued on September 3, 1996, that directs compliance officers to issue citations only when an overexposure exceeds 0.1 mg/m^3 as an 8-hour TWA.*

[16] *ACGIH also has a "skin" notation for elemental mercury, indicating that dermal absorption is another possible exposure route. Refer to ACGIH (1994). 1994-1995 Threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.*

[17] *The inhalation Reference Concentration (RfC) is intended to identify a maximum safe level for chronic exposure for the general population and is analogous to the oral RfD. The inhalation RfC considers both toxic effects for the respiratory system and toxic effects peripheral to the respiratory system (extrarespiratory effects). In general, the RfC is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily inhalation exposure of the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. The mercury RfC is based on a human lowest observed effect level (LOEL) of 0.025 mg/m^3. See Integrated Risk Information System (IRIS) website (www.epa.gov/iris/index.html) for further discussion.*

- On the first day at each site, before performing any crushing activities, two analytical air samples were collected in the vicinity of the study area, to measure ambient mercury concentrations in the lamp recycling facility (*refer to Table 4. 1*).

- During testing at AERC Melbourne and the second round of testing at AERC Ashland, one analytical air sample was taken overnight outside the containment structure at the end of each day of testing (*refer to Table 4. 1 for overnight background results and refer to Section 4.7 for information on overnight tests*).

- Jerome readings from a Jerome analyzer positioned outside the containment structure were manually recorded during PVS – Phase II and during the EFTS as time allowed (*refer to Table 4. 2*).

Table 4. 1: Background Mercury Results – Analytical Air Samples

Studies	Date	Location	Mercury Concentration (mg/m^3)	Mean (mg/m^3)
Performance Validation I	2/25/2003	Middle of E. bay	0.0039	0.0043
	2/25/2003	E. bay by center bay door	0.0047	
Extended Field Test #1	3/24/2003	N. of containment in bay	0.014	0.010
	3/24/2003	E. of containment in bay	0.0059	
Extended Field Test #2	4/29/2003	24 ft. E. of dock door	0.016	0.0164
	4/29/2003	18 ft. N. of dock door	0.012	
	4/29/2003	Outside containment-night	0.021	
	4/30/2003	Outside containment-night	0.016	
	5/01/2003	Outside containment-night	0.017	
Extended Field Test #3 & Performance Validation II	6/09/2003	Middle of E. bay	0.013	0.0166
	6/09/2003	E. bay by center bay door	0.0086	
	6/10/2003	Outside containment-night	0.017	
	6/11/2003	Outside containment-night	0.00052	
	6/12/2003	Outside containment-night	0.044	

Table 4. 2: Background Mercury Results – Jerome Analyzer Measurements

Studies	Date	Location	Mercury Concentration (mg/m^3)	Mean (mg/m^3)
Performance Validation I		No data	No data	
Extended Field Test #1	3/24/2003	Inside containment before crushing	0.020	0.029
	3/24/2003	Inside manager's desk	0.023	
	3/24/2003	Inside manager's desk	0.022	
	3/24/2003	Inside manager's desk	0.023	
	3/24/2003	Minimum outside containment during crushing	0.030	
	3/24/2003	Maximum outside containment during crushing	0.050	
	3/25/2003	Outside containment	0.040	

Studies	Date	Location	Mercury Concentration (mg/m^3)	Mean (mg/m^3)
	3/26/2003	Outside containment	< 0.003	
	3/27/2003	Inside containment before crushing	0.035	
	3/27/2003	Minimum outside containment during crushing	0.035	
	3/27/2003	Maximum outside containment during crushing	0.045	
Extended Field Test #2	4/29/2003	Outside containment	0.007	0.0074
	4/29/2003	Outside containment	< 0.003	
	5/01/2003	Outside containment	0.004	
	5/01/2003	Outside containment	0.017	
Extended Field Test #3 & Performance Validation II	6/10/2003	Outside containment-after EFT #3, before PVS-II	0.008	0.014
	6/10/2003	Inside containment-after EFT #3, before PVS-II	0.009	
	6/10/2003	Inside containment-after EFT #3, before PVS-II	0.012	
	6/11/2003	Outside containment during operation	< 0.003	
	6/11/2003	Outside containment during operation	0.01	
	6/11/2003	Outside containment during operation	< 0.003	
	6/11/2003	Outside containment during operation	0.004	
	6/11/2003	Outside containment during drum change	0.017	
	6/11/2003	Outside containment-after EFT #3, before PVS-II	0.005	
	6/11/2003	Inside containment-after EFT #3, before PVS-II	0.03	
	6/12/2003	Outside containment before starting	0.013	
	6/12/2003	Outside containment before starting	0.014	
	6/12/2003	Inside containment before starting	0.021	
	6/12/2003	Outside containment between drum 1 & 2, during EFT #3	0.014	
	6/12/2003	Minimum outside containment, during PVS-II	0.020	
	6/12/2003	Maximum outside containment, during PVS-II	0.040	

Each facility had measurable concentrations of mercury in the indoor ambient air. According to research by Garetano, et al. outdoor mercury vapor concentrations generally range from $2 \cdot 10^{-6}$ to $2 \cdot 10^{-5}$ mg/m^3, with higher concentrations in urban/ industrial areas.[18] None of the analytical air samples were below the detection limit (0.01 μg/sample), and only four of the 31 mercury concentrations taken with the Jerome analyzer were below the instrument detection limit (0.003 mg/m^3).

The samples taken at the end of each day of testing during EFT #2 and EFT #3 were compared to the background samples taken at the two sites before the DTC device was operated to determine if the industrial lamp crushing activities at the lamp recycling facilities created a significant increase in the background concentration of mercury throughout the week. Based on the four samples collected before beginning DTC device operation and six samples collected overnight after DTC device operation (N=10), there was no significant correlation between the measured background concentration of mercury and the day of the week that the air sample was collected. The background mercury concentrations are considered in the results

[18] *Refer to Garetano, Gary; Gochfeld, Michael; and Stern, Alan H. 2006. Comparison of Indoor Mercury Vapor in Common Areas of Residential Buildings with Outdoor Levels in a Community Where Mercury Is Used for Cultural Purposes. Environmental Health Perspectives. 114(1): 59–62.*

discussions in this chapter. The overall effect of the elevated background mercury levels on the Study is discussed in Chapter 6.

4.3 Blank Air Samples

As described in Section 3.1, NIOSH Analytical Method N6009 was used for mercury air sampling. Data Chem included in all laboratory air sample reports the fact that each Hydrar tube was contaminated with 0.035 to 0.045 micrograms (µg) of mercury.

At the beginning of each portion of the Study, three Hydrar sorbent tubes were set aside as trip blanks. These tubes were never opened during the field sampling and were submitted to the laboratory for analysis with the air samples to determine the level of mercury present in the sorbent material when no air sampling had occurred.

Additionally, at the beginning of each day of sampling, two Hydrar tubes were removed and designated as field blanks. The ends of the glass tubes were opened for several seconds to expose the sampling media to the air in the calibration room, and then were capped and submitted to the laboratory for analysis.

All blank air samples were only handled in the pump calibration room, a room at each facility that was separate from the areas where lamps were being crushed, such as a conference room or an office. The tubes used as blanks were never in the lamp processing areas. Table 4. 3 summarizes the trip blank data, and Table 4. 4 summarizes the field blank data. The means and standard deviations (Std Dev) are included with the results.

Table 4. 3: Trip Blank Results

Study	Blank 1 (µg)	Blank 2 (µg)	Blank 3 (µg)	Mean (µg)	Std Dev
Performance Validation I	NA	NA	NA	NA	NA
Extended Field Test #1	0.056	0.060	0.065	0.0603	0.00451
Extended Field Test #2	0.046	0.048	0.049	0.0477	0.00153
Extended Field Test #3 & Performance Validation II	0.040	0.047	0.040	0.0423	0.00404

NA - Not Analyzed

The analytical results for the trip blanks confirmed the presence of mercury in the sorbent material and were generally slightly higher than the laboratory-provided information regarding mercury contamination associated with Hydrar sorbent tubes.

Table 4. 4: Field Blank Results

Study	Date	Blank 1 (µg)	Blank 2 (µg)	Daily Mean (µg)	Site Mean (µg)	Std Dev
Performance Validation I	2/26/2003	0.040	0.041	0.0405	0.0403	0.0014
	2/27/2003	0.041	0.038	0.0395		
	2/28/2003	0.042	0.040	0.041		
Extended Field Test #1	3/24/2003	0.078	0.086	0.082	0.118	0.0807
	3/25/2003	0.075	0.071	0.073		

Study	Date	Blank 1 (µg)	Blank 2 (µg)	Daily Mean (µg)	Site Mean (µg)	Std Dev
	3/26/2003	0.28	0.21	0.245		
	3/27/2003	0.073	0.071	0.072		
Extended Field Test #2	4/29/2003	0.046	0.044	0.045	0.0470	0.0020
	4/30/2003	0.045	0.048	0.0465		
	5/1/2003	0.046	0.049	0.0475		
	5/2/2003	0.049	0.049	0.049		
Extended Field Test #3 & Performance Validation II	6/10/2003	0.039	0.041	0.040	0.0395	0.0022
	6/11/2003	0.041	0.038	0.0395		
	6/12/2003	0.040	0.038	0.039		
	6/13/2003	0.036	0.043	0.0395		

The field blank results were similar to the trip blank results for EFT #2 (only 0.7% relative percent difference) and for EFT #3 (only 3.4% relative percent difference). The results for the field blanks from EFT #1 (conducted at the EPSI facility) were much higher than the trip blanks for that test (32% relative percent difference). This suggests possible contamination of Hydrar tubes at this site and is not surprising given that background mercury levels, as measured by the Jerome analyzer, were highest at the EPSI facility.

4.4 Performance Validation Study

The Performance Validation Study (PVS) was conducted to assess the performance of DTC devices over time and determine if they lose efficiency in capturing and retaining mercury after a specified period of routine operation and crushing a substantial number of lamps. This section presents the measurements collected during Phases I and II, and compares these measurements to evaluate the performance of each device. Phases I and II are separated by five months, and each DTC device, except the Manufacturer D device, was used in the EFTS during this time, crushing approximately 3,800 – 4,300 lamps at three locations.

4.4.1 Performance Validation Study - Phase I

Phase I of the PVS was conducted at the AERC facility in Ashland, Virginia (AERC Ashland) during the week of February 24, 2003. As described in Chapter 3, analytical air samples were collected to measure the concentrations of mercury in the containment structure during operation of the new DTC devices, [19] and the Jerome analyzer was used to collect direct-reading measurements.

Temperature and humidity in Richmond, Virginia for each day at this study location were obtained from an online weather service archive. The average outdoor temperatures during this testing interval ranged between 28.4 and 42.6 degrees Fahrenheit. The average outdoor relative humidity ranged between 57.5 and 99.3

[19] *The Manufacturer A device is a prototype and, therefore, is not considered a new device.*

percent. Due to the cold weather conditions, the bay doors to the outside remained closed during the tests.[20]

Background measurements of mercury vapor concentrations, as measured using Hydrar tubes, were 0.0039 mg/m³ and 0.0047 mg/m³. These levels were most likely due to the ongoing, high throughput volume crushing of fluorescent bulbs conducted by AERC in the adjacent bay. A large doorway connected the bay where testing was conducted and the bay where AERC operated its industrial-sized bulb crusher. The facility separated the bays by keeping a pull-down door in-between the two bays closed for the majority of testing; however, the pull-down door was opened occasionally to move materials back and forth between bays (e.g., lamps required for the test). The effect of background concentrations on study results is further discussed in Section 6.1.

In this phase of the Study, one drum of lamps was processed through each device. Table 4. 5 summarizes the number of Phillips Lighting "Alto®" lamps processed to fill one drum. The number of lamps is specific to each device.

Table 4. 5: Total Lamps Processed in Each Device, Performance Validation Study I

Device	Number of Lamps Processed	Type of Lamp
Manufacturer A	637	T-12 fluorescent (3.5-4.2 mg Hg/lamp)
Manufacturer B [a]	611	T-8 fluorescent (3.0 mg Hg/lamp)
Manufacturer B [a]	113	T-12 fluorescent (3.5-4.2 mg Hg/lamp)
Manufacturer C	706	T-12 fluorescent (3.5-4.2 mg Hg/lamp)
Manufacturer D [b]	276	T-12 fluorescent (3.5-4.2 mg Hg/lamp)

[a] Manufacturer B device processed mostly T-8 lamps due to a temporary shortage of T-12 lamps.
[b] Manufacturer D device was shut-down before processing a full drum. Refer to Section 3.5.3.

It is important to note that during PVS - Phase I, all of the lamps processed were Alto® fluorescent lamps. These lamps were specifically selected for use in Phase I because these data were also used for the Mass Balance Study, and Alto® lamps are manufactured with more precise doses of mercury than other lamps.

4.4.1.1 Analytical Air Sample Results

The results of the air samples collected during Phase I of the PVS inside the containment structure are presented in Figure 4. 1. Air sample results for the Manufacturer A, Manufacturer B, and Manufacturer C devices were generally below both the OSHA PEL and the ACGIH TLV values. The Manufacturer D device exceeded the PEL and the TLV values for seven of the eight samples collected.

For a separate graphical depiction of the analytical air sample results collected for each DTC device, refer to Appendix A, Figures 1 through 5. To review the actual results for each analytical air sample, refer to Appendix A, Table 1. The Data Chem reports are available in Appendix C.

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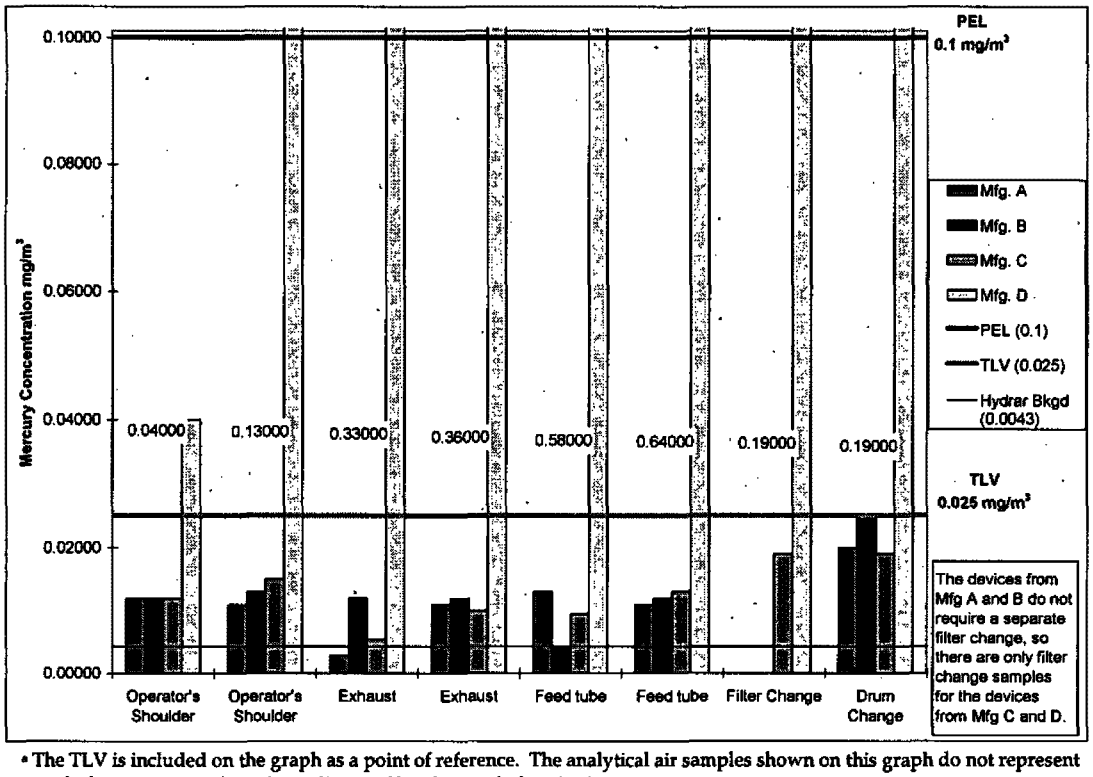
[20] *Outdoor temperature and humidity data were collected at the request of the EPA Work Group. While indoor data, when collected, better characterize the operating environment for the devices, the outdoor data are still significant.*

Figure 4. 1: Analytical Air Sampling Results, Performance Validation Study I[a]



[a] The TLV is included on the graph as a point of reference. The analytical air samples shown on this graph do not represent eight-hour TWAs (*refer to Appendix A, Table 1 for sample durations*).

4.4.1.2 Jerome Mercury Vapor Analyzer Results

The Jerome analyzer results from Phase I of the PVS inside the containment structure are displayed in Table 4. 6.

Table 4. 6: Jerome Analyzer Measurements - Inside Containment, Performance Validation Study I

Device	Jerome Mercury Vapor Analyzer Readings (mg/m³)		
	During Operation	Filter Change	Drum Change
Manufacturer A	0.005 – 0.009	NA [d]	0.005 – 0.009 [a]
Manufacturer B	0.007 – 0.009	NA [d]	0.026 [a]
Manufacturer C	<0.003 – 0.005	0.008 [b]	0.008 [b]
Manufacturer D	0.44 - 0.89[c]	No data [c]	No data [c]

NA – Not applicable

[a] During the drum change, the measurements were at the maximum levels recorded.

[b] During the filter change and the drum change, measurements were at the maximum levels recorded.

[c] See paragraph below and Section 3.5.3.

[d] The Manufacturer A and Manufacturer B devices do not have a separate filter change.

The real-time mercury vapor concentrations measured inside the containment structure using the Jerome analyzer during operation of the Manufacturer A, Manufacturer B, and Manufacturer C devices were all below the OSHA PEL and the ACGIH TLV values (with the exception of the Manufacturer B device during the drum change, which exceeded the TLV value). The Jerome analyzer readings

collected while operating the Manufacturer D device exhibited a continuous increase in mercury concentrations. After processing approximately 25 to 30 lamps, the Jerome analyzer measured mercury vapor at 0.44 mg/m^3, and processing was suspended to allow the operator to don respiratory protection. Crushing operations then continued for approximately 45 minutes, until the Jerome analyzer readings increased to 0.89 mg/m^3. Testing of the Manufacturer D device at this facility was permanently suspended after processing a total of 276 lamps, due to the persistent TLV and PEL exceedances in the test area. Further discussion of the Manufacturer D device is provided in Section 3.5.3.

4.4.2 Performance Validation Study – Phase II

Phase II of the PVS was conducted at AERC Ashland during the week of June 9, 2003. The Manufacturer A, Manufacturer B, and Manufacturer C devices were tested during Phase II; as noted earlier, the Manufacturer D device was removed from the Study due to airborne mercury concentrations consistently above the PEL during Phase I. The average outdoor temperature during this testing interval ranged between 70.0 and 79.0 degrees Fahrenheit, and average outdoor relative humidity ranged between 73.0 and 80.6 percent. The indoor temperature and relative humidity were measured using a Velocicalc instrument.

- Temperatures: ranged between 73.0 and 86.2 degrees Fahrenheit, with a weekly average of 81.2 degrees Fahrenheit.

- Relative humidity: ranged between 54.5 and 74.4 percent, with an average of 63.1 percent.

As described in the Sampling and Study Plan *(refer to Appendix D)*, the Phase II testing was conducted after each DTC device had processed six to seven drums' worth of lamps.

Table 4. 7 summarizes the number of lamps processed to fill one drum. The number of lamps is specific to the unique operation of each device.

Table 4. 7: Total Lamps Processed in Each Device, Performance Validation Study II

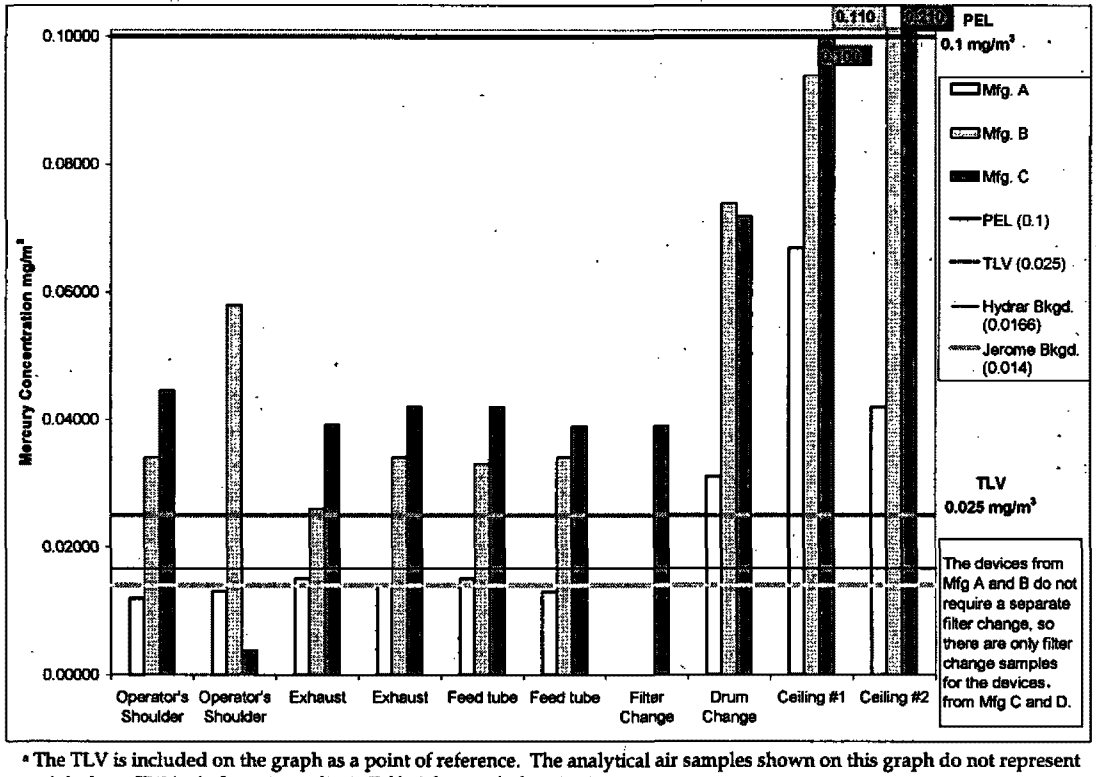
Device	Number of Lamps Processed
Manufacturer A	667
Manufacturer B	617
Manufacturer C	801

During Phase II of the PVS, some of the lamps processed were not Phillips Alto® lamps because there were not enough of them available. The inclusion of conventional lamps in the second phase of the PVS may have affected the measured mercury concentrations because most conventional fluorescent lamps contain more mercury than Alto® lamps.

4.4.2.1 Analytical Air Sample Results

For Phase II, a majority of the results for the analytical air samples were below the OSHA PEL value, but not the ACGIH TLV value, as shown below in Figure 4. 2.

Figure 4. 2: Analytical Air Sampling Results, Performance Validation Study II[a]



[a] The TLV is included on the graph as a point of reference. The analytical air samples shown on this graph do not represent eight-hour TWAs (*refer to Appendix A, Table 1 for sample durations*).

The Ceiling #1 sample for the Manufacturer C device met, but did not exceed, the PEL value. [21] The two samples that exceeded the PEL were two of the three Ceiling #2 samples (Manufacturer B and Manufacturer C devices). Throughout Phase II of the PVS, air sample concentrations for the Manufacturer A device were consistently lower relative to the other two devices, usually below the TLV. To review the results for each analytical air sample, refer to Appendix A, Table 1. For a separate graphical depiction of the air sample results collected for each DTC device, refer to Appendix A, Figures 6 through 9. The Data Chem reports are available in Appendix C.

4.4.2.2 Jerome Mercury Vapor Analyzer Results

The field team experienced software performance problems while attempting to record the mercury concentration on both data loggers attached to the vapor analyzers during Phase II. The only available logged readings were those from

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[21] *It is important to note that the drum-change and ceiling samples are not time-weighted averages (TWA) and should not be compared to the TLV, which is a TWA. The PEL for mercury was promulgated as a ceiling value in 1971 (36 FR 10505, May 29, 1971). A memorandum to OSHA compliance personnel was issued on September 3, 1996, that directs compliance officers to issue citations only when an overexposure exceeds 0.1 mg/m³ as an 8-hour TWA.*

operation of the Manufacturer A and Manufacturer B devices inside the containment structure. Mercury vapor analyzer measurements for the Manufacturer C device were manually recorded, as time allowed. (Prior to beginning the Phase II test for the Manufacturer C device, the Jerome analyzer recorded 0.008 mg/m³ outside the containment structure and readings between 0.009 mg/m³ and 0.012 mg/m³ inside the containment structure.) Refer to Table 4. 8 for the Jerome analyzer readings taken inside the containment structure during PVS - Phase II.

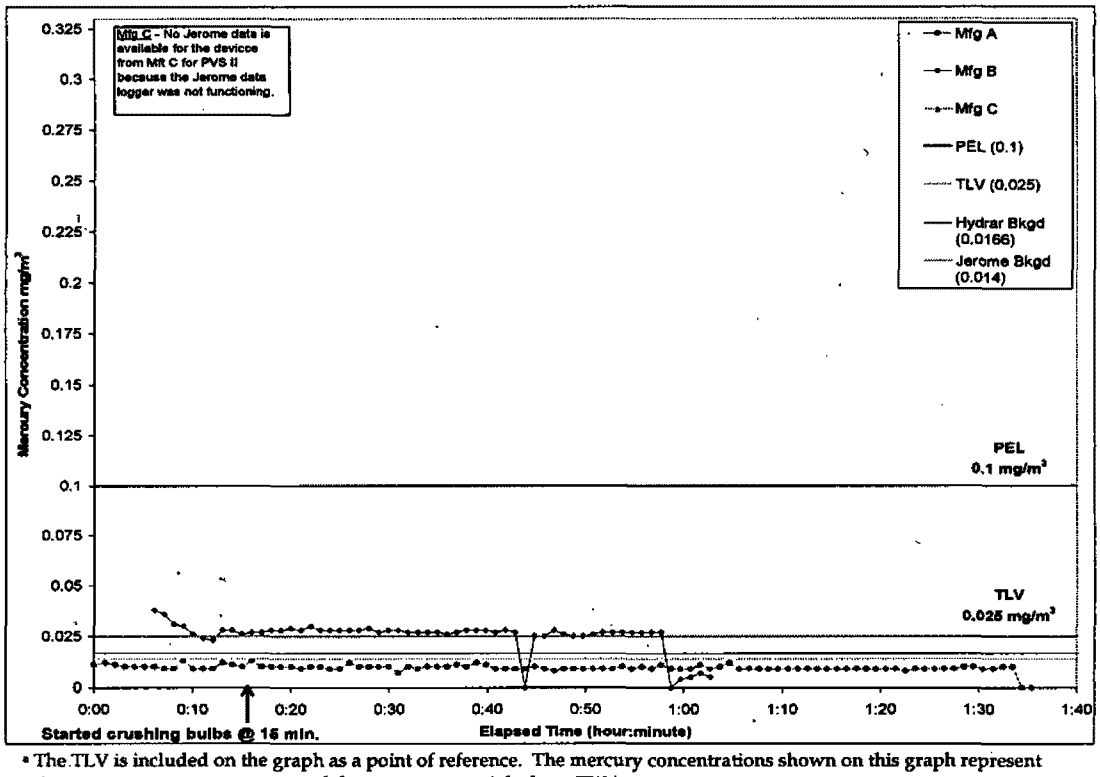
Table 4. 8: Jerome Analyzer Measurements - Inside Containment, Performance Validation Study II

Device	Jerome Mercury Vapor Analyzer Readings (mg/m³)		
	During Operation	Filter Change	Drum Change
Manufacturer A	0.007 - 0.013	No data [a]	No data [b]
Manufacturer B	<0.003 - 0.030	No data [a]	No data [b]
Manufacturer C	0.02 - 0.04 [c]	No data [c]	No data [c]

[a] The Manufacturer A and Manufacturer B devices do not have a separate filter change.
[b] Drum was changed the following day.
[c] Values were manually recorded, as time permitted, because data logger was not functioning.
[d] Data logger was communicating with Jerome analyzer to collect samples but did not record data.

For a graphical depiction of the logged Jerome analyzer data, refer to Figure 4. 3 and Appendix A, Figures 10 through 12.

Figure 4. 3: Jerome Results - Inside Containment, Performance Validation Study II[a]

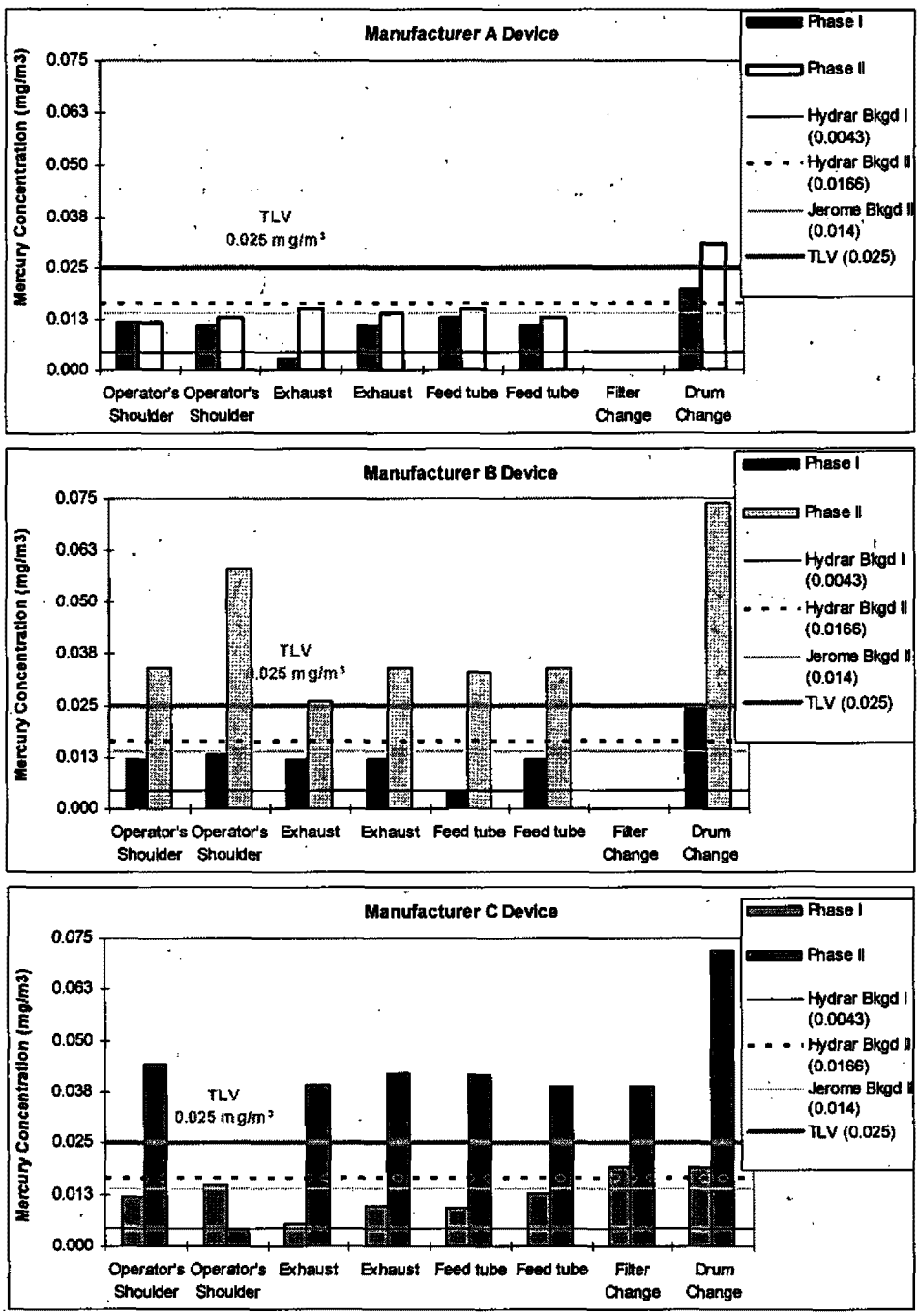


[a] The TLV is included on the graph as a point of reference. The mercury concentrations shown on this graph represent instantaneous measurements and do not represent eight-hour TWAs.

4.4.3 Comparison of Performance Validation Study Phases I and II

Overall, analytical air sample results for all three DTC devices during the PVS were higher during Phase II than Phase I (*refer to Figure 4. 4 and Figures 13, 14, and 15 in Appendix A*). The ceiling samples collected during Phase II are not included in the graphs below because no ceiling samples were collected during Phase I.

Figure 4. 4: Analytical Air Sampling Results, Performance Validation Study – Phases I & II [a]



[a] The TLV is included on the graph as a point of reference. The analytical air samples shown on this graph do not represent eight-hour TWAs (*refer to Appendix A, Table 1 for sample durations*).

Background mercury levels inside the AERC Ashland facility were higher during Phase II than during Phase I. Several one-way Analyses of Variance (ANOVAs) were calculated using the data from Phase I and Phase II. Table 4. 9 compares the results from the Phase I and II PVS tests to background mercury levels and to each other. The ceiling samples are not included in these comparisons because no ceiling samples were taken during Phase I.

Table 4. 9: Performance Validation Study Air Sampling Data Comparison [a, b]

Device	Significant Difference from Background Concentrations		Significant Difference between Phase I and Phase II Concentrations	
	Phase I	Phase II	Measured Value	Background Corrected Values [c]
Manufacturer A	yes p-value = 0.0782	no p-value = 0.6682	no [d] p-value = 0.1700	no [d] p-value = 0.5172
Manufacturer B	yes p-value = 0.0432	yes p-value = 0.0402	yes p-value = 0.0013	yes p-value = 0.0076
Manufacturer C	yes p-value = 0.0380	yes p-value = 0.0869	yes p-value = 0.0011	yes p-value = 0.0081

[a] Data from limited operation of the Manufacturer D device not included because of failure during Phase I.
[b] If p-value < alpha (0.1), the data being compared are significantly different from each other (90% confidence).
[c] The mean background concentration of mercury for specific Phase was subtracted from each of the concentrations measured for each of the devices during that Phase of the Study.
[d] The comparisons for the Manufacturer A device may not be valid because the concentrations of mercury measured in Phase II were not significantly different from the background concentrations; however, they are given here for reference.

As show in Figure 4. 4, the background levels measured in Phase I using the Hydrar tubes averaged 0.0043 mg/m^3, in contrast to the Phase II Hydrar tube background levels, shown in Figure 4. 5, that averaged 0.0166 mg/m^3. (Jerome readings are not comparable because no Jerome background data are available for Phase I.) During Phase I, the concentrations of mercury detected using the personal and area air samples were significantly different from the background concentrations for all three devices. During Phase II, the background concentrations were significantly different from the analytical air sample results from the Manufacturer B and Manufacturer C devices, but not significantly different from the analytical air sample results for the Manufacturer A device.

These statistical comparisons are empirically illustrated by the fact that in the second phase of the PVS, during the operation of the Manufacturer B and Manufacturer C devices, most samples exceeded the ACGIH TLV value. However, during the operation of the Manufacturer A device, all samples other than the drum change and ceiling samples were below the TLV value. The Manufacturer A device features a larger particulate filter and a larger carbon absorption bed than the other two devices. The more substantial pollution control equipment could, at least partially, explain why the PEL value was never exceeded by the Manufacturer A device during the PVS, and the TLV value was only exceeded by three samples.

A number of additional factors, external to actual device performance, may have contributed to the differences between the results for the two phases. During the

Phase II tests (performed in June 2003), the outdoor temperature was 25°F-50°F higher than during Phase I (performed in February 2003), which could have elevated the indoor temperature during air volume changes (e.g., doors opening). An increase in temperature, over a range of 40 to 85 degrees Fahrenheit, has been shown to cause an increase in volatilization of mercury, resulting in greater detected concentrations.[22] Moreover, the lamps processed in Phase II consisted of a mixture of the Alto® Phillips Lighting lamps (which have lower nominal quantities of mercury per lamp) and ordinary fluorescent lamps, with higher nominal mercury content, whereas the Phase I test used Alto® lamps exclusively. Additionally, the DTC devices were not decontaminated before performing the PVS – Phase II testing, so the results from Phase II may be biased high due to residual mercury that may have been in the device before the testing began. These factors may have contributed to the higher mercury vapor concentrations measured in Phase II. However, these factors may not have significantly affected the outcome of the Performance Validation Study because the results in Phase II for the device from Manufacturer A were not significantly different from the results in Phase I.

Overall, these data suggest possible deterioration in DTC device performance for the devices from Manufacturer B and Manufacturer C from Phase I to Phase II, as measured by the ambient mercury vapor concentration during device operation. For the Manufacturer C device, airborne concentrations increased by factors of between two and five, with the most notable decrease in performance indicated in the device exhaust samples and the drum change samples. For the Manufacturer B device, airborne concentrations increased by factors of between two and four, with the most notable decrease in performance indicated in the device feed tube samples and the drum change samples.

4.5 Extended Field Test Study

4.5.1 Extended Field Test #1

The first Extended Field Test (EFT #1) was conducted at the EPSI facility in Phoenix, Arizona (EPSI Phoenix), during the week of March 23, 2003. Temperature and humidity in Phoenix, AZ for each day of testing were obtained from an on-line weather service archive. The average outdoor temperatures during this testing interval ranged between 63.5 and 73.0 degrees Fahrenheit. The average outdoor relative humidity ranged between 12.1 and 31.5 percent.

As described in Chapter 3, area and personal air samples were collected using sampling pumps, and real-time vapor measurements were recorded on Jerome analyzers. Originally, all four devices were going to be tested during EFT #1. However, the Manufacturer D device testing was terminated when mercury concentrations well above the OSHA PEL value were detected in the device operator's breathing zone after processing 16 lamps. The mercury release was likely

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[22] *Refer to Raposo, Cláudio; Windomöller, Cláudio Carvalhinho; and Júnior, Walter Alves Durão. 2003. Mercury speciation in fluorescent lamps by thermal release analysis. Waste Management. 23 879-886. and Aucott, et al, 2003. Release of Mercury from Broken Fluorescent Bulbs. J. Air & Waste Manage. Assoc. 53: 143-151.*

due to the fact that the Manufacturer D device arrived at EPSI Phoenix with a large crack in the vacuum assembly (*refer to Section 3.5.3 for further discussion*).

The following table summarizes the number of lamps processed to fill each drum for the Manufacturer A, Manufacturer B, and Manufacturer C devices, by device. The Sampling and Study Plan (*refer to Appendix D*) specified that enough lamps would be crushed to fill two 55-gallon drums for each DTC device during each EFT.

Table 4. 10: Total Lamps Processed in Each Device, Extended Field Test #1

Device	Number of Lamps – 1st Drum	Number of Lamps – 2nd Drum
Manufacturer A	684	700
Manufacturer B	534	580
Manufacturer C [a]	750	336
Manufacturer D [b]	16	--

[a] Refer to Section 3.5.2 for an explanation of the differences between the 1st and 2nd drums.

[b] Refer to Section 3.5.3 for an explanation as to why the Manufacturer D device processed very few lamps.

4.5.1.1 Analytical Air Sample Results

As shown on Figure 4. 5, most of the results for analytical air samples collected during operation of the Manufacturer A, Manufacturer B, and Manufacturer C devices exceeded the ACGIH TLV value, including all samples collected in the breathing zone of the operator. A few results from these three devices also exceeded the OSHA PEL value:

- The Manufacturer A device exceeded the PEL value on a feed tube sample.[23]
- The Manufacturer B and Manufacturer C devices exceeded the PEL value in the breathing zone of the operator during the second drum change.

Consistent with the observations made during PVS – Phase I, the Manufacturer D device was unable to control its air emissions in that both samples collected in the operator's breathing zone during operation of this device exceeded the PEL value.

For a graphical depiction of the air sample results collected for each DTC device, refer to Appendix A, Figures 16 through 20. To review the actual results for each analytical air sample, refer to Appendix A, Table 1. The Data Chem reports are available in Appendix C.

One possible issue with actual mercury emissions from the DTC devices was the large number of broken lamps visually identified in the shipping boxes as they arrived at the facility. The study team suspected that boxes containing broken lamps were contaminated with mercury vapor existing in air spaces inside the corrugated matrix of the cardboard, as well as mercury particles absorbed into the cardboard. Although the broken lamps were recognized as a possible confounding factor during

[23] *A visible leak was observed at the feed tube flange of Manufacturer A for the first drum. The cause of the leak was determined to be due to a missing flange gasket that was not installed during assembly. After the first drum was filled, the missing gasket was installed at the feed tube flange for the second drum, and the leak problem was corrected.*

EFT #1, no testing to quantify the mercury contribution of the broken lamps and assess this possibility was done until EFT #2 (the box test discussed in Section 4.6).

4.5.1.2 Jerome Mercury Vapor Analyzer Results

Review of the Jerome analyzer readings taken inside the containment structure at one-minute intervals indicated a similar pattern of measured mercury concentrations similar to the air sample analytical results (*refer to Appendix A, Figure 26*). Table 4. 11 presents ranges of mercury concentrations measured by both Jerome analyzers, while testing each DTC device.

Table 4. 11: Jerome Analyzer Measurements, Extended Field Test #1

Device	ACGIH TLV (mg/m^3)	OSHA PEL (mg/m^3)	Jerome Mercury Vapor Analyzer Results (mg/m^3)			
			# of Samples	Jerome #1		Jerome #2
				Range	Mean	Range [a]
Manufacturer A	0.025	0.1	212	0.017 - 0.041	0.027	0.029 - 0.060
Manufacturer B	0.025	0.1	121	0.021 - 0.102	0.049	0.026 - 0.131
Manufacturer C	0.025	0.1	140	0.036 - 0.211	0.074	0.0 – 0.102
Manufacturer D	0.025	0.1	11	0.011 - 0.406[b]	0.175	0.0 – 0.580[c]

[a] Jerome #2 was used to measure the concentrations at the device exhaust, at the seal around the drum, adjacent to the feed tube, and in the operator's breathing zone.

[b] When the unit was started, the readings immediately increased to concentrations above the PEL, and testing was concluded after processing only 16 fluorescent lamps.

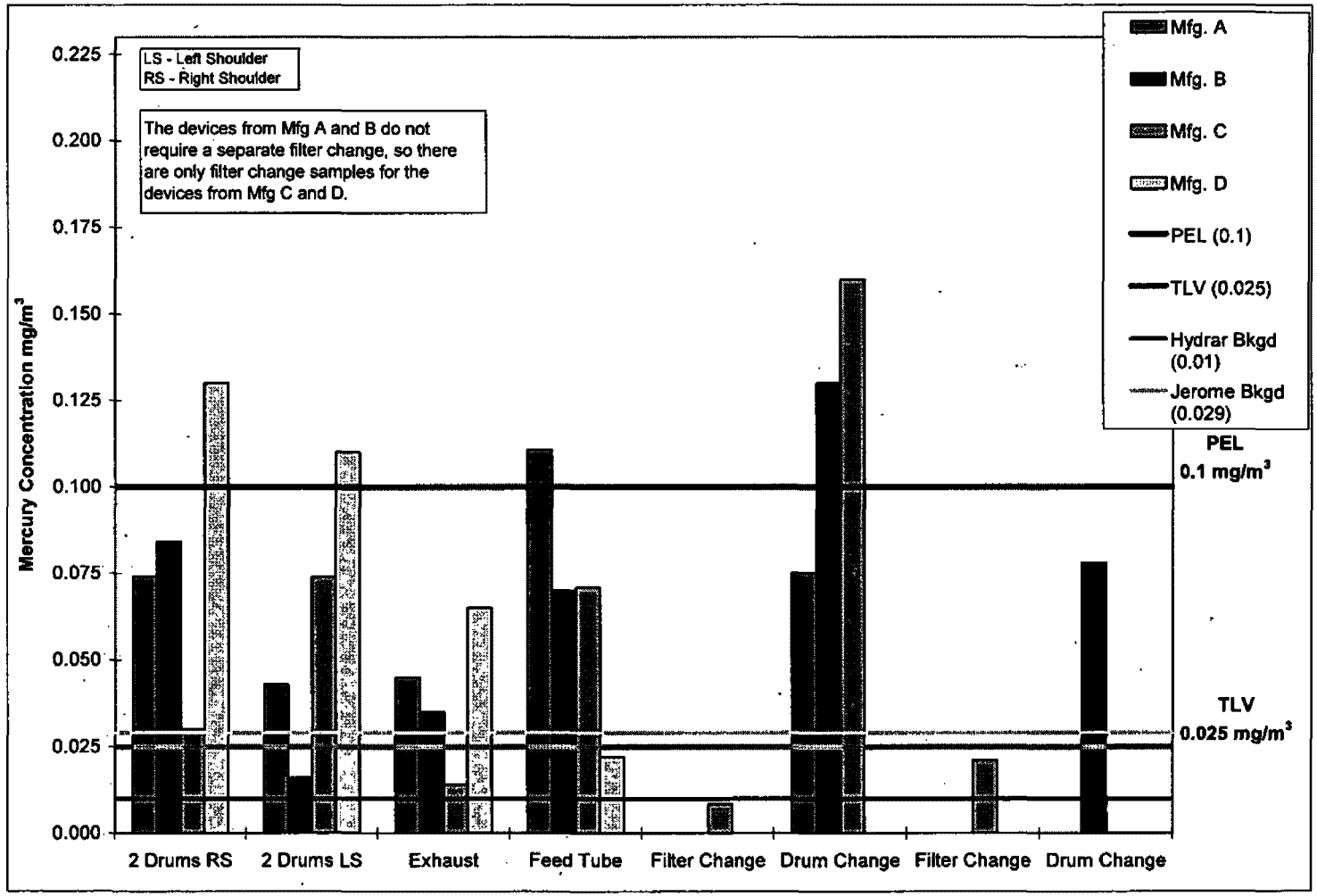
[c] Jerome #2 was stationed inside the containment structure and recorded similar readings above the PEL.

Mercury concentrations in the ambient air in the headspace of a representative drum of crushed lamps were also measured using the Jerome analyzer. This activity was not in the Sampling and Study Plan, but was added in the field. Not unexpectedly, a headspace reading of 0.909 mg/m^3 was registered above a full drum immediately after the DTC device was removed from on top of the drum. A reading taken next to the drum after removing the DTC device from the top of the drum and affixing the drum lid was considerably lower, as expected (0.03 mg/m^3).

While operating the Manufacturer C device, some operational difficulties delayed the start of testing and may have had an effect on the concentrations measured on the Jerome analyzers *(refer to Section 3.5.2 for further discussion regarding the operational problems)*. The Jerome results were above the TLV value and below the PEL value at the beginning, but increased to exceed the PEL value toward the end of testing. During the first drum change, the Jerome readings inside the containment structure slightly exceeded the PEL value; once the drum was changed, readings reverted to levels between the TLV and PEL values. During the second drum change, readings were already elevated above the PEL value, and the test was therefore terminated.

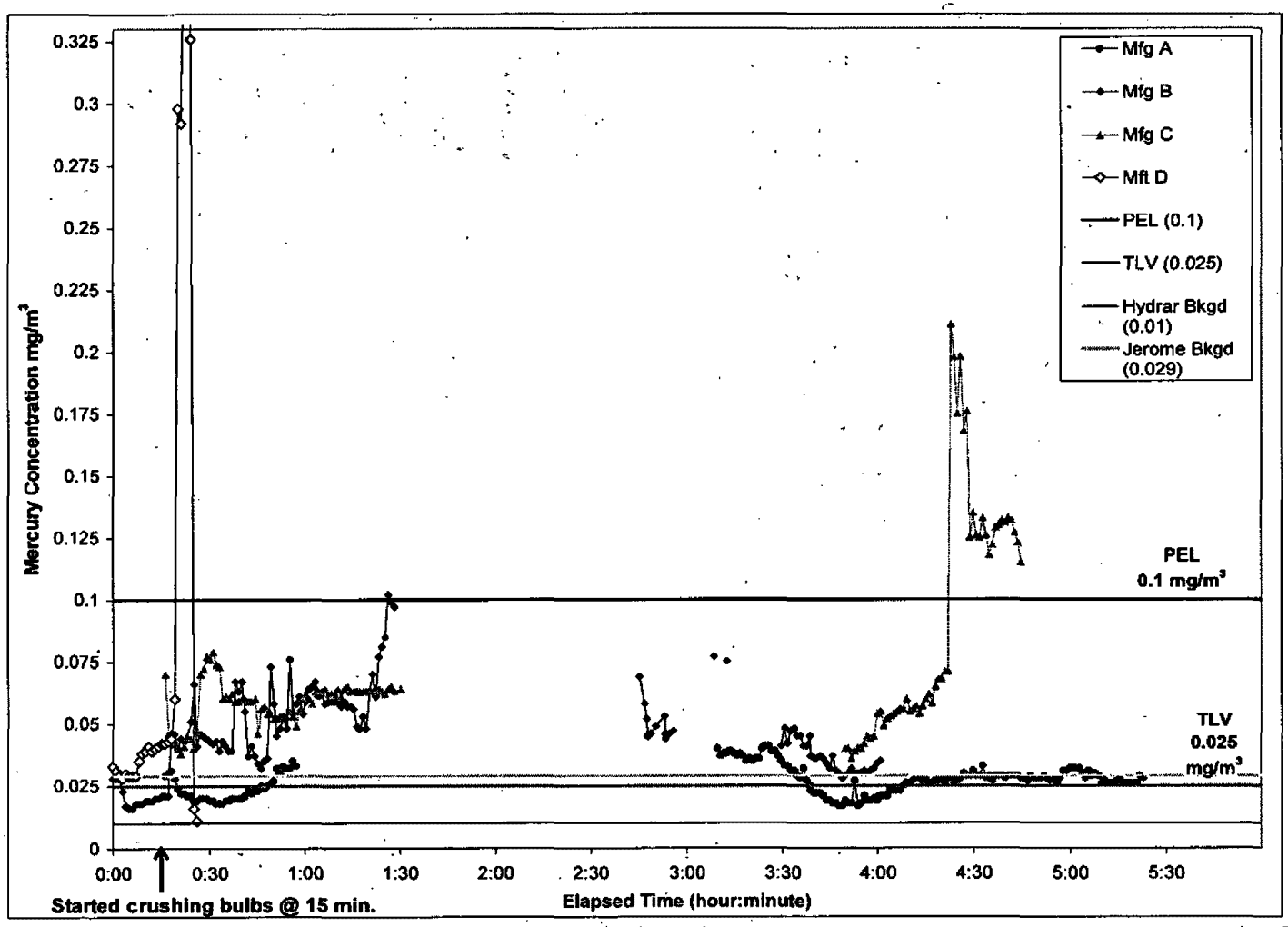
For a graphical depiction of each measurement, refer to Figure 4. 6 and Appendix A, Figures 21 through 25. The graphs also include significant milestones encountered during the device operation to better understand and interpret the measurements.

Figure 4. 5: Analytic Air Sampling Results, All Devices, Extended Field Test #1[a]



[a] The TLV is included on the graph as a point of reference. The analytical air samples shown on this graph do not represent eight-hour TWAs (*refer to Appendix A, Table 1 for sample durations*).

Figure 4. 6: Jerome Results – Inside the Containment, Extended Field Test #1[a]



[a] The TLV is included on the graph as a point of reference. The mercury concentrations shown on this graph represent instantaneous measurements and do not represent eight-hour TWAs.

4.5.2 Extended Field Test #2

The second Extended Field Test (EFT #2) was conducted at the AERC facility in Melbourne, Florida (AERC Melbourne) during the week of April 28, 2003. The temperature and relative humidity was measured using a Velocicalc instrument. The average outdoor temperatures during this testing interval ranged between 73.6 and 77.4 degrees Fahrenheit. The average outdoor relative humidity ranged between 73.9 and 84.4 percent. Indoor temperatures and relative humidity were also measured and recorded during this test and were as follows:

- Temperatures: ranged between 80.1 and 89.4 degrees Fahrenheit, with an average of 84.9 degrees Fahrenheit.

- Relative humidity: ranged between 68 and 85.5 percent, with an average of 75.2 percent.

As described in Chapter 3, analytical air samples were collected with sample pumps and Jerome analyzers. DTC devices from Manufacturer A, Manufacturer B, and Manufacturer C were tested during the EFTS at AERC Melbourne. Table 4. 12 summarizes the number of lamps processed to fill each drum, by device. The number of lamps is specific to the unique operation of each device.

Table 4. 12: Total Lamps Processing in Each Device, Extended Field Test #2

Device	Number of Lamps - 1st Drum	Number of Lamps - 2nd Drum
Manufacturer A	721	678
Manufacturer B #1 [a]	658	609
Manufacturer B #2 [a]	554	--
Manufacturer C	660	639

[a] Refer to Section 3.5.1.

4.5.2.1 Air Sample Results

Several analytical air sample results collected for all three DTC devices during EFT #2 exceeded the OSHA PEL value, and most of the samples exceeded the ACGIH TLV value *(refer to Figure 4. 7)*.[24]

For the Manufacturer A device, the sample on the operator's right shoulder, collected while filling the first drum, exceeded the TLV value. Also, the two ceiling samples exceeded the PEL value.

For the Manufacturer B device, the only sample collected that did not exceed the TLV value was the one collected during the first drum change. Both ceiling samples taken during the first test of the Manufacturer B device were above the PEL value. No ceiling samples were taken during the second Manufacturer B test. Six personal

[24] *It is important to note that the drum-change and ceiling samples are not time-weighted averages (TWA) and should not be compared to the TLV, which is a TWA. The PEL for mercury was promulgated as a ceiling value in 1971 (36 FR 10505, May 29, 1971). A memorandum to OSHA compliance personnel was issued on September 3, 1996, that directs compliance officers to issue citations only when an overexposure exceeds 0.1 mg/m³ as an 8-hour TWA.*

and area air samples were collected during Manufacturer B test #1, and five were collected during Manufacturer B test #2. For the first test, four of these samples were above the PEL value, while only one sample was above the PEL value during the second Manufacturer B test (*refer to Section 3.5.1 for a description of the two tests*).

The samples that exceeded the PEL value during the first test of the Manufacturer B device included both operator shoulder samples collected during filling of first drum, the exhaust area sample during filling of two drums, and the feed tube area sample during filling of two drums. The only sample that exceeded the PEL value during the second test of the Manufacturer B device was the drum change sample.

For the Manufacturer C device, the only sample that did not exceed the TLV value was the one collected on the operator's right shoulder, while filling the first drum. The first drum change sample and both ceiling samples exceeded the PEL value.

For a graphical depiction of the air sample results collected for each DTC device, refer to Appendix A, Figures 27 through 30. To review the actual results for each analytical air sample, refer to Appendix A, Table 1. The Data Chem reports are available in Appendix C.

4.5.2.2 Jerome Mercury Vapor Analyzer Results

Review of the Jerome analyzer readings taken at one-minute intervals indicated a pattern of concentrations similar to the air sample analytical results (*refer to Appendix A, Figure 35*).

The Jerome analyzer was also used to take direct readings of ambient air in the headspace of a representative drum of crushed lamps. This activity was not in the Sampling and Study Plan but was added in the field. A headspace reading of 0.619 mg/m^3 was registered above a full drum on the morning after lamp crushing, and a reading of off-scale (>0.999 mg/m^3) was registered above a full drum immediately after filling the drum. (These data do not directly relate to operator health and safety because they were not measurements of the air in or near the operator breathing zone.) Table 4. 13 presents the range of mercury concentrations detected by both Jerome analyzers for each device during EFT #2.

Table 4. 13: Jerome Analyzer Measurements, Extended Field Test #2

Device	ACGIH TLV (mg/m^3)	OSHA PEL (mg/m^3)	Jerome Mercury Vapor Analyzer Results (mg/m^3)			
			# of Samples	Jerome #1 Range	Jerome #1 Mean	Jerome #2 Range
Manufacturer A	0.025	0.1	347	0.003 - 0.046	0.013	0.006 - 0.06[a]
Manufacturer B #1	0.025	0.1	296	0.00 - 0.328	0.078	0.004 - 0.045[c]
Manufacturer B #2	0.025	0.1	74	0.021 - 0.177	0.066	0.004 - 0.017[b]
Manufacturer C	0.025	0.1	430	0.008 - 0.128	0.034	0.008 - 0.154[c]

[a] Jerome #2 was used to measure concentrations outside the containment structure, the operator's breathing zone, the device exhaust, and at the feed tube connection to the device.

[b] Jerome #2 was used to measure concentrations outside the containment structure.

[c] Jerome #2 was used to measure concentrations outside the containment structure, in the operator's breathing zone, at the device exhaust, and on top of the device.

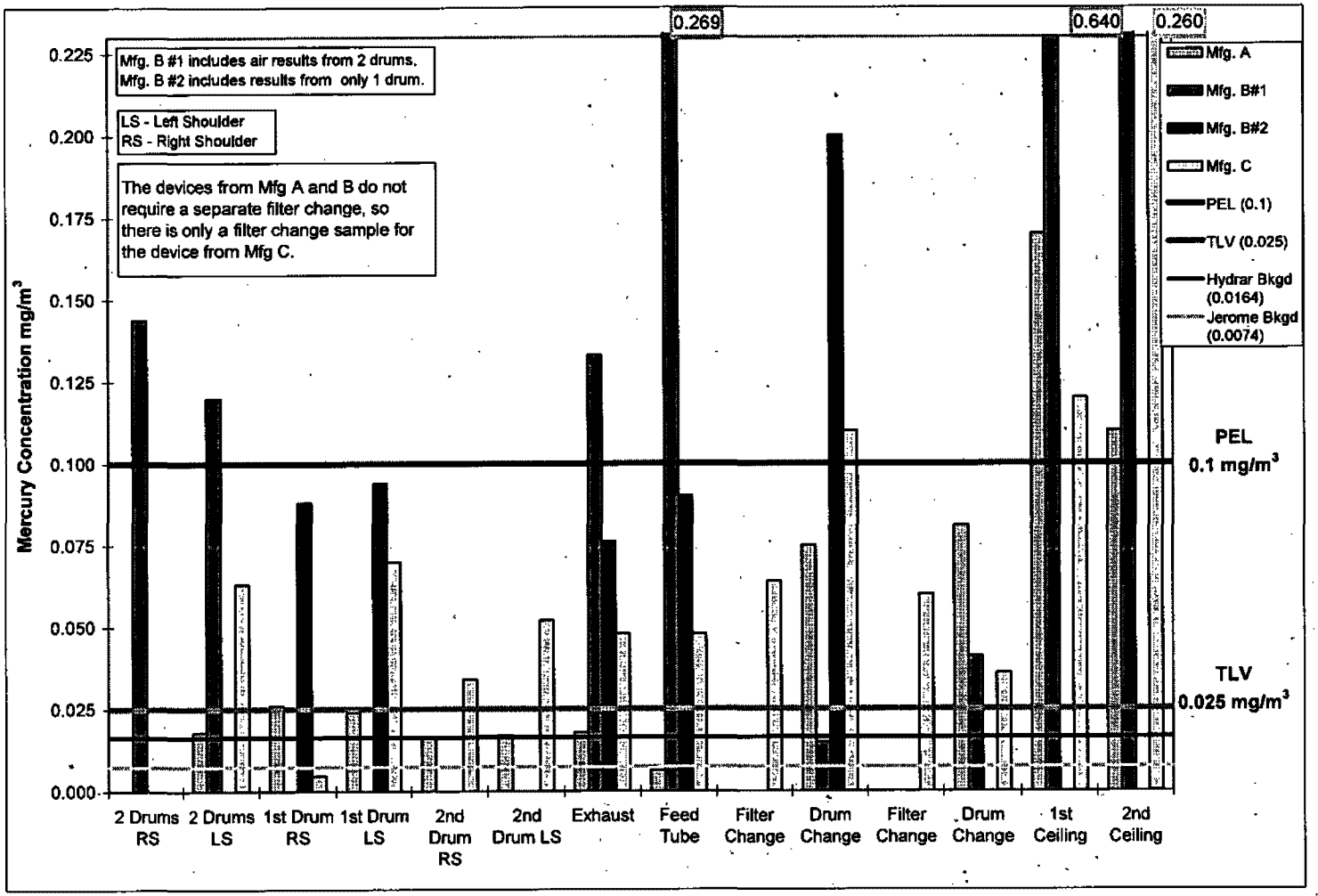
Most of the Jerome readings taken inside the containment structure for the Manufacturer A unit were below the TLV value, with no readings inside the containment structure above the PEL value. The highest reading (0.046 mg/m^3) was measured during the first drum change. The average concentration was 0.013 mg/m^3. Most readings for the Jerome analyzer located outside the containment structure were below the TLV value, and none exceeded the PEL value.

For the Manufacturer B #1 test, the readings from the Jerome analyzer located inside the containment structure were consistently above the TLV and PEL values. In contrast, most of the readings taken with the Jerome analyzer inside the containment structure during the Manufacturer B #2 test were above the TLV value, but below the PEL value. When the drum was changed during the Manufacturer B #2 test, levels inside the containment structure began to exceed the PEL value.

While bulbs were being crushed in the Manufacturer C device, the readings inside the containment structure were consistently above the TLV value but remained below the PEL value, with the exception of the reading taken during the third filter change. The highest reading (0.154 mg/m^3) was obtained after the third filter change and adjacent to a full drum of crushed lamps. The average Jerome analyzer reading inside the containment structure was 0.034 mg/m^3. Measurements recorded by the Jerome analyzer outside the containment structure were below both the TLV and the PEL values and generally did not exceed 0.010 mg/m^3.

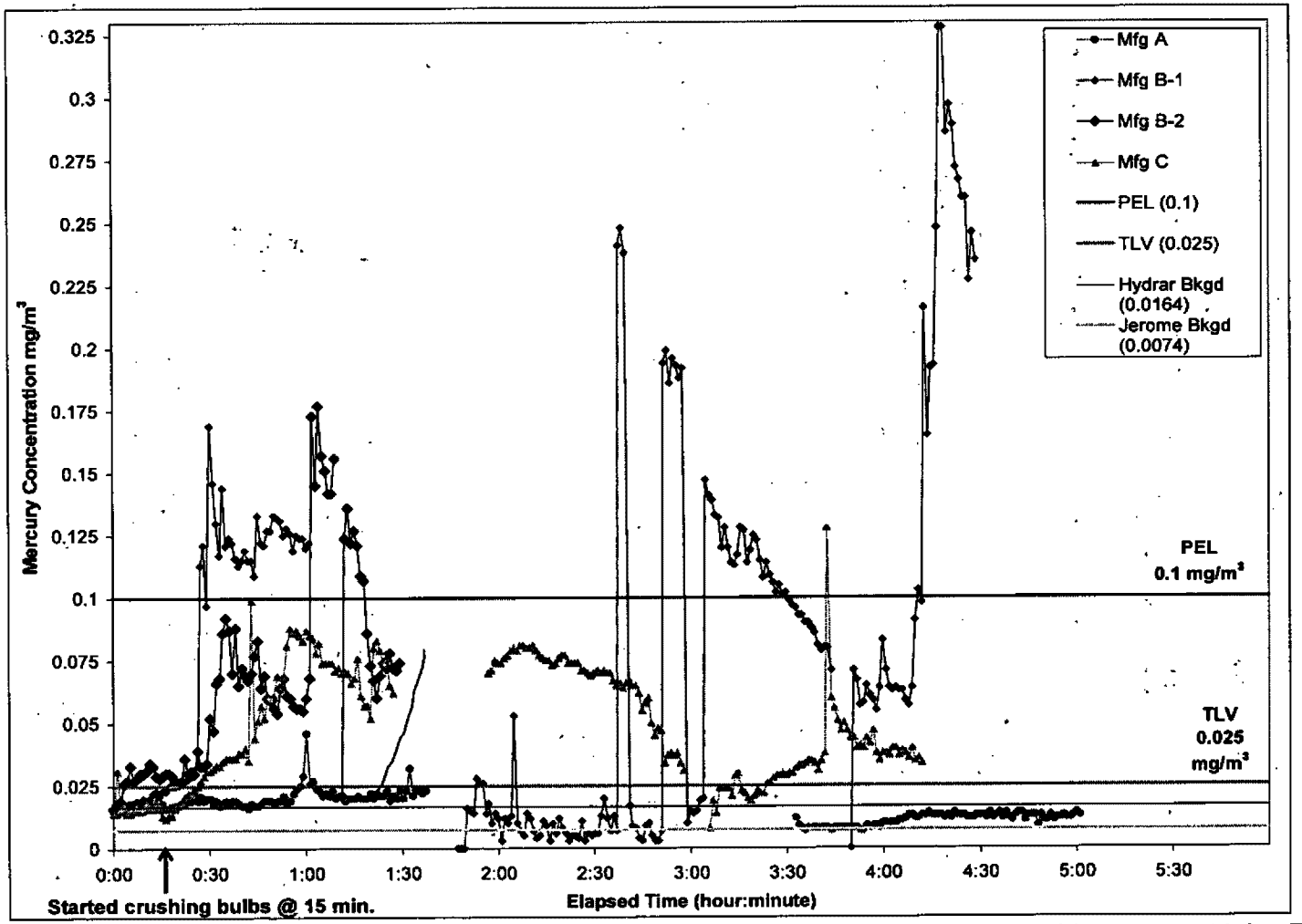
For a graphical depiction of each measurement refer to Figure 4. 8 and Appendix A, Figures 31 through 34. The graphs also include significant milestones encountered during the operation of the devices to better understand and interpret the measurements.

Figure 4. 7: Analytic Air Sampling Results, All Devices, Extended Field Test #2[a]



[a] The TLV is included on the graph as a point of reference. The analytical air samples shown on this graph do not represent eight-hour TWAs (*refer to Appendix A, Table 1 for sample durations*).

Figure 4. 8: Jerome Results – Inside the Containment, Extended Field Test #2[a]



[a] The TLV is included on the graph as a point of reference. The mercury concentrations shown on this graph represent instantaneous measurements and do not represent eight-hour TWAs.

4.5.3 Extended Field Test #3

EFT #3 was conducted at AERC Ashland during the week of June 9, 2003. The average outdoor temperatures during this testing interval ranged between 70.0 and 79.0 degrees Fahrenheit. The average outdoor relative humidity ranged between 73.0 and 80.6 percent. The indoor temperature and relative humidity were measured using a Velocicalc instrument.

- Temperatures: ranged between 73.0 and 86.2 degrees Fahrenheit, with a weekly average of 81.2 degrees Fahrenheit.

- Relative humidity: ranged between 54.5 and 74.4 percent, with an average of 63.1 percent.

As described in Chapter 3, ambient mercury concentrations were measured using sample pumps and Jerome analyzers, and wipe samples were collected inside the containment structure on nine surfaces for the Mass Balance Study (*refer to Appendix F for wipe sample results*). DTC devices from the following manufacturers were tested during EFT #3: Manufacturer A, Manufacturer B, and Manufacturer C. Table 4. 14 summarizes the number of lamps processed to fill each drum, by device. The number of lamps is specific to the unique operation of each device.

Table 4. 14: Total Lamps Processed in Each Device During Extended Field Test #3

Device	Number of Lamps - 1st Drum	Number of Lamps - 2nd Drum
Manufacturer A	767	719
Manufacturer B	594	539
Manufacturer C	794	689

4.5.3.1 Air Sample Results

The air sampling results from the Manufacturer B and Manufacturer C devices were consistently greater than the ACGIH TLV value (*refer to Figure 4. 9*). Air sampling results also indicated that the Manufacturer C device and, to a lesser extent, the Manufacturer B device were prone to excursions above the OSHA PEL value during EFT #3. This occurred most frequently during drum changes and in ceiling samples. With the exception of one sample for the Manufacturer B device, the air samples within the operator's breathing zone (shoulder samples) were the TLV and PEL values during the Manufacturer B and Manufacturer C tests. In contrast, during the Manufacturer A test, breathing zone concentrations remained below the TLV value. [25] No samples taken during the Manufacturer A test exceeded the PEL value.

For a graphical depiction of the air samples collected for each DTC device, refer to Appendix A, Figures 36 through 39. To review the actual results for each analytical

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[25] *It is important to note that the drum-change and ceiling samples are not time-weighted averages (TWA) and should not be compared to the TLV, which is a TWA. The PEL for mercury was promulgated as a ceiling value in 1971 (36 FR 10505, May 29, 1971). A memorandum to OSHA compliance personnel was issued on September 3, 1996, that directs compliance officers to issue citations only when an overexposure exceeds 0.1 mg/m³ as an 8-hour TWA.*

air sample, refer to Appendix A, Table 1. The Data Chem reports are available in Appendix C.

4.5.3.2 Jerome Mercury Analyzer Results

The field team experienced software performance problems while attempting to record the mercury concentration on both data loggers attached to the vapor analyzers during EFT #3. During testing of the first device (from Manufacturer A), the Jerome analyzer appeared to be communicating properly with the data logger (i.e., it was automatically collecting samples at one minute intervals); however, upon downloading the data from the data logger, it was discovered that the data logger had not recorded any measurements. Therefore, there are no logged readings or manual readings for the Jerome analyzer for the Manufacturer A device for EFT #3. Also, due to time constraints, the study team was not able to take readings of the mercury concentration in the head space of a full drum as was done previously.

Review of the Jerome analyzer readings indicate a similar pattern of measured mercury concentrations, compared with the analytical air sample results (*refer to Appendix A, Figure 43*). Table 4. 15 presents a range of results from both Jerome analyzers for the devices from Manufacturer B and Manufacturer C.

Table 4. 15: Jerome Analyzer Measurements, Extended Field Test #3

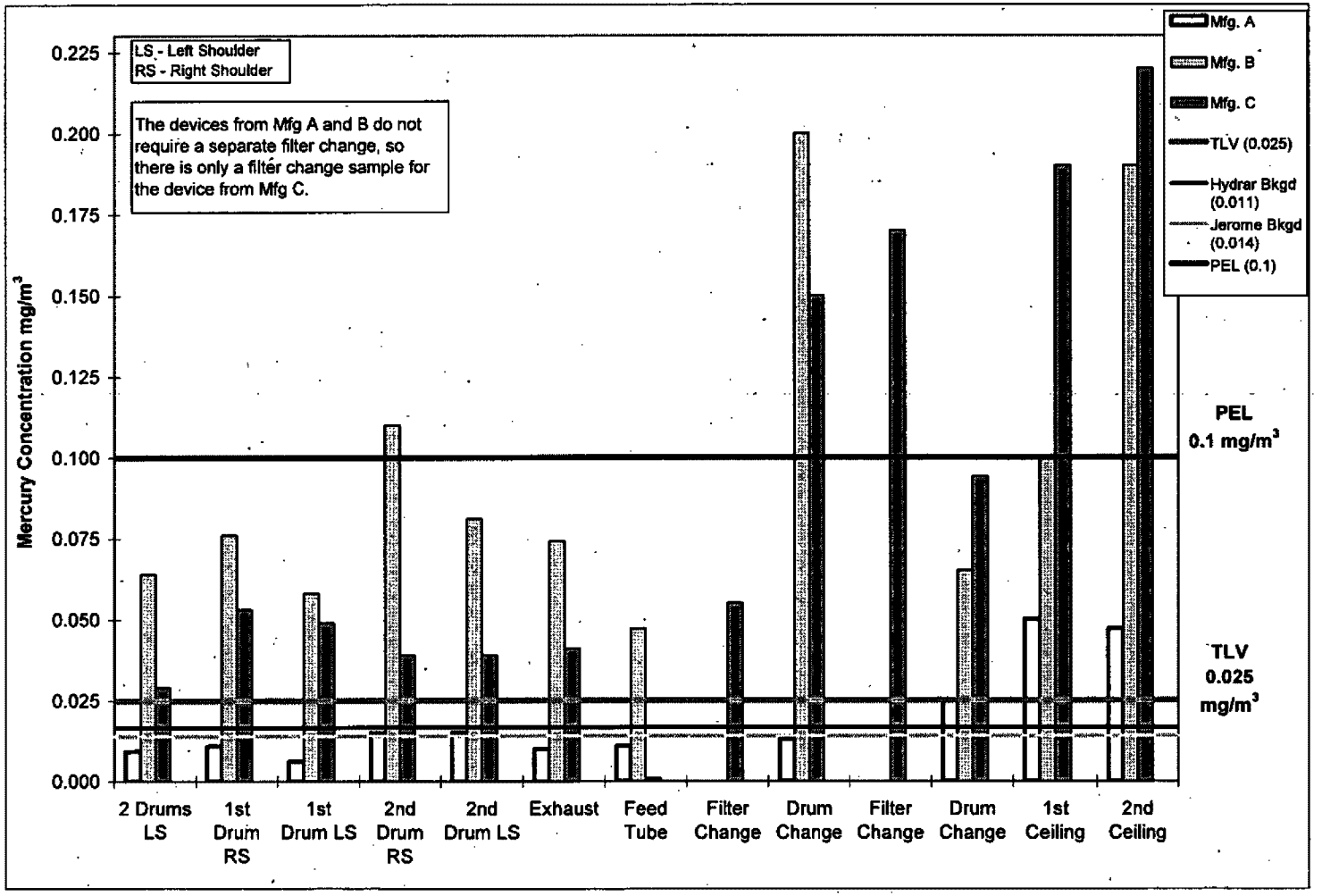
Device	AGCIH TLV (mg/m^3)	OSHA PEL (mg/m^3)	Mercury Vapor Analyzer Results (mg/m^3)			
			# of Samples	Jerome #1		Jerome #2[a]
				Range	Mean	Range
Manufacturer B	0.025	0.1	234	0.009 - 0.258	0.051	<0.003 - 0.017
Manufacturer C	0.025	0.1	218	0.008 - 0.121	0.040	0.008 - 0.02

[a] Jerome #2 unit was kept outside of the containment structure during EFT #3.

For the Manufacturer B device, most measurements (except right after startup) were above the TLV value. There were two sets of excursions above the PEL value. After approximately one hour of operation, readings increased to a maximum of 0.26 mg/m^3 and remained above the PEL value until the first drum change (10 readings within nine minutes). After the drum change, a total of four exceedances were recorded before levels dropped to between the PEL and TLV values and then stabilized. Just before the second drum change, a reading of 0.13 mg/m^3 was registered. After the second drum change, all levels remained below the PEL value and stabilized in a range just above the TLV value, until the conclusion of the test. During operation of the Manufacturer C device, nearly all of the readings (except right after startup, including startup after the first drum change) were above the TLV value. There was also a brief excursion above the PEL value, three readings within an eight-minute period, right before the first drum change. The highest reading registered during this period was 0.12 mg/m^3.

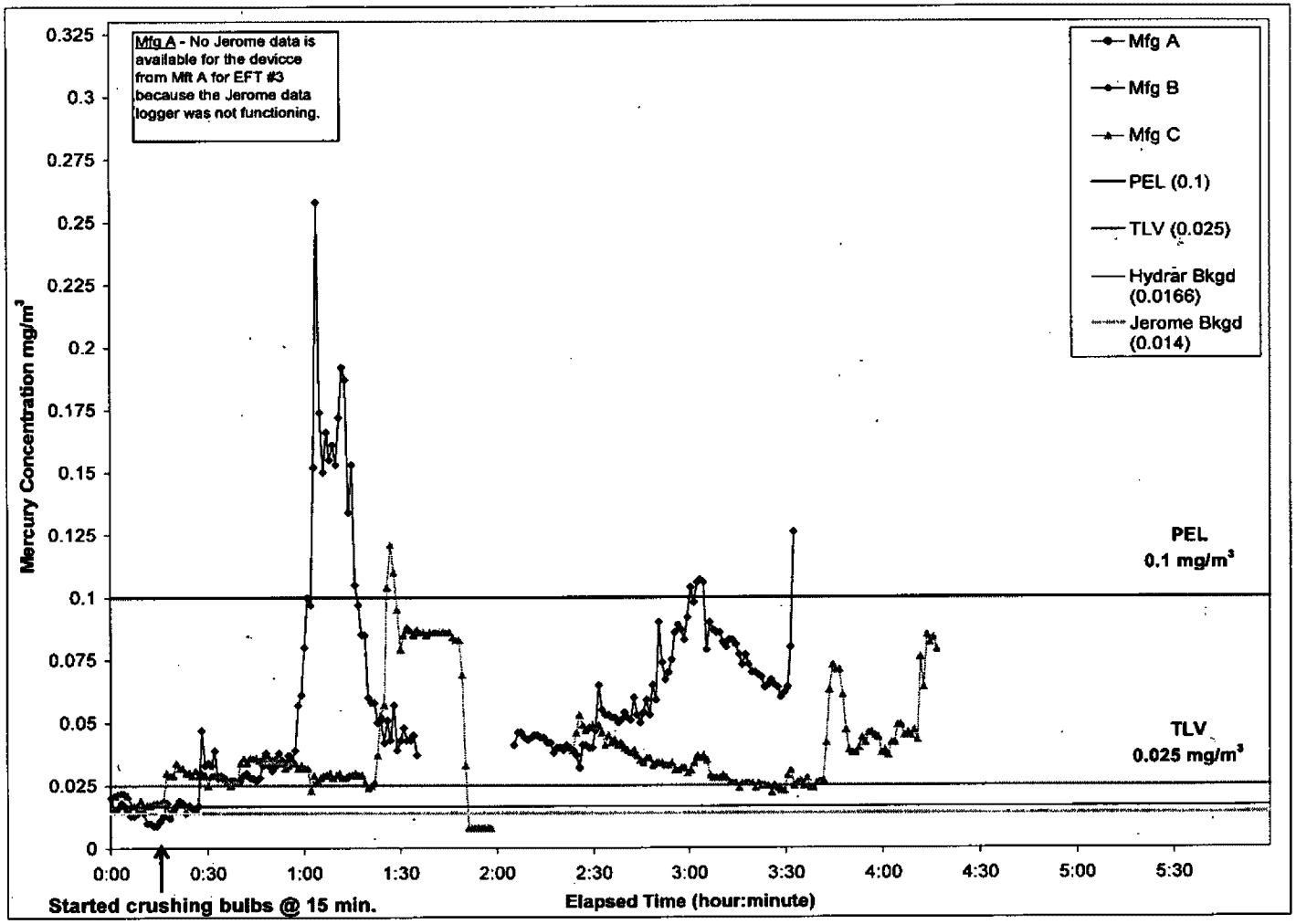
For a graphical depiction of each measurement, refer to Figure 4. 10 and Appendix A, Figures 40 through 42. The graphs also include significant milestones encountered during the operation of the devices to better understand and interpret the measurements.

Figure 4. 9: Analytical Air Sampling Results, All Devices, Extended Field Test #3 [a]



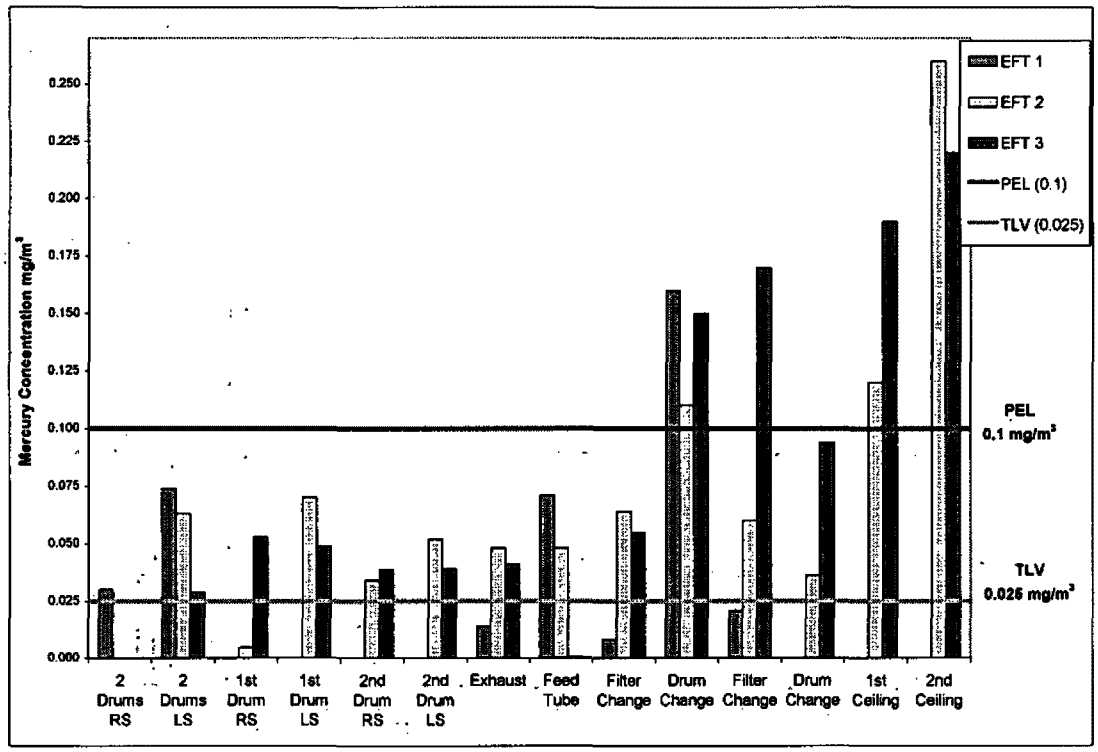
[a] The TLV is included on the graph as a point of reference. The analytical air samples shown on this graph do not represent eight-hour TWAs (*refer to Appendix A, Table 1 for sample durations*).

Figure 4. 10: Jerome Results – Inside the Containment, Extended Field Test #3 [a]



[a] The TLV is included on the graph as a point of reference. The mercury concentrations shown on this graph represent instantaneous measurements and do not represent eight-hour TWAs.

Figure 4. 13: Analytical Air Sampling Results, Extended Field Test Study - Manufacturer C [a]



[a] The TLV is included on the graph as a point of reference. The analytical air samples shown on this graph do not represent eight-hour TWAs (*refer to Appendix A, Table 1 for sample durations*).

In comparing performance over time (i.e., EFT #1, EFT #2, and EFT #3), not all of the air samples could be included. This was because no ceiling samples were taken for EFT #1. The ceiling samples were designed to assess maximum operator exposure. Therefore, inclusion of the samples would skew any statistical comparisons. Comparisons were based on the personal samples during operation and during filter changes and drum changes, the area samples within the containment structure, and the overnight samples within the containment structure (*refer to Section 4.7*).

The Manufacturer A device had significantly poorer performance during EFT #1 than during EFT #2 and EFT #3 (95 percent confidence). This was most likely due to a problem with assembly of the device in that test (*refer to footnote 23 in Section 4.5.1.1*). There was no significant difference in the performance of the Manufacturer B device or the Manufacturer C device during the EFTS.

4.6 Box Tests

During the first two portions of the Study (PVS I and EFT #1), the study team recognized that lamps that were broken in their shipping boxes could contribute mercury to the air in the containment structure during operation of the DTC devices and confound the air sample results. In order to evaluate and quantify the contribution of mercury to ambient mercury concentrations inside the containment structure by broken lamps, air samples were collected at AERC Melbourne and AERC Ashland, during EFT #2 and EFT #3, respectively.

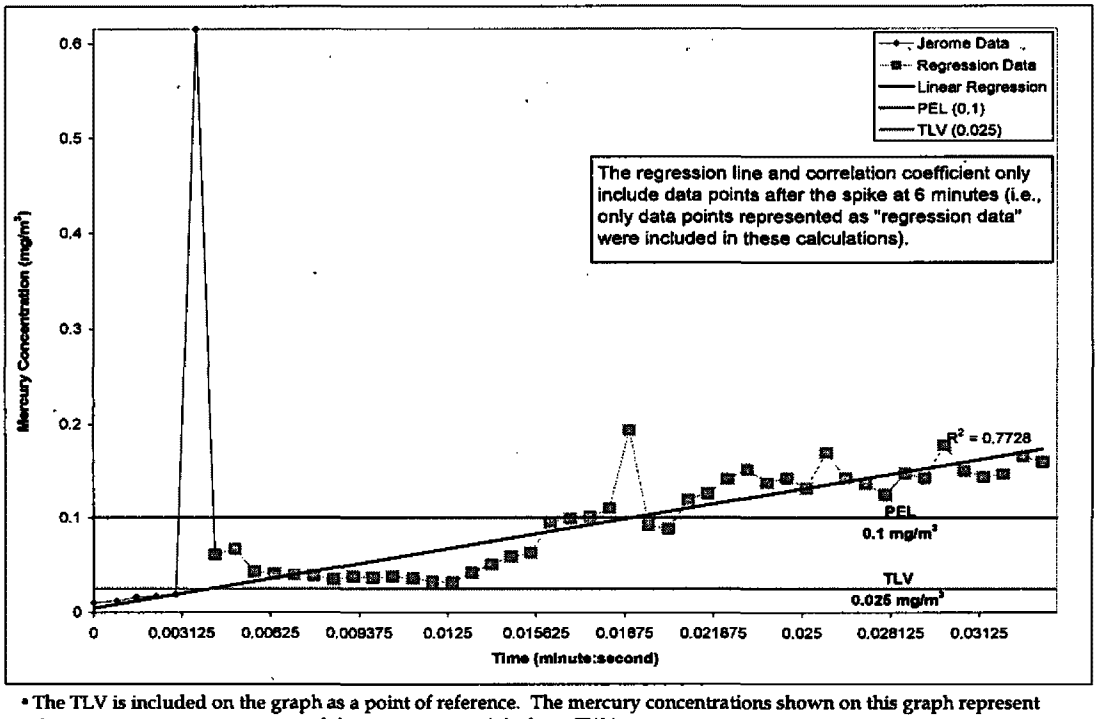
4.6.1 AERC Melbourne Box Test

As described in Section 3.5.1, the Manufacturer B device was tested twice during EFT #2. The first test was performed with boxes of broken lamps inside the containment structure, while the second test was performed without the boxes of broken lamps inside the containment structure. During both tests, personal air samples were collected during drum filling and drum changes, and area samples were collected near the device exhaust and near the device feed tube.

Four out of six sample results collected during the Manufacturer B #1 test exceeded the PEL value, and one out of the five sample results collected during the Manufacturer B #2 test exceeded the PEL value. The fact that 66.7 percent of the samples in test #1, when there were boxes with broken bulbs inside the containment structure, exceeded the PEL value, while only 20 percent of the samples in test #2, when there were not boxes inside the containment structure, exceeded the PEL value suggests a relationship between storing boxes of broken lamps inside the containment structure and elevated mercury concentrations.

The Jerome analyzer was used to measure mercury concentrations when the crushing activity had ceased and when boxes of broken bulbs were present inside the containment structure (*refer to Figure 4. 14*).

Figure 4. 14: Jerome Results – Inside Containment, AERC Melbourne Box Test [a]



[a] The TLV is included on the graph as a point of reference. The mercury concentrations shown on this graph represent instantaneous measurements and do not represent eight-hour TWAs.

After an initial spike in mercury concentration to 0.6 mg/m³, measurements dropped below the PEL and then steadily increased over time. After 30 minutes, all readings were above the PEL. There was a positive correlation ($R^2 = 0.7728$) between

mercury concentrations and time. These results show that it is highly likely that the boxes containing broken lamps did contribute to increases in mercury concentrations within the containment structure.

4.6.2 AERC Ashland Box Test

For each device, after conducting EFT #3, two new air sampling pumps were set up in the containment structure. Boxes containing broken bulbs were placed in the containment structure, but no crushing activities were performed. One analytical air sample was collected on the east side of the containment structure, next to the boxes, and one was collected on the west side of the containment structure, away from the boxes. Samples were collected for 36 – 64 minutes (*refer to Appendix A, Table 1 for sample durations*). Table 4. 17 contains the air sampling results for the box test conducted at AERC Ashland.

Table 4. 17: Results for AERC Ashland Box Test

Device	East Side of Containment (Next to Boxes)	West Side of Containment (Away from Boxes)	Sample Duration (min)
Manufacturer A	0.018 mg/m^3	0.10 mg/m^3	64
Manufacturer B	0.12 mg/m^3	0.12 mg/m^3	36
Manufacturer C	0.050 mg/m^3	0.014 mg/m^3	45

While three of the six samples met or exceeded the OSHA PEL, there was no correlation between sample location (proximity to boxes with broken lamps) and mercury concentration. The Jerome analyzer was used at the same time as the analytical air samples, but the readings are not available due to data logger failure. No manual Jerome readings were taken because there was not anyone in the containment structure during the box tests.

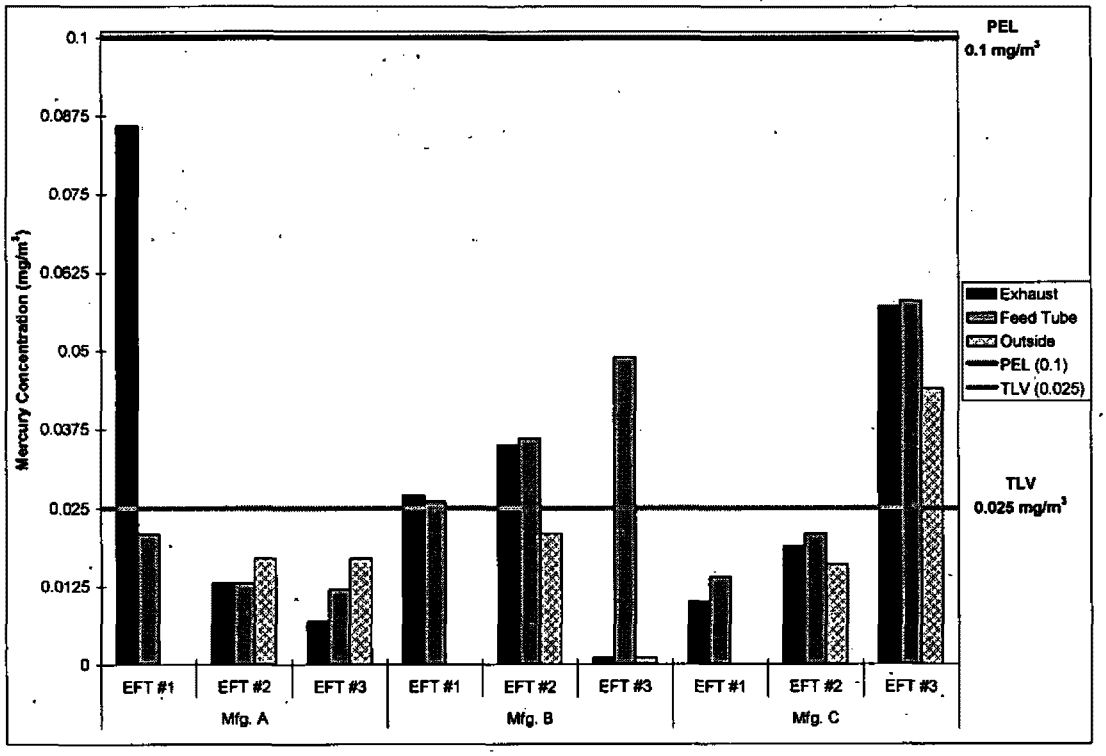
The results from the AERC Ashland box test do not suggest that the broken bulbs in the boxes contribute to elevated mercury concentrations because there was no relationship between the concentration of mercury in the air and the proximity of the air sampling pump to the boxes of broken lamps. However, direct-reading data are not available, so it is not possible to determine whether or not the trend of increasing mercury concentrations in the containment structure over time that was observed in the AERC Melbourne box test is truly representative of what would happen in such a scenario (i.e., boxes containing broken bulbs being stored in a confined space). Therefore, this is an area where future research may be appropriate.

4.7 Overnight Samples

In order to ascertain whether measurable amounts of mercury escaped from the DTC devices during non-operational periods when the devices were assembled on the top of a drum full of crushed lamps, analytical air samples were collected overnight after the operation of each DTC device. The Manufacturer A device blower was kept running (per the manufacturer's instructions) during the overnight test. In accordance with the manufacturers' instructions, the power to the Manufacturer B

and Manufacturer C devices were shut down when the devices were not in use. The results of the overnight tests are presented in Figure 4. 15.

Figure 4. 15: Overnight Test Sample Results



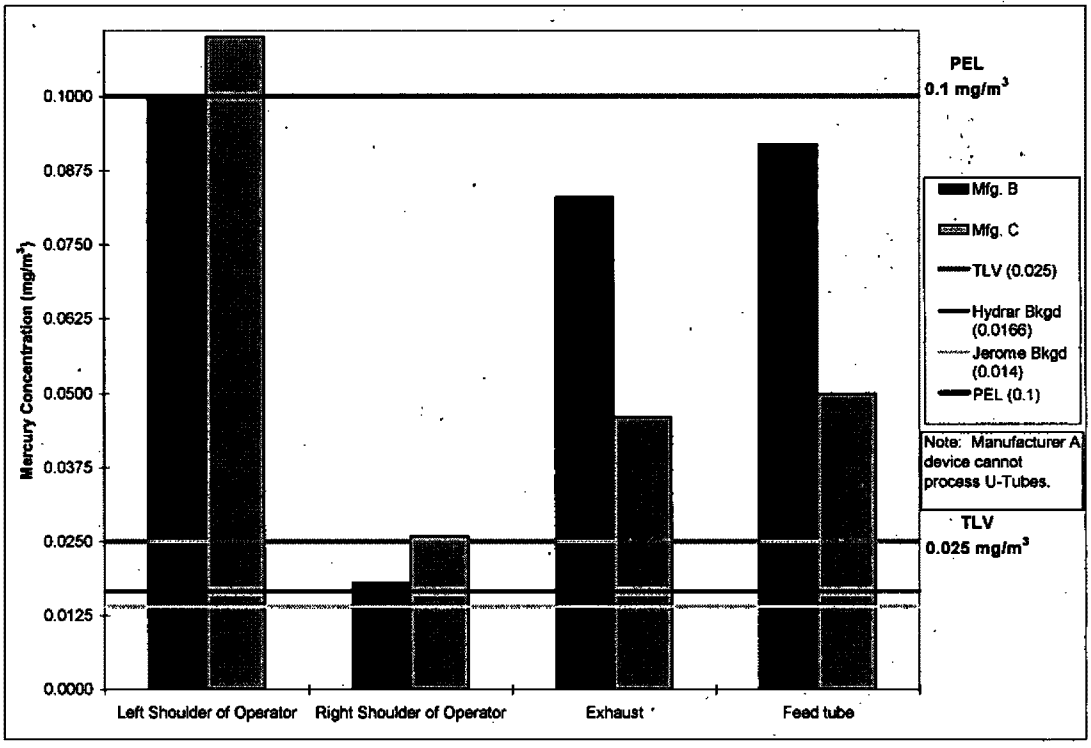
Because overnight samples were collected to assess general release during non-operational periods, values should not be compared to the OSHA PEL or the ACGIH TLV, which is a standard for worker exposure during a regular work day. The lines for the PEL and the TLV are included on the graph as points of reference. The overnight sampling was inconclusive as to whether idle DTC devices attached to partially filled drums of lamps leaked mercury vapors. The concentrations measured overnight were variable. In EFT #1, the overnight sample collected for the Manufacturer A device near the exhaust was much higher than any of the other samples. This may somehow relate to the fact that the Manufacturer A device was the only device that was left on overnight, per instructions in the operations manual.

In EFT #2 and EFT #3, air samples were collected outside the containment structure, as well as inside the containment structure. The overnight samples collected in the containment structure after operating the Manufacturer A device were below the values measured outside the containment structure. Three of the four overnight samples collected inside the containment structure after crushing lamps for the Manufacturer B device measured above the levels measured outside the containment structure. All four of the overnight samples collected inside the containment structure during EFT #2 and EFT #3 for the Manufacturer C device were higher than the outside samples.

4.8 U-Tube Test

The Manufacturer B and Manufacturer C devices have attachments that enable them to process "U" tube lamps (U-tubes). As discussed in Section 3.1.4.2, at the end of EFT #3 at AERC Ashland, a test was conducted to evaluate the airborne mercury levels from the two devices while processing U-tubes. The intent was for both the Manufacturer B and Manufacturer C devices to process enough U-tubes to fill a 55-gallon drum. However, the facility was only able to collect a limited number of U-tubes for the U-tube study, so the available U-tubes were divided between the two devices. The Manufacturer B device processed a total of 85 U-tubes, and the Manufacturer C device processed a total of 89 U-tubes. The sampling duration was 12 minutes for the Manufacturer B device and 14 minutes for the Manufacturer C device. The U-tube air sampling results are presented in Appendix A, Table 1 and shown in Figure 4. 16.

Figure 4. 16: U-tube Test Sample Results[a]



[a] The TLV is included on the graph as a point of reference. The analytical air samples shown on this graph do not represent eight-hour TWAs (*refer to Appendix A, Table 1 for sample durations*).

All samples, except for the Manufacturer B sample on the operator's right shoulder, were above the TLV value. Furthermore, two of the operator breathing zone samples (one for the Manufacturer B device and one for the Manufacturer C device) equaled or slightly exceeded the PEL value. These levels are generally higher than the results from processing the straight lamps, especially in light of the fact that so few U-tubes were processed by each device. A possible explanation for the high mercury levels is the fact that the opening for the U-tube attachment was much larger than the opening for the feed tube for the straight lamps.

5. MASS BALANCE STUDY

The goal of the Mass Balance Study was to estimate for each DTC device its effectiveness in capturing and retaining mercury in the device, expressed as a percent of the total mass of mercury fed into the DTC device. A successful Mass Balance Study would also allow assessment of the total mercury released to the environment due to DTC use, and also to support assessment of potential secondary exposures to mercury from lamp crushing. For each DTC device, the total mercury contained in enough lamps to fill one drum was estimated, and this quantity was then compared with the total mercury detected in samples collected during PVS – Phase I, including: crushed lamps from the drum, DTC pollution control media (particulate, HEPA, and carbon filters), and analytical air samples. See Section 5.1 for the mathematical mass balance equation.

The following sections describe the methodology for, and present the results of, the Mass Balance Study. Note that these results represent the best achievable efforts based on the techniques, methods, equipment, and conditions tested. In some cases (e.g., estimating the quantities of mercury in the unprocessed lamps), there are no agency-approved test methods; therefore, it was necessary to rely on either the manufacturer's internal testing results (i.e., QC testing) or on the results from the methods improvised by the project laboratory, which were intended to simulate the manufacturer's test apparatus. The objectives of this project were strictly research and investigation, and the data generated may or may not be suitable for other purposes, such as human health risk assessment.

5.1 Mass Balance Equation

The mass balance mathematical equation is:

$$Hg_T = Hg_C + Hg_R \qquad \textbf{Equation 5. 1}$$

where: Hg_T is the estimated total mercury content of unprocessed lamps
Hg_C is mercury captured in the DTC device (specifically within the air filter media or "filters" and crushed lamps)
Hg_R is mercury released to the ambient air from the DTC device

Hg_T is determined by the average quantity of mercury in a typical fluorescent lamp, multiplied by the number of lamps processed in the DTC device *(refer to Section 5.2)*. Hg_C is determined by the quantity of mercury measured in the crushed lamps and in the various filters *(refer to Section 5.3)*. Hg_R is determined by the quantity of mercury measured in the ambient air within the containment structure, as determined by area and personnel air samples *(refer to Section 5.4)*.

5.2 Estimating Total Mercury Content of Unprocessed Lamps (Hg_T)

As mentioned above, the first important step in the Mass Balance Study was to estimate the input mercury, or the quantity of mercury contained in a typical set (i.e., one drum's worth) of unprocessed lamps. In theory, this amount should be 100 percent of the total mercury available for potential release to the crushed lamps, the

air filtration system, and as fugitive emissions to the surrounding indoor air. Any difference between this amount and the total of the component terms on the right-hand side of Equation 5.1 thus is a measurement of the potential error in this study.

Philips Lighting (Philips) "Alto®" fluorescent lamps (also referred to as "green tip" lamps) were used during this part of the DTC Study. According to e-mail correspondence from Mr. Steve McGuire of Philips to Mr. Tad Radzinski of EPA, these lamps are manufactured to achieve a specific mass content of mercury, depending on the type of lamp (Table 5. 1), and the tolerance on the mercury content is +/- 0.1 mg of mercury. The mercury content is determined using a test procedure and testing apparatus that Philips has developed specifically for this purpose. Energized (lighted) mercury lamps are attached to the testing apparatus and then chilled using dry ice or other super-cooled vapor. The cooling process condenses the mercury vapor, eventually causing the light to be extinguished. After cooling, a hole is drilled in the metal end cap of the lamp, and an acid extraction method is used via the hole in the metal end cap to recover the mercury for quantitative analysis (*refer to Appendix E*).

Table 5. 1: Mass of Mercury in Philips Lighting Alto® Fluorescent Lamps

Type of Lamp	Mass of Mercury Per Lamp (mg)	Manufacturer's Tolerance (mg)
T-8	3.5	+/- 0.1
T-12 (34 Watt)	4.4	+/- 0.1
T-12 (39 Watt)	3.5	+/- 0.1
T-12 (40 Watt)	4.4	+/- 0.1

In order to approximate real-world operating conditions for the DTC Device Study, spent lamps were processed. To obtain data regarding the mercury content of the spent lamps, a sample of unbroken, Alto® lamps were removed from the stockpile and submitted to Data Chem for analysis of total mercury. These results are contained in Table 5. 2. The data are generally lower than the results provided by Philips for new lamps. This difference is possibly due to small leaks of mercury that occurred during the operating lives of the lamps. Other factors, such as reaction of mercury vapor with lamp components leading to conversion of elemental mercury into salts, dissolution of the mercury into the lamp glass, or binding of mercury to other lamp components, might contribute to this disparity but were not a subject of this study. (The reaction of mercury vapor with lamp components was studied by Hildenbrand, et al.[26] and Jang, et al. [27])

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[26] *Refer to Hildenbrand, V. D.; Denissen, C. J. M.; Geerdinck, L. M.; van der Marel, C.; Snijders, J. H. M.; and Tamminga, Y. 2000. Interactions of thin oxide films with low-pressure mercury discharge. Thin Solid Films. 371: 295-302.*

[27] *Refer to Jang, Min; Hong, Seung Mo; and Park, Jae K. 2005. Characterization of recovery of mercury from spent fluorescent lamps. Waste Management. 25: 5-14.*

Table 5. 2: Total Mercury in Spent Philips Lighting Alto® Fluorescent Lamps [a]

Type of Lamp	Fluorescent Lamp Mercury Quantity (mg)	Mean Mercury Quantity (mg)	Standard Deviation
T-8	3.0	3.0 (10 - 15 mg/kg)	0.082
	2.9		
	3.1		
T-12 (34 Watt)	4.2	4.2 (14 - 21 mg/kg)	0.12
	4.4		
	4.1		
T-12 (40 Watt)	4.3	3.6 (12 - 18 mg/kg)	0.75
	2.8		

[a] No samples of T-12 39 Watt lamps were available for this analysis.

The total mass of mercury in the lamps processed in each DTC device was estimated using the total number of each type of lamp processed and the mean mercury content of each lamp, as shown in Equation 5.2.

$$Hg_T = N_L * Hg_L \qquad \text{Equation 5. 2}$$

where: Hg_T is the estimated total mercury content of unprocessed lamps
N_L is the total number of lamps processed
Hg_L is the mean mercury content of a single lamp

Means for mercury content for each lamp type were determined from either the unbroken lamp samples collected during the study or the information provided by Philips Lighting. In general, use of the study sampling results was preferred, except in the case of the T-12 39 Watt lamp type, where no data were available (*see footnote to Table 5. 2*). The rationale for using the study data over the manufacturer's averages was that the unbroken lamps were obtained from the broader collection of actual used lamps arriving at the respective facilities and thus were believed to be more representative for this study.

After the conclusion of the DTC Study, research was published regarding the efficacy of acid extraction of mercury from fluorescent bulbs (*refer to footnote 27 is Section 5.2*). This issue is discussed further in Sections 5.6 and 5.7.

Table 5. 3 provides an inventory of the types of lamps processed by each device and the estimated total mass of mercury processed through each device during the Mass Balance Study (Hg_T).

Table 5. 3: Mass of Mercury Processed for Each DTC (Hg_T)

Device	Lamp Type	Number of Lamps	Amount of Mercury per Lamp (mg/lamp)	Total Quantity of Mercury (mg)
Manufacturer A	T-12 (34 Watt)	637	4.2	2,675
Total - Hg_T				**2,675 mg**
Manufacturer B	T-12 (34 Watt)	113	4.2	475
	T-8	611	3.0	1,833
Total - Hg_T				**2,308 mg**
Manufacturer C	T-12 (34 Watt)	621	4.2	2,608
	T-12 (39 Watt)	49	3.5	172
	T-12 (40 Watt)	36	3.6	130g
Total - Hg_T				**2,910 mg**

5.3 Estimating Mercury Mass Captured in the DTC Devices (Hg_C)

Mercury was captured inside the DTC devices in either one of two ways:

- Contained within the crushed lamps collected inside the 55-gallon drum beneath the device; or
- Retained as particulate or vapor air emissions retained within the air filtration system that was supplied with the particular device (listed in Table 5. 4).

Section 3.3 provides details regarding the collection of bulk samples, including crushed lamps and pollution control media, for each device. Table 5. 4 summarizes the number and type of bulk samples.

Table 5. 4: Samples Collected for the Mass Balance Study

Manufacturer A Device	Manufacturer B Device	Manufacturer C Device
Crushed lamps - 3 samples	Crushed lamps - 3 samples	Crushed lamps - 3 samples
Top carbon canister - 3 samples	Pre-filter - 1 sample	Pre-filter - 3 samples
Middle carbon canister - 3 samples	Carbon canister - 3 samples	Carbon canister - 3 samples
HEPA filter - 3 samples		HEPA filter - 1 samples

The analytical results for the samples collected for Manufacturer A, Manufacturer B, and Manufacturer C devices are provided in Table 5. 5. Samples from the Manufacturer D device are not presented below because the Manufacturer D device was removed from the Study (*refer to Section 3.5.1*).[28]

[28] During the Mass Balance Study, when only "low mercury" lamps were used and outdoor temperatures were low, operation of the Manufacturer D device resulted in ambient mercury concentrations nearly 9 times the OSHA PEL, highlighting the problems inherent in the use of a poorly designed DTC device.

Table 5. 5: Mass Balance Study Sample Results

DTC Device	Sample Material	Result (w/w)[a]	Result (w/a)[b]	Mean Result	Std. Dev.
Manufacturer A	Crushed Lamps	5.84 µg/g	NA	3.70 µg/g	1.852
Manufacturer A	Crushed Lamps	2.70 µg/g	NA		
Manufacturer A	Crushed Lamps	2.57 µg/g	NA		
Manufacturer A	Carbon Canister (top)	84 µg/g	NA	62 µg/g	25.534
Manufacturer A	Carbon Canister (top)	34 µg/g	NA		
Manufacturer A	Carbon Canister (top)	68 µg/g	NA		
Manufacturer A	Carbon Canister (middle)	39 µg/g	NA	15 µg/g	20.649
Manufacturer A	Carbon Canister (middle)	5.0 µg/g	NA		
Manufacturer A	Carbon Canister (middle)	1.7 µg/g	NA		
Manufacturer A	HEPA Filter	NA	4.2 µg/100 cm^2	5.5 µg/100cm^2	1.253
Manufacturer A	HEPA Filter	NA	6.7 µg/100cm^2		
Manufacturer A	HEPA Filter	NA	5.6 µg/100cm^2		
Manufacturer B	Crushed Lamps	5.17 µg/g	NA	5.11 µg/g	0.4880
Manufacturer B	Crushed Lamps	4.59 µg/g	NA		
Manufacturer B	Crushed Lamps	5.56 µg/g	NA		
Manufacturer B	Pre-Filter [c]	490 µg/g	NA	490 µg/g	N/A
Manufacturer B	Carbon Canister	11 µg/g	NA	22 µg/g	12.220
Manufacturer B	Carbon Canister	19 µg/g	NA		
Manufacturer B	Carbon Canister	35 µg/g	NA		
Manufacturer C	Crushed Lamps	6.07 µg/g	NA	4.69 µg/g	1.975
Manufacturer C	Crushed Lamps	5.58 µg/g	NA		
Manufacturer C	Crushed Lamps	2.43 µg/g	NA		
Manufacturer C	Pre-Filter [c]	180 µg/g	NA	180 µg/g	0.0
Manufacturer C	Pre-Filter [c]	180 µg/g	NA		
Manufacturer C	Pre-Filter [c]	180 µg/g	NA		
Manufacturer C	Carbon Canister	2.7 µg/g	NA	5.8 µg/g	3.053
Manufacturer C	Carbon Canister	6.0 µg/g	NA		
Manufacturer C	Carbon Canister	8.8 µg/g	NA		
Manufacturer C	HEPA Filter	NA	2.3 µg/100 cm^2	2.3 µg/100 cm^2	N/A

[a] Result w/w column of the Bulk Sample Results table is a proportion of weight per weight.
[b] Result w/a column of the Bulk Sample Results table is a proportion of weight per area.
[c] "Pre-filter" primarily consisted of phosphor with a few glass fines. The pre-filter was collected off a paper sock filter (Manufacturer B device) or a vacuum-bag type filter (Manufacturer C device).
NA – Not applicable
µg/g – micrograms per gram
µg/100 cm^2 – micrograms per 100 square centimeters

The device manufacturers were instructed to submit clean filter media to Data Chem for quality control (QC) samples. These clean materials were used for laboratory blanks and matrix spikes. The blank sample values are shown in Table 5. 6. The spike values and recoveries are listed in Table 5. 11 and discussed in Section 5.6.2. Table 5. 6 also presents the weight or area information for the samples, as applicable. Results are reported as either a mass of mercury per weight or a mass of mercury per area. The methods used to measure the weight of the samples are described in Section 3.3. The manufacturers provided the nominal areas of each type of filter used in the various devices. Prior to performing the mass balance calculations, all values were converted from standard units (i.e., pounds [lb] or square inches [in^2]) to metric units (i.e., grams [g] or square centimeters [cm^2]). Table 5. 7 presents the measured mass of mercury captured in each of the different media (i.e., [mean concentration]•[applicable weight or area]), in milligrams (mg).

Table 5. 6: Total Weights, Areas, and Blank Mercury Concentrations of Bulk Sample Media

Device	Weight of Crushed Lamps		Weight of Pre-Filter		Area of HEPA Filter Media		HEPA Filter Blank (µg/sample)		Weight of Carbon Canister		Carbon Canister Blank (µg/g)	
	lb[a]	g	lb[a]	g	in^2[a]	cm^2			lb[a]	g		
Manufacturer A	466	211,374	NA	NA	7,632	49,239	ND	ND	29/bag	13,154	7.4	20.0
Manufacturer B	331	150,139	0.056	25.4	NA	NA	NA	NA	- 0.742	337	ND	ND
Manufacturer C	436	197,766	0.58	263	194	1,250	ND	ND	22	9,979	ND	ND

[a] Actual measured weight or area of the media.
NA – Not applicable
ND – Not detected

Table 5. 7: Estimated Mercury Mass Captured inside DTC Devices (Hg_C)

Device	Sample Type	Concentration	Weight or Area	Total Hg (mg)
Manufacturer A	Crushed Lamps	3.70 µg/g	211,374 g	782
	HEPA Filter	5.5 µg/100 cm^2	49,239 cm^2	2.7
	Carbon Canister (top)	62 µg/g	13,154 g	816
	Carbon Canister (middle)	15 µg/g	13,154 g	197
Total – Hg_T				**1,798**
Manufacturer B	Crushed Lamps	5.11 µg/g	150,139 g	767
	Pre-Filter	490 µg/g	25.4 g	12
	Carbon Canister	22 µg/g	337 g	7.4
Total – Hg_T				**786**
Manufacturer C	Crushed Lamps	4.69 µg/g	197,766 g	928
	Pre-Filter	180 µg/g	263 g	47.3
	HEPA Filter	2.3 µg/100 cm^2	1,250 cm^2	0.029
	Carbon Canister	5.8 µg/g	9,979 g	58
Total – Hg_T				**1,033**

5.4 Estimated Mercury Released To The Ambient Air (Hg_R)

The total mass of mercury released to the ambient air from each DTC device (Hg_R) was estimated using the air sampling data collected during PVS – Phase I. The method for calculating Hg_R is shown in Equation 5.3.

$$Hg_R = N_{AE} \cdot [Hg] \cdot V \qquad \textbf{Equation 5. 3}$$

where: Hg_R is mercury released to the ambient air from the DTC device
N_{AE} is the estimated number of air exchanges
[Hg] mean air concentration in containment structure during PVS I
V is the volume of the containment structure

The mean of the four area air sample results (two samples at the feed tube and two samples at the device exhaust) was calculated for each DTC device. The containment structure measured 12 feet by 12 feet by 10 feet, for a volume of 1,440 cubic feet (ft^3), which converts to 40.78 cubic meters (m^3).

During the operation of all devices, movement in and out of the containment structure was limited to supplying boxes of lamps to the operator and the industrial hygienist collecting the air samples, thus limiting (to the extent practicable) the exchange of air between the containment volume and the outside. In addition, as described previously in Section 2.2, the construction of the containment space itself (e.g., taped and overlapping plastic sheeting) aided in isolating the space and limiting air movement. While the number of air exchanges was not specifically measured, it was estimated using Equation 5.4.

$$N_{AE} = (Q \cdot t) / V \qquad \textbf{Equation 5. 4}$$

where: N_{AE} is the estimated number of air exchanges
Q is the volumetric flow rate of air coming out of the device exhaust
t is the duration of the area air sampling
V is the volume of the containment structure

Table 5. 8 presents the mean mercury concentrations in the air samples and the estimated mass of mercury released (Hg_R) for each device:

Table 5. 8: Mercury Released from DTC Devices (Hg_R)

Device	Flow Rate (ft^3/min)	Time (min)	Number of Air Exchanges	Mean Mercury Concentration (mg/m^3)	Volume (m^3)	Mercury Released (Hg_R)
Manufacturer A	25 [a]	112	1.9	0.0094	40.78	0.75 mg
Manufacturer B	34 [b]	86	2.0	0.010	40.78	0.82 mg
Manufacturer C	42 [b]	100	2.9	0.0095	40.78	1.3 mg

[a] Estimate from owner's manual.
[b] Measured during operation.

While the reported values for the number of air exchanges are estimates, they do not significantly affect the mass balance because $Hg_R << Hg_C$ (refer to Table 5. 9).

Originally, it was also intended to include the wipe sampling results from the interior surfaces of the polyethylene containment structure, to attempt to quantify the contribution of mercury vapor condensation to the overall mass balance. However, this process was impacted by the unexpectedly high ambient concentrations of mercury inside the facilities. Due to these high ambient concentrations, it would not have been possible to effectively differentiate mercury vapors released by the device and condensing on the polyethylene sheeting from vapors already existing in the air and condensing on the sheeting. Furthermore, some of the mercury mass might have been double-counted under such a scenario. Therefore, wipe sampling results were excluded from the Mass Balance Study. Refer to Appendix F for a discussion of the wipe sample results.

5.5 Mass Balance Results

Sections 5.2, 5.3, and 5.4 described the methods used to derive the mass of mercury that was used in the mass balance calculations. Table 5. 9 is a summary of the total mass of mercury contributed by each source.

Table 5. 9: Summary of Mercury Mass Contributions, By Source

Device	Hg_C					Hg_R
	Crushed Lamps	Pre-Filter	HEPA Filter	Carbon Canister(s)	Total	
Manufacturer A	782 mg	NA	2.7 mg	1,013 mg[a]	1797.7 mg	0.75 mg
Manufacturer B	767 mg	12 mg	NA	7.4 mg	786.4 mg	0.82 mg
Manufacturer C	928 mg	47.3 mg	0.029 mg	58 mg	1033.329 mg	1.3 mg

[a] Combined recovery by the top and middle carbon canisters on the Manufacturer A device.

Table 5. 10 contains the results of the mercury mass balance calculation for each device, as well as the percentage of mercury accounted for compared to the estimated mass of mercury processed (i.e., the mercury content of the unprocessed whole lamps).

Table 5. 10: Mass Balance Calculation Results

Device	Hg Processed (Hg_T)	Hg Recovered ($Hg_C + Hg_R$)	% Recovery
Manufacturer A	2,675 mg	1,798 mg	67.3 %
Manufacturer B	2,308 mg	787 mg	34.1 %
Manufacturer C	2,910 mg	1,035 mg	35.6 %

5.6 Mass Balance Discussion

Based on the mass balance results obtained from this study and presented in Table 5. 10, the total mercury mass accounted for ($Hg_C + Hg_R$) was about one third to two thirds less than the estimated input of mercury (Hg_T). Several variables may have contributed to the inability to account for a fairly large percentage of the mercury. Three of the most likely variables that would affect the mass balance are: 1) inaccuracies in the determination of mercury in the crushed lamps; 2) inaccuracies in the determination of mercury in the filter media due to poor recovery during the laboratory analysis; and 3) absorption of mercury on polyethylene (the containment structure) and inside the DTC device. In addition, there is no approved laboratory procedure to estimate the mercury content of whole fluorescent lamps, making this factor another possible cause of the imbalances noted during this study.

5.6.1 Mercury Mass in Crushed Lamps

As indicated by the results summarized in Table 5. 9, a substantial fraction of the mercury produced during the crushing of lamps in the DTC devices accumulates in the crushed lamps. Therefore, this variable has a substantial influence on the mass balance results. It was closely studied to attempt to understand the reason for the disparity between the total mercury mass in the lamps before processing and the mercury mass accounted for after processing.

The proportion of the total mercury mass detected ($Hg_C + Hg_R$) in the crushed lamps was 43 percent for the Manufacturer A device, 97 percent for the Manufacturer B device, and 90 percent for the Manufacturer C device. The lower percentage observed for the Manufacturer A device can be attributed to the relatively larger capture of mercury mass in the more extensive air filtration equipment (HEPA filter and carbon filters) associated with this device. As can be noted from Table 5. 9, the actual mercury mass in the crushed lamps from each of the three devices are similar (having the same orders of magnitude).

The sample results for the crushed lamps for all devices in general may have been biased low, for three reasons.

- The method of collecting the samples of crushed lamps involved digging as deep into the drum as possible to collect the samples. However, due to the high density of the crushed lamps (caused by the unaided compaction of the crushed glass and other debris), the samples could only be collected at a depth of approximately eight inches. The operation of each DTC device causes the drum to vibrate, and this vibration may have caused the phosphor powder fraction of the crushed lamps to stratify vertically within the drum. An analysis of the crushed lamps components indicates that the majority of the mercury will be condensed onto this fine phosphor powder *(refer to Appendix G)*, thus causing an unequal distribution of mercury mass with lower concentrations on top. Jang, et

al. (2005) [29] and Raposo, et al. (2003)[30] provide further information on the distribution of mercury in spent fluorescent lamps. Because of this likely distribution of phosphor powder in the drum, samples collected at a depth of eight inches would likely not be representative of the contents of the drum.

- Some mercury likely volatized and was released during the collection of the crushed lamps samples from the drum, compositing the samples, and transfer of the material to the sample containers.

- Additional handling and sorting of the composite samples at the laboratory may have resulted in further volatilization of mercury.

Due to a miscommunication between Booz Allen Hamilton and Data Chem, the laboratory initially analyzed only the phosphor powder and glass fines portion of the crushed lamps bulk samples. The results for the mercury concentration in crushed lamps that were obtained in this first analysis were greater than the mercury concentrations in unbroken lamps by an order of magnitude.

When this error was identified, the laboratory was instructed to analyze the remaining crushed lamp sample material (i.e., the broken glass and lamp end caps). The combined results from both analyses were used to estimate mass of mercury in the crushed lamps for the mass balance. Appendix G presents a discussion of the two sets of results.

5.6.2 Mercury Mass in Air Filtration System Elements

An important variable in the mass balance equation is the analytical results for mercury in the various air filtration media associated with the DTC devices. As discussed below, the laboratory-reported concentrations of mercury from the carbon media and the HEPA filters contained significant errors. Because the pre-filters were easily accessible and the amount of material collected in the pre-filters was limited, the pre-filter sampling data are likely to be accurate, and thus, the efforts to identify probable sources of error focused on the HEPA filters and the activated carbon.

Laboratory spike samples were prepared and analyzed, to assess potential matrix interferences from the filter or carbon media, as applicable. Manufacturer A, Manufacturer B, and Manufacturer C were contacted and instructed to submit clean filter media samples to Data Chem. Manufacturer A and Manufacturer C each submitted a HEPA filter and carbon canister, and Manufacturer B submitted its composite filtration cartridge, which consists of a particulate/pre-filter and a carbon canister. The quantity of mercury with which to spike each media was based on the results obtained during prior DTC device tests in this study. Data Chem prepared and analyzed four spike samples and two blank samples per media.

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[29] *Refer to Jang, Min; Hong, Seung Mo; and Park, Jae K. 2005. Characterization of recovery of mercury from spent fluorescent lamps. Waste Management. 25: 5-14.*

[30] *Refer to Raposo, Cláudio; Windomöller, Cláudio Carvalhinho; and Júnior, Walter Alves Durão. 2003. Mercury speciation in fluorescent lamps by thermal release analysis. Waste Management. 23: 879-886.*

The results for these QA/QC samples are given in Table 5. 11.

Table 5. 11: Spike and Blank Analytical Results for Pollution Control Media

Device	Media	Spiked Concentration	Recovered Concentration	Percent Recovery
Manufacturer A	Carbon (C1)	60 µg/g	67 µg/g	112%
Manufacturer A	Carbon (C2)	60 µg/g	56 µg/g	93%
Manufacturer A	Carbon (C3)	60 µg/g	60 µg/g	100%
Manufacturer A	Carbon (C4)	60 µg/g	100 µg/g	167%
Manufacturer A	Carbon Blank (CB1)	0 µg/g	7.4 µg/g	NA
Manufacturer A	Carbon Blank (CB2)	0 µg/g	20 µg/g	NA
Manufacturer A	HEPA Filter (F1)	2 µg/sample	2.2 µg/sample	110%
Manufacturer A	HEPA Filter (F2)	2 µg/sample	2.1 µg/sample	105%
Manufacturer A	HEPA Filter (F3)	2 µg/sample	2.2 µg/sample	110%
Manufacturer A	HEPA Filter (F4)	2 µg/sample	2.2 µg/sample	110%
Manufacturer A	HEPA Filter Blank (FB1)	0 µg/g	ND	NA
Manufacturer A	HEPA Filter Blank (FB2)	0 µg/g	ND	NA
Manufacturer B	Carbon (C1)	20 µg/g	4.5 µg/g	23%
Manufacturer B	Carbon (C2)	20 µg/g	4.4 µg/g	22%
Manufacturer B	Carbon (C3)	20 µg/g	4.3 µg/g	22%
Manufacturer B	Carbon (C4)	20 µg/g	4.3 µg/g	22%
Manufacturer B	Carbon Blank (CB1)	0 µg/g	ND	NA
Manufacturer B	Carbon Blank (CB2)	0 µg/g	ND	NA
Manufacturer C	Carbon (C1)	6 µg/g	3.4 µg/g	57%
Manufacturer C	Carbon (C2)	6 µg/g	3.6 µg/g	60%
Manufacturer C	Carbon (C3)	6 µg/g	3.6 µg/g	60%
Manufacturer C	Carbon (C4)	6 µg/g	3.6 µg/g	60%
Manufacturer C	Carbon Blank (CB1)	0 µg/g	ND	NA
Manufacturer C	Carbon Blank (CB2)	0 µg/g	ND	NA
Manufacturer C	HEPA Filter (F1)	1 µg/sample	0.67 µg/sample	67%
Manufacturer C	HEPA Filter (F2)	1 µg/sample	0.84 µg/sample	84%
Manufacturer C	HEPA Filter (F3)	1 µg/sample	0.72 µg/sample	72%
Manufacturer C	HEPA Filter (F4)	1 µg/sample	0.76 µg/sample	76%
Manufacturer C	HEPA Filter Blank (FB1)	0 µg/g	ND	NA
Manufacturer C	HEPA Filter Blank (FB2)	0 µg/g	ND	NA

ND – Not detected above the analytical limit of detection.
NA – Not applicable

Differences between the spiked concentration and detected concentration generally reflect potential interferences caused by the pollution control media, as well as

analytical error. As indicated above, the Manufacturer B carbon media, Manufacturer C carbon media, and Manufacturer C HEPA filter produced results with very low recoveries. Thus, portions of the mercury that are not accounted for in the mass balance could have been retained in the pollution control media for these two devices but may not have been detected in the laboratory analysis. The Manufacturer A carbon media spikes generally produced results above 100 percent, which is consistent with the mercury detected in the manufacturer-supplied blanks. The HEPA filter spikes were also slightly above 100 percent in all cases, but are within $\pm$ 10 percent of the actual spiked value. No mercury was detected in the HEPA filter blanks.

5.6.3 Mercury Mass Adhering to Surfaces

Difficulties with contamination prevented the use of the wipe samples collected for the mass balance. Bulk samples of the polyethylene used for each containment structure were not collected. Because mercury permeates through and adheres to polyethylene, a significant portion of the mercury not accounted for in the mass balance may have been associated with the containment structure. It is also possible that some amount of mercury adhered to the insides of the DTC devices.

5.6.4 Mercury Mass in Ambient Air

The mass of mercury released during DTC device operation (Hg_R) was calculated based on Equation 5.3, which included the number of air exchanges, the concentration of mercury in the air inside the containment structure, and the volume of the containment structure. The number of air exchanges was not measured during the Study; numbers of air exchanges were calculated for each device based on the speeds of the exhaust fans. However, the errors associated with these numbers are not known, and these errors would affect the result of the Hg_R calculation. Additionally, it is possible that some portion of the mercury released from the DTC devices permeated through the containment structure and, therefore, was not accounted for in the mass balance equation.

5.7 Mass Balance Study Observations

A Mass Balance Study was conducted in order to determine whether the mercury from lamps crushed in the various DTC devices could be accounted for in recognizable mass flows associated with operation of the devices (i.e., crushed lamps, air filtration equipment, and fugitive emissions to the air). The study was unable to establish a concrete relationship between mass input and output, based on the media and waste streams that could be readily sampled during these tests. For all three devices, the estimated input mercury quantities on a mass basis were substantially larger than the measured output quantities. The following factors should be considered in designing any future Mass Balance Study.

- Appropriate sampling procedures for the crushed lamp samples need to be developed. The drum used for sampling the crushed lamps could be retrofitted to allow multiple samples to be collected at various depths within the drum.

- Any steps taken to avoid releases to the air when creating a composite sample and expediting transfer of the sample to the container will likely reduce mercury losses.

- A validated and approved test method for quantifying the mercury in whole unbroken lamps is needed, including an understanding of the relative accuracy and error inherent to such a test.

- An approved test method for quantifying the mercury in the pollution control media (HEPA, carbon, and particle filters) is needed, including an understanding of the relative accuracy and error inherent to such a test.

- The material used to construct the containment structure could have a significant affect on the containment and measurement of mercury. A material better suited to mercury sampling, such as vinyl, should be considered if a containment structure is used.

- Wipe sampling procedures need to be improved and pre and post samples of the material used to construct the containment structure may be necessary.

No scientific methodology was applied to attempt to understand the relative impact of each of the above factors on the results presented here because it was beyond the scope of this Mass Balance Study.

6. LIMITATIONS

After reviewing the data collected during the Study, a number of factors were identified that may have affected the study results:

- Mercury background levels inside the facilities where the tests were performed
- Differences in environmental conditions (i.e., temperature and relative humidity) at each test site resulting in greater or lesser volatilization of mercury
- Cross-contamination from lamps broken during shipment to the processing site
- Contamination from lamps broken during operation.

This section provides a summary of how these factors may have influenced the study results.

6.1 Background Levels of Mercury

The DTC Device Study was conducted at operational lamp recycling facilities that crush large quantities of spent fluorescent lamps. At AERC Ashland and AERC Melbourne, the DTC devices were operated in a separate bay from the primary lamp processing areas. At EPSI Phoenix, due to the configuration of the plant, the tests could not be isolated from the normal plant operations as effectively as at the other sites. The Study was conducted at fluorescent lamp recycling facilities for several reasons:

- These facilities possessed the appropriate permits to process mercury-containing fluorescent lamps.

- These facilities had ample supplies of fluorescent lamps that were provided at no cost to the study team.

- The facilities had the capacity to process and dispose of the drums of crushed lamps, with no shipping, manifesting, or disposal arrangement required of the study team.

The study team made every effort to isolate the study area from normal lamp processing operations. At all three locations, a containment structure of plastic sheeting was constructed around the study area; however, as discussed below, this was only partially effective as a barrier to ambient, background mercury contamination.

At the beginning of testing at each location, two analytical air samples were collected in the immediate vicinity of the study area, to attempt to measure background mercury concentrations inside the lamp recycling facility. The results indicated that each facility had elevated concentrations of mercury in the ambient air. (*Refer to Table 4. 1 and Table 4. 2 for the background concentration measurements for each facility.*)

The background mercury concentration affected, to some extent, the analytical sample results. Elevated background concentrations would have the potential to

bias any study results and may affect the validity of conclusions drawn from the Study by:

- Elevating the ambient air sampling analytical results and real-time (i.e., Jerome) readings above what they would have been if background conditions were not characterized by elevated levels of mercury; and

- Causing deposition of mercury on the containment area surfaces, which later could have re-volatilized during the tests and created "false positives" or led to exceedances of OSHA or ACGIH standards.

The high background mercury made it more difficult to definitively attribute the mercury measurements to the DTC devices. In retrospect, background sampling was likely inadequate to fully characterize this confounding factor. If future research is conducted in an industrial lamp recycling facility, it will be important that rigorous background sampling be performed, which could include collecting analytical air samples and direct-reading air measurements before, during, and after testing.

6.2 Experimental Conditions

As mentioned in Section 4.4.3, the outside temperatures were 25°F-50°F higher during Phase II of the PVS (performed in June 2003) than during Phase I (performed in February 2003), which could have elevated the indoor temperature during air volume changes (e.g., doors opening). An increase in ambient temperature has been shown to cause an increase in volatilization of mercury, resulting in greater detected concentrations (*see footnote 22 in Section 4.4.3*). The Study was not designed to account for the change in ambient temperature when comparing the results from PVS – Phase I to the results from PVS – Phase II. As a result, it is difficult to determine the extent to which any differences in measured mercury concentrations were directly caused by a decline in device performance. To make such a determination possible, in conducting future research, the environmental conditions of the test should be maintained at constant levels.

6.3 Contamination from Lamps Broken During Shipment

Another source of potential contamination of mercury during the Study was the shipping boxes containing the fluorescent lamps that were received at the lamp recycling facilities. On average, approximately 10 percent of the lamps in each box were observed to be broken during shipment to, and/or pre-handling in, the lamp recycling facility. In order to investigate this hypothesis, box tests were conducted. The box test results were discussed in Section 4.6.

At AERC Melbourne, measurable ambient concentrations of mercury were recorded in the containment structure, while boxes of broken lamps were present and open, and no lamps were being crushed (*refer to Figure 4. 14*). Many of these concentrations exceeded the PEL and/or TLV values. Measurable concentrations, the majority of which were also above the PEL and/or TLV values, were also noted from ambient air sampling during a follow-up box test conducted at AERC Ashland. The study results

suggest that, to minimize operator exposures, boxes of lamps (especially those with significant breakage) should be staged in a separate area from the DTC device and preferably one where: 1) worker contact is minimal (e.g., a locked storage closet); and 2) workers accessing the area have the necessary PPE, respiratory protection. This information is important for all persons working with or around spent lamps, not just DTC device operators.

6.4 Contamination from Lamps Broken During DTC Device Operation

As will be discussed in Chapter 7, lamps occasionally broke while they were being fed into the DTC devices. The mercury released from these lamps directly relates to operator exposure during DTC device operation. The occurrences of lamp breakage were not consistent throughout the Study, so it is difficult to determine the average impact that lamp breakage during device operation had on the results of the Study.

7. DISCUSSION

Purposely breaking large numbers of mercury-containing fluorescent lamps can release substantial amounts of mercury to the air. Containing the released mercury is the central goal in the design and operation of drum top lamp crushing devices. The basic purpose of this Study was to examine how well the tested DTC devices met the design goal of containing mercury (as measured by operator exposure) when in routine use. The Study examined the performance of four devices over a five month period. Over the course of the Study, approximately 5,500 lamps were crushed by each of the three devices used throughout the Study, inside a constructed enclosure over a range of environmental and operational conditions. A considerable amount of data was generated that provides insight into the performance of DTC devices during field applications.

Testing in this Study was performed under low ventilation conditions, within a constructed containment structure. This was done both to measure ambient mercury concentrations during device operation in a controlled environment (i.e., segregated from the ambient background mercury at the lamp recycling facilities) and to evaluate performance under plausible, worst-case operating conditions (such as in an unventilated truck trailer).[31] Operator exposures would be expected to be lower than found in this Study if a DTC device is operated in a room with higher ventilation rates or if far fewer lamps are crushed over a longer period of time (i.e., 40-80 lamps crushed per day as apposed to 400-800 lamps crushed per hour). The containment structure was only partially effective in isolating the Study operations from the background mercury produced by the lamp recycling activities at the facilities used as testing locations in the Study because mercury is able to permeate through and sorb onto polyethylene, which was the material used to construct the containment (*refer to Chapter 6 for further discussion*). Measurements made before testing and during non-operational periods indicated that elevated background levels, which varied by facility, were present throughout the entire Study.

The following discussion is based on the evaluation of results from the air monitoring and sample data collected during the course of the Study. Observations and experience gained during the operation of these devices provide further important information about the use of DTC devices.

7.1 Summary of Results

Over the course of the Study, a total of 185 analytical air samples were collected during device operation (not including overnight and background air samples). Sixty-five samples (35.1 percent) were below both the ACGIH TLV and the OSHA PEL values. Eighty-four samples (45.4 percent) were equal to or above the TLV but

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[31] *The facilities used to conduct the Study had background mercury levels that were higher than would be expected at a location that was not routinely handling mercury, as discussed in detail in Sections 4.2 and 6.1. Correction of data by subtracting the background levels from the sample results may be an appropriate way to view the data, although doing so would not reduce all the exceedances of the PEL or TLV to below those levels.*

below the PEL value, and thirty-six samples (19.5 percent) were greater than or equal to the PEL value.[32]

7.1.1 Exposures during Routine Crushing Operations

Overall, seven operator shoulder samples (i.e., average mercury concentration in the operator breathing zone air) exceeded the PEL value. Three of these samples were collected while testing the Manufacturer B device, one was collected while testing the Manufacturer C device, and three were collected while testing the Manufacturer D device, which was removed from the Study. It is important to note that the shoulder samples were average measurements, taken over the time period required to crush one or two drums of lamps (typically one to three hours). The Jerome analyzer readings, taken inside the containment structure, show the fact that there were a number of excursions above the PEL during routine crushing operations, even when the analytical air samples were not above the PEL. Refer to Figure 4. 3, Figure 4. 6, Figure 4. 8, Figure 4. 10, and Appendix A for graphs of the Jerome analyzer readings.

All three devices that completed the Study, especially the Manufacturer B and Manufacturer C devices, experienced problems in maintaining operator exposures below the ACGIH recommended TLV of 0.025mg/m^3 within the containment structure during routine lamp processing. The TLV value is a time-weighted average (TWA) calculated over a normal eight hour work day that is considered protective of worker health and safety.[33] Analytical air samples collected in the operator's breathing zone and Jerome analyzer results show that the concentration of mercury inside the containment structure was above the TLV value the majority of the time.

The Manufacturer A device maintained operator shoulder sample concentrations below the mercury TLV value during four of the five rounds of testing; the Manufacturer A device exceeded the TLV during EFT #1, when the feeding tube was not properly connected to the drum-top assembly (*refer to footnote 23 in Section 4.5.1.1*). The Manufacturer B and Manufacturer C devices exceeded the TLV value in at least one operator shoulder sample during four of the five testing occurrences, even when corrected for background mercury levels. The only test in which all operator shoulder samples for all three devices were below the TLV value was PVS – Phase I at AERC Ashland in February 2003; this may have been, in part, due to the fact that the devices were new, the outside temperature was lower, and only low mercury, Alto® lamps (manufactured by Phillips Lighting) were processed.

Exhaust or feed tube air samples (sometimes both) for all three devices also exceeded the TLV value during portions of the Study. The Manufacturer A device had feed tube and exhaust samples that exceeded the TLV value only during EFT #1, most

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[32] *This discussion of the number of data that exceeded the TLV and the PEL does not correct for background. There were not enough background data to reasonably estimate the contribution that background mercury could have made to the measured mercury concentrations.*

[33] *The results obtained in the Study were not normalized to an eight hour workday because DTC device use patterns may vary significantly. In some cases only a dozen lamps may be crushed in a single day. In other cases a device may be used to process thousands of lamps from different sources, so the operator may be using the device forty hours a week or more. Therefore, sample results that are greater than the TLV should not necessarily be interpreted to indicate that use of one of the DTC devices included in the Study would result intime-weighted, operator exposure above the TLV.*

likely, because of a missing gasket on the feed tube (*refer to footnote 23 in Section 4.5.1.1*). All exhaust and feed tube samples for the Manufacturer B device were above the TLV value, except those taken during PVS - Phase I. Six of the 10 exhaust and feed tube samples collected for the Manufacturer C device were above the TLV value. The degrees to which temperature and changes in device performance affected these data are topics for future research.

As discussed in Section 3.5.3, the Manufacturer D device performed poorly, allowing the mercury concentrations inside the containment structure to exceed the OSHA PEL value by nearly 9 fold. This device was removed from the test after two rounds of testing due to its poor performance (*refer to Appendix I*).

7.1.2 Exposures during Routine Drum and Filter Changes

When the drum beneath a DTC device is filled with crushed lamps, the DTC device must be secured to a new drum. This operation involves unsealing the DTC device from the drum, lifting it off the drum, and placing it on a new, empty drum. During this operation, the full drum of crushed lamps is open to the air for some period of time during which mercury vapor is released uncontrolled to the air (in this Study, drum changes lasted approximately two to 10 minutes). Because of mercury's volatility under typical indoor conditions, the drum change operation poses the potential for significant mercury release, particularly while the full drum is open to the air (as illustrated by the results below). Minimizing the time during which the full drum is open to the air will help reduce operator exposure to mercury and mercury releases to the environment.

Two types of samples were collected for all three devices during drum changes: drum change samples and ceiling samples.[34] All of the DTC devices tested exceeded the PEL value at least once during drum changes. PEL value exceedances during drum changes were frequent for the Manufacturer B and Manufacturer C devices. The drum change samples for the Manufacturer A device exceeded the PEL value in only one of the five tests (EFT #2). The Manufacturer A device features a larger particulate filter and a larger amount of activated carbon than the other two devices. The more substantial pollution control equipment could, at least partially, explain the differences between the results for the Manufacturer A device and the results for the other devices.

7.1.3 Exposures Resulting From DTC Device Malfunction

There were two major types of malfunctions that occurred and caused increased mercury release and operator exposure - improper device assembly and feed tube jamming. The Manufacturer A device was not assembled correctly during EFT #1 (*refer to footnote 23 in Section 4.5.1.1*), which caused average ambient mercury concentrations to exceed the PEL in the sample collected near the feed tube, and to reach 0.074 ug/m^3 in one operator shoulder sample. The samples collected for EFT #1 were collected over the course of filling two drums, meaning that the mercury

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[34] *Drum change samples and ceiling samples are described in Section 3.1.*

concentrations as measured by analytical air samples were averages of the concentrations in the air throughout the filling of both drums.

The missing seal was replaced for the second drum, so during the second drum, the mercury concentrations inside the containment were most likely lower because the device was assembled correctly. With average mercury concentrations at 74 percent of the PEL value, it is very likely that the mercury concentrations in the operator's breathing zone exceeded the PEL at some point during the filling of the first drum. (There are no Jerome data available for this time period to verify this because the Jerome was in regeneration mode.) These levels were nearly four times the average concentrations measured for this device in the other portions of the Study, showing a higher rate of mercury release as a result of seal failure/improper assembly.

A common malfunction experienced with all the devices was jamming of the feed tube. The Study was not designed to quantify increased ambient mercury concentrations or increased operator exposure caused by this malfunction. When the lamps jammed in the feed tube, debris from inside the DTC device and the drum occasionally blew back towards the operator, indicating that a fraction of the mercury in the lamp that jammed was not being captured by the DTC device.

The high operator exposures experienced during the use of the Manufacturer D device were likely due to poor design and malfunction. As noted in Section 3.5.3 and Appendix I, Manufacturer D sent two different DTC devices of different design for the first two rounds of testing, and the device for the second round of testing was clearly damaged, with a visible crack in the vacuum pump motor housing. However, during Phase I of the PVS, when the device had no visible damage, only "low mercury," Alto® lamps were crushed, and outdoor temperatures were between 28 and 43 degrees Fahrenheit, operation of the Manufacturer D device resulted in ambient mercury concentration nearly 9 times the OSHA PEL value. This highlights the importance of design and optimal operation.

7.1.4 Changes in DTC Performance over Time

The performance validation study was designed to examine the change in performance over time. The Study included five rounds of testing over a 5-month period, and approximately 5,500 lamps were crushed by each device. The data generated by the Study indicate that one device (from Manufacturer A) maintained its ability to contain the mercury released when lamps were crushed over the duration of the Study, while the other two devices that completed the Study declined in performance over this time frame and use. The Study was not designed to determine the reason for the decline in performance by the Manufacturer B and C devices. However, there are several possibilities, including possible saturation of the carbon filter material and wear and tear on DTC device seals. The changes in performance over time documented in the Study may be evidence of potential difficulties in maintaining optimal performance by DTC devices. Careful attention to inspection and maintenance of the devices may make it possible for operators to detect and repair any worn components before their deterioration could result in mercury exposures.

7.1.5 Overnight Tests

Air samples were also collected within the containment structure, near the devices, during non-operational periods, with the DTC devices attached to drums that were full or partially full of crushed lamps. These tests were conducted overnight at all three locations during the EFTS. Per manufacturer instructions, the Manufacturer A device was left running on ventilation mode throughout the course of the tests (that is, the fan/vacuum pump was running, with air being exhausted through the carbon filter, whenever a drum was attached to the device), and the Manufacturer B and Manufacturer C devices were turned off. The results from the overnight samples were inconclusive as to whether or not mercury was released from DTC devices that were attached to drums containing crushed lamps.

7.1.6 U-Tube Test

The Manufacturer B and Manufacturer C devices have attachments that enable them to process U-tubes. A test was conducted to evaluate airborne mercury levels from the two devices while processing U-tubes. The facility was only able to collect a limited number of U-tubes for this test, so each device processed fewer than 90 U-tubes. Seven of the eight U-tube samples were above the TLV value, and two of the operator breathing zone samples (one for each device) equaled or slightly exceeded the PEL value. These levels are generally higher than the levels measured when crushing straight lamps, especially in light of the fact that so few U-tubes were processed by each device. A possible explanation for the high mercury levels is the fact that the U-tube attachments have larger openings than the feed tubes for the straight lamps, which could have allowed some air to flow from inside the device out into the containment structure.

7.1.7 Exposures Resulting from Lamp Breakage

Another source of mercury release associated with use of DTC devices was breakage of lamps either before they were fed into the device, or as they were being fed in. Studies of lamp breakage inside the containment structure via the Box Test indicated that lamps broken during handling may have had an affect on the sample results. Lamps also sometimes broke and shattered while being fed into the DTC. No testing of the resulting mercury release was attempted, because this breakage occurred sporadically and was a random event. However, during the first test of the Manufacturer B device at the EPSI Phoenix facility (EFT #2), the Jerome analyzer readings demonstrate that the ambient mercury concentration increased inside the containment structure when a bulb was broken.

As shown in Figure 4. 8 and Appendix A, Figure 32, the mercury concentration was 0.033 mg/m^3 before a lamp was broken and increased to 0.169 mg/m^3 four minutes after a lamp was broken. This was an increase of 400 percent in ambient mercury concentrations. These data are further supported by research performed by Aucott, et al., in which it was shown that "between 17 and 40 percent of the mercury in broken low-mercury fluorescent bulbs is released to the air during a two-week period

immediately following breakage, with higher temperatures contributing to higher release rates."[35] The potential for lamp breakage outside the DTC device is inherent to device use. Possible release of and exposure to mercury vapor, as a result of broken lamps, is an important consideration as part of any operations managing fluorescent bulbs.

Because of the multiple potential sources of mercury being released during normal DTC device operations – during drum changes, through the degradation of seals over time (leading to leaks), possible leakage due to improper assembly or malfunction, and the breakage of lamps outside the DTC device, either during handling or feeding lamps into the device – a respirator was always available to the operator during the Study. Either use of a respirator, or continuous air monitoring for mercury with a mercury vapor monitor, such as a Jerome or Lumex, were the only ways to ensure that operator mercury exposures remained below the OSHA PEL and AGCIH TLV throughout the Study.[36]

7.2 Safety Concerns when Operating DTC Devices

Throughout the DTC Device Study, field observations were made and documented by the study team. These observations provide insight into potential safety issues and mitigation measures that were undertaken during the Study (and could be used by other device operators) to enhance the safety of operating DTC devices.

7.2.1 Operator Safety

As noted above, when lamps were being fed into the DTC devices, they would occasionally break and/or jam in the feed tubes. This was an issue common to all devices. Lamps sometimes broke before they could be fully fed into the devices, causing, in some instances, visible release of phosphor powder, as well as flying shards of glass. The configuration of the feed tubes on several devices exacerbated this problem, where, for example, the operator either had to lower the lamps to waist level or raise them up to shoulder level in order to insert them into the feed tube.

Various articles of personal protective equipment (PPE) were used by the study team during operation of DTC devices to ensure operator safety (*refer to Photograph 7. 1*). These included safety glasses, full-face shields, puncture-resistant (Kevlar®) gloves, hearing protection, and air-purifying, negative pressure respirators (when air monitoring readings were above pre-determined safe levels). Disposable Tyvek® coveralls were also worn by the DTC device operator and assistant, to reduce both skin exposure to the airborne mercury and the possibility of tracking mercury residues out of the testing facility.

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[35] *Aucott, Michael; McLinden, Michael; and Winka, Michael. 2003. Release of Mercury from Broken Fluorescent Bulbs. Journal of Air & Waste Management Association. 53: 143-151. The lamps used in this investigation were Phillips four-foot Econ-o-watt F40 CW/RS/EW, 0 8E bulbs, which are reported to contain 4.4 mg or 4.7 mg of mercury.*

[36] *The traditional hierarchy of occupational chemical exposure control specifies that engineering controls (i.e., adequate monitoring and ventilation) be used before relying on PPE.*

Photograph 7. 1: Clearing Jammed Feed Tube of Manufacturer A Device

Due to the possibility of mercury release from lamp breakage outside the DTC device or leaks from the DTC device, respiratory protection was always available to the operator and assistants throughout the Study and was used most of the time.

7.2.2 Number of Operators

During the Study, two people operated the DTC devices at each location. One person fed the lamps into the device, and the other person supplied the operator with full boxes of lamps, removed the empty lamp boxes, and handed lamps to the machine operator, allowing for efficiency in feeding lamps. While one person could probably operate the DTC device, the study team found it much easier and more efficient to use the two-person team. This was particularly important when it came to changing drums. Having a two person team available allowed drum changes to be performed much more securely and quickly (the Manufacturer B device required a two-person team to change drums, but the other devices did not). The advantages of a two-person team included both help in lifting the DTC off the full drum and positioning it correctly on the empty drum, as well as allowing the full drum to be more quickly covered and sealed.

7.2.3 Location and Ventilation for Lamp Crushing Activities

As discussed in Section 4.2, the background mercury concentrations in the industrial lamp crushing facilities were several orders of magnitude higher than background mercury concentrations that would be expected outside or in a building that is not associated with mercury processing activities, such as a home or an office building. One of the reasons that this Study was conducted at lamp recycling facilities was that these facilities already have safeguards in place to prevent exposure to visitors to the facility and to residents in the surrounding neighborhood.

These safeguards include a separate ventilation system for the offices, which does not cycle the air from the crushing area into the offices, and fume hoods on the industrial lamp crushers that vent fumes through carbon filters. The separate ventilation system protects the office workers from exposure to mercury. The production workers at the facility (i.e., those operating recycling equipment) are

aware of the potential of mercury exposure and have been trained in practices that will prevent mercury release and exposure. Production workers at lamp recycling facilities are required to have OSHA Safety Training. Additionally, material safety data sheets (MSDS) for mercury must be made available to these workers.

7.3 Potential DTC Design Modifications

Drum top lamp crusher design is an evolving field, and many aspects of device design can affect its ability to contain mercury (e.g., see Section 3.5.1). The devices tested in this Study are only the second generation of drum-top lamp crushers and, while they represent a significant improvement over the first generation of such devices, further improvements in design and operation procedures would be beneficial.[37] Based on operator observations, the following areas for potential improvements in DTC device design were noted by the study team:

- Development of Leak Detection Systems: As discussed above, DTC devices may develop undetected leaks and release significant amounts of mercury as a result. While a portable mercury vapor monitor can easily detect rising airborne mercury concentrations, these devices are expensive to purchase and operate, ranging from $15,000- $22,000. Development of an effective leak detection system, such as a continuously operating pressure monitor, may reduce the need for continuous monitoring of DTC devices in operation to ensure operator safety and compliance with regulatory standards.

- Improvement in Mercury Capture during Drum Change: Drum changes were identified in the Study as the routine activity with the highest potential for operator exposure to mercury concentrations above the PEL. None of the devices tested were capable of maintaining mercury concentrations below the PEL during drum changes, so improvements in device designs to reduce mercury releases during this operation would be very beneficial.

- Chemical Treatment of Released Mercury Vapor: Most of the mercury released from lamps in DTC devices is elemental mercury vapor, which is volatile at room temperatures. Elemental mercury reacts with sulfiding agents very readily and quickly under environmental conditions to form mercuric sulfide. Because mercuric sulfide is a solid (powder) at room temperature, its release to the air should be much easier to control than mercury vapor. Airborne mercury sulfide powder inside a drum would most likely settle into the crushed lamps in the drum or be captured by the pollution control media of DTC devices. Incorporating sulfiding-agent injectors into a device design could potentially reduce mercury release during all activities associated with DTC device use (except lamp breakage outside the device). The study team did not explore this possibility, so we are unable provide any specific design recommendations.

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[37] *Based on a 1994 EPA study, some of the first DTC device designs (not necessarily designs from the manufacturers that participated in this Study) may have used no mercury emissions controls.*

- Increase in the Amount of Pollution Control Used in the Device: The Manufacturer A device showed the best performance overall. This device used approximately 87 pounds of activated carbon, which most likely contributed to its good performance. The other devices included much less activated carbon in their air filtration systems (*refer to Table 5. 6 for the specifications of the pollution control media for each device*).

This Study was designed to assess the potential for operator exposure to mercury, while operating the four DTC devices tested. The areas of improvement noted above resulted from observations made by the study team in the course of testing the devices and preparing this report. This list is not meant to be exhaustive.

7.4 Future Areas for Study

There are several areas in which additional study would be beneficial:

- Environmental Impacts of DTC Device Use: DTC devices have the potential to be used in a wide variety of places. It is possible that the use of these devices will decrease the overall release of mercury to the environment by decreasing the uncontrolled disposal of mercury fluorescent lamps (i.e., disposal in a dumpster). Future research to assess the potential impacts of DTC device use could include:
  - How much the use of DTC devices can impact the total amount of mercury being released into the environment;
  - How much mercury is emitted from DTC devices for each lamp crushed or each drum full of lamps crushed;
  - Who (in addition to the operator) may be exposed to mercury releases related to operation of a DTC device;
  - How the emissions from DTC devices compare to the emissions from other mercury emissions sources, including industrial lamp recycling facilities; and
  - Whether significant amounts of mercury collect in areas where DTC devices are stored and operated.

- Mercury Release from DTC Devices during Non-operational Periods: The overnight tests conducted in this Study were inconclusive (*refer to Section 4.7*). Because it is probable that in many cases drums partially filled with lamps will be stored for extended periods of time, more information about the release of mercury from DTC devices which are attached to partially filled drums is needed in order to fully characterize the mercury exposure that could be realized as a result of the use of a DTC device.

- Mass Balance Study: A concrete relationship between mercury input and mercury retention and release was not established for any of the devices in the Mass Balance Study. The following factors should be considered if a future Mass Balance Study is undertaken:
  - Appropriate procedures for representative sampling of the crushed lamps in the drum need to be developed;

- A validated and approved test method for quantifying the mercury in whole unbroken lamps is needed, including the relative accuracy and error inherent in such a test;
- An approved test method for quantifying the mercury in the pollution control media (HEPA, carbon, and particle filters) is needed, including the relative accuracy and error inherent in such a test;
- A study design specific to measuring all system inputs and outputs, including the use of a clean-room and the measurement of emissions; and
- Wipe sampling procedures need to be improved, including pre and post sampling of the material used to construct the containment structure.

- Development of a Standard Test Method(s) for DTC Device Performance: A standard DTC device evaluation protocol that can be used by DTC device manufacturers would ensure that manufacturer performance data are generated in a consistent manner, under known conditions. A true evaluation of crusher performance can be developed only if the volume of the crushing room, the air exchange rate, the lamp crushing rate, the duration of crushing, and all sampling and analytical methods are known and validated. Absent this information, a poorly performing DTC device could be "tested" and shown to perform well with regard to operator exposure because the test was performed using unrealistic ventilation rates or room size or was performed outdoors. Evaluating DTC performance under consistent, known conditions would also allow meaningful comparison of the performance of different lamp crushers. A standardized test method would help ensure the repeatability and accuracy of any tests results.

- Investigation of Mercury Release through Different Lamp Management Methods: This Study only examines mercury release from fluorescent lamps as a result of the use of DTC devices (as measured by operator exposure). When lamps are handled and recycled as whole lamps, there is the potential for breakage and, therefore, the potential for mercury release, during the storage and shipping of the lamps. Information about the frequency of breakage and the amount of mercury released when whole lamps are stored and then shipped to a recycler is needed in order to compare these different lamp recycling methods. Additionally, more information on releases of mercury resulting from disposal of lamps would provide a useful baseline with which to compare releases due to recycling.

- Aerosolization of Mercury: Additional study may be appropriate to determine whether aerosol mercury was not detected using the MCE filters because no aerosolization occurred or because any aerosol mercury collected on the filter was vaporized by the sampling vacuum pump.

7.5 Conclusions

The potential use of DTC devices involves a number of trade-offs. Spent mercury lamps contain elemental mercury, some of which is released to the air when lamps are broken. If thrown into a dumpster for disposal at a municipal solid waste landfill, breakage will occur either in the dumpster or at the landfill. In either case, a portion of the mercury contained in the lamps is immediately released to the

environment by volatilization, and the remaining mercury is available for release to the environment, over time, by leaching or in landfill gas.

Recycling of spent lamps represents one of the best ways to control the release of mercury to the environment from landfilling of fluorescent lamps, by keeping mercury out of landfills in the first place. Recycling can be done either on an individual lamp basis (i.e., sending whole, boxed lamps to a recycler), or by using a DTC device at the point where lamps are removed from service. Use of DTC devices has obvious appeal in that the devices reduce lamp volume, allowing several hundred crushed lamps to occupy the space that 40 or 50 whole lamps would occupy, thereby reducing storage and shipping costs. This leads to a reduction in recycling costs on a per-lamp basis. Crushing lamps before shipment also has the advantage of allowing shipping to the recycler in a well-sealed, durable container that is unlikely to release substantial amounts of mercury during shipment, while whole lamps may be broken during shipment and release mercury.

The DTC devices evaluated as part of this Study all released some mercury when used and so have the concern of creating new mercury exposures. The mercury released during DTC device use will inevitably create certain new mercury exposure situations. The DTC device operator and any assistants handling lamps or working directly with the DTC device are the most obvious new exposures. Less direct mercury exposures that could be created by DTC device use include anyone working in or visiting buildings in which DTC devices are used. The only way to eliminate these unnecessary indirect mercury exposures would be to keep the ventilation of the lamp crushing room completely separate from the general building ventilation system as is done at industrial lamp recycling facilities.

The data collected in the course of this Study indicate that none of the DTC devices evaluated completely controlled mercury emissions during lamp processing operations, even with optimal operation. The Study further indicates that maintaining optimal performance consistently over years of DTC device use for the current generation of devices will be challenging. Even generally well designed devices released mercury in routine use, particularly during drum changes. Device malfunctions increased mercury release by a small amount (i.e., when lamps jammed in the feed tube) or by a significant amount (i.e., when the flange gasket was not included in assembly). Use of a poorly designed device could result in mercury exposures nearly an order of magnitude above the OSHA PEL. Fundamental design changes to reduce the reliance on fallible components (such as seals) would be needed to improve the ruggedness of drum-top crushing devices.

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Appendix A

Air and Wipe Sample Results

Table 1: Analytical Air Sample Results

Performance Validation Study – Phase I – Ashland, Virginia – February 24-28, 2003								
Type	Media	Device	Location	Flow Rate (lpm)	Sample time (min)	Volume (liters)	Result (mg/m^3)	Sample #
Background	Hydrar	All	E. bay by center bay door	0.209	278	58.24	0.0047	3705-B-225-04
Background	MCEF	All	E. bay by center bay door	0.209	278	58.24	<0.00017	3705-B-225-03
Background	Hydrar	All	Middle of E. bay	0.212	278	58.94	0.0039	3705-B-225-02
Background	MCEF	All	Middle of E. bay	0.212	278	58.94	<0.00017	3705-B-225-01
Personal	Hydrar	Manufacturer A	Device operation	0.1535	112	17.19	0.012	3705-RA-227-22
Personal	MCEF	Manufacturer A	Device operation	0.1535	112	17.19	<0.00058	3705-RA-227-21
Personal	Hydrar	Manufacturer A	Device operation	0.154	112	17.25	0.011	3705-RA-227-24
Personal	MCEF	Manufacturer A	Device operation	0.154	112	17.25	<0.00058	3705-RA-227-23
Personal	Hydrar	Manufacturer A	Drum change	0.2525	12	3.03	0.02	3705-RA-227-34
Personal	MCEF	Manufacturer A	Drum change	0.2525	12	3.03	<0.0033	3705-RA-227-33
Area	Hydrar	Manufacturer A	By device exhaust	0.1515	112	16.97	0.0028	3705-RA-227-30
Area	MCEF	Manufacturer A	By device exhaust	0.1515	112	16.97	<0.00059	3705-RA-227-29
Area	Hydrar	Manufacturer A	By device exhaust	0.1535	112	17.19	0.011	3705-RA-227-32
Area	MCEF	Manufacturer A	By device exhaust	0.1535	112	17.19	<0.00058	3705-RA-227-31
Area	Hydrar	Manufacturer A	By device feed tube	0.1515	112	16.97	0.013	3705-RA-227-26
Area	MCEF	Manufacturer A	By device feed tube	0.1515	112	16.97	<0.00059	3705-RA-227-25
Area	Hydrar	Manufacturer A	By device feed tube	0.1545	112	17.3	0.011	3705-RA-227-28
Area	MCEF	Manufacturer A	By device feed tube	0.1545	112	17.3	<0.00058	3705-RA-227-27
Personal	Hydrar	Manufacturer B	Device operation	0.153	86	13.16	0.012	3705-DA-228-50
Personal	MCEF	Manufacturer B	Device operation	0.153	86	13.16	<0.00076	3705-DA-228-49
Personal	Hydrar	Manufacturer B	Device operation	0.151	86	12.99	0.013	3705-DA-228-52
Personal	MCEF	Manufacturer B	Device operation	0.151	86	12.99	<0.00077	3705-DA-228-51
Personal	Hydrar	Manufacturer B	Drum change	0.253	13	3.29	0.025	3705-DA-228-62
Personal	MCEF	Manufacturer B	Drum change	0.253	13	3.29	<0.0030	3705-DA-228-61

Performance Validation Study – Phase I – Ashland, Virginia – February 24-28, 2003								
Type	Media	Device	Location	Flow Rate (lpm)	Sample time (min)	Volume (liters)	Result (mg/m^3)	Sample #
Area	Hydrar	Manufacturer B	By device exhaust	0.1535	86	13.2	0.012	3705-DA-228-58
Area	MCEF	Manufacturer B	By device exhaust	0.1535	86	13.2	<0.00076	3705-DA-228-57
Area	Hydrar	Manufacturer B	By device exhaust	0.1515	86	13.03	0.012	3705-DA-228-60
Area	MCEF	Manufacturer B	By device exhaust	0.1515	86	13.03	<0.00077	3705-DA-228-59
Area	Hydrar	Manufacturer B	By device feed tube	0.145	86	12.47	0.0039	3705-DA-228-54
Area	MCEF	Manufacturer B	By device feed tube	0.145	86	12.47	<0.00080	3705-DA-228-53
Area	Hydrar	Manufacturer B	By device feed tube	0.1515	86	13.03	0.012	3705-DA-228-56
Area	MCEF	Manufacturer B	By device feed tube	0.1515	86	13.03	<0.00077	3705-DA-228-55
Personal	Hydrar	Manufacturer C	Device operation	0.153	100	15.3	0.012	3705-AA-226-06
Personal	MCEF	Manufacturer C	Device operation	0.153	100	15.3	<0.00065	3705-AA-226-05
Personal	Hydrar	Manufacturer C	Device operation	0.1505	100	15.05	0.015	3705-AA-226-08
Personal	MCEF	Manufacturer C	Device operation	0.1505	100	15.05	<0.00066	3705-AA-226-07
Personal	Hydrar	Manufacturer C	Drum change	0.2545	18	4.58	0.019	3705-AA-226-20
Personal	MCEF	Manufacturer C	Drum change	0.2545	18	4.58	<0.0022	3705-AA-226-19
Personal	Hydrar	Manufacturer C	Filter change	0.2555	12	3.07	0.019	3705-AA-226-18
Personal	MCEF	Manufacturer C	Filter change	0.2555	12	3.07	<0.00033	3705-AA-226-17
Area	Hydrar	Manufacturer C	By device exhaust	0.1209	100	12.09	0.0055	3705-AA-226-10
Area	MCEF	Manufacturer C	By device exhaust	0.1209	100	12.09	<0.00083	3705-AA-226-09
Area	Hydrar	Manufacturer C	By device exhaust	0.15	100	15	0.01	3705-AA-226-12
Area	MCEF	Manufacturer C	By device exhaust	0.15	100	15	<0.00067	3705-AA-226-11
Area	Hydrar	Manufacturer C	By device feed tube	0.125	100	12.56	0.0095	3705-AA-226-14
Area	MCEF	Manufacturer C	By device feed tube	0.125	100	12.56	<0.00080	3705-AA-226-13
Area	Hydrar	Manufacturer C	By device feed tube	0.158	100	15.8	0.013	3705-AA-226-16
Area	MCEF	Manufacturer C	By device feed tube	0.158	100	15.8	<0.00063	3705-AA-226-15
Personal	Hydrar	Manufacturer D	Device operation	0.153	55	8.42	0.04	3705-HA-227-36
Personal	MCEF	Manufacturer D	Device operation	0.153	55	8.42	<0.0012	3705-HA-227-35

Performance Validation Study – Phase I – Ashland, Virginia – February 24-28, 2003								
Type	Media	Device	Location	Flow Rate (lpm)	Sample time (min)	Volume (liters)	Result (mg/m^3)	Sample #
Personal	Hydrar	Manufacturer D	Device operation	0.156	55	8.58	0.13	3705-HA-227-38
Personal	MCEF	Manufacturer D	Device operation	0.156	55	8.58	<0.0012	3705-HA-227-37
Personal	Hydrar	Manufacturer D	Drum change	0.154	6	0.924	0.19	3705-HA-227-48
Personal	MCEF	Manufacturer D	Drum change	0.154	6	0.924	<0.011	3705-HA-227-47
Area	Hydrar	Manufacturer D	By device exhaust	0.1505	55	8.28	0.33	370-5-HA-227-44
Area	MCEF	Manufacturer D	By device exhaust	0.1505	55	8.28	<0.0012	3705-HA-227-43
Area	Hydrar	Manufacturer D	By device exhaust	0.253	55	13.92	0.36	3705-HA-227-46
Area	MCEF	Manufacturer D	By device exhaust	0.253	55	13.92	<0.00072	3705-HA-227-45
Area	Hydrar	Manufacturer D	By device feed tube	0.1515	55	8.33	0.58	3705-HA-227-40
Area	MCEF	Manufacturer D	By device feed tube	0.1515	55	8.33	<0.0013	3705-HA-227-39
Area	Hydrar	Manufacturer D	By device feed tube	0.155	53	8.23	0.64	3705-HA-227-42
Area	MCEF	Manufacturer D	By device feed tube	0.155	53	8.23	<0.0012	3705-HA-227-41

Performance Validation Study – Phase II – Ashland, Virginia – June 9-13, 2003								
Type	Media	Device	Location	Flow Rate (lpm)	Sample time (min)	Volume (liters)	Result (mg/m^3)	Sample #
Personal	Hydrar	Manufacturer A	Device operation (RS)	0.195	64	12.5	0.012	3705-RA-610-33
Personal	MCEF	Manufacturer A	Device operation (RS)	0.195	64	12.5	<0.00080	3705-RA-610-34
Personal	Hydrar	Manufacturer A	Device operation (LS)	0.196	64	12.5	0.013	3705-RA-610-35
Personal	MCEF	Manufacturer A	Device operation (LS)	0.196	64	12.5	<0.00080	3705-RA-610-36
Personal	Hydrar	Manufacturer A	Drum change	0.261	12	3.1	0.031	3705-RA-610-45
Personal	MCEF	Manufacturer A	Drum change	0.261	12	3.1	<0.0032	3705-RA-610-46
Personal	Hydrar	Manufacturer A	Ceiling #1	0.247	4	1	0.067	3705-RA-610-51
Personal	MCEF	Manufacturer A	Ceiling #1	0.247	4	1	<0.010	3705-RA-610-52

Performance Validation Study – Phase II – Ashland, Virginia – June 9-13, 2003								
Type	Media	Device	Location	Flow Rate (lpm)	Sample time (min)	Volume (liters)	Result (mg/m^3)	Sample #
Personal	Hydrar	Manufacturer A	Ceiling #2	0.247	4	1	0.042	3705-RA-610-53
Personal	MCEF	Manufacturer A	Ceiling #2	0.247	4	1	<0.010	3705-RA-610-54
Area	Hydrar	Manufacturer A	By device exhaust	0.197	58	11.4	0.015	3705-RA-610-37
Area	MCEF	Manufacturer A	By device exhaust	0.197	58	11.4	<0.00088	3705-RA-610-38
Area	Hydrar	Manufacturer A	By device exhaust	0.198	58	11.5	0.014	3705-RA-610-39
Area	MCEF	Manufacturer A	By device exhaust	0.198	58	11.5	<0.00087	3705-RA0610-40
Area	Hydrar	Manufacturer A	By device feed tube	0.2	58	11.6	0.015	3705-RA-610-41
Area	MCEF	Manufacturer A	By device feed tube	0.2	58	11.6	<0.00086	3705-RA-610-42
Area	Hydrar	Manufacturer A	By device feed tube	0.186	58	10.8	0.013	3705-RA-610-43
Area	MCEF	Manufacturer A	By device feed tube	0.186	58	10.8	<0.00093	3705-RA-610-44
Personal	Hydrar	Manufacturer B	Device operation (RS)	0.2	34	6.8	0.034	3705-DA-611-91
Personal	MCEF	Manufacturer B	Device operation (RS)	0.2	34	6.8	<0.0015	3705-DA-611-92
Personal	Hydrar	Manufacturer B	Device operation (LS)	0.2	34	6.8	0.034	3705-DA-611-93
Personal	MCEF	Manufacturer B	Device operation (LS)	0.2	34	6.8	<0.0015	3705-DA-611-94
Personal	Hydrar	Manufacturer B	Drum change	0.257	12	3.1	0.074	3705-DA-611-103
Personal	MCEF	Manufacturer B	Drum change	0.257	12	3.1	<0.0032	3705-DA-611-104
Personal	Hydrar	Manufacturer B	Ceiling #1	0.26	4	1	0.094	3705-DA-611-105
Personal	MCEF	Manufacturer B	Ceiling #1	0.26	4	1	<0.010	3705-DA-611-106
Personal	Hydrar	Manufacturer B	Ceiling #2	0.26	4	1	0.11	3705-DA-611-107
Personal	MCEF	Manufacturer B	Ceiling #2	0.26	4	1	<0.010	3705-DA-611-108
Area	Hydrar	Manufacturer B	By device exhaust	0.212	34	7.2	0.026	3705-DA-611-95
Area	MCEF	Manufacturer B	By device exhaust	0.212	34	7.2	<0.0014	3705-DA-611-96
Area	Hydrar	Manufacturer B	By device exhaust	0.198	34	6.7	0.034	3705-DA-611-97
Area	MCEF	Manufacturer B	By device exhaust	0.198	34	6.7	<0.0015	3705-DA-611-98
Area	Hydrar	Manufacturer B	By device feed tube	0.202	34	6.9	0.033	3705-DA-611-99
Area	MCEF	Manufacturer B	By device feed tube	0.202	34	6.9	<0.0014	3705-DA-611-100

Performance Validation Study – Phase II – Ashland, Virginia – June 9-13, 2003								
Type	Media	Device	Location	Flow Rate (lpm)	Sample time (min)	Volume (liters)	Result (mg/m^3)	Sample #
Area	Hydrar	Manufacturer B	By device feed tube	0.2	34	6.8	0.034	3705-DA-611-101
Area	MCEF	Manufacturer B	By device feed tube	0.2	34	6.8	<0.0015	3705-DA-611-102
Personal	Hydrar	Manufacturer C	Device operation (LS)	0.203	37	7.5	0.039	3705-AA-612-147
Personal	MCEF	Manufacturer C	Device operation (LS)	0.203	37	7.5	<0.0013	3705-AA-612-148
Personal	Hydrar	Manufacturer C	Device operation (RS)	0.199	37	7.4	0.018	3705-AA-612-145
Personal	MCEF	Manufacturer C	Device operation (RS)	0.199	37	7.4	<0.0013	3507-AA-612-146
Personal	Hydrar	Manufacturer C	Filter change	0.255	12	3.1	0.039	3705-AA-612-157
Personal	MCEF	Manufacturer C	Filter change	0.255	12	3.1	<0.0032	3705-AA-612-158
Personal	Hydrar	Manufacturer C	Drum change	0.255	14	3.6	0.072	3705-AA-612-159
Personal	MCEF	Manufacturer C	Drum change	0.255	14	3.6	<0.0028	3705-AA-612-160
Personal	Hydrar	Manufacturer C	Ceiling #1	0.254	4	1	0.1	3705-AA-612-161
Personal	MCEF	Manufacturer C	Ceiling #1	0.254	4	1	<0.010	3705-AA-612-162
Personal	Hydrar	Manufacturer C	Ceiling #2	0.254	4	1	0.21	3705-AA-612-163
Personal	MCEF	Manufacturer C	Ceiling #2	0.254	4	1	<0.010	3705-AA-612-164
Area	Hydrar	Manufacturer C	By device exhaust	0.2	37	7.4	0.039	3705-AA-612-149
Area	MCEF	Manufacturer C	By device exhaust	0.2	37	7.4	<0.0013	3705-AA-612-150
Area	Hydrar	Manufacturer C	By device exhaust	0.206	37	7.6	0.042	3705-AA-612-151
Area	MCEF	Manufacturer C	By device exhaust	0.206	37	7.6	<0.0013	3705-AA-612-152
Area	Hydrar	Manufacturer C	By device feed tube	0.209	37	7.7	0.042	3705-AA-612-153
Area	MCEF	Manufacturer C	By device feed tube	0.209	37	7.7	<0.0013	3705-AA-612-154
Area	Hydrar	Manufacturer C	By device feed tube	0.203	37	7.5	0.039	3705-AA-612-155
Area	MCEF	Manufacturer C	By device feed tube	0.203	37	7.5	<0.0013	3705-AA-612-156

Extended Field Test #1 – Phoenix, Arizona – March 24-28, 2003								
Type	Media	Device	Location	Flow Rate (lpm)	Sample time (min)	Volume (liters)	Result (mg/m^3)	Sample #
Background	Hydrar	All	E. of containment in warehouse	0.1365	205	27.98	0.0059	3705-B-324-03
Background	MCEF	All	E. of containment in warehouse	0.1365	205	27.98	<0.00036	3705-B-324-04
Background	Hydrar	All	N. of containment in warehouse	0.155	205	31.78	0.014	3705-B-324-01
Background	MCEF	All	N. of containment in warehouse	0.155	205	31.78	<0.00031	3705-B-324-02
Personal	Hydrar	Manufacturer A	Device operation - 2 drums	0.1635	162	26.49	0.074	3705-RA-324-05
Personal	MCEF	Manufacturer A	Device operation - 2 drums	0.1635	162	26.49	0.00053	3705-RA-324-06
Personal	Hydrar	Manufacturer A	Device operation - 2 drums	0.1505	162	24.38	0.043	3705-RA-324-07
Personal	MCEF	Manufacturer A	Device operation - 2 drums	0.1505	162	24.38	<0.00041	3705-RA-324-08
Personal	Hydrar	Manufacturer A	2nd drum change	0.257	22	5.65	0.075	3705-RA-324-13
Personal	MCEF	Manufacturer A	2nd drum change	0.257	22	5.65	<0.0018	3705-RA-324-14
Area	Hydrar	Manufacturer A	By device exhaust	0.156	162	25.27	0.045	3705-RA-324-09
Area	MCEF	Manufacturer A	By device exhaust	0.156	162	25.27	<0.00040	3705-RA-324-10
Area	Hydrar	Manufacturer A	By device feed tube	0.1765	162	28.59	0.11	3705-RA-324-11
Area	MCEF	Manufacturer A	By device feed tube	0.1765	162	28.59	0.0022	3705-RA-324-12
Overnight	Hydrar	Manufacturer A	By device exhaust	0.163	418	68.13	0.086	3705-RA-324-15
Overnight	MCEF	Manufacturer A	By device exhaust	0.163	418	68.13	<0.00015	3705-RA-324-16
Overnight	Hydrar	Manufacturer A	By device feed tube	0.1515	438	66.36	0.021	3705-RA-324-17
Overnight	MCEF	Manufacturer A	By device feed tube	0.1515	438	66.36	<0.00015	3705-RA-324-18
Personal	Hydrar	Manufacturer B	Device operation - 2 drums	0.23	125	28.75	0.084	3705-DA-325-19
Personal	MCEF	Manufacturer B	Device operation - 2 drums	0.23	125	28.75	0.00059	3705-DA-325-20
Personal	Hydrar	Manufacturer B	Device operation - 2 drums	0.1355	125	16.94	0.016	3705-DA-325-21
Personal	MCEF	Manufacturer B	Device operation - 2 drums	0.1355	125	16.94	<0.00059	3705-DA-325-22
Personal	Hydrar	Manufacturer B	1st drum change	0.2115	12	2.54	0.13	3705-DA-325-27
Personal	MCEF	Manufacturer B	1st drum change	0.2115	12	2.54	<0.0039	3705-DA-325-28
Personal	Hydrar	Manufacturer B	2nd drum change	0.2275	13	2.96	0.078	3705-DA-325-33
Personal	MCEF	Manufacturer B	2nd drum change	0.2275	13	2.96	<0.0034	3705-DA-325-34

Extended Field Test #1 – Phoenix, Arizona – March 24-28, 2003								
Type	Media	Device	Location	Flow Rate (lpm)	Sample time (min)	Volume (liters)	Result (mg/m^3)	Sample #
Area	Hydrar	Manufacturer B	By device exhaust	0.136	125	17	0.035	3705-DA-325-23
Area	MCEF	Manufacturer B	By device exhaust	0.136	125	17	<0.00059	3705-DA-325-24
Area	Hydrar	Manufacturer B	By device feed tube	0.1995	125	24.94	0.07	3705-DA-325-25
Area	MCEF	Manufacturer B	By device feed tube	0.1995	125	24.94	<0.00040	3705-DA-325-26
Overnight	Hydrar	Manufacturer B	By device exhaust	0.1218	516	62.85	0.027	3705-DA-325-29
Overnight	MCEF	Manufacturer B	By device exhaust	0.1218	516	62.85	<0.00016	3705-DA-325-30
Overnight	Hydrar	Manufacturer B	By device feed tube	0.1345	516	69.4	0.026	3705-DA-325-31
Overnight	MCEF	Manufacturer B	By device feed tube	0.1345	516	69.4	<0.00014	3705-DA-325-32
Personal	Hydrar	Manufacturer C	Device operation - 2 drums	0.1515	196	29.69	0.03	3705-AA-327-43
Personal	MCEF	Manufacturer C	Device operation - 2 drums	0.1515	196	29.69	<0.00034	3705-AA-327-44
Personal	Hydrar	Manufacturer C	Device operation - 2 drums	0.162	196	31.75	0.074	3705-AA-327-45
Personal	MCEF	Manufacturer C	Device operation - 2 drums	0.162	196	31.75	<0.00031	3705-AA-327-46
Personal	Hydrar	Manufacturer C	1st filter change	0.2455	22	5.4	0.076	3705-AA-327-51
Personal	MCEF	Manufacturer C	1st filter change	0.2455	22	5.4	<0.0018	3705-AA-327-52
Personal	Hydrar	Manufacturer C	1st drum change	0.2425	14	3.4	0.16	3705-AA-327-53
Personal	MCEF	Manufacturer C	1st drum change	0.2425	14	3.4	<0.0029	3705-AA-327-54
Personal	Hydrar	Manufacturer C	3rd filter change	0.2545	12	3.05	0.021	3705-AA-327-59
Personal	MCEF	Manufacturer C	3rd filter change	0.2454	12	3.05	<0.0033	3705-AA-327-60
Area	Hydrar	Manufacturer C	By device exhaust	0.149	196	29.2	0.014	3705-AA-327-47
Area	MCEF	Manufacturer C	By device exhaust	0.149	196	29.2	<0.00034	3705-AA-327-48
Area	Hydrar	Manufacturer C	By device feed tube	0.1395	196	27.34	0.071	3705-AA-327-49
Area	MCEF	Manufacturer C	By device feed tube	0.1395	196	27.34	<0.00037	3705-AA-327-50
Overnight	Hydrar	Manufacturer C	By device exhaust	0.1	776	77.6	0.0095	3705-AA-327-55
Overnight	MCEF	Manufacturer C	By device exhaust	0.1	776	77.6	<0.00013	3705-AA-327-56
Overnight	Hydrar	Manufacturer C	By device feed tube	0.1012	776	78.53	0.014	3705-AA-327-57
Overnight	MCEF	Manufacturer C	By device feed tube	0.1012	776	78.53	<0.00013	3705-AA-327-58

Extended Field Test #1 – Phoenix, Arizona – March 24-28, 2003								
Type	Media	Device	Location	Flow Rate (lpm)	Sample time (min)	Volume (liters)	Result (mg/m^3)	Sample #
Personal	Hydrar	Manufacturer D	Device operation - 2 drums	0.189	21	3.97	0.13	3705-HA-326-35
Personal	MCEF	Manufacturer D	Device operation - 2 drums	0.189	21	3.97	<0.0025	3705-HA-326-36
Personal	Hydrar	Manufacturer D	Device operation - 2 drums	0.1485	21	3.12	0.11	3705-HA-326-37
Personal	MCEF	Manufacturer D	Device operation - 2 drums	0.1485	21	3.12	<0.0032	3705-HA-326-38
Area	Hydrar	Manufacturer D	By device exhaust	0.1555	186	28.92	0.065	3705-HA-326-39
Area	MCEF	Manufacturer D	By device exhaust	0.1555	186	28.92	<0.00035	3705-HA-326-40
Area	Hydrar	Manufacturer D	By device feed tube	0.1605	186	29.85	0.022	3705-HA-326-41
Area	MCEF	Manufacturer D	By device feed tube	0.1605	186	29.85	<0.00034	3705-HA-326-42

Extended Field Test #2 – Melbourne, Florida – April 28 - May 2, 2003								
Type	Media	Device	Location	Flow Rate (lpm)	Sample time (min)	Volume (liters)	Result (mg/m^3)	Sample #
Background	Hydrar	All	18 ft N. of dock door	0.2175	298	64.8	0.012	3705-B-429-03
Background	MCEF	All	18 ft N. of dock door	0.2175	298	64.8	<0.00015	3705-B-429-04
Background	Hydrar	All	24 ft. E. of dock door	0.20525	298	61.16	0.016	3705-B-429-01
Background	MCEF	All	24 ft. E. of dock door	0.20525	298	61.16	<0.00016	3705-B-429-02
Personal	Hydrar	Manufacturer A	Device operation (LS) - 2 drums	0.154	142	21.87	0.018	3705-RA-51-61
Personal	MCEF	Manufacturer A	Device operation (LS) - 2 drums	0.154	142	21.87	<0.00046	3705-RA-51-62
Personal	Hydrar	Manufacturer A	Device operation (RS) - 1st drum	0.1515	79	11.97	0.026	3705-RA-51-65
Personal	MCEF	Manufacturer A	Device operation (RS) - 1st drum	0.1515	79	11.97	<0.00083	3705-RA-51-66
Personal	Hydrar	Manufacturer A	Device operation (LS) - 1st drum	0.1495	79	11.81	0.024	3705-RA-51-63
Personal	MCEF	Manufacturer A	Device operation (LS) - 1st drum	0.1495	79	11.81	<0.00085	3705-RA-51-64
Personal	Hydrar	Manufacturer A	Device operation (RS) - 2nd drum	0.15	63	9.45	0.016	3705-RA-51-81
Personal	MCEF	Manufacturer A	Device operation (RS) - 2nd drum	0.15	63	9.45	<0.0011	3705-RA-51-82

Extended Field Test #2 – Melbourne, Florida – April 28 - May 2, 2003								
Type	Media	Device	Location	Flow Rate (lpm)	Sample time (min)	Volume (liters)	Result (mg/m^3)	Sample #
Personal	Hydrar	Manufacturer A	Device operation (LS) - 2nd drum	0.148	63	9.32	0.017	3705-RA-51-79
Personal	MCEF	Manufacturer A	Device operation (LS) - 2nd drum	0.148	63	9.32	<0.0011	3705-RA-51-80
Personal	Hydrar	Manufacturer A	1st drum change	0.256	12	3.07	0.075	3705-RA-51-71
Personal	MCEF	Manufacturer A	1st drum change	0.256	12	3.07	<0.0033	3705-RA-51-72
Personal	Hydrar	Manufacturer A	2nd drum change	0.2485	12	2.98	0.081	3705-RA-52-43
Personal	MCEF	Manufacturer A	2nd drum change	0.2485	12	2.98	<0.0034	3705-RA-52-44
Personal	Hydrar	Manufacturer A	Ceiling #1 - 1st drum change	0.253	4	1.01	0.17	3705-RA-51-75
Personal	MCEF	Manufacturer A	Ceiling #1 - 1st drum change	0.253	4	1.01	<0.0099	3705-RA-51-76
Personal	Hydrar	Manufacturer A	Ceiling #2 - 1st drum change	0.253	4	1.01	0.11	3705-RA-51-77
Personal	MCEF	Manufacturer A	Ceiling #2 - 1st drum change	0.253	4	1.01	<0.0099	3705-RA-51-78
Area	Hydrar	Manufacturer A	By device exhaust	0.1565	142	22.22	0.018	3705-RA-51-67
Area	MCEF	Manufacturer A	By device exhaust	0.1565	142	22.22	<0.00045	3705-RA-51-68
Area	Hydrar	Manufacturer A	By device feed tube	0.1555	142	22.08	0.0063	3705-RA-51-69
Area	MCEF	Manufacturer A	By device feed tube	0.1555	142	22.08	<0.00045	3705-RA-51-70
Overnight	Hydrar	Manufacturer A	By device exhaust	0.154	874	134.6	0.013	3705-RA-51-83
Overnight	MCEF	Manufacturer A	By device exhaust	0.154	874	134.6	<0.00007	3705-RA-51-84
Overnight	Hydrar	Manufacturer A	By device feed tube	0.154	874	134.6	0.013	3705-RA-51-85
Overnight	MCEF	Manufacturer A	By device feed tube	0.154	874	134.6	<0.00007	3705-RA-51-86
Overnight	Hydrar	Manufacturer A	Outside containment	0.1575	874	137.66	0.017	3705-RA-51-87
Overnight	MCEF	Manufacturer A	Outside containment	0.1575	874	137.66	<0.00007	3705-RA-51-88
Personal	Hydrar	Manufacturer B	Device operation (RS) - 2 drums [1]	0.15833	163	25.81	0.14	3705-DA-429-05
Personal	MCEF	Manufacturer B	Device operation (RS) - 2 drums [1]	0.15833	163	25.81	0.00066	3705-DA-429-06
Personal	Hydrar	Manufacturer B	Device operation (LS) - 2 drums [1]	0.14867	163	24.23	0.12	3705-DA-429-07
Personal	MCEF	Manufacturer B	Device operation (LS) - 2 drums [1]	0.14867	163	24.23	<0.00041	3705-DA-429-08
Personal	Hydrar	Manufacturer B	1st drum change [1]	0.2535	12	3.04	0.015	3705-DA-429-13
Personal	MCEF	Manufacturer B	1st drum change [1]	0.2535	12	3.04	<0.0033	3705-DA-429-14

Extended Field Test #2 – Melbourne, Florida – April 28 - May 2, 2003								
Type	Media	Device	Location	Flow Rate (lpm)	Sample time (min)	Volume (liters)	Result (mg/m^3)	Sample #
Personal	Hydrar	Manufacturer B	2nd drum change [1]	0.254	20	5.08	0.041	3705-DA-429-15
Personal	MCEF	Manufacturer B	2nd drum change [1]	0.254	20	5.08	<0.0020	3705-DA-429-16
Personal	Hydrar	Manufacturer B	Ceiling #1 - 2nd drum change [1]	0.2535	4	1.01	0.23	3705-DA-429-23
Personal	MCEF	Manufacturer B	Ceiling #1 - 2nd drum change [1]	0.2535	4	1.01	<0.0099	3705-DA-429-24
Personal	Hydrar	Manufacturer B	Ceiling #2 - 2nd drum change [1]	0.2535	4	1.01	0.64	3705-DA-429-25
Personal	MCEF	Manufacturer B	Ceiling #2 - 2nd drum change [1]	0.2535	4	1.01	<0.0099	3705-DA-429-26
Area	Hydrar	Manufacturer B	By device exhaust [1]	0.153	163	24.94	0.13	3705-DA-429-09
Area	MCEF	Manufacturer B	By device exhaust [1]	0.153	163	24.94	0.00072	3705-DA-429-10
Area	Hydrar	Manufacturer B	By device feed tube [1]	0.154	163	25.1	0.27	3705-DA-429-11
Area	MCEF	Manufacturer B	By device feed tube [1]	0.154	163	25.1	0.0019	3705-DA-429-12
Overnight	Hydrar	Manufacturer B	By device exhaust [1]	0.147	714	104.96	0.035	3705-DA-429-17
Overnight	MCEF	Manufacturer B	By device exhaust [1]	0.147	714	104.96	<0.00009	3705-DA-429-18
Overnight	Hydrar	Manufacturer B	By device feed tube [1]	0.149	714	106.39	0.036	3705-DA-429-19
Overnight	MCEF	Manufacturer B	By device feed tube [1]	0.149	714	106.39	<0.00009	3705-DA-429-20
Overnight	Hydrar	Manufacturer B	Outside containment [1]	0.153	714	109.24	0.021	3705-DA-429-21
Overnight	MCEF	Manufacturer B	Outside containment [1]	0.153	714	109.24	<0.00009	3705-DA-429-22
Personal	Hydrar	Manufacturer B	Device operation (RS) - 1 drum [2]	0.1535	56	8.6	0.088	3705-DA-52-91
Personal	MCEF	Manufacturer B	Device operation (RS) - 1 drum [2]	0.1535	56	8.6	<0.0012	3705-DA-52-92
Personal	Hydrar	Manufacturer B	Device operation (LS) - 1 drum [2]	0.1535	56	8.6	0.094	3705-DA-52-89
Personal	MCEF	Manufacturer B	Device operation (LS) - 1 drum [2]	0.1535	56	8.6	<0.0012	3705-DA-52-90
Area	Hydrar	Manufacturer B	By device exhaust [2]	0.1525	57	8.69	0.076	3705-DA-52-93
Area	MCEF	Manufacturer B	By device exhaust [2]	0.1525	57	8.69	<0.0012	3705-DA-52-94
Area	Hydrar	Manufacturer B	By device feed tube [2]	0.152	57	8.66	0.09	3705-DA-52-95
Area	MCEF	Manufacturer B	By device feed tube [2]	0.152	57	8.66	<0.0012	3705-DA-52-96
Personal	Hydrar	Manufacturer B	3rd drum change [2]	0.256	12	3.07	0.2	3705-DA-52-97
Personal	MCEF	Manufacturer B	3rd drum change [2]	0.256	12	3.07	<0.0033	3705-DA-52-98

Extended Field Test #2 – Melbourne, Florida – April 28 - May 2, 2003								
Type	Media	Device	Location	Flow Rate (lpm)	Sample time (min)	Volume (liters)	Result (mg/m^3)	Sample #
Personal	Hydrar	Manufacturer C	Device operation (LS) - 2 drums	0.154	145	22.33	0.063	3705-AA-430-27
Personal	MCEF	Manufacturer C	Device operation (LS) - 2 drums	0.154	145	22.33	<0.00045	3705-AA-430-28
Personal	Hydrar	Manufacturer C	Device operation (RS) - 1st drum	0.1545	81	12.51	0.0047	3705-AA-430-29
Personal	MCEF	Manufacturer C	Device operation (RS) - 1st drum	0.1545	81	12.51	<0.00080	3705-AA-430-30
Personal	Hydrar	Manufacturer C	Device operation (LS) - 1st drum	0.153	81	12.39	0.07	3705-AA-430-31
Personal	MCEF	Manufacturer C	Device operation (LS) - 1st drum	0.153	81	12.39	<0.00081	3705-AA-430-32
Personal	Hydrar	Manufacturer C	Device operation (RS) - 2nd drum	0.1555	67	10.42	0.034	3705-AA-430-55
Personal	MCEF	Manufacturer C	Device operation (RS) - 2nd drum	0.1555	67	10.42	<0.00096	3705-AA-430-56
Personal	Hydrar	Manufacturer C	Device operation (LS) - 2nd drum	0.1505	67	10.08	0.052	3705-AA-430-57
Personal	MCEF	Manufacturer C	Device operation (LS) - 2nd drum	0.1505	67	10.08	<0.00099	3705-AA-430-58
Personal	Hydrar	Manufacturer C	1st filter change	0.2485	12	2.98	0.064	3705-AA-430-37
Personal	MCEF	Manufacturer C	1st filter change	0.2485	12	2.98	<0.0034	3705-AA-430-38
Personal	Hydrar	Manufacturer C	1st drum change	0.2485	17	4.22	0.11	3705-AA-430-39
Personal	MCEF	Manufacturer C	1st drum change	0.2485	17	4.22	<0.0024	3705-AA-430-40
Personal	Hydrar	Manufacturer C	3rd filter change	0.2485	12	2.98	0.06	3705-AA-430-41
Personal	MCEF	Manufacturer C	3rd filter change	0.2485	12	2.98	<0.0034	3705-AA-430-42
Personal	Hydrar	Manufacturer C	2nd drum change	0.2555	12	3.07	0.036	3705-AA-430-59
Personal	MCEF	Manufacturer C	2nd drum change	0.2555	12	3.07	<0.0033	3705-AA-430-60
Personal	Hydrar	Manufacturer C	Ceiling #1 - 1st drum change	0.2475	4	0.99	0.12	3705-AA-430-45
Personal	MCEF	Manufacturer C	Ceiling #1 - 1st drum change	0.2475	4	0.99	<0.010	3705-AA-430-46
Personal	Hydrar	Manufacturer C	Ceiling #2 - 1st drum change	0.2475	4	0.99	0.26	3705-AA-430-47
Personal	MCEF	Manufacturer C	Ceiling #2 - 1st drum change	0.2475	4	0.99	<0.010	3705-AA-430-48
Area	Hydrar	Manufacturer C	By device exhaust	0.154	148	22.79	0.048	3705-AA-430-33
Area	MCEF	Manufacturer C	By device exhaust	0.154	148	22.79	<0.00044	3705-AA-430-34
Area	Hydrar	Manufacturer C	By device feed tube	0.154	148	22.79	0.048	3705-AA-430-35
Area	MCEF	Manufacturer C	By device feed tube	0.154	148	22.79	<0.00044	3705-AA-430-36

Extended Field Test #2 – Melbourne, Florida – April 28 - May 2, 2003								
Type	Media	Device	Location	Flow Rate (lpm)	Sample time (min)	Volume (liters)	Result (mg/m^3)	Sample #
Overnight	Hydrar	Manufacturer C	By device exhaust	0.152	991	150.63	0.019	3705-AA-430-49
Overnight	MCEF	Manufacturer C	By device exhaust	0.152	991	150.63	<0.00007	3705-AA-430-50
Overnight	Hydrar	Manufacturer C	By device feed tube	0.1505	991	149.15	0.021	3705-AA-430-51
Overnight	MCEF	Manufacturer C	By device feed tube	0.1505	991	149.15	<0.00007	3705-AA-430-52
Overnight	Hydrar	Manufacturer C	Outside containment	0.1555	991	154.1	0.016	3705-AA-430-53
Overnight	MCEF	Manufacturer C	Outside containment	0.1555	991	154.1	<0.00006	3705-AA-430-54

Extended Field Test #3 – Ashland, Virginia – June 9-13,2003								
Type	Media	Device	Location	Flow Rate (lpm)	Sample time (min)	Volume (liters)	Result (mg/m^3)	Sample #
Background	Hydrar	All	E. bay near door to W. bay	0.205	264	54.1	0.0086	3705-BA-69-03
Background	MCEF	All	E. bay near door to W. bay	0.205	264	54.1	<0.00018	3705-BA-69-04
Background	Hydrar	All	Middle of E. bay	0.221	264	58.3	0.013	3705-BA-69-01
Background	MCEF	All	Middle of E. bay	0.221	264	58.3	<0.00017	3705-BA-69-02
Personal	Hydrar	AERC	AERC personnel sample	0.202	89	18	0.089	3705-FA-611-113
Personal	MCEF	AERC	AERC personnel sample	0.202	89	18	0.0023	3705-FA-611-114
Personal	Hydrar	AERC	AERC personnel sample	0.202	89	18	0.073	3705-FA-611-115
Personal	MCEF	AERC	AERC personnel sample	0.202	89	18	0.0023	3705-FA-611-116
Personal	Hydrar	Manufacturer A	Device operation (LS) - 2 drums	0.195	129	25.2	0.0093	3705-RA-610-05
Personal	MCEF	Manufacturer A	Device operation (LS) - 2 drums	0.195	129	25.2	<0.00040	3705-RA-610-06
Personal	Hydrar	Manufacturer A	Device operation (RS) - 1st drum	0.202	67	13.5	0.011	3705-RA-610-09
Personal	MCEF	Manufacturer A	Device operation (RS) - 1st drum	0.202	67	13.5	<0.00074	3705-RA-610-10
Personal	Hydrar	Manufacturer A	Device operation (LS) - 1st drum	0.2	67	13.4	0.0062	3705-RA-610-07
Personal	MCEF	Manufacturer A	Device operation (LS) - 1st drum	0.2	67	13.4	<0.00075	3705-RA-610-08
Personal	Hydrar	Manufacturer A	Device operation (RS) - 2nd drum	0.198	62	12.3	0.015	3705-RA-610-25
Personal	MCEF	Manufacturer A	Device operation (RS) - 2nd drum	0.198	62	12.3	<0.00081	3705-RA-610-26

Extended Field Test #3 – Ashland, Virginia – June 9-13,2003								
Type	Media	Device	Location	Flow Rate (lpm)	Sample time (min)	Volume (liters)	Result (mg/m^3)	Sample #
Personal	Hydrar	Manufacturer C	Device operation (LS) - 1st drum	0.2	79	15.8	0.049	3705-AA-612-119
Personal	MCEF	Manufacturer C	Device operation (LS) - 1st drum	0.2	79	15.8	<0.00063	3705-AA-612-120
Personal	Hydrar	Manufacturer C	Device operation (RS) - 2nd drum	0.212	52	11	0.039	3705-AA-612-137
Personal	MCEF	Manufacturer C	Device operation (RS) - 2nd drum	0.212	52	11	<0.00091	3705-AA-612-138
Personal	Hydrar	Manufacturer C	Device operation (LS) - 2nd drum	0.198	52	10.3	0.039	3705-AA-612-135
Personal	MCEF	Manufacturer C	Device operation (LS) - 2nd drum	0.198	52	10.3	<0.00097	3705-AA-612-136
Personal	Hydrar	Manufacturer C	1st filter change	0.255	12	3.1	0.055	3705-AA-612-127
Personal	MCEF	Manufacturer C	1st filter change	0.255	12	3.1	<0.0032	3705-AA-612-128
Personal	Hydrar	Manufacturer C	1st drum change	0.255	12	3.1	0.15	3705-AA-612-129
Personal	MCEF	Manufacturer C	1st drum change	0.255	12	3.1	<0.0032	3705-AA-612-130
Personal	Hydrar	Manufacturer C	3rd filter change	0.255	12	3.1	0.17	3705-AA-612-165
Personal	MCEF	Manufacturer C	3rd filter change	0.255	12	3.1	<0.0032	3705-AA-612-166
Personal	Hydrar	Manufacturer C	2nd drum change	0.255	13	3.3	0.094	3705-AA-612-167
Personal	MCEF	Manufacturer C	2nd drum change	0.255	13	3.3	<0.0030	3705-AA-612-168
Personal	Hydrar	Manufacturer C	Ceiling #1 - 1st drum change	0.26	4	1	0.19	3705-AA-612-131
Personal	MCEF	Manufacturer C	Ceiling #1 - 1st drum change	0.26	4	1	<0.010	3705-AA-612-132
Personal	Hydrar	Manufacturer C	Ceiling #2 - 1st drum change	0.26	4	1	0.22	3705-AA-612-133
Personal	MCEF	Manufacturer C	Ceiling #2 - 1st drum change	0.26	4	1	<0.010	3705-AA-612-134
Area	Hydrar	Manufacturer C	By device exhaust	0.2	132	26.4	0.041	3705-AA-612-123
Area	MCEF	Manufacturer C	By device exhaust	0.2	132	26.4	<0.00038	3705-AA-612-124
Area	Hydrar	Manufacturer C	By device feed tube	0.201	132	26.5	0.00075	3705-AA-612-125
Area	MCEF	Manufacturer C	By device feed tube	0.201	132	26.5	<0.00038	3705-AA-612-126
Overnight	Hydrar	Manufacturer C	By device exhaust	0.144	821	118.2	0.057	3705-AA-612-139
Overnight	MCEF	Manufacturer C	By device exhaust	0.144	821	118.2	<0.00008	3705-AA-612-140
Overnight	Hydrar	Manufacturer C	By device feed tube	0.157	821	128.9	0.058	3705-AA-612-141
Overnight	MCEF	Manufacturer C	By device feed tube	0.157	821	128.9	<0.00008	3705-AA-612-142

Extended Field Test #3 – Ashland, Virginia – June 9-13,2003								
Type	Media	Device	Location	Flow Rate (lpm)	Sample time (min)	Volume (liters)	Result (mg/m^3)	Sample #
Overnight	Hydrar	Manufacturer C	Outside containment	0.15	821	123.1	0.044	3705-AA-612-143
Overnight	MCEF	Manufacturer C	Outside containment	0.15	821	123.1	<0.00008	3705-AA-612-144
Box Test – Ashland, Virginia								
Box test	Hydrar	Manufacturer A	E. side of containment	0.199	64	12.7	0.018	3705-TA-610-47
Box test	MCEF	Manufacturer A	E. side of containment	0.199	64	12.7	<0.00079	3705-TA-610-48
Box test	Hydrar	Manufacturer A	W. side of containment	0.203	64	13	0.1	3705-TA-610-49
Box test	MCEF	Manufacturer A	W. side of containment	0.203	64	13	<0.00077	3705-TA-610-50
Box test	Hydrar	Manufacturer B	E. side of containment	0.201	36	7.2	0.12	3705-TA-611-109
Box test	MCEF	Manufacturer B	E. side of containment	0.201	36	7.2	<0.0014	3705-TA-611-110
Box test	Hydrar	Manufacturer B	W. side of containment	0.199	36	7.2	0.12	3705-TA-611-111
Box test	MCEF	Manufacturer B	W. side of containment	0.199	36	7.2	<0.0014	3705-TA-611-112
Box test	Hydrar	Manufacturer C	E. side of containment	0.201	45	9	0.05	3705-TA-612-167
Box test	MCEF	Manufacturer C	E. side of containment	0.201	45	9	<0.0011	3705-TA-612-168
Box test	Hydrar	Manufacturer C	W. side of containment	0.201	45	9	0.014	3705-TA-612-169
Box test	MCEF	Manufacturer C	W. side of containment	0.201	45	9	<0.0010	3705-TA-612-170
"U" Tube Test – Ashland, Virginia								
Personal	Hydrar	Manufacturer B	"U" tubes - device operation (LS)	0.2	12	2.4	0.1	3705-DA-611-83
Personal	MCEF	Manufacturer B	"U" tubes - device operation (LS)	0.2	12	2.4	<0.0042	3705-DA-611-84
Personal	Hydrar	Manufacturer B	"U" tubes - device operation (RS)	0.197	12	2.4	0.018	3705-DA-611-85
Personal	MCEF	Manufacturer B	"U" tubes - device operation (RS)	0.197	12	2.4	<0.0042	3705-DA-611-86
Area	Hydrar	Manufacturer B	"U" tubes - by device exhaust	0.198	12	2.4	0.083	3705-DA-611-87
Area	MCEF	Manufacturer B	"U" tubes - by device exhaust	0.198	12	2.4	<0.0042	3705-DA-611-88
Area	Hydrar	Manufacturer B	"U" tubes - by device feed tube	0.205	12	2.5	0.092	3705-DA-611-89
Area	MCEF	Manufacturer B	"U" tubes - by device feed tube	0.205	12	2.5	<0.0040	3705-DA-611-90
Personal	Hydrar	Manufacturer C	"U" tubes - device operation (LS)	0.209	14	2.9	0.11	3705-AA-612-171
Personal	MCEF	Manufacturer C	"U" tubes - device operation (LS)	0.209	14	2.9	<0.0034	3705-AA-612-172

Extended Field Test #3 – Ashland, Virginia – June 9-13,2003								
Type	Media	Device	Location	Flow Rate (lpm)	Sample time (min)	Volume (liters)	Result (mg/m^3)	Sample #
Personal	Hydrar	Manufacturer C	"U" tubes - device operation (RS)	0.207	14	2.9	0.026	3705-AA-612-173
Personal	MCEF	Manufacturer C	"U" tubes - device operation (RS)	0.207	14	2.9	<0.0034	3705-AA-612-174
Area	Hydrar	Manufacturer C	"U" tubes - by device exhaust	0.205	14	2.8	0.046	3705-AA-612-175
Area	MCEF	Manufacturer C	"U" tubes - by device exhaust	0.205	14	2.8	<0.0036	3705-AA-612-176
Area	Hydrar	Manufacturer C	"U" tubes - by device feed tube	0.201	14	2.8	0.05	3705-AA-612-177
Area	MCEF	Manufacturer C	"U" tubes - by device feed tube	0.201	14	2.8	<0.0036	3705-AA-612-178

Table 2: Wipe Sample Results

Performance Validation Study – Phase I – Ashland, Virginia – February 24-28, 2003						
Device	Date	Sample Location	Pre-Wipe #1	Post-Wipe #1	Pre-Wipe #2	Post-Wipe #2
Blank	2/27/2003	Blank	<0.01	<0.01	<0.01	<0.01
Blank	2/27/2003	Blank	<0.01	<0.01	<0.01	<0.01
Manufacturer A	2/27/2003	Floor-2 ft from device	0.36	0.14	0.16	0.19
Manufacturer A	2/27/2003	Floor-5 ft from device	0.21	0.11	0.18	0.15
Manufacturer A	2/27/2003	Ceiling	0.49	0.071	0.16	0.049
Manufacturer A	2/27/2003	East wall of containment	0.026	0.033	0.014	0.024
Manufacturer A	2/27/2003	West wall of containment	0.11	0.032	0.071	0.013
Manufacturer A	2/27/2003	Exterior drum surface-side	0.059	0.12	0.017	0.046
Manufacturer A	2/27/2003	DTC device	0.4	0.2	0.32	0.17
Manufacturer A	2/27/2003	DTC device feed tube exterior	0.48	0.053	0.055	0.062
Manufacturer A	2/27/2003	Floor at device exhaust	0.14	0.14	0.048	0.11
Blank	2/28/2003	Blank	<0.01	<0.01	<0.01	<0.01
Blank	2/28/2003	Blank	<0.01	<0.01	<0.01	<0.01
Manufacturer B	2/28/2003	Floor-2 ft from device	0.065	0.054	0.064	0.13
Manufacturer B	2/28/2003	Floor-5 ft from device	0.14	0.074	0.12	0.067
Manufacturer B	2/28/2003	Ceiling	0.053	0.2	0.045	0.097
Manufacturer B	2/28/2003	East wall of containment	0.017	0.02	0.029	<0.01
Manufacturer B	2/28/2003	West wall of containment	0.044	0.015	0.015	0.015
Manufacturer B	2/28/2003	Exterior drum surface-side	0.17	0.073	0.038	0.053
Manufacturer B	2/28/2003	DTC device	0.017	0.18	0.019	1.2
Manufacturer B	2/28/2003	DTC device feed tube exterior	<0.01	0.33	<0.01	0.64
Manufacturer B	2/28/2003	Floor at device exhaust	0.049	0.27	0.048	0.12
Blank	2/26/2003	Blank	<0.01	<0.01	<0.01	<0.01
Blank	2/26/2003	Blank	<0.01	<0.01	<0.01	<0.01
Manufacturer C	2/26/2003	Floor-2 ft from device	0.13	3.1	0.43	0.33
Manufacturer C	2/26/2003	Floor-5 ft from device	0.11	0.62	0.11	0.15
Manufacturer C	2/26/2003	Ceiling	0.71	0.27	0.2	0.15
Manufacturer C	2/26/2003	East wall of containment	<0.01	0.12	0.02	0.024
Manufacturer C	2/26/2003	West wall of containment	<0.01	0.034	<0.01	0.021
Manufacturer C	2/26/2003	Exterior drum surface-side	0.067	0.027	0.051	0.044
Manufacturer C	2/26/2003	DTC device	0.041	0.27	0.037	0.93
Manufacturer C	2/26/2003	DTC device feed tube exterior	0.02	0.052	0.017	0.047
Manufacturer C	2/26/2003	Floor at device exhaust	0.12	0.45	0.072	0.48
Manufacturer D	2/27/2003	Floor-2 ft from device	0.088	0.06	0.076	0.041
Manufacturer D	2/27/2003	Floor-5 ft from device	0.053	0.063	0.088	0.072

Performance Validation Study – Phase I – Ashland, Virginia – February 24-28, 2003						
Device	Date	Sample Location	Pre-Wipe #1	Post-Wipe #1	Pre-Wipe #2	Post-Wipe #2
Manufacturer D	2/27/2003	Ceiling	0.63	0.1	0.25	0.082
Manufacturer D	2/27/2003	East wall of containment	0.39	0.019	0.41	0.015
Manufacturer D	2/27/2003	West wall of containment	0.11	<0.01	0.028	0.017
Manufacturer D	2/27/2003	Exterior drum surface-side	0.31	0.052	0.4	0.037
Manufacturer D	2/27/2003	DTC device	0.067	0.067	0.049	0.051
Manufacturer D	2/27/2003	DTC device feed tube exterior	0.069	0.027	0.039	0.029
Manufacturer D	2/27/2003	Floor at device exhaust	0.27	0.097	0.31	0.085

Performance Validation Study – Phase II – Ashland, Virginia – June 9-13, 2003				
Device	Date	Sample Location	Pre-Wipe	Post-Wipe
Manufacturer A	6/10/2003	Floor-2 ft from device	0.22	0.98
Manufacturer A	6/10/2003	Floor-5 ft from device	0.093	0.47
Manufacturer A	6/10/2003	Ceiling	0.011	0.029
Manufacturer A	6/10/2003	East wall of containment	0.019	0.026
Manufacturer A	6/10/2003	West wall of containment	0.012	0.026
Manufacturer A	6/10/2003	Exterior drum surface-side	0.052	0.024
Manufacturer A	6/10/2003	DTC device	1.7	1.1
Manufacturer A	6/10/2003	DTC device feed tube exterior	0.39	0.36
Manufacturer A	6/10/2003	Floor at device exhaust	0.45	0.37
Manufacturer B	6/11/2003	Floor-2 ft from device	0.49	0.41
Manufacturer B	6/11/2003	Floor-5 ft from device	0.17	0.31
Manufacturer B	6/11/2003	Ceiling	0.081	0.16
Manufacturer B	6/11/2003	East wall of containment	0.039	0.068
Manufacturer B	6/11/2003	West wall of containment	0.048	0.073
Manufacturer B	6/11/2003	Exterior drum surface-side	0.31	0.043
Manufacturer B	6/11/2003	DTC device	0.98	0.45
Manufacturer B	6/11/2003	DTC device feed tube exterior	0.49	0.24
Manufacturer B	6/11/2003	Floor at device exhaust	0.54	0.22
Manufacturer C	6/12/2003	Floor-2 ft from device	0.13	0.17
Manufacturer C	6/12/2003	Floor-5 ft from device	0.19	0.22
Manufacturer C	6/12/2003	Ceiling	0.046	0.019
Manufacturer C	6/12/2003	East wall of containment	0.016	0.023
Manufacturer C	6/12/2003	West wall of containment	0.024	0.022
Manufacturer C	6/12/2003	Exterior drum surface-side	0.57	0.31
Manufacturer C	6/12/2003	DTC device	0.98	0.43
Manufacturer C	6/12/2003	DTC device feed tube exterior	0.25	0.17
Manufacturer C	6/12/2003	Floor at device exhaust	0.069	0.41

Extended Field Test #1 – Phoenix, Arizona – March 24-28, 2003				
Device	Date	Sample Location	Pre Wipe	Post Wipe
Background	3/24/2003	Ground in front of containment	1.4	
Background	3/24/2003	Ground in front of containment	0.69	
Blank	3/24/2003	Blank	<0.01	
Blank	3/24/2003	Blank	<0.01	
Manufacturer A	3/24/2003	Floor-2 ft from device	0.22	0.41
Manufacturer A	3/24/2003	Floor-5 ft from device	0.034	1.3
Manufacturer A	3/24/2003	Ceiling	<0.01	0.81
Manufacturer A	3/24/2003	East wall of containment	0.011	0.11
Manufacturer A	3/24/2003	West wall of containment	0.053	0.058
Manufacturer A	3/24/2003	Exterior drum surface-side	0.037	0.22
Manufacturer A	3/24/2003	DTC device	0.94	0.53
Manufacturer A	3/24/2003	DTC device feed tube exterior	0.16	0.17
Manufacturer A	3/24/2003	Floor at device exhaust	0.26	5
Blank	3/25/2003	Blank	<0.01	
Blank	3/25/2003	Blank	<0.01	
Manufacturer B	3/25/2003	Floor-2 ft from device	0.73	0.44
Manufacturer B	3/25/2003	Floor-5 ft from device	0.43	1.6
Manufacturer B	3/25/2003	Ceiling	0.18	0.51
Manufacturer B	3/25/2003	East wall of containment	0.21	0.8
Manufacturer B	3/25/2003	West wall of containment	0.088	0.11
Manufacturer B	3/25/2003	Exterior drum surface-side	0.14	0.05
Manufacturer B	3/25/2003	DTC device	0.8	0.61
Manufacturer B	3/25/2003	DTC device feed tube exterior	0.091	0.48
Manufacturer B	3/25/2003	Floor at device exhaust	0.17	0.45
Blank	3/27/2003	Blank	<0.01	
Blank	3/27/2003	Blank	<0.01	
Manufacturer C	3/27/2003	Floor-2 ft from device	0.17	1.3
Manufacturer C	3/27/2003	Floor-5 ft from device	0.042	0.17
Manufacturer C	3/27/2003	Ceiling	0.071	0.14
Manufacturer C	3/27/2003	East wall of containment	0.019	2.7
Manufacturer C	3/27/2003	West wall of containment	0.032	1
Manufacturer C	3/27/2003	Exterior drum surface-side	0.065	0.36
Manufacturer C	3/27/2003	DTC device	0.067	0.85
Manufacturer C	3/27/2003	DTC device feed tube exterior	0.11	0.23
Manufacturer C	3/27/2003	Floor at device exhaust	0.083	2.6

Extended Field Test #1 – Phoenix, Arizona – March 24-28, 2003				
Device	Date	Sample Location	Pre Wipe	Post Wipe
Blank	3/26/2003	Blank	<0.01	
Blank	3/26/2003	Blank	0.018	
Manufacturer D	3/26/2003	Floor-2 ft from device	0.28	3.1
Manufacturer D	3/26/2003	Floor-5 ft from device	0.18	0.23
Manufacturer D	3/26/2003	Ceiling	0.034	0.038
Manufacturer D	3/26/2003	East wall of containment	5.3	4.5
Manufacturer D	3/26/2003	West wall of containment	0.96	0.4
Manufacturer D	3/26/2003	Exterior drum surface-side	1.1	0.88
Manufacturer D	3/26/2003	DTC device	2.1	1.2
Manufacturer D	3/26/2003	DTC device feed tube exterior	1.3	0.56
Manufacturer D	3/26/2003	Floor at device exhaust	0.33	4.5

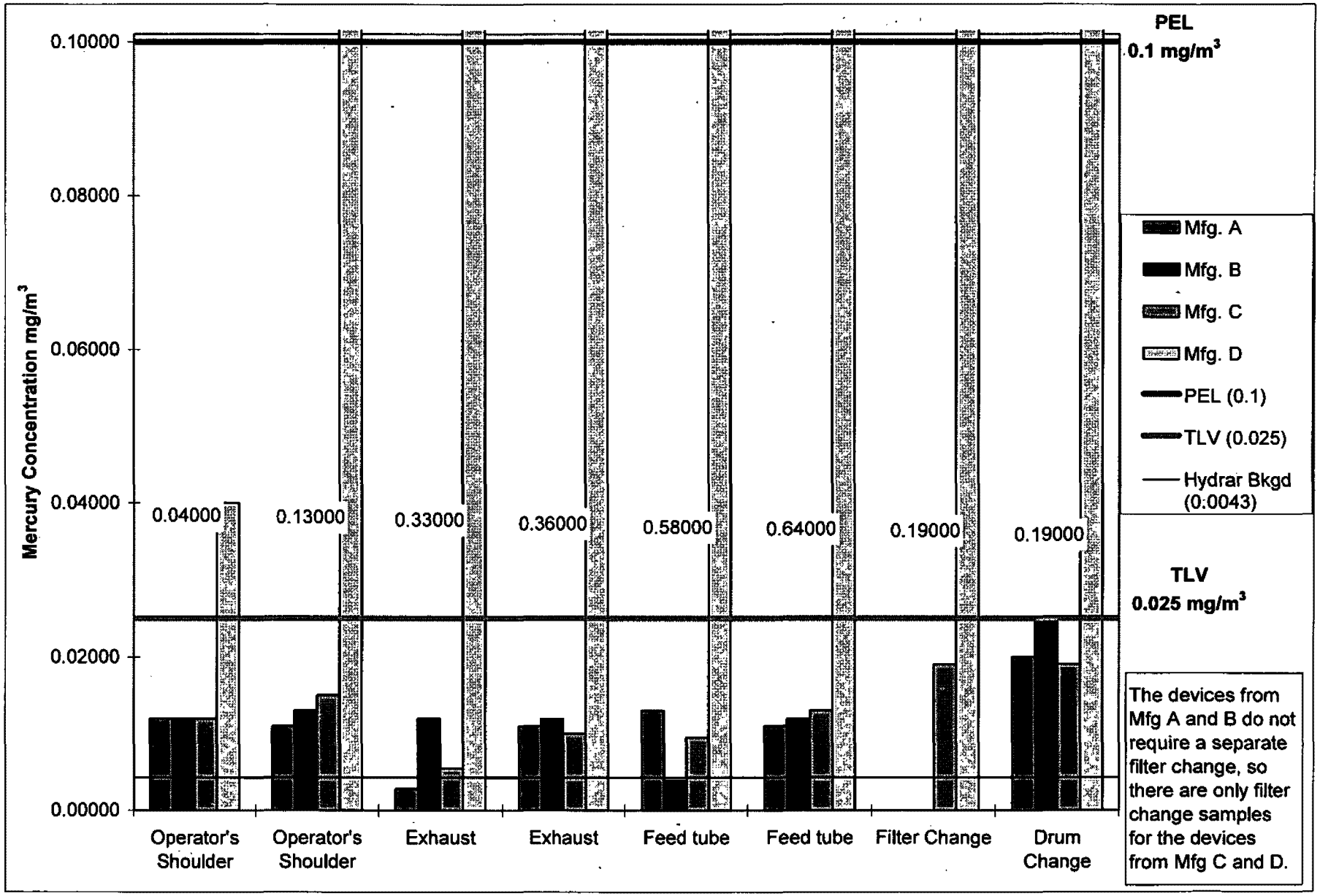
Extended Field Test #2 – Melbourne, Florida – April 28 - May 2, 2003				
Device	Date	Sample Location	Pre-Wipe	Post-Wipe
Blank	5/1/2003	Blank	<0.01	
Blank	5/1/2003	Blank	<0.01	
Manufacturer A	5/1/2003	Floor-2 ft from device	0.095	0.61
Manufacturer A	5/1/2003	Floor-5 ft from device	0.083	0.46
Manufacturer A	5/1/2003	Ceiling	0.036	0.1
Manufacturer A	5/1/2003	East wall of containment	0.015	0.14
Manufacturer A	5/1/2003	West wall of containment	0.019	0.052
Manufacturer A	5/1/2003	Exterior drum surface-side	0.036	0.18
Manufacturer A	5/1/2003	DTC device	0.54	1.3
Manufacturer A	5/1/2003	DTC device feed tube exterior	0.2	0.2
Manufacturer A	5/1/2003	Floor at device exhaust	0.1	3.6
Manufacturer A	5/2/2003	Next day: Floor-2 ft from device		0.86
Manufacturer A	5/2/2003	Next day: E. wall of containment		0.078
Blank	4/29/2003	Blank	<0.01	
Blank	4/29/2003	Blank	<0.01	
Manufacturer B	4/29/2003	Floor-2 ft from device	0.67	17
Manufacturer B	4/29/2003	Floor-5 ft from device	0.46	6
Manufacturer B	4/29/2003	Ceiling	0.057	0.39
Manufacturer B	4/29/2003	East wall of containment	0.074	0.28
Manufacturer B	4/29/2003	West wall of containment	0.035	0.17
Manufacturer B	4/29/2003	Exterior drum surface-side	0.13	0.12
Manufacturer B	4/29/2003	DTC device	0.3	2.2

Extended Field Test #2 – Melbourne, Florida – April 28 - May 2, 2003				
Device	Date	Sample Location	Pre-Wipe	Post-Wipe
Manufacturer B	4/29/2003	DTC device feed tube exterior	0.63	0.63
Manufacturer B	4/29/2003	Floor at device exhaust	0.1	11
Manufacturer B	4/29/2003	Inside drum before crushing	0.024	
Manufacturer B	4/30/2003	Next day: Floor-2 ft from device		17.00
Manufacturer B	4/30/2003	Next day: E. wall of containment		0.550
Blank	4/30/2003	Blank	<0.01	
Blank	4/30/2003	Blank	0.017	
Manufacturer C	4/30/2003	Floor-2 ft from device	0.21	0.16
Manufacturer C	4/30/2003	Floor-5 ft from device	0.17	0.18
Manufacturer C	4/30/2003	Ceiling	0.11	0.1
Manufacturer C	4/30/2003	East wall of containment	0.11	0.02
Manufacturer C	4/30/2003	West wall of containment	0.086	0.022
Manufacturer C	4/30/2003	Exterior drum surface-side	0.11	0.046
Manufacturer C	4/30/2003	DTC device	0.25	0.24
Manufacturer C	4/30/2003	DTC device feed tube exterior	0.18	0.15
Manufacturer C	4/30/2003	Floor at device exhaust	0.08	0.49
Manufacturer C	5/1/2003	Next day: Floor-2 ft from device		0.650
Manufacturer C	5/1/2003	Next day: E. wall of containment		0.026

Extended Field Test #3 – Ashland, Virginia – June 9-13,2003				
Device	Date	Sample Location	Pre-Wipe	Post-Wipe
Blank	6/10/2003	Blank	<0.01	
Blank	6/10/2003	Blank	<0.01	
Manufacturer A	6/10/2003	Floor-2 ft from device	0.055	1.6
Manufacturer A	6/10/2003	Floor-5 ft from device	0.21	1.4
Manufacturer A	6/10/2003	Ceiling	0.025	0.19
Manufacturer A	6/10/2003	East wall of containment	<0.01	0.21
Manufacturer A	6/10/2003	West wall of containment	0.1	0.11
Manufacturer A	6/10/2003	Exterior drum surface-side	0.73	0.13
Manufacturer A	6/10/2003	DTC device	0.5	1.1
Manufacturer A	6/10/2003	DTC device feed tube exterior	0.061	0.32
Manufacturer A	6/10/2003	Floor at device exhaust	0.12	1.7
Manufacturer A	6/11/2003	Next day: Floor-2 ft from device		1.00
Manufacturer A	6/11/2003	Next day: E. wall of containment		0.022
Operator	6/10/2003	Tad's Hands	1.8	
Operator	6/10/2003	Steve's Hands	1.9	

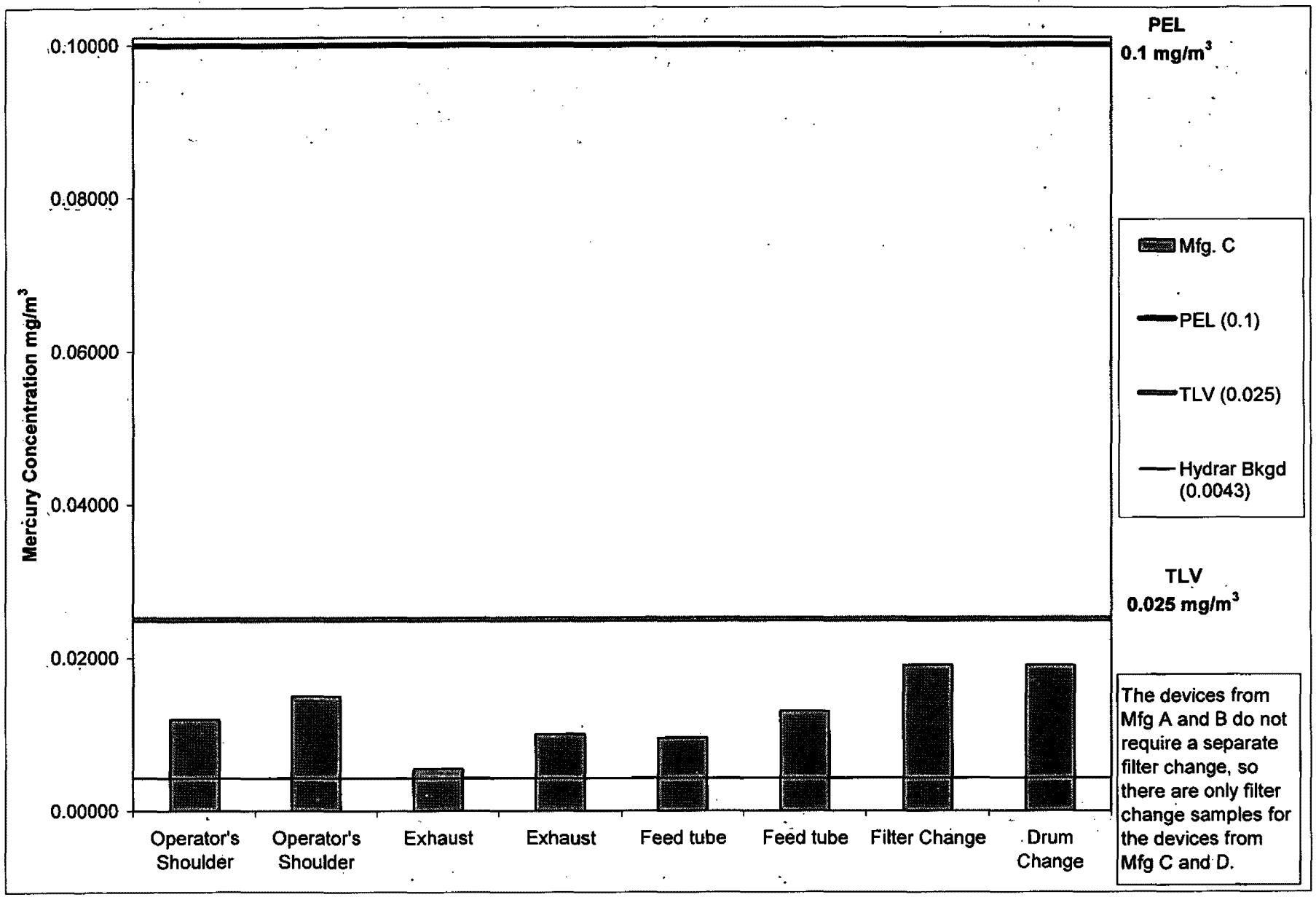
Extended Field Test #3 – Ashland, Virginia – June 9-13,2003				
Device	Date	Sample Location	Pre-Wipe	Post-Wipe
Operator	6/10/2003	Tad's Face	0.055	
Operator	6/10/2003	Steve's Face	0.53	
Blank	6/11/2003	Blank	<0.01	
Blank	6/11/2003	Blank	<0.01	
Manufacturer B	6/11/2003	Floor-2 ft from device	0.14	1.1
Manufacturer B	6/11/2003	Floor-5 ft from device	0.048	0.79
Manufacturer B	6/11/2003	Ceiling	0.031	0.099
Manufacturer B	6/11/2003	East wall of containment	0.035	0.072
Manufacturer B	6/11/2003	West wall of containment	0.024	0.055
Manufacturer B	6/11/2003	Exterior drum surface-side	0.14	0.058
Manufacturer B	6/11/2003	DTC device	0.23	3.8
Manufacturer B	6/11/2003	DTC device feed tube exterior	0.22	0.8
Manufacturer B	6/11/2003	Floor at device exhaust	0.17	1.5
Manufacturer B	6/12/2003	Next day: Floor-2 ft from device		0.230
Manufacturer B	6/12/2003	Next day: E. wall of containment		0.065
Blank	6/12/2003	Blank	<0.01	
Blank	6/12/2003	Blank	0.012	
Manufacturer C	6/12/2003	Floor-2 ft from device	0.051	1.1
Manufacturer C	6/12/2003	Floor-5 ft from device	0.059	0.12
Manufacturer C	6/12/2003	Ceiling	0.061	0.44
Manufacturer C	6/12/2003	East wall of containment	0.02	0.097
Manufacturer C	6/12/2003	West wall of containment	0.034	0.092
Manufacturer C	6/12/2003	Exterior drum surface-side	0.2	0.12
Manufacturer C	6/12/2003	DTC device	1.7	1.8
Manufacturer C	6/12/2003	DTC device feed tube exterior	0.096	0.36
Manufacturer C	6/12/2003	Floor at device exhaust	0.22	2.8
Manufacturer C	6/13/2003	Next day: Floor-2 ft from device		0.830
Manufacturer C	6/13/2003	Next day: E. wall of containment		0.017
Blank	6/13/2003	Blank	<0.01	
Blank	6/13/2003	Blank	<0.01	

Figure 1: Performance Validation Study – Phase I Analytical Air Results
All Devices – Ashland, Virginia – February 24-28, 2003



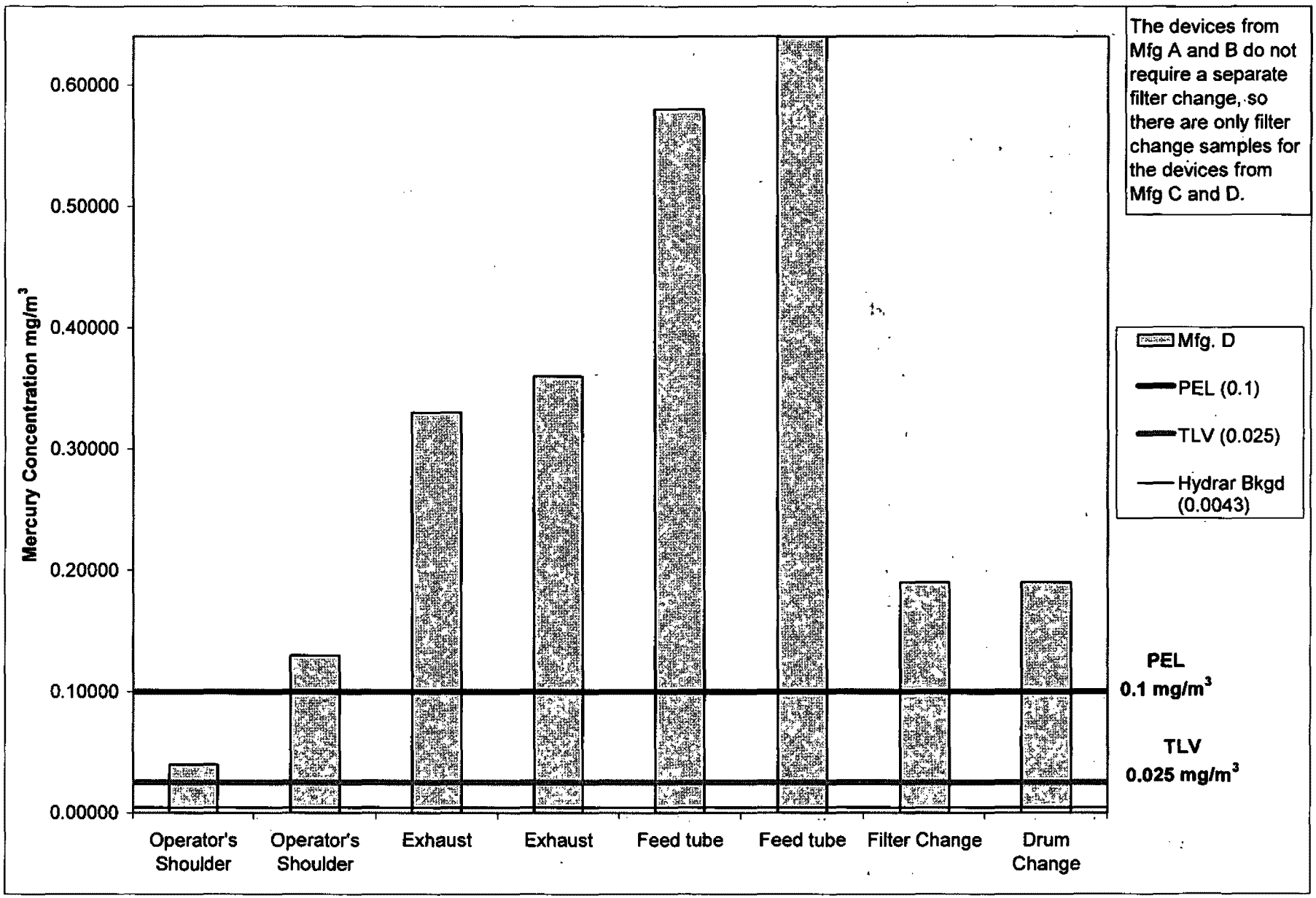
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 4: Performance Validation Study – Phase I Analytical Air Results
Manufacturer C – Ashland, Virginia – February 24-28, 2003



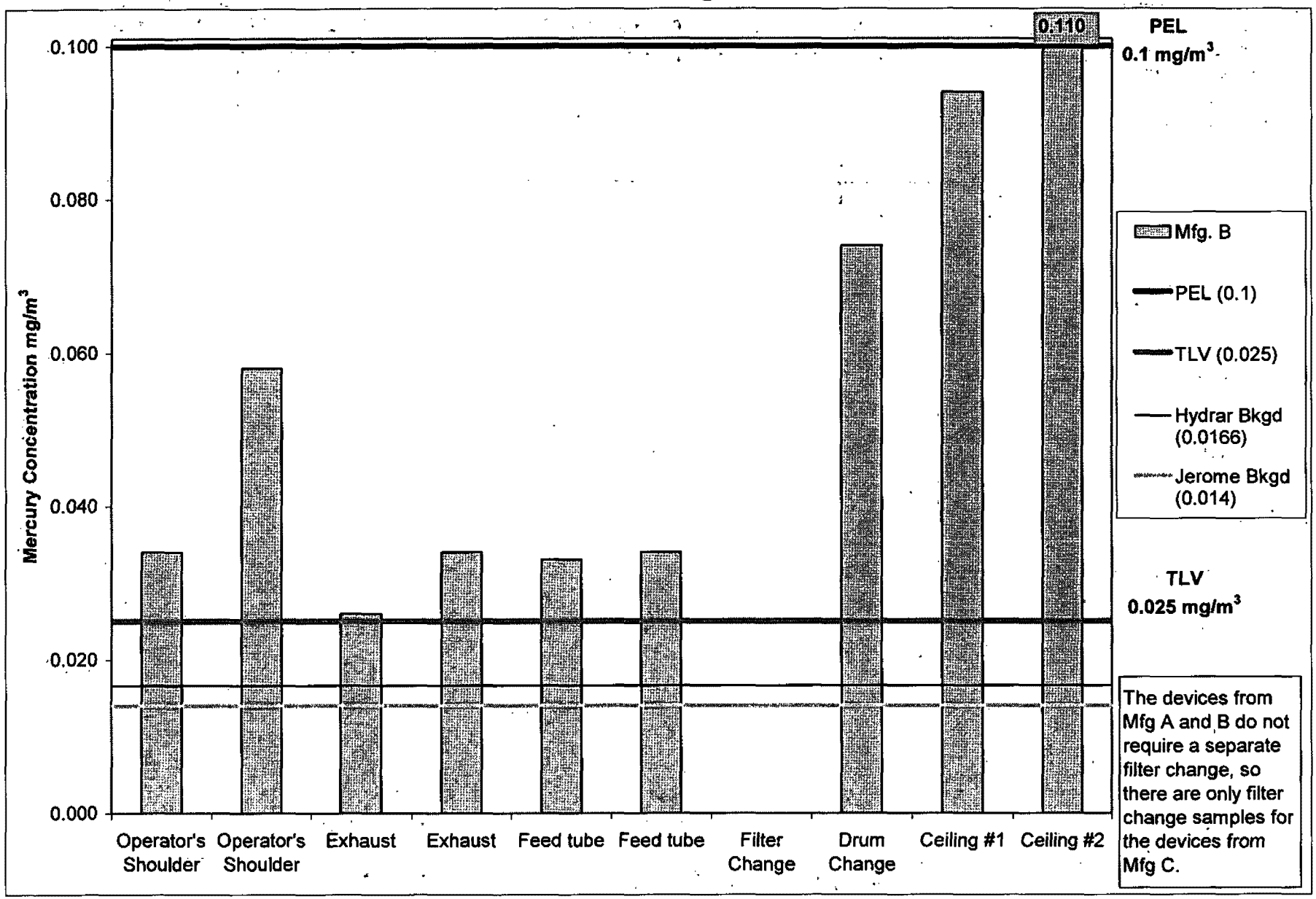
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 5: Performance Validation Study – Phase I Analytical Air Results
Manufacturer D – Ashland, Virginia – February 24-28, 2003



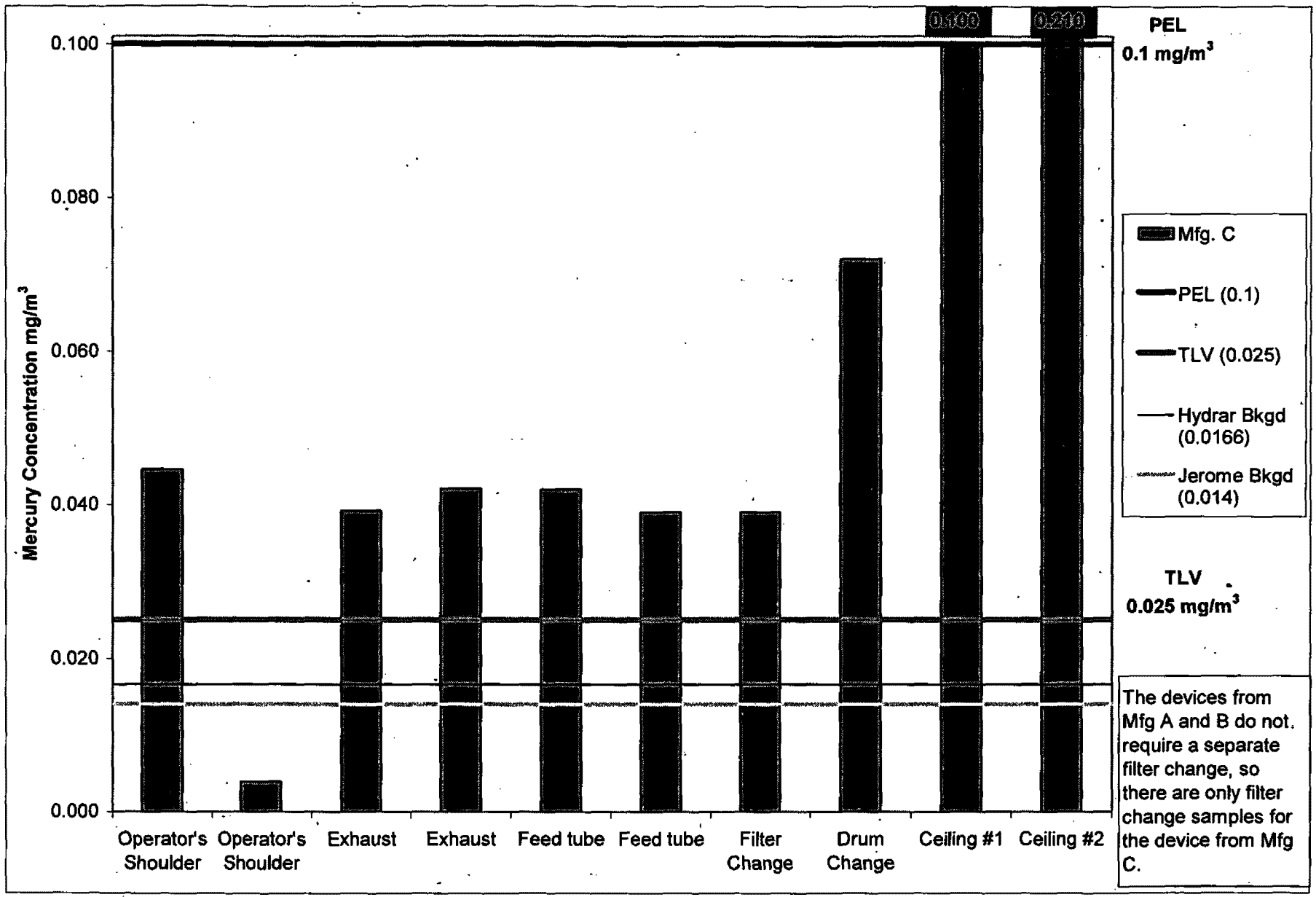
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 8: Performance Validation Study – Phase II Analytical Air Results
Manufacturer B – Ashland, Virginia – June 9-13, 2003



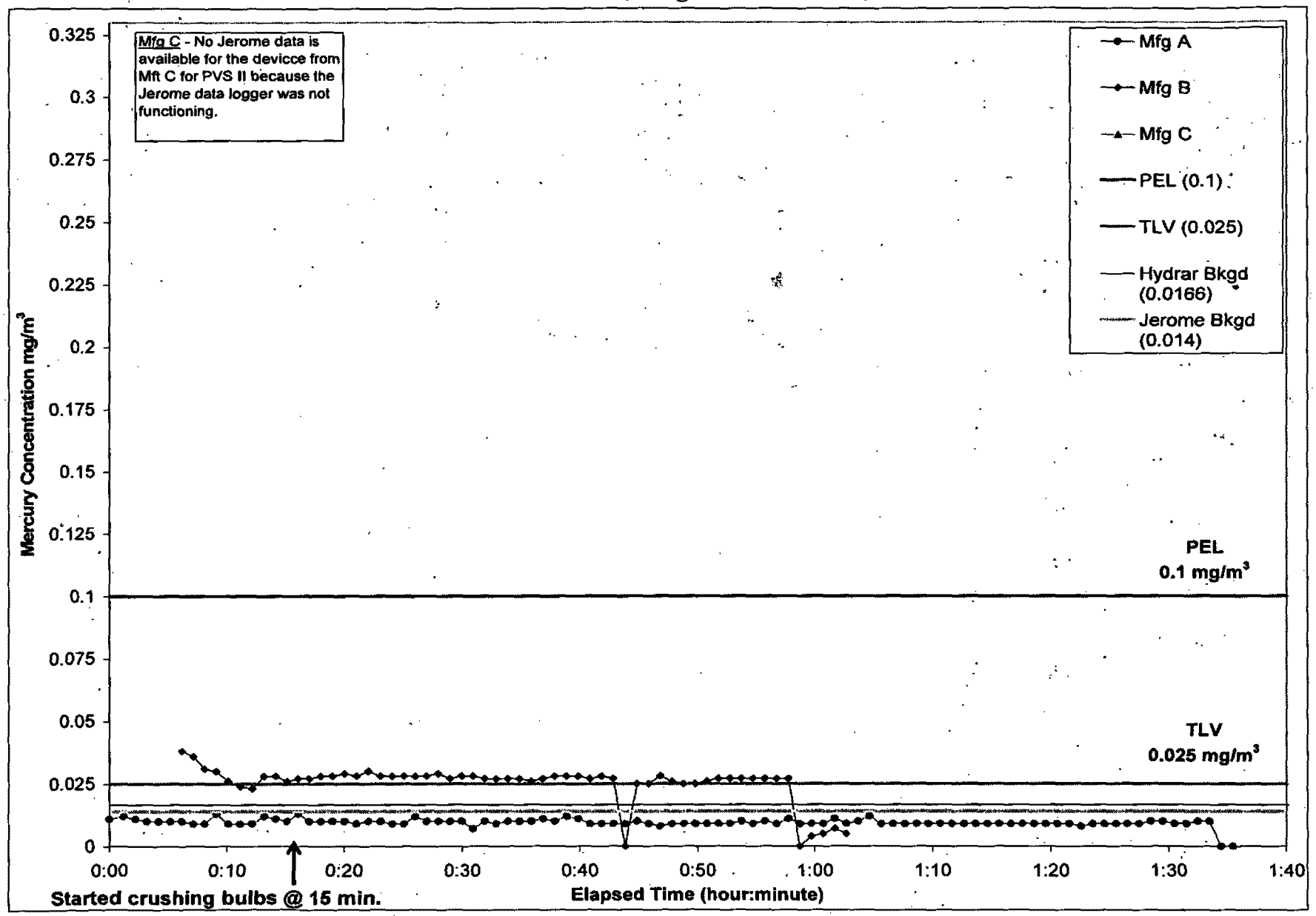
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 9: Performance Validation Study – Phase II Analytical Air Results
Manufacturer C – Ashland, Virginia – June 9-13, 2003



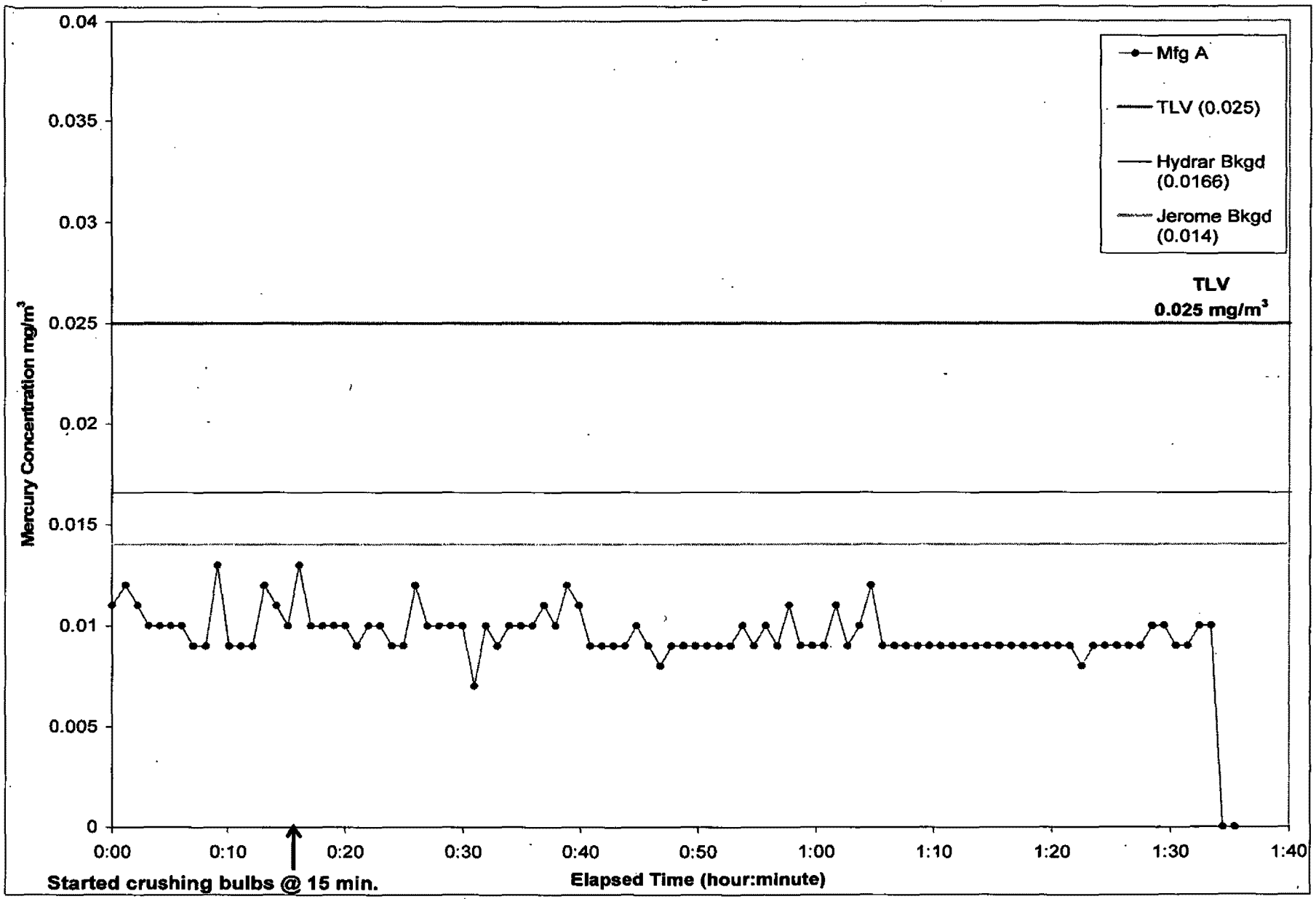
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 10: Performance Validation Study – Phase II Jerome Results
All Devices – Ashland, Virginia – June 9-13, 2003



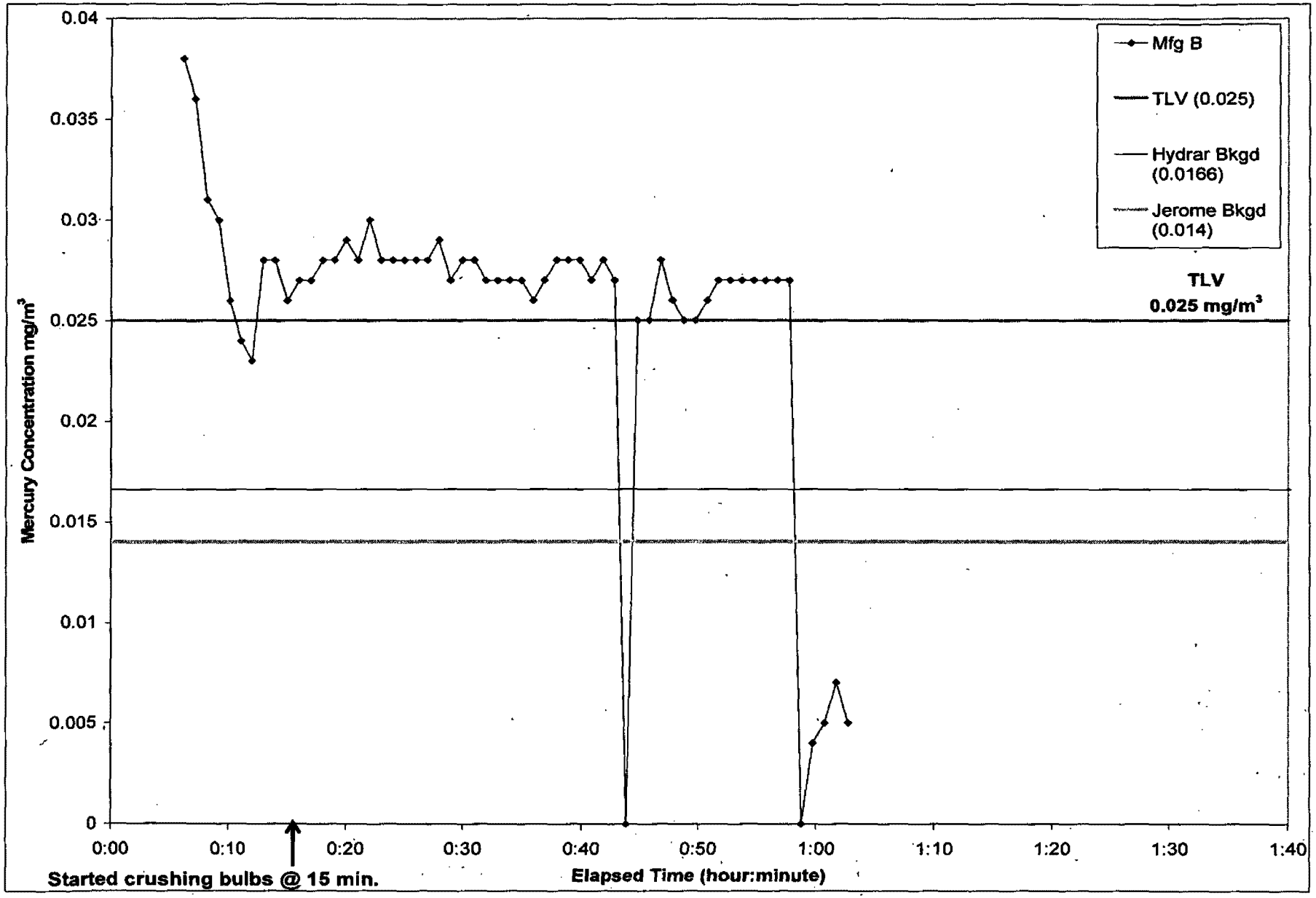
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 11: Performance Validation Study – Phase II Jerome Results
Manufacturer A – Ashland, Virginia – June 9-13, 2003



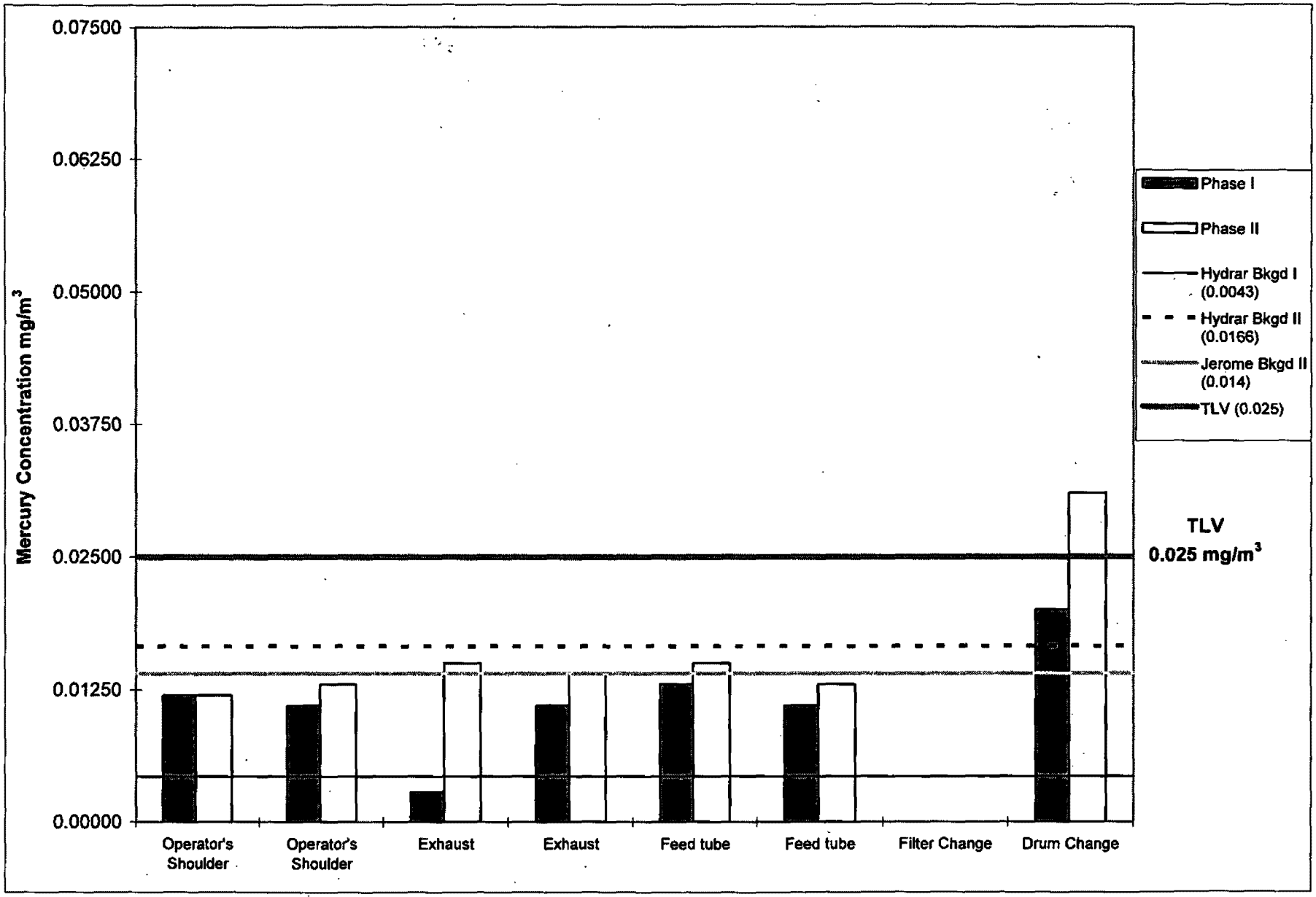
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 12: Performance Validation Study – Phase II Jerome Results
Manufacturer B – Ashland, Virginia – June 9-13, 2003



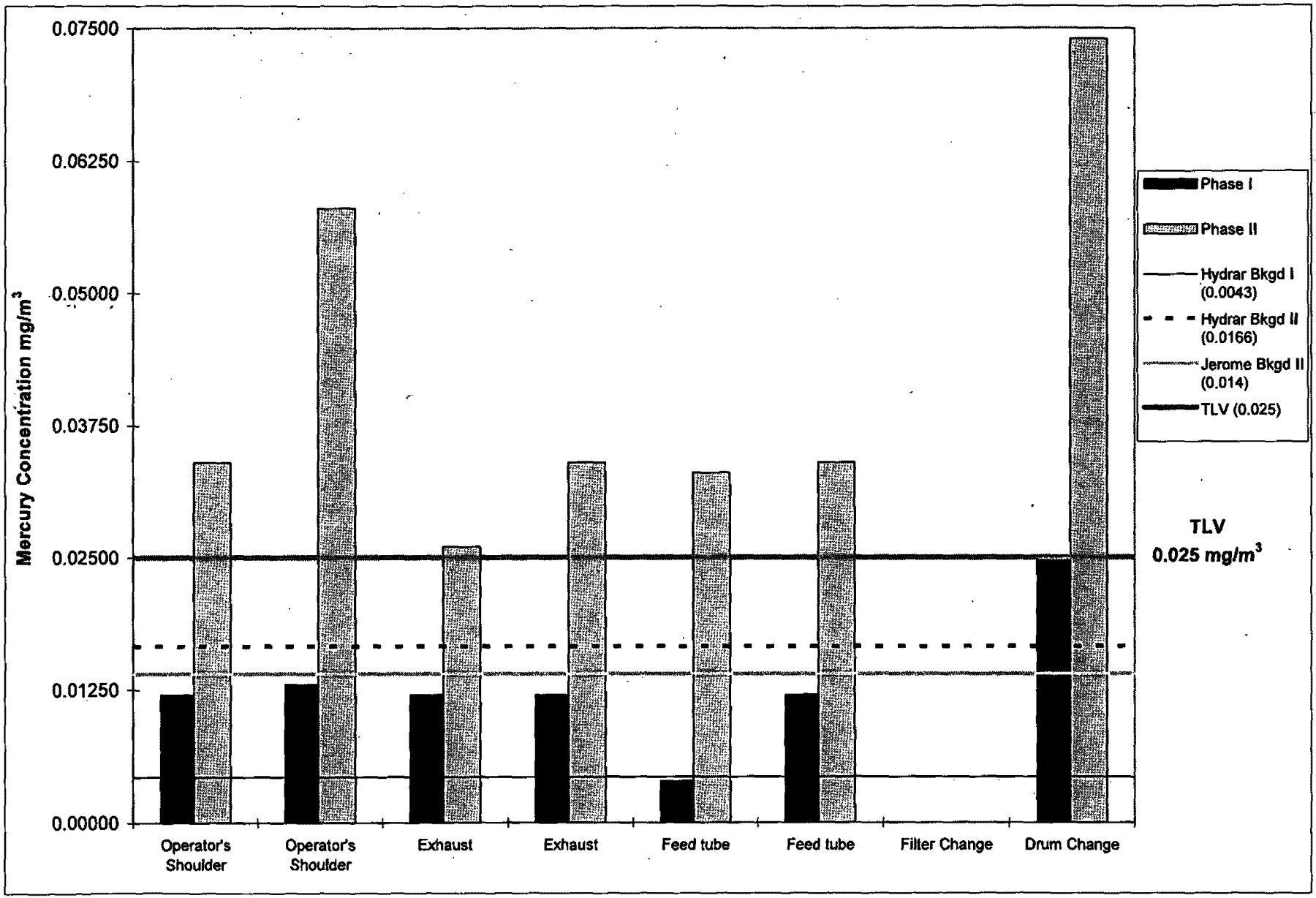
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 13: Performance Validation Study – Phase I and Phase II Analytical Air Results
Manufacturer A Device



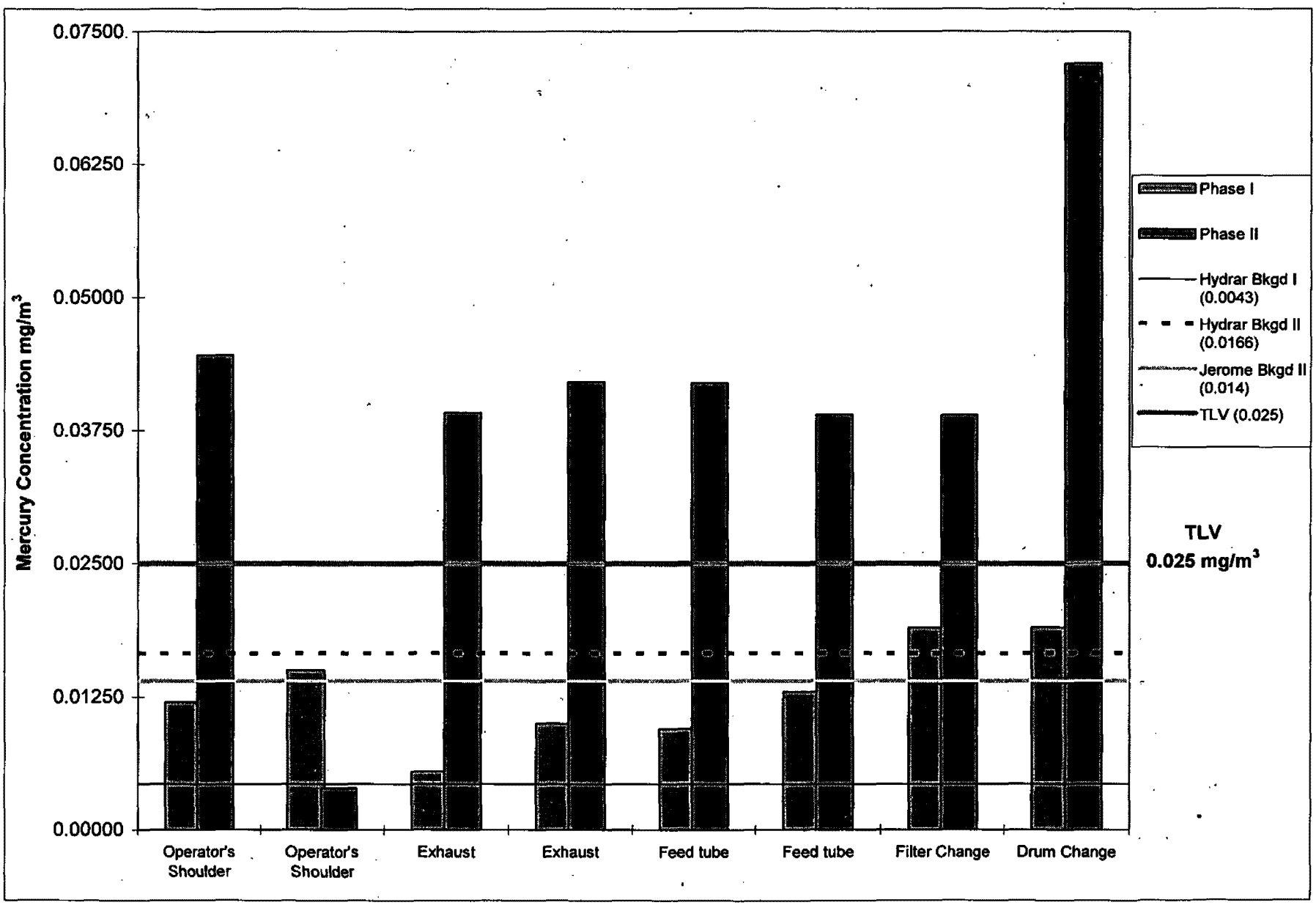
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 14: Performance Validation Study – Phase I and Phase II Analytical Air Results
Manufacturer B Device



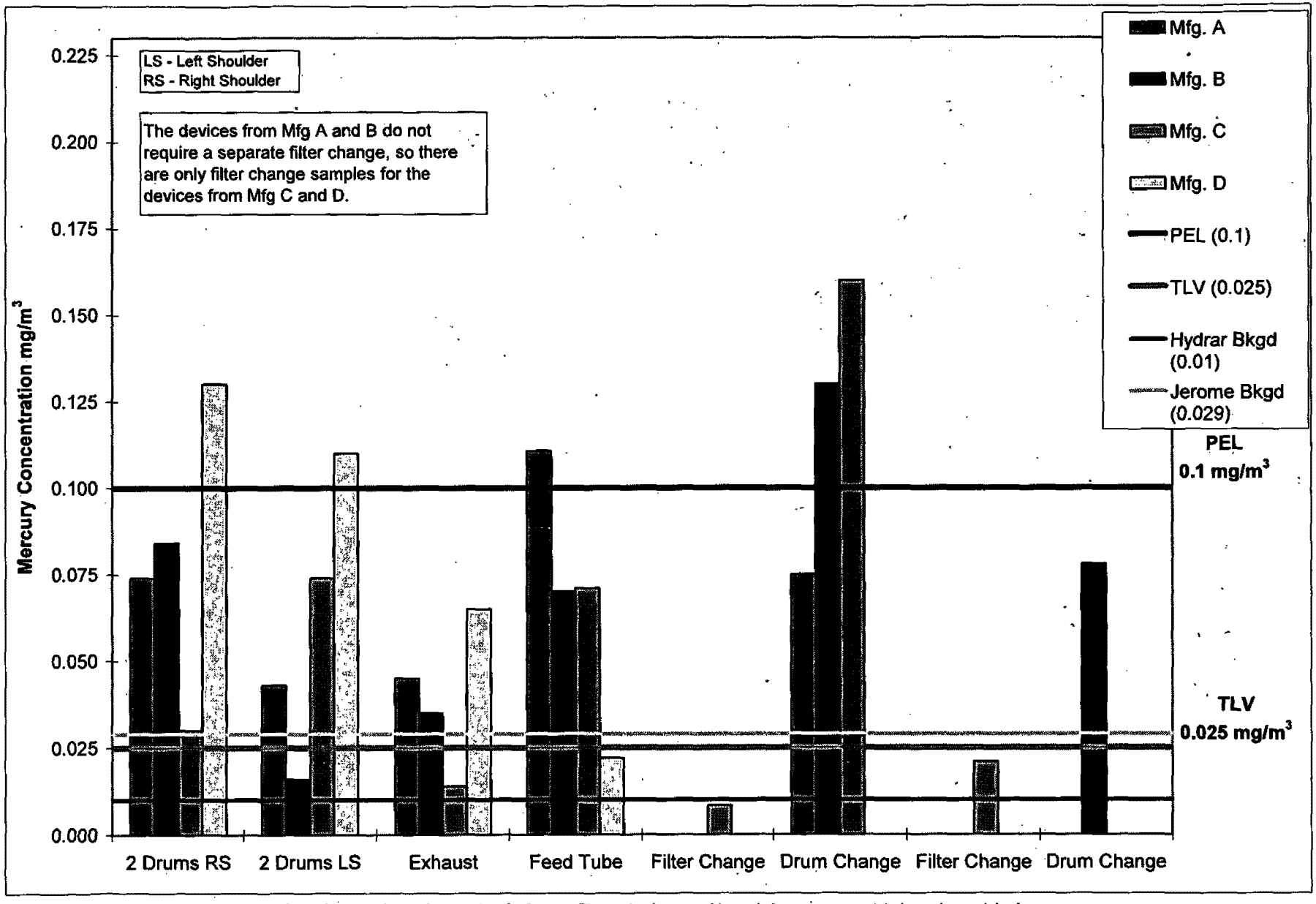
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 15: Performance Validation Study – Phase I and Phase II Analytical Air Results Manufacturer C Device



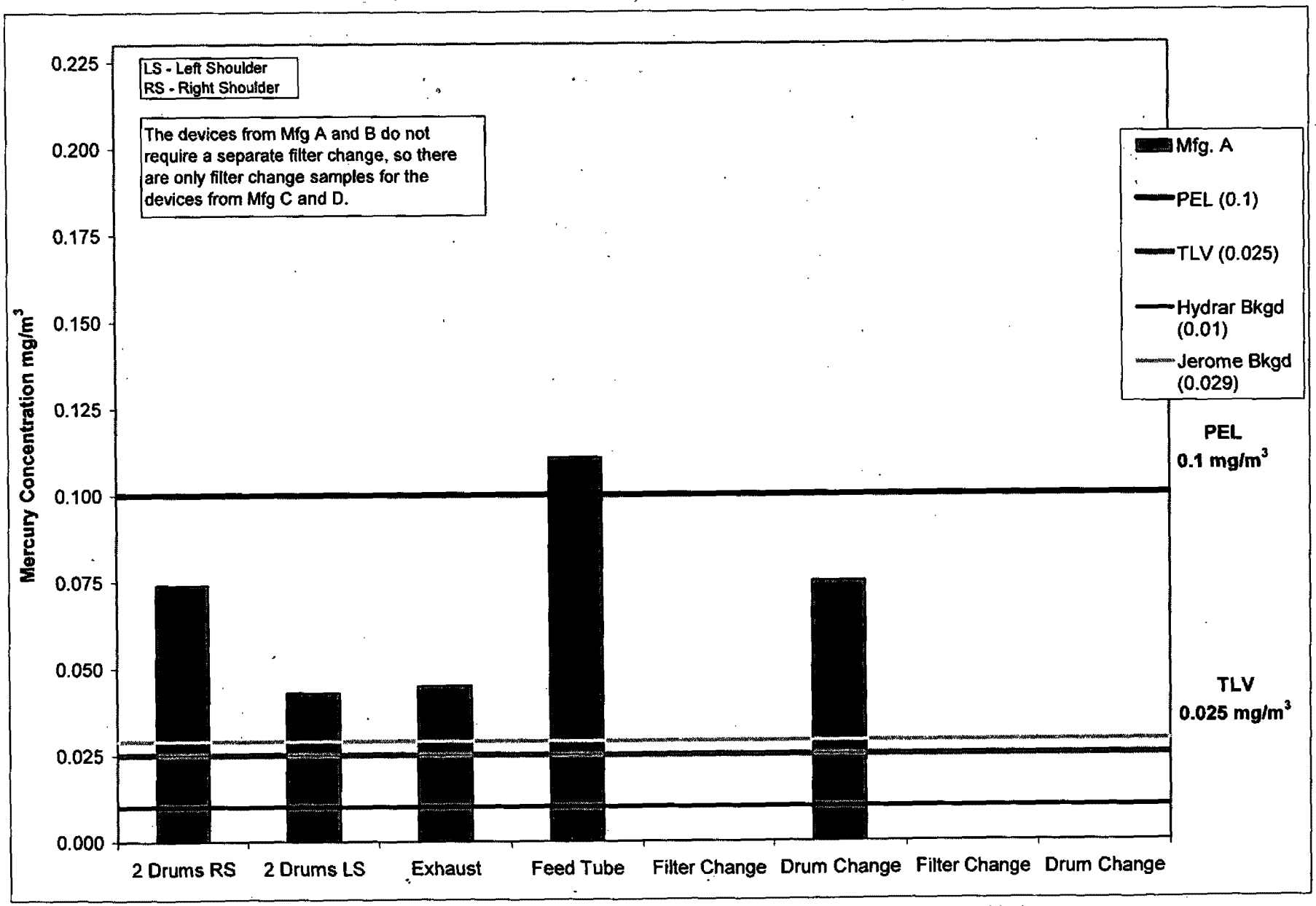
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 16: Extended Field Test #1 Analytical Air Results
All Devices – Phoenix, Arizona – March 24-28, 2003



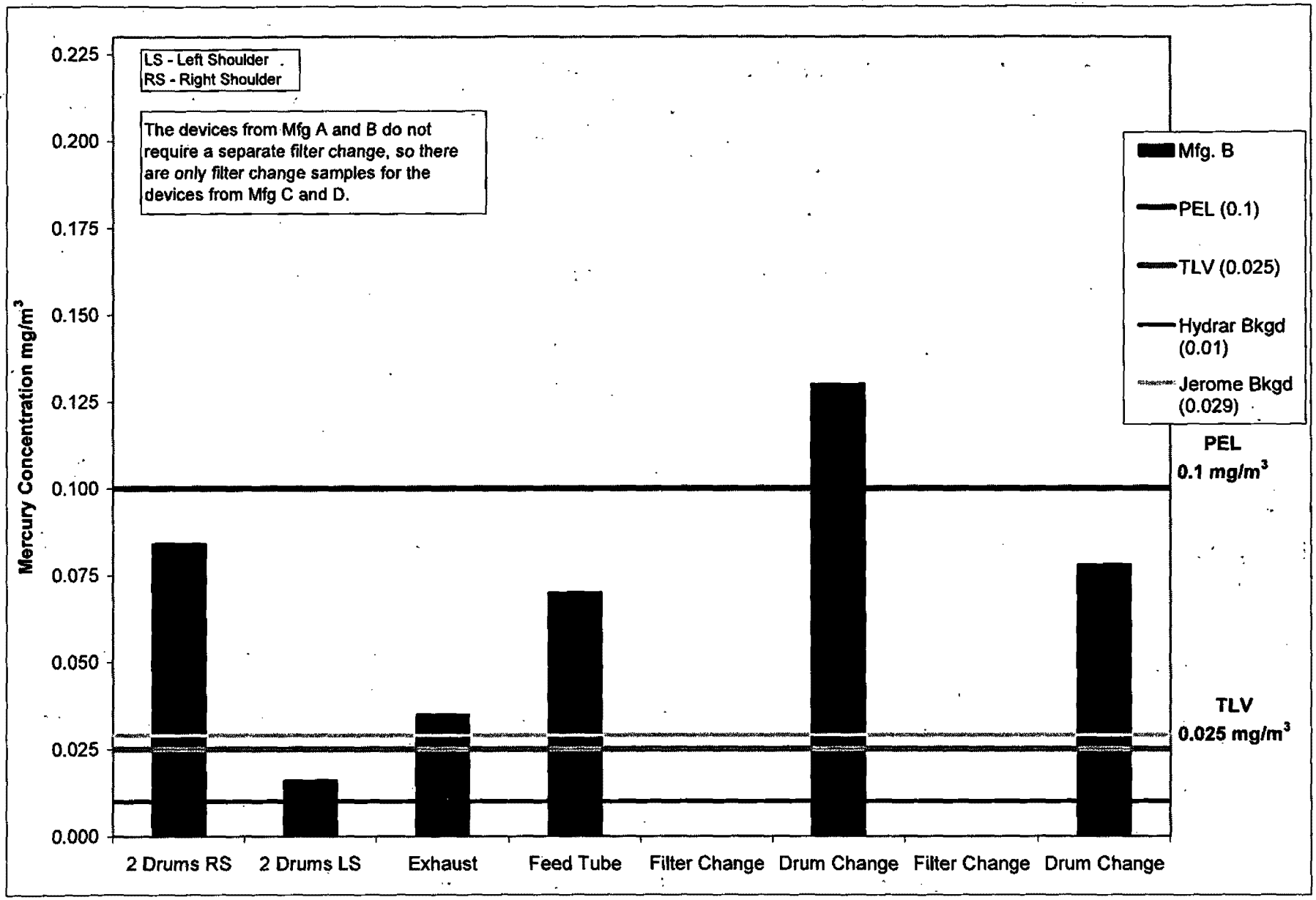
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 17: Extended Field Test #1 Analytical Air Results
Manufacturer A – Phoenix, Arizona – March 24-28, 2003



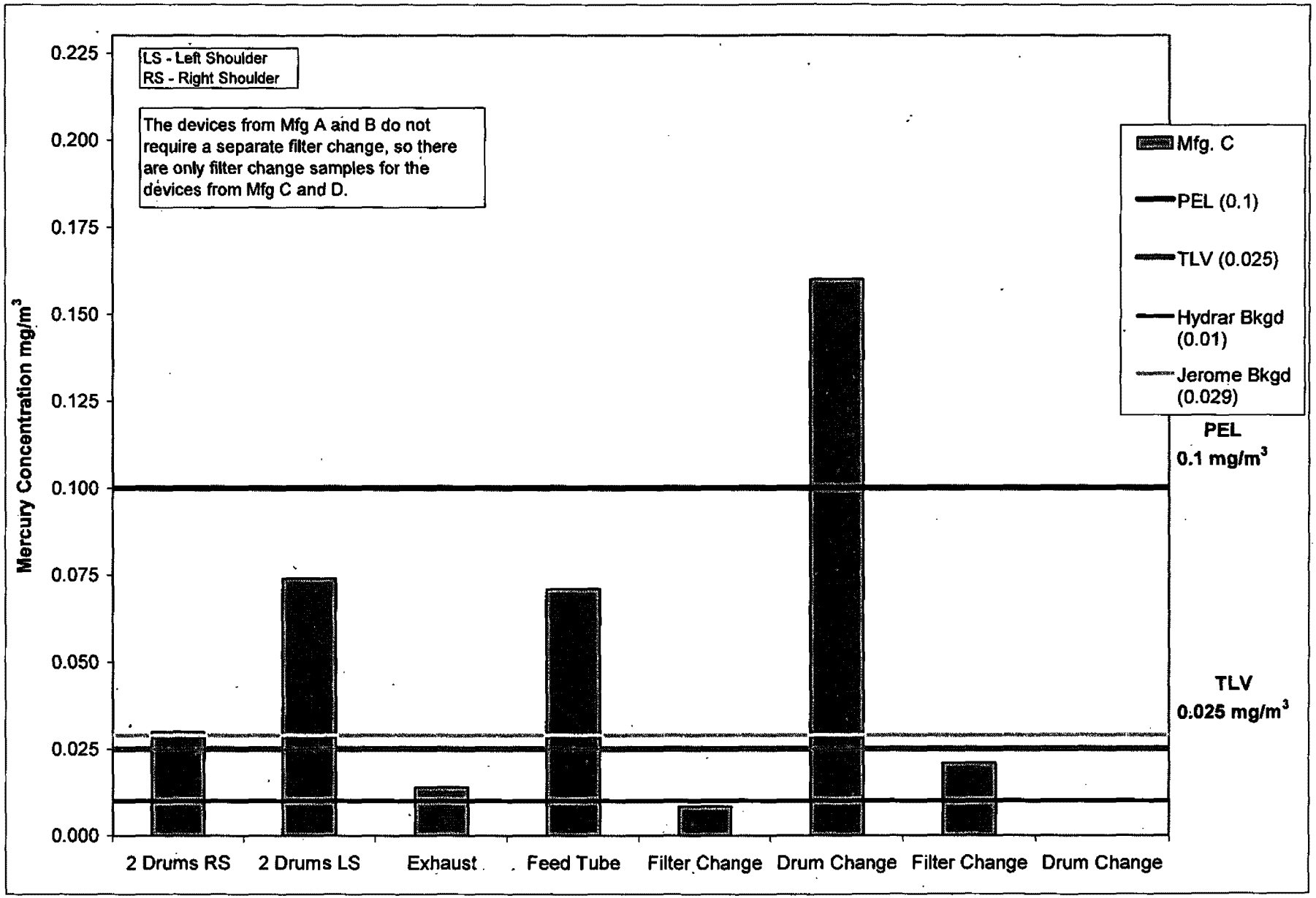
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 18: Extended Field Test #1 Analytical Air Results
Manufacturer B – Phoenix, Arizona – March 24-28, 2003



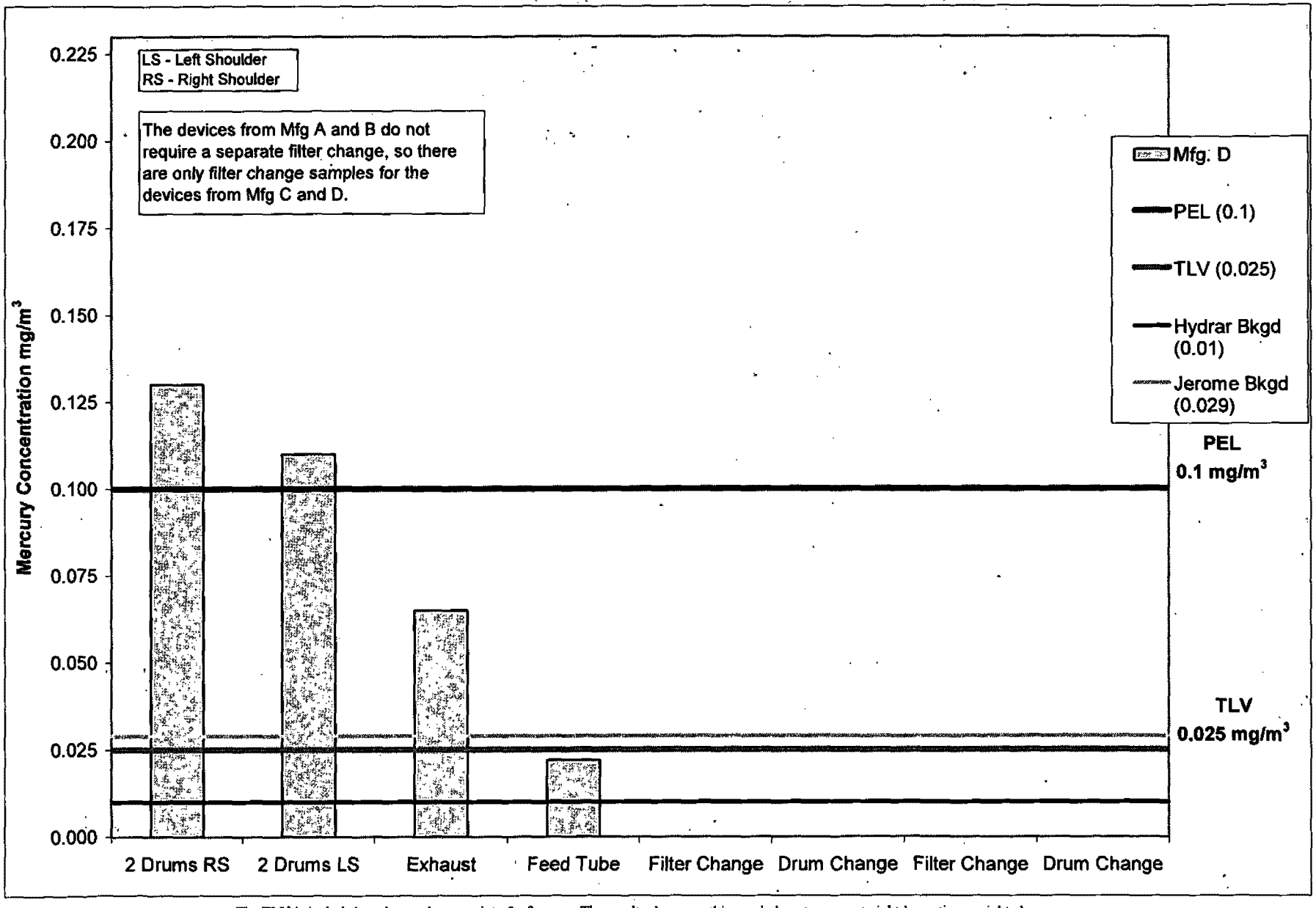
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 19: Extended Field Test #1 Analytical Air Results
Manufacturer C – Phoenix, Arizona – March 24-28, 2003



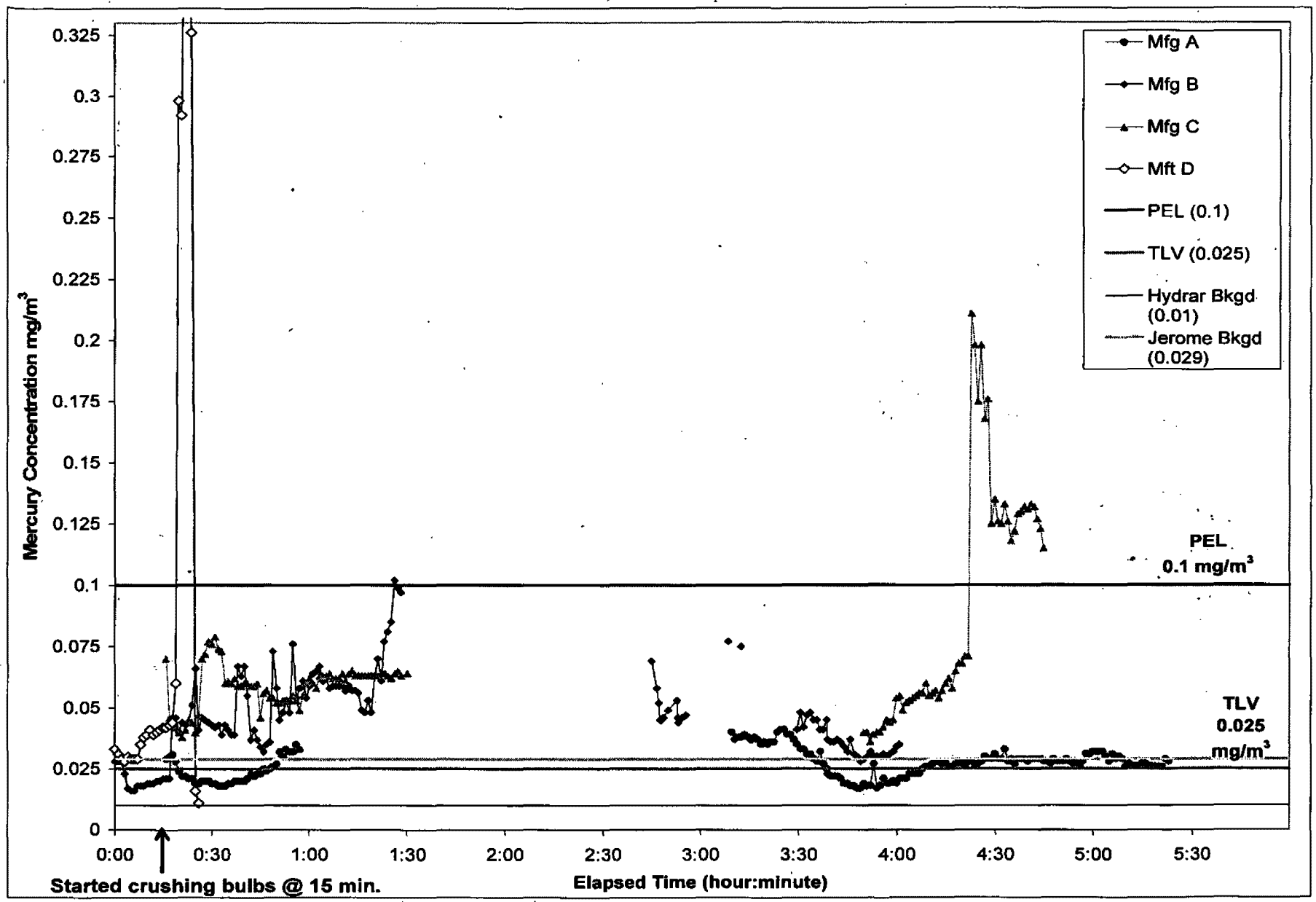
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 20: Extended Field Test #1 Analytical Air Results
Manufacturer D – Phoenix, Arizona – March 24-28, 2003



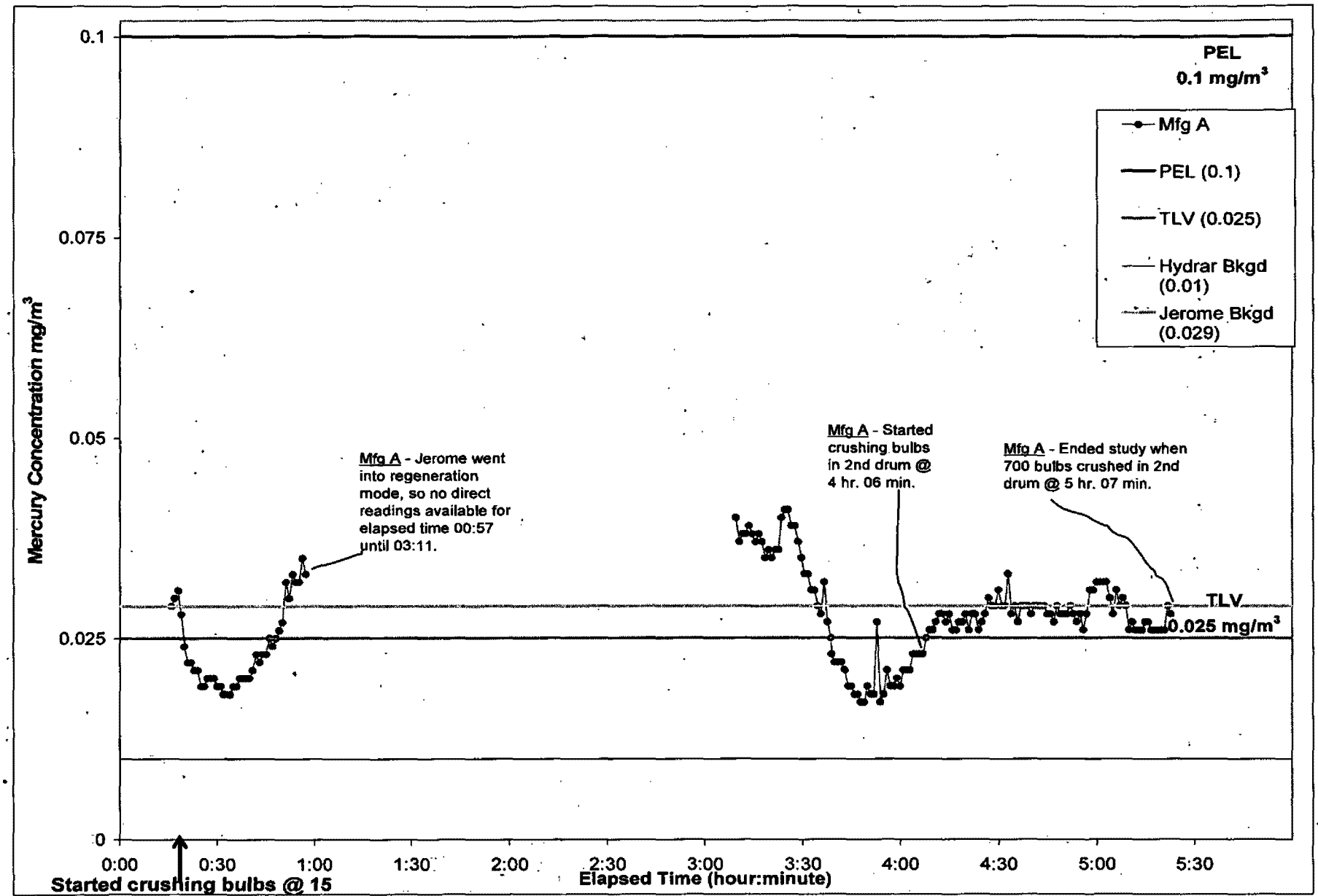
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 21: Extended Field Test #1 Jerome Results
All Devices – Phoenix, Arizona – March 24-28, 2003



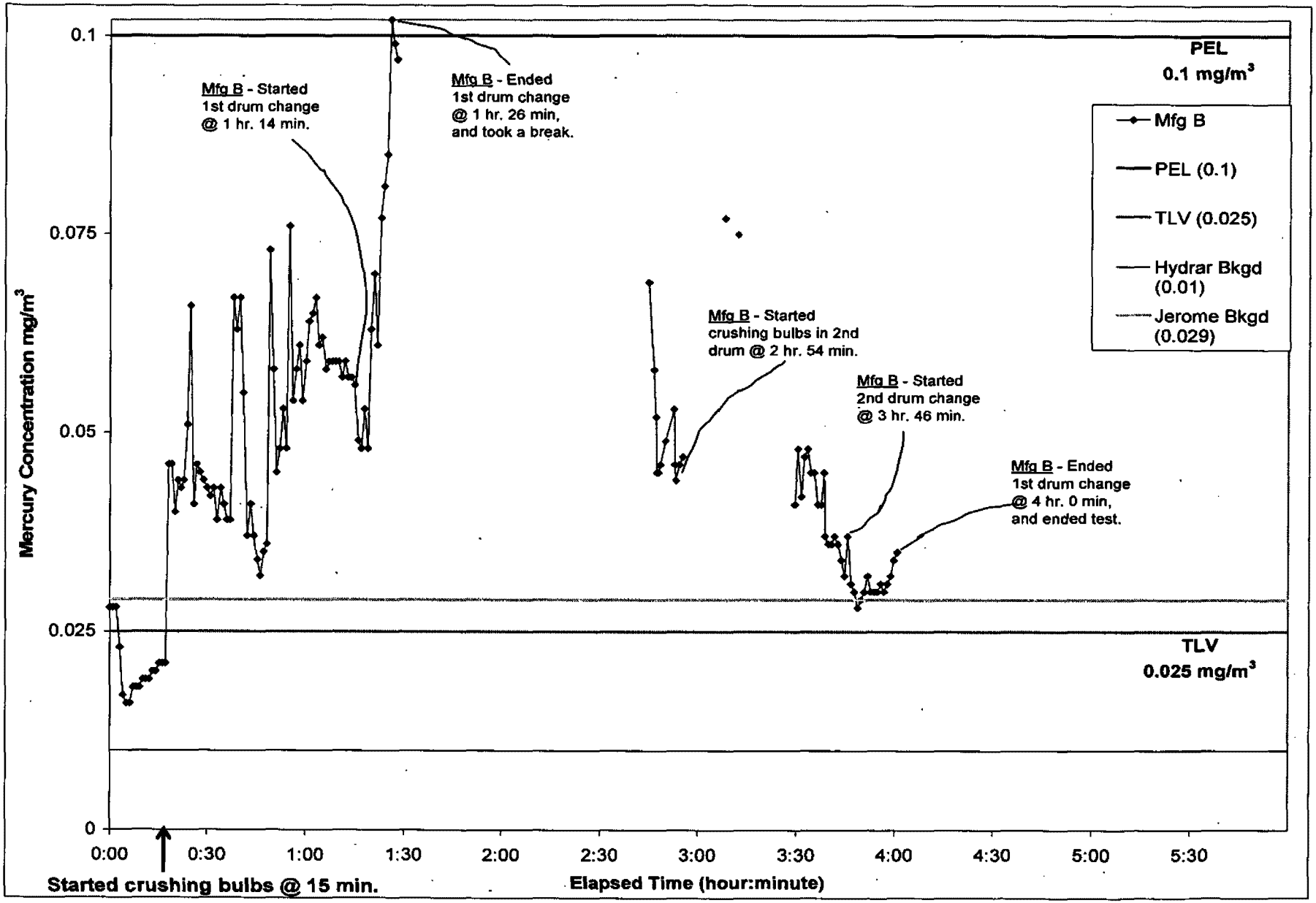
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 22: Extended Field Test #1 Jerome Results
Manufacturer A – Phoenix, Arizona – March 24-28, 2003



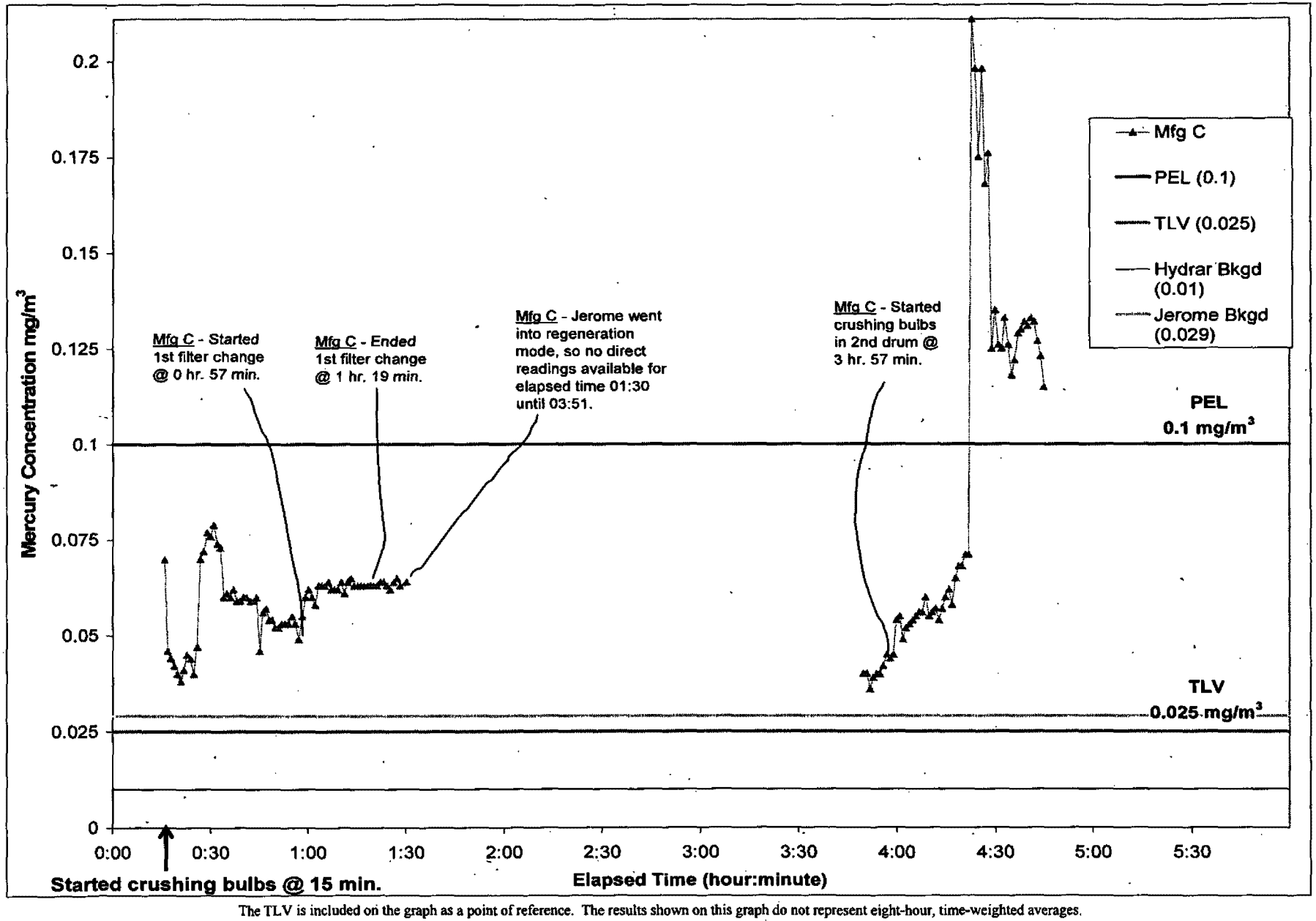
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 23: Extended Field Test #1 Jerome Results
Manufacturer B – Phoenix, Arizona – March 24-28, 2003



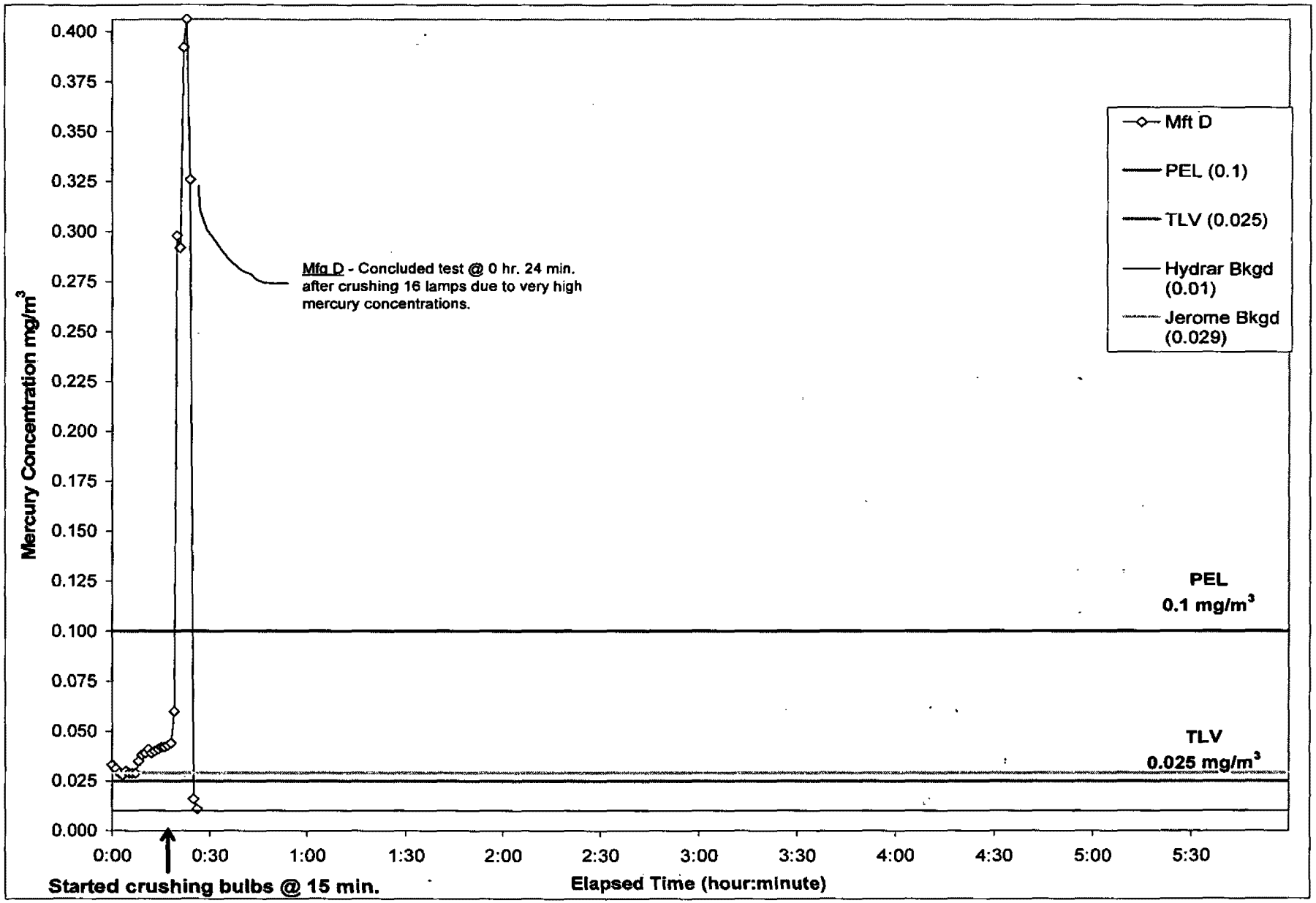
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 24: Extended Field Test #1 Jerome Results
Manufacturer C – Phoenix, Arizona – March 24-28, 2003



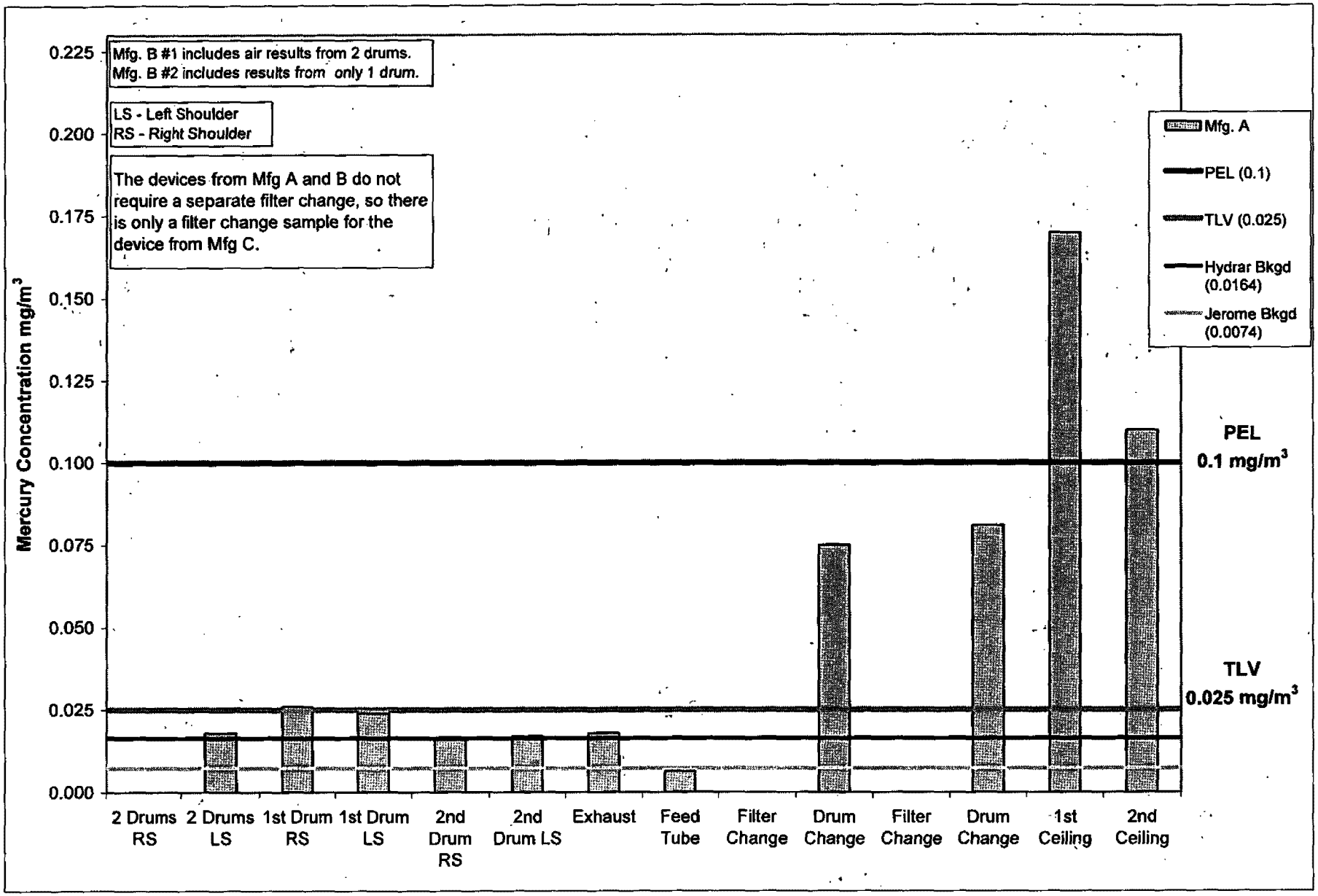
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 25: Extended Field Test #1 Jerome Results
Manufacturer D – Phoenix, Arizona – March 24-28, 2003



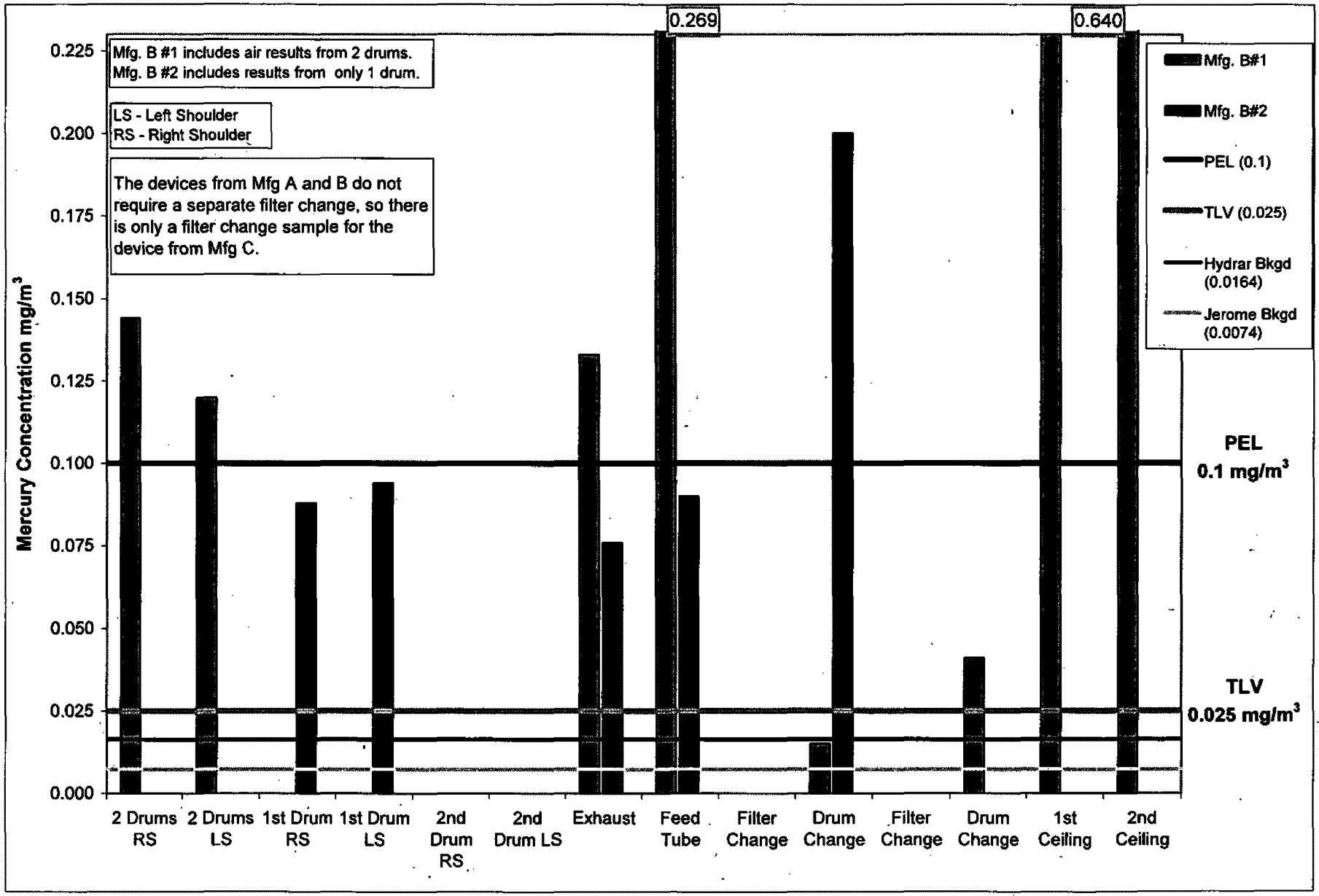
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 28: Extended Field Test #2 Analytical Air Results
Manufacturer A – Melbourne, Florida – April 28-May 2, 2003



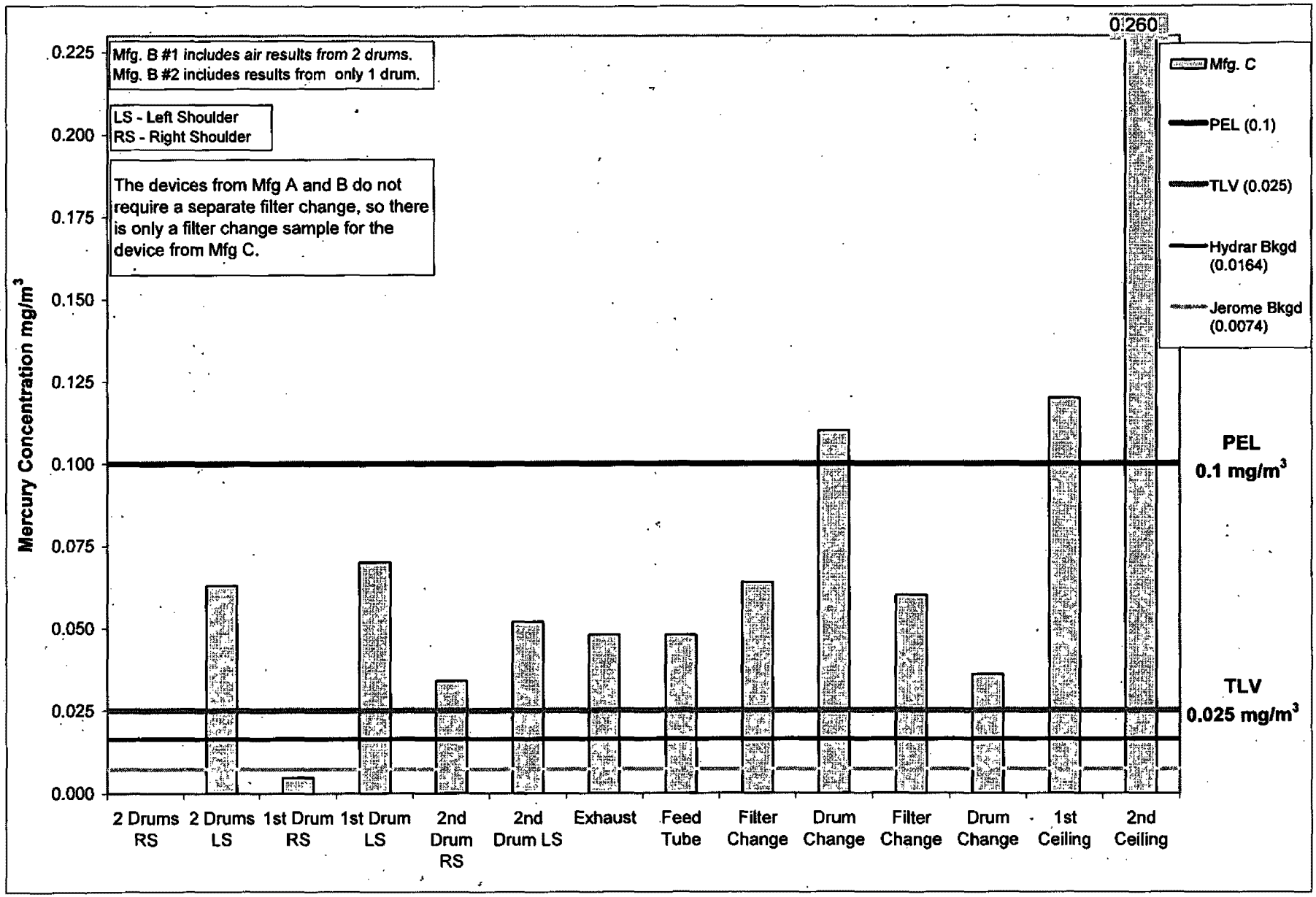
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 29: Extended Field Test #2 Analytical Air Results
Manufacturer B – Melbourne, Florida – April 28-May 2, 2003



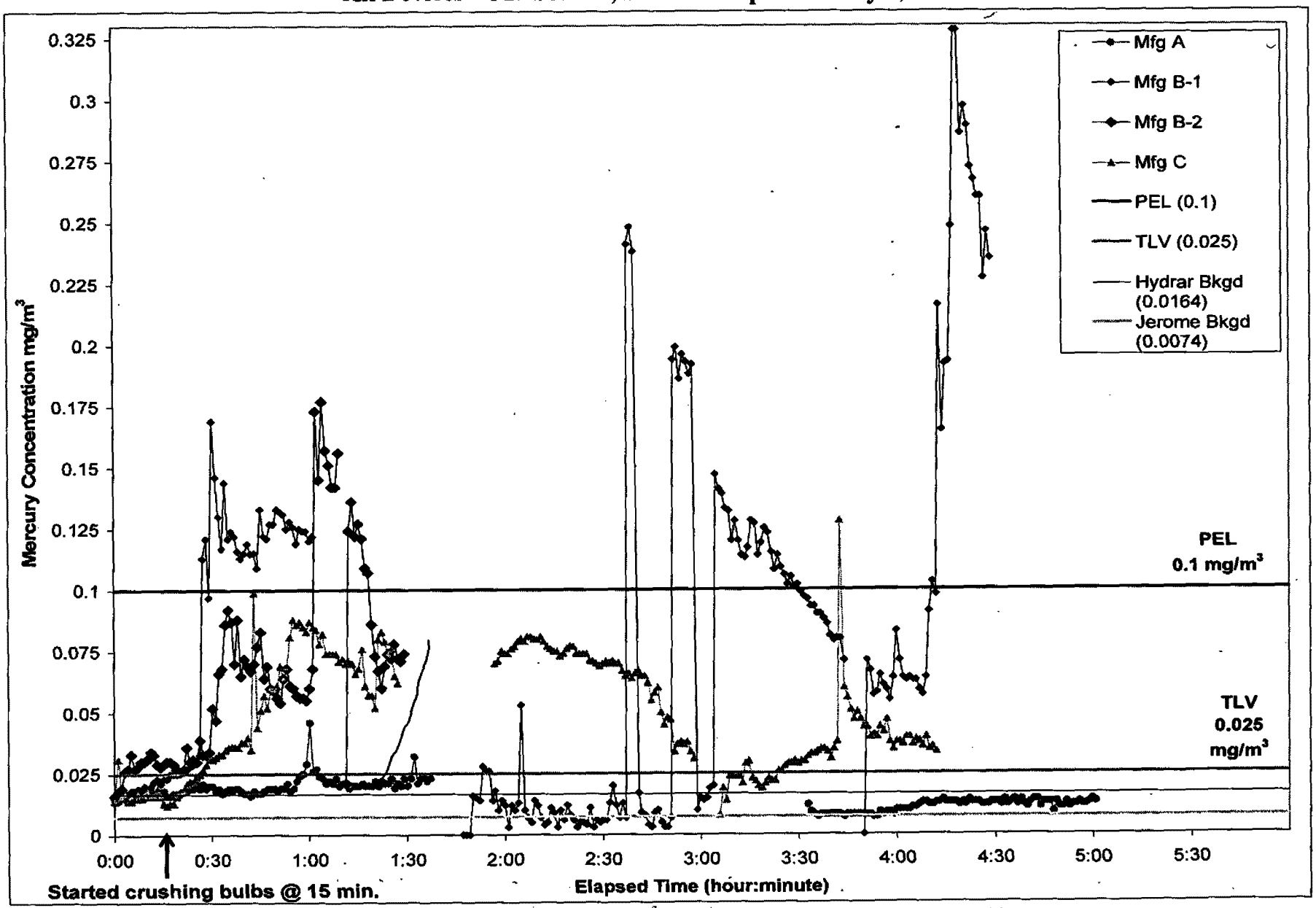
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 30: Extended Field Test #2 Analytical Air Results
Manufacturer C – Melbourne, Florida – April 28-May 2, 2003



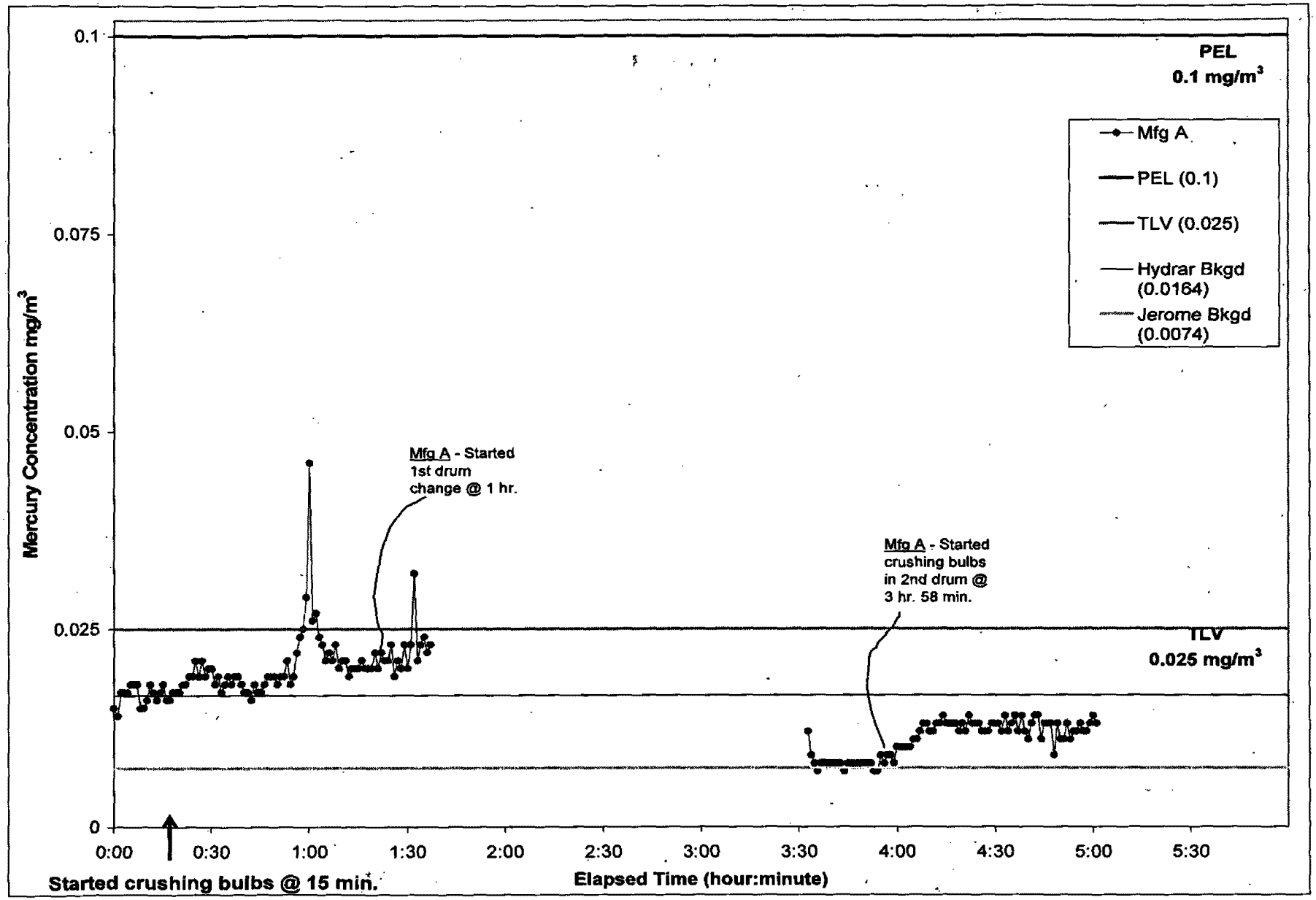
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 31: Extended Field Test #2 Jerome Results
All Devices – Melbourne, Florida – April 28-May 2, 2003



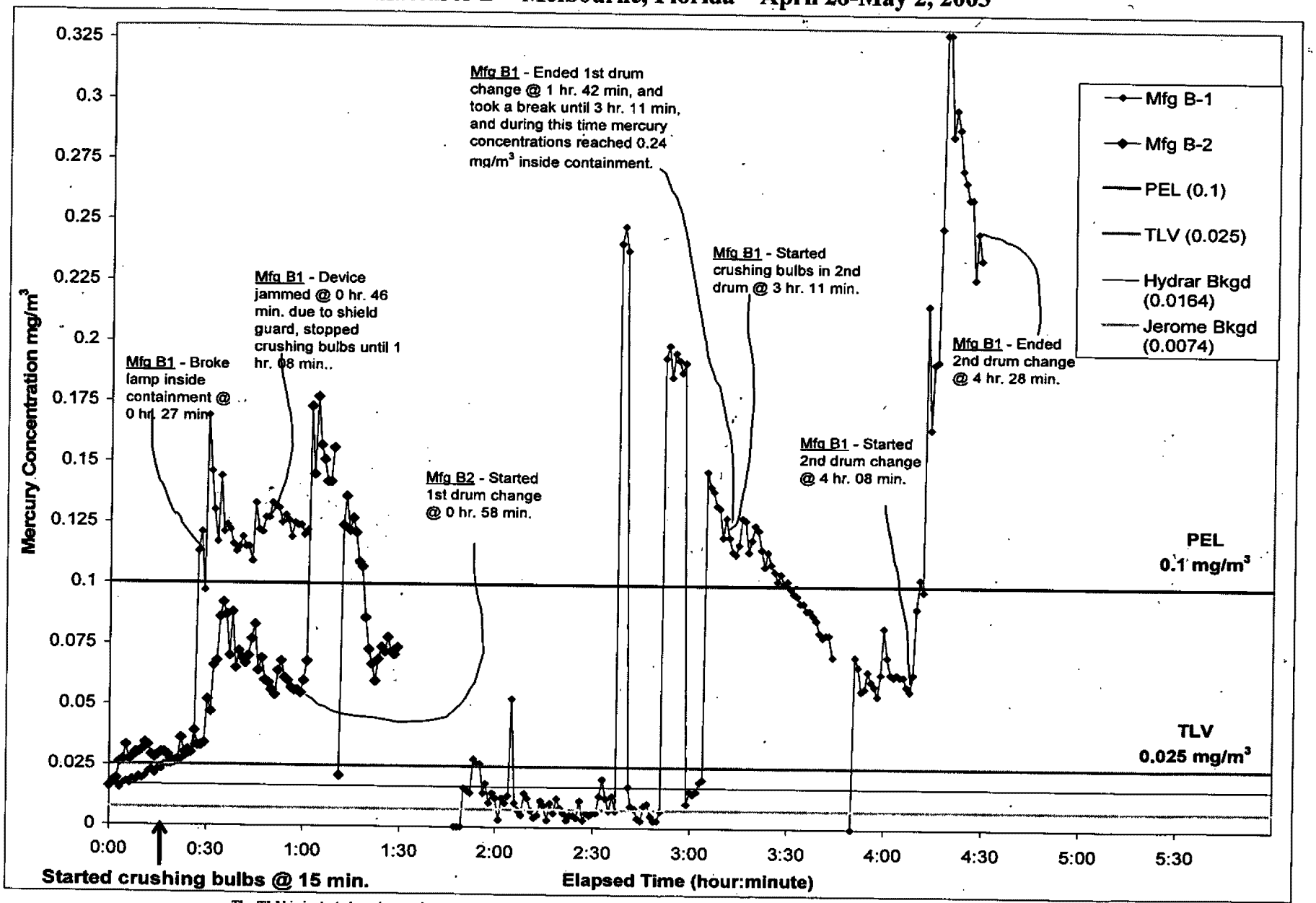
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 32: Extended Field Test #2 Jerome Results
Manufacturer A – Melbourne, Florida – April 28-May 2, 2003



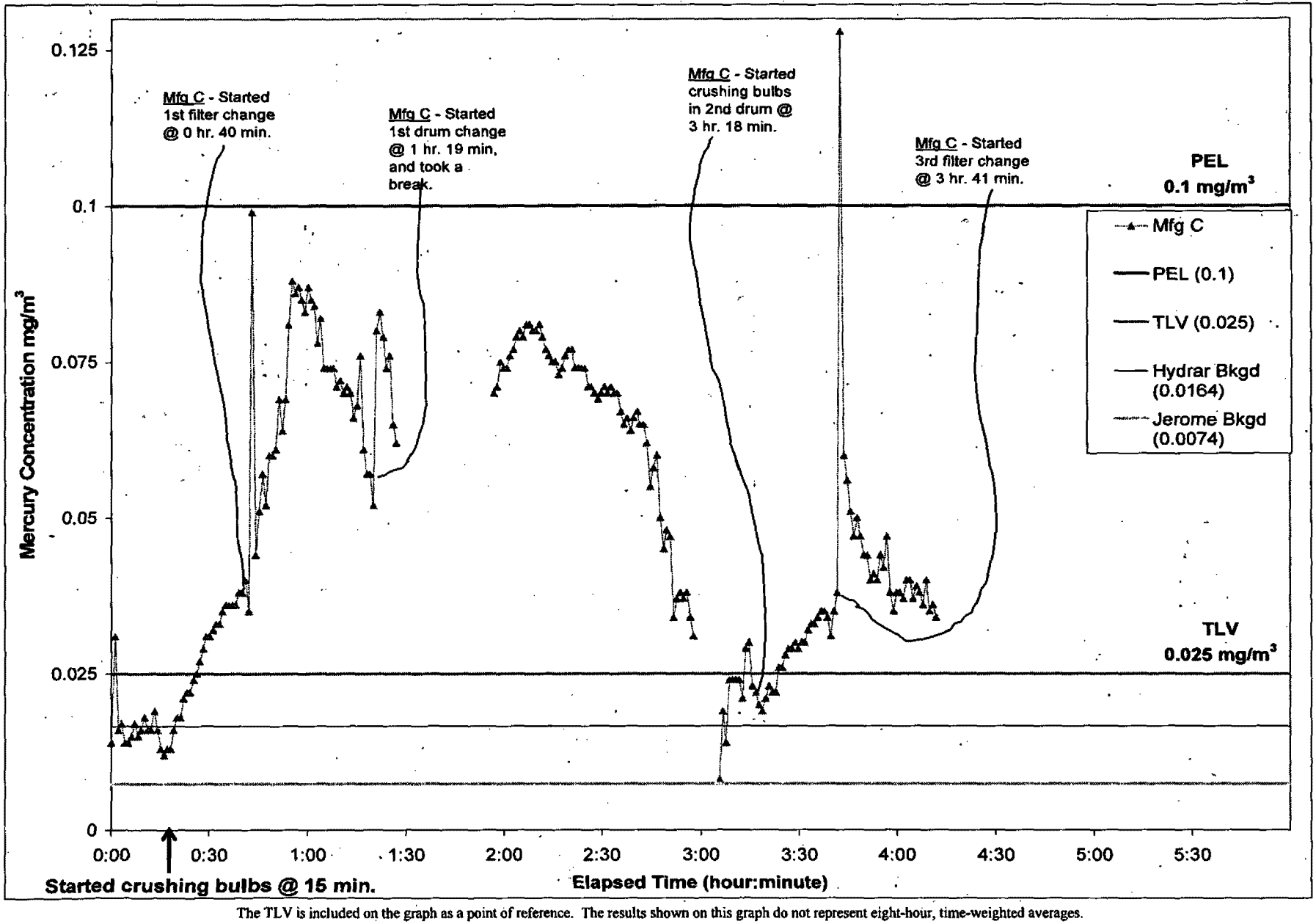
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 33: Extended Field Test #2 Jerome Results
Manufacturer B – Melbourne, Florida – April 28-May 2, 2003



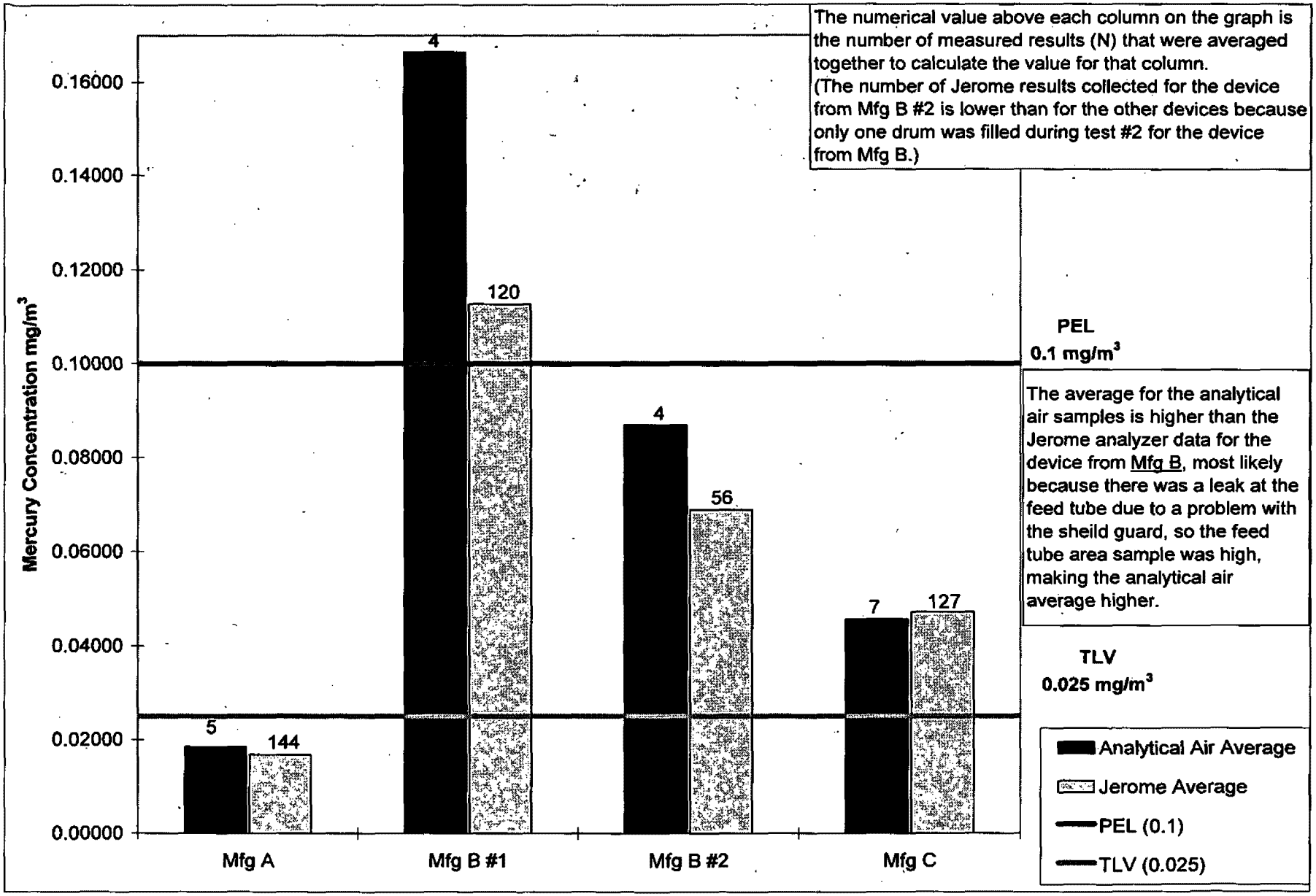
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 34: Extended Field Test #2 Jerome Results
Manufacturer C – Melbourne, Florida – April 28-May 2, 2003



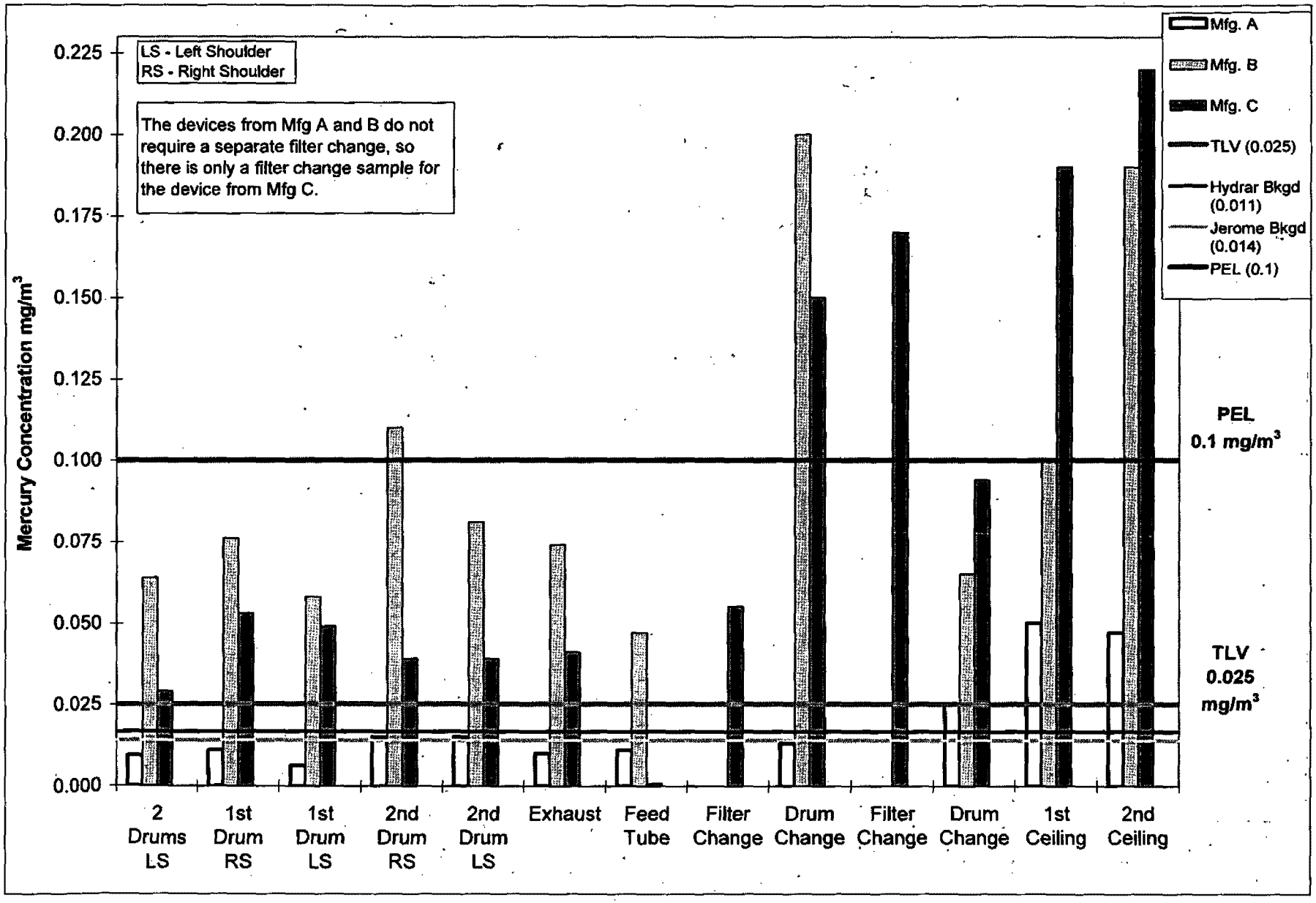
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 35: Extended Field Test #2 – Comparison of Analytical Air and Jerome Results All Devices – Melbourne, Florida – April 28-May 2, 2003



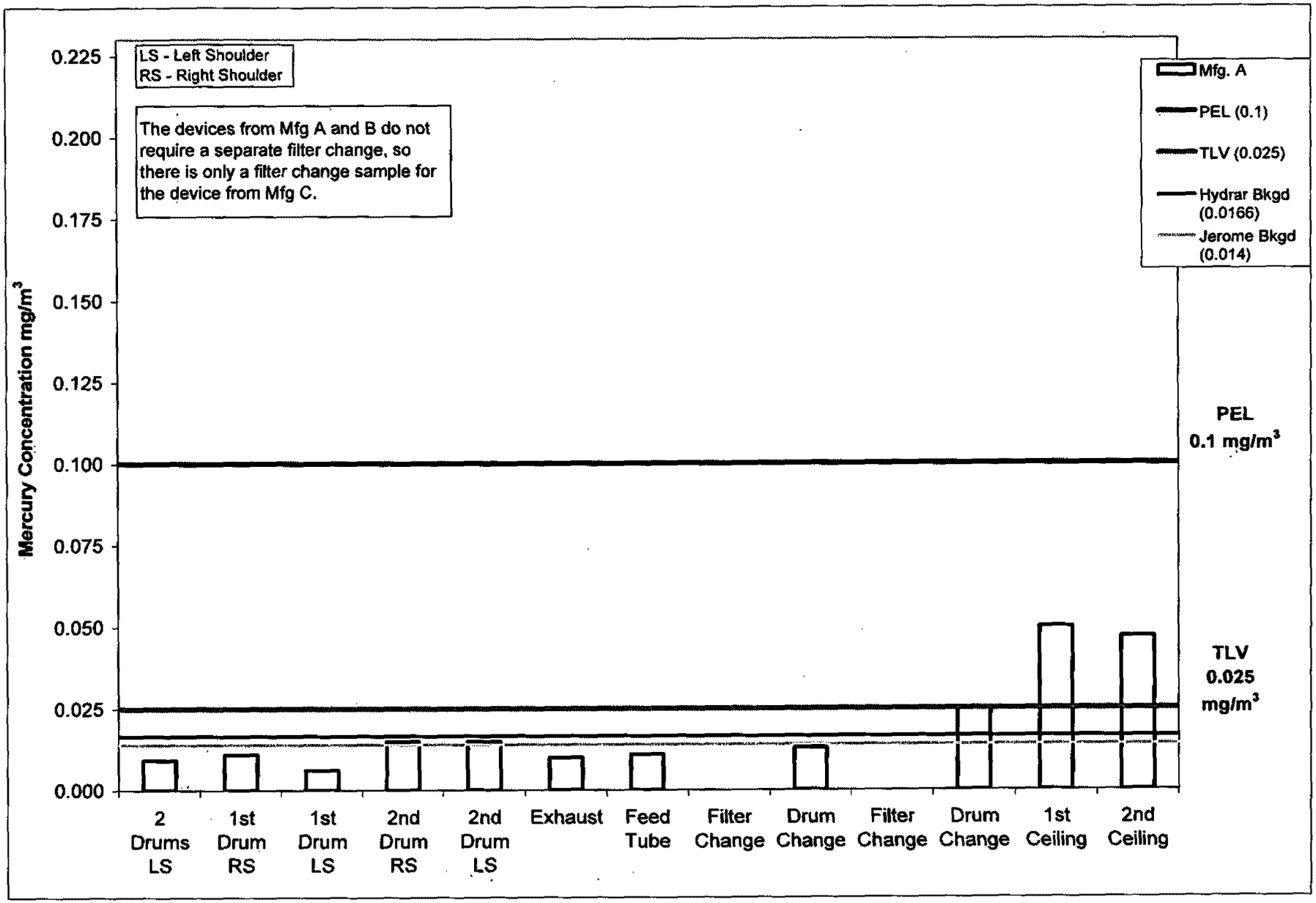
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 36: Extended Field Test #3 Analytical Air Results
All Devices – Ashland, Virginia – June 9-13, 2003



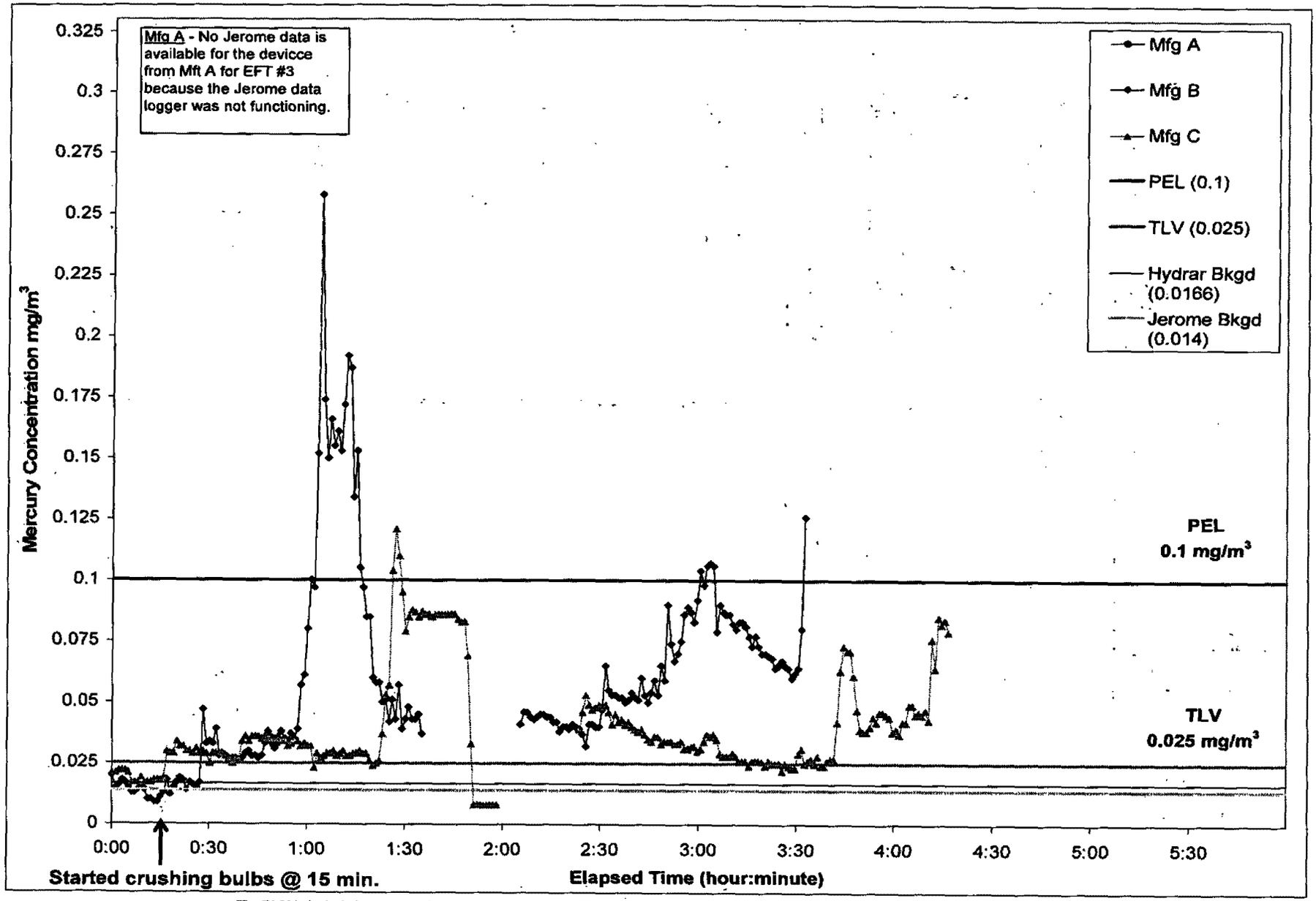
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 37: Extended Field Test #3 Analytical Air Results
Manufacturer A – Ashland, Virginia – June 9-13, 2003



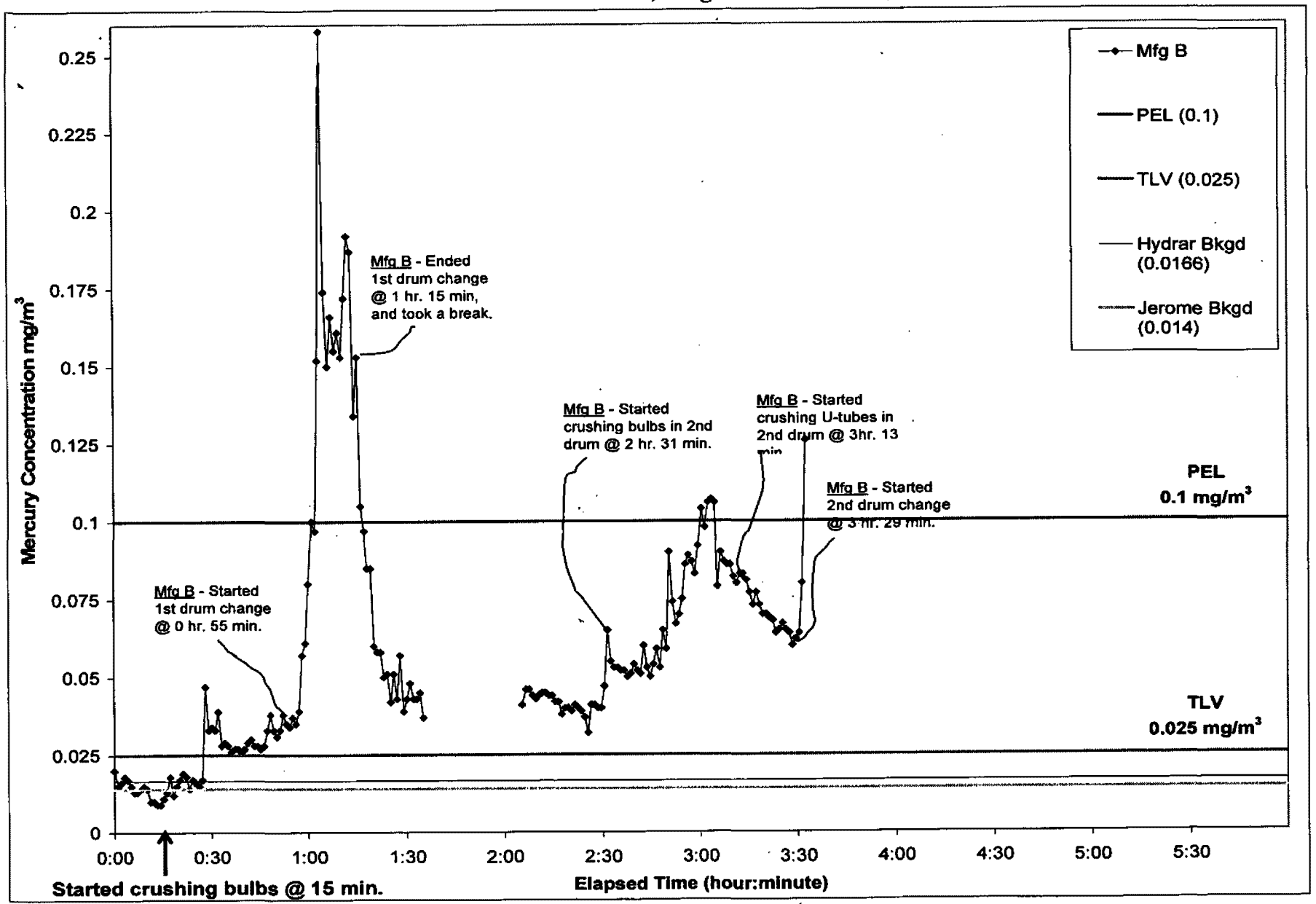
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 40: Extended Field Test #3 Jerome Results
All Devices – Ashland, Virginia – June 9-13, 2003



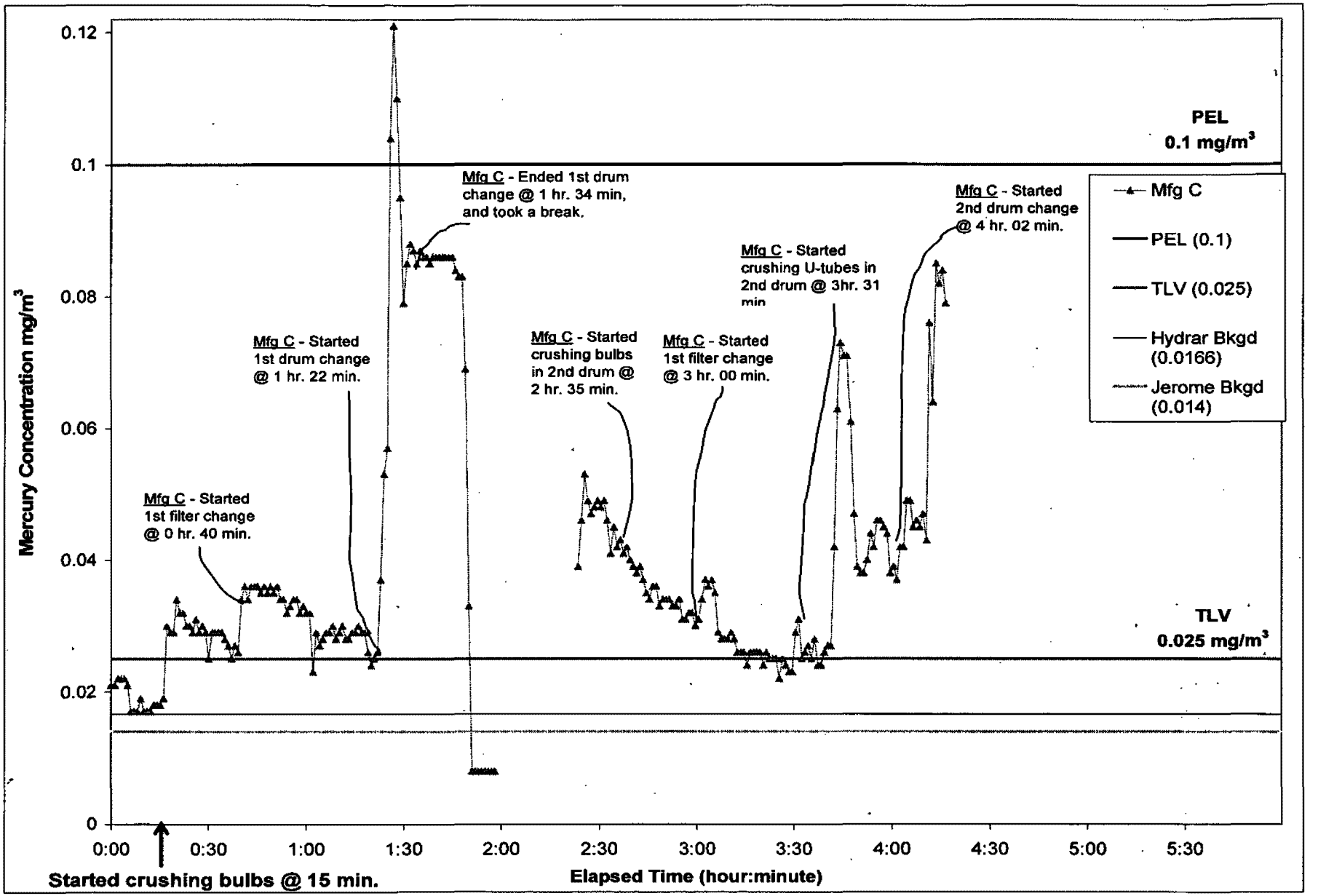
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 41: Extended Field Test #3 Jerome Results
Manufacturer B – Ashland, Virginia – June 9-13, 2003



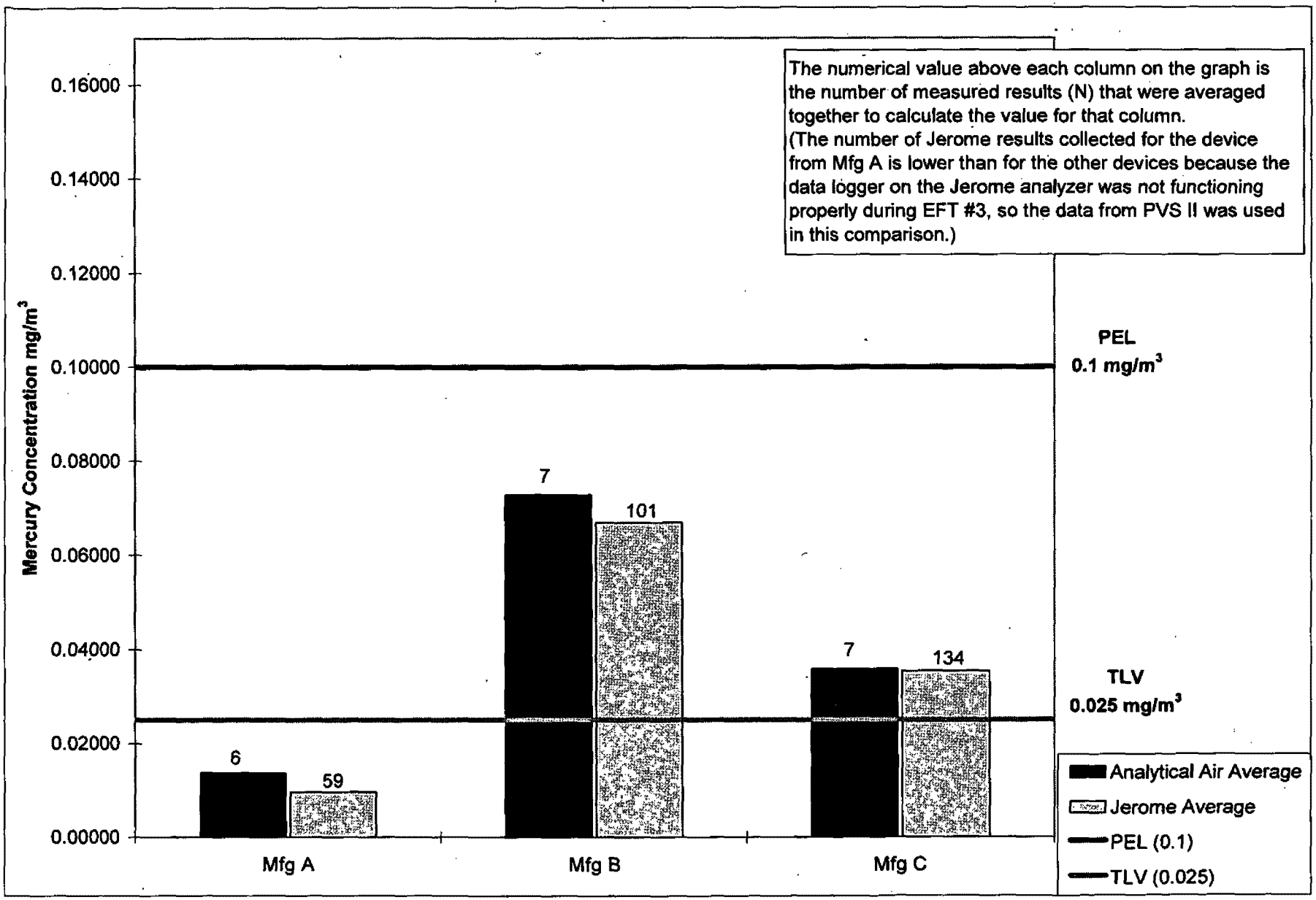
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 42: Extended Field Test #3 Jerome Results
Manufacturer C – Ashland, Virginia – June 9-13, 2003



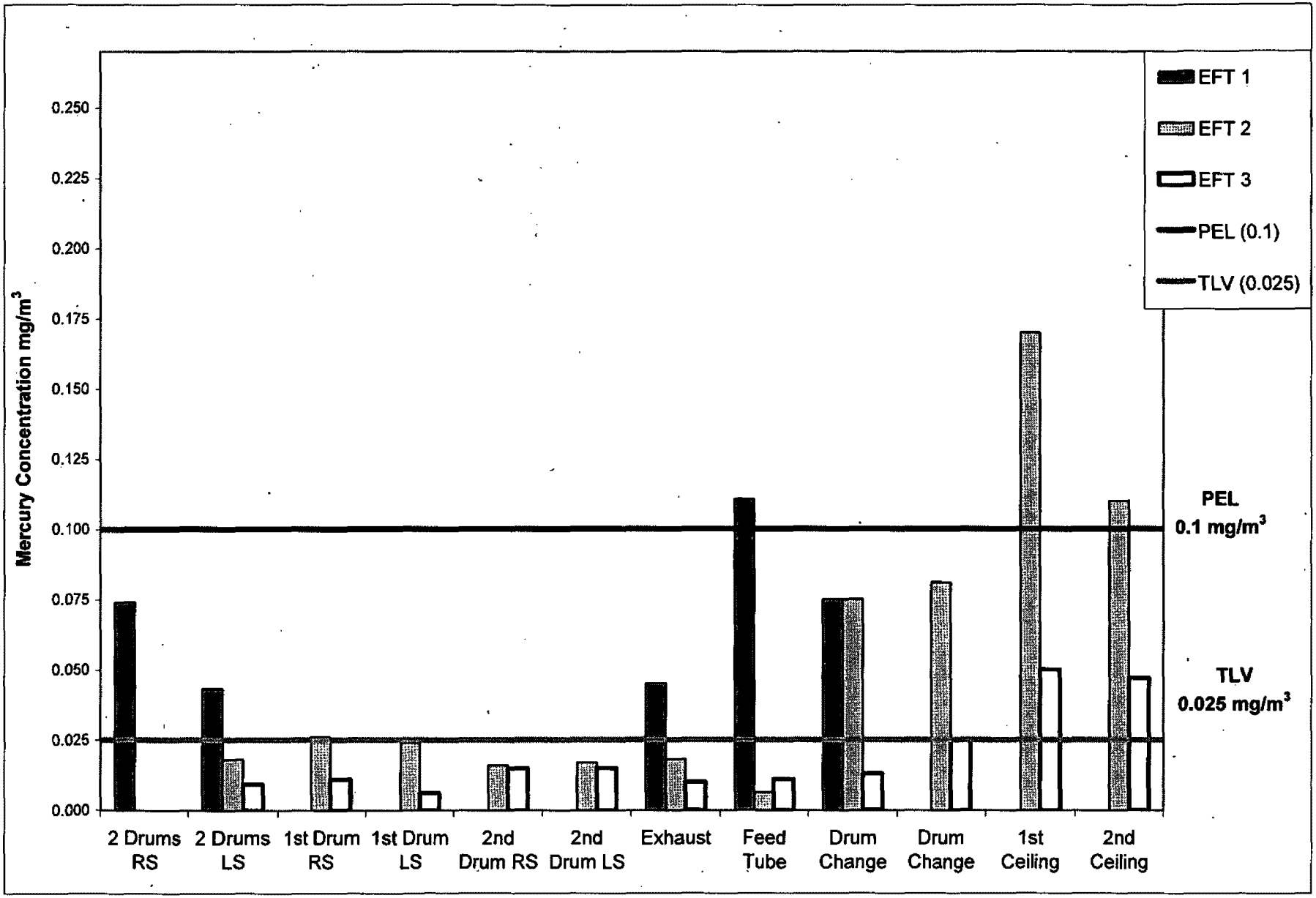
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 43: Extended Field Test #3 – Comparison of Analytical Air and Jerome Results All Devices – Ashland, Virginia – June 9-13, 2003



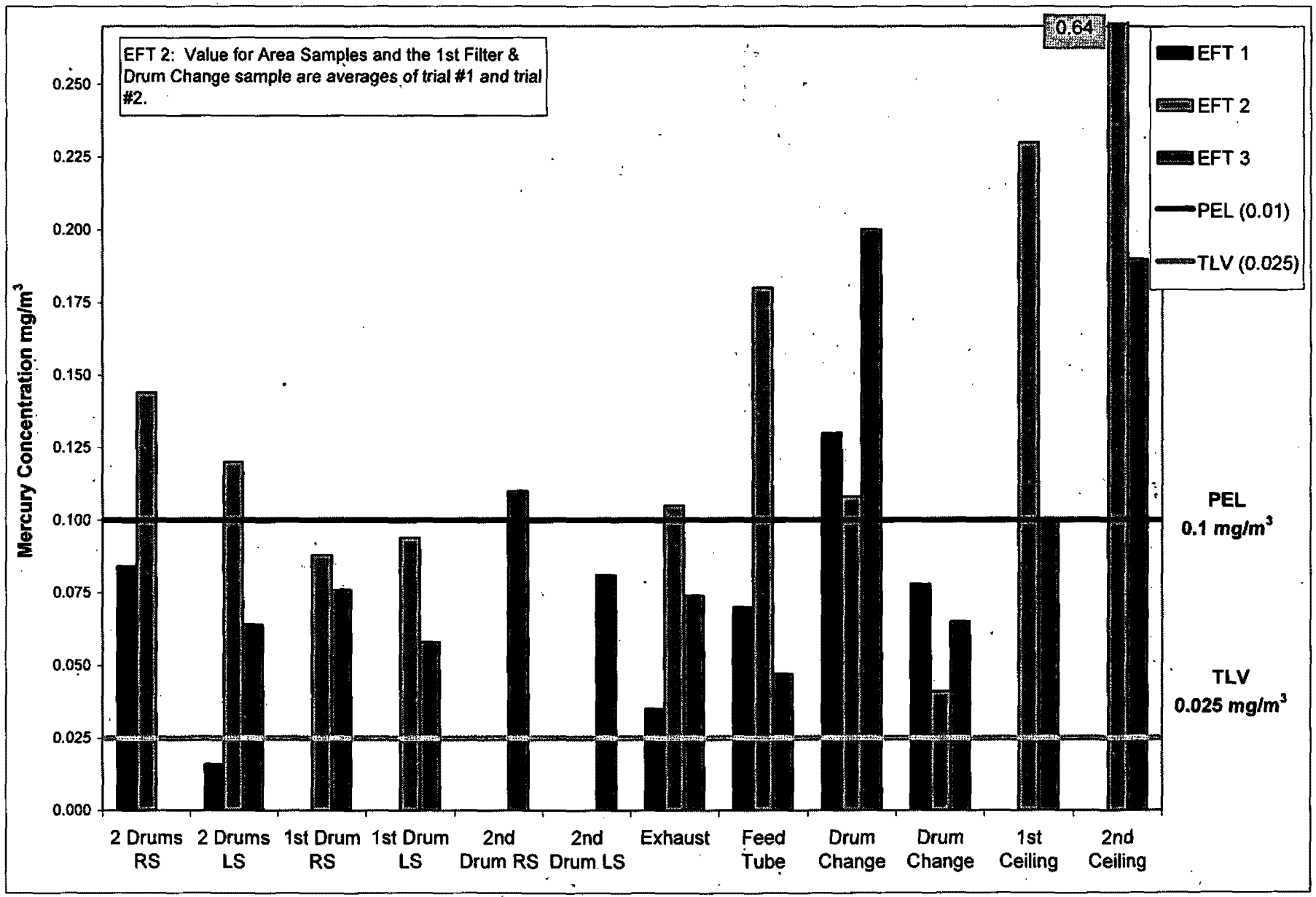
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 44: Analytical Air Results – Manufacturer A
Extended Field Test Study



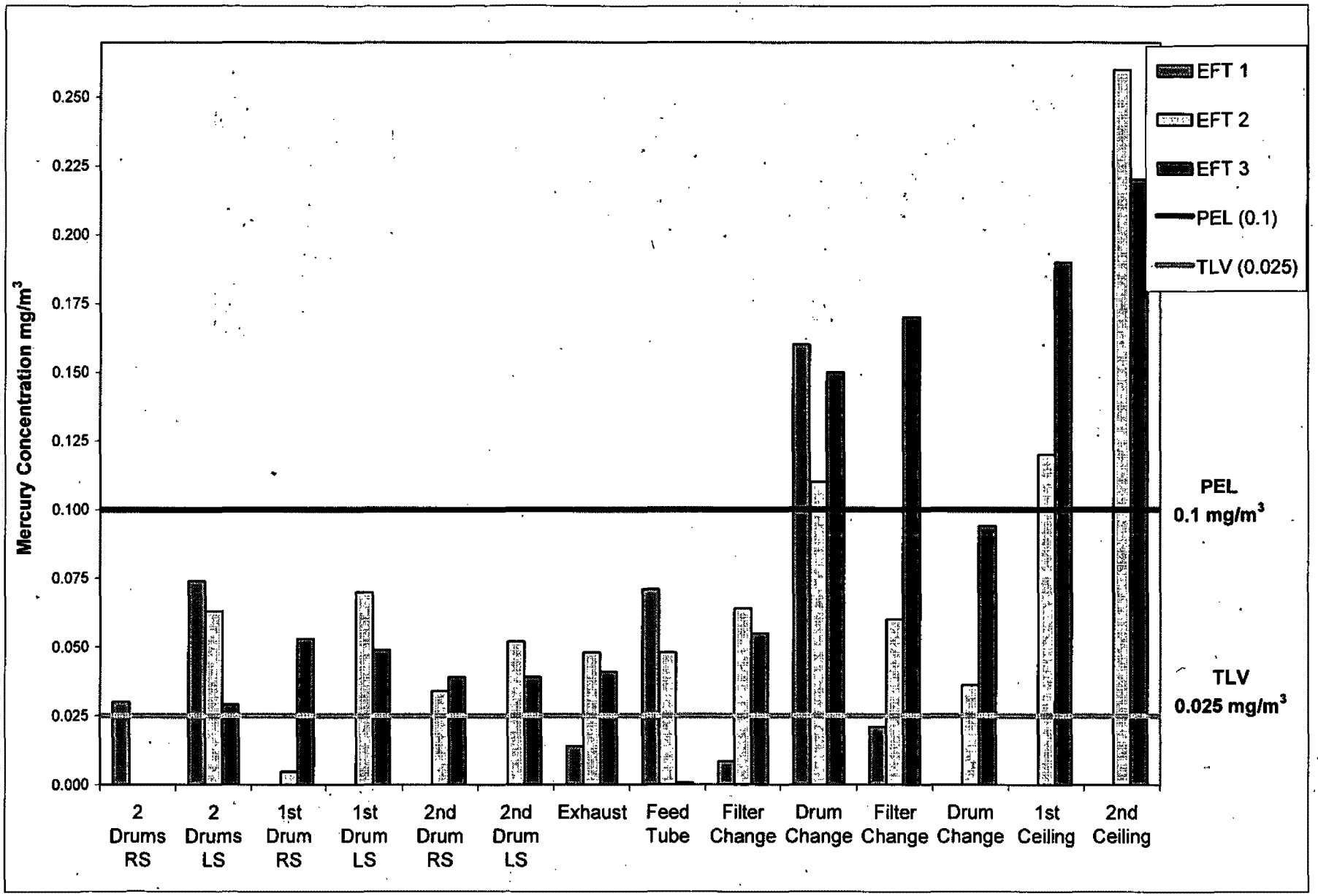
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 45: Analytical Air Results – Manufacturer B
Extended Field Test Study



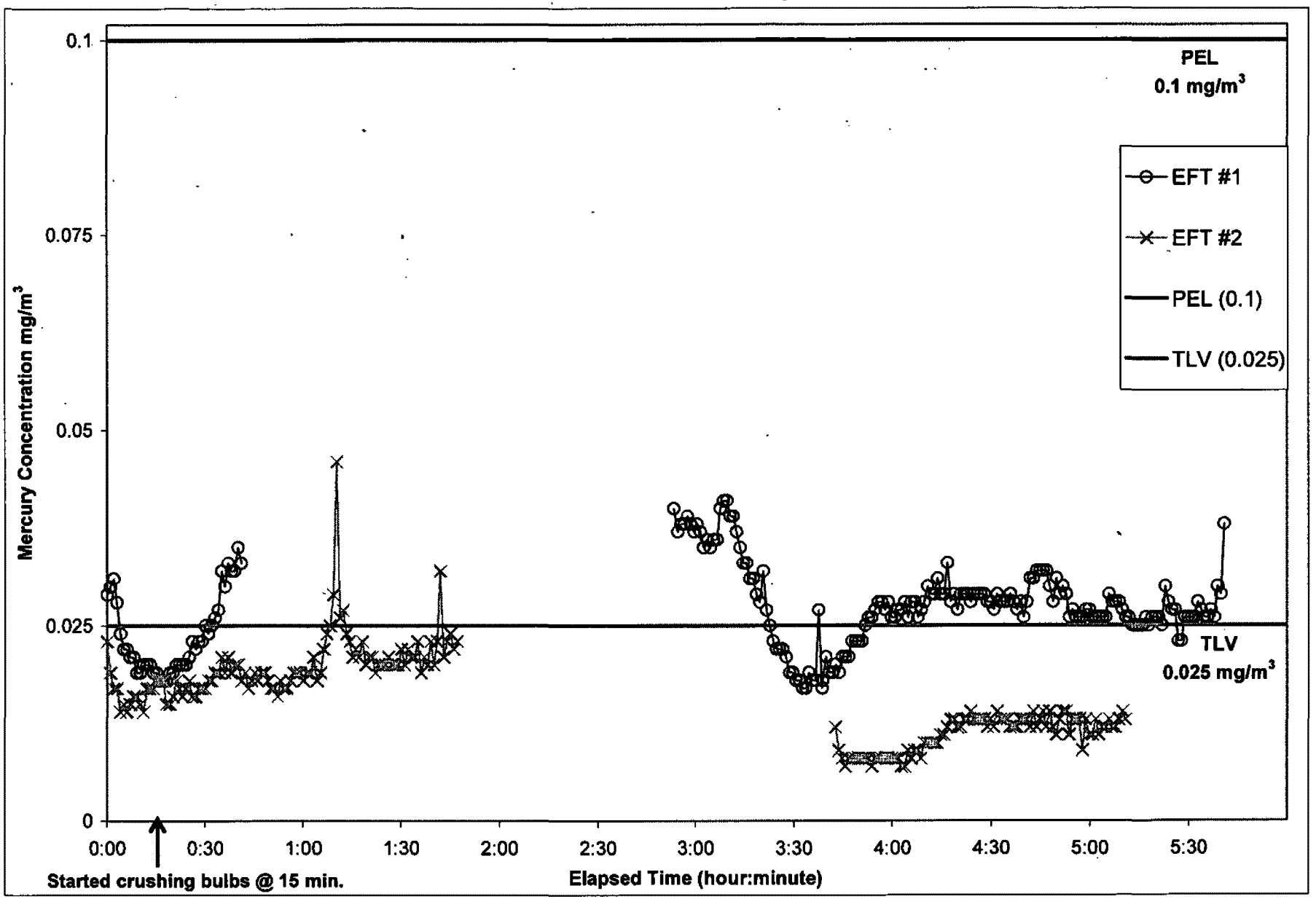
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 46: Analytical Air Results – Manufacturer C
Extended Field Test Study



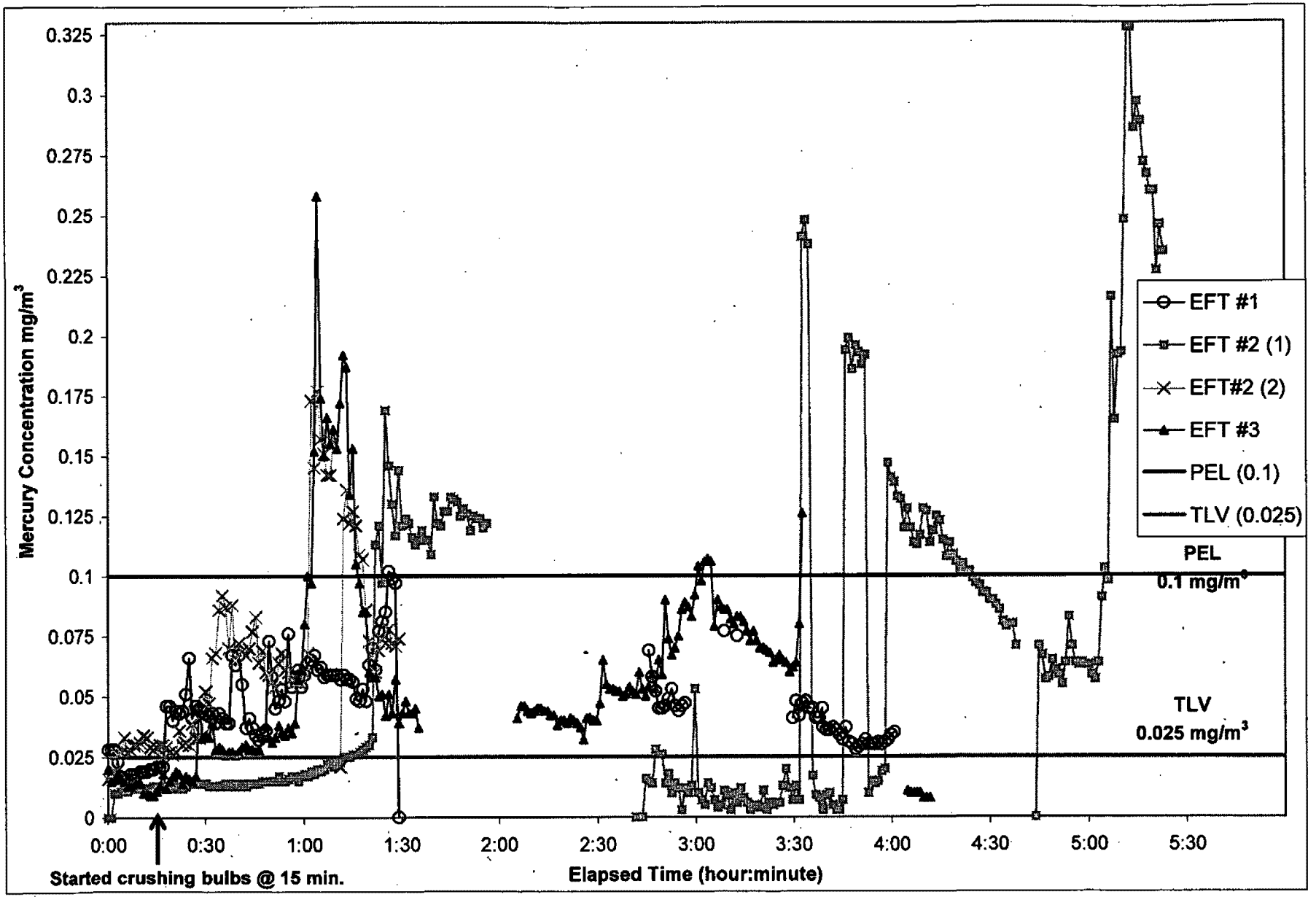
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 47: Jerome Results – Manufacturer A
Extended Field Test Study



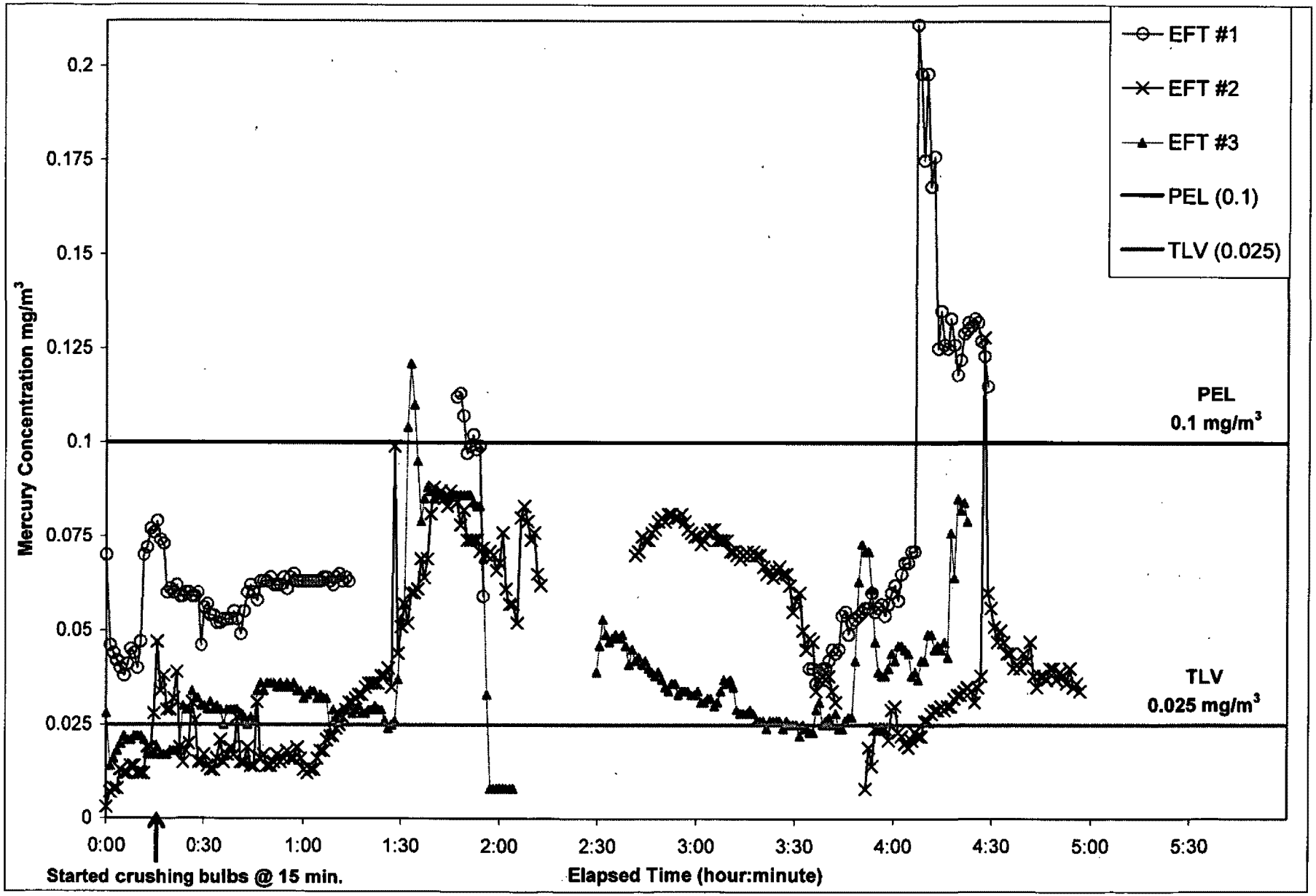
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 48: Jerome Results – Manufacturer B
Extended Field Test Study



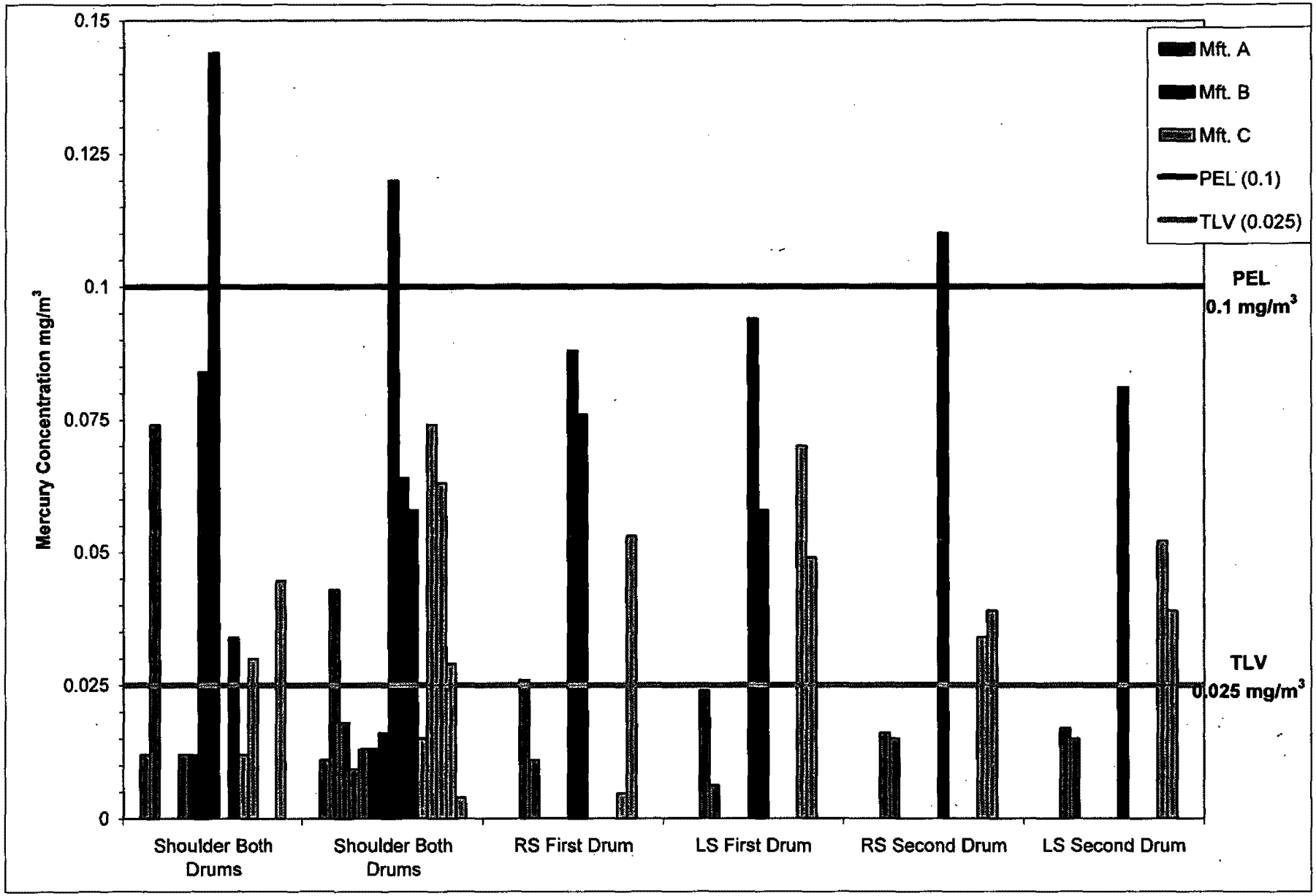
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 49: Jerome Results – Manufacturer C
Extended Field Test Study



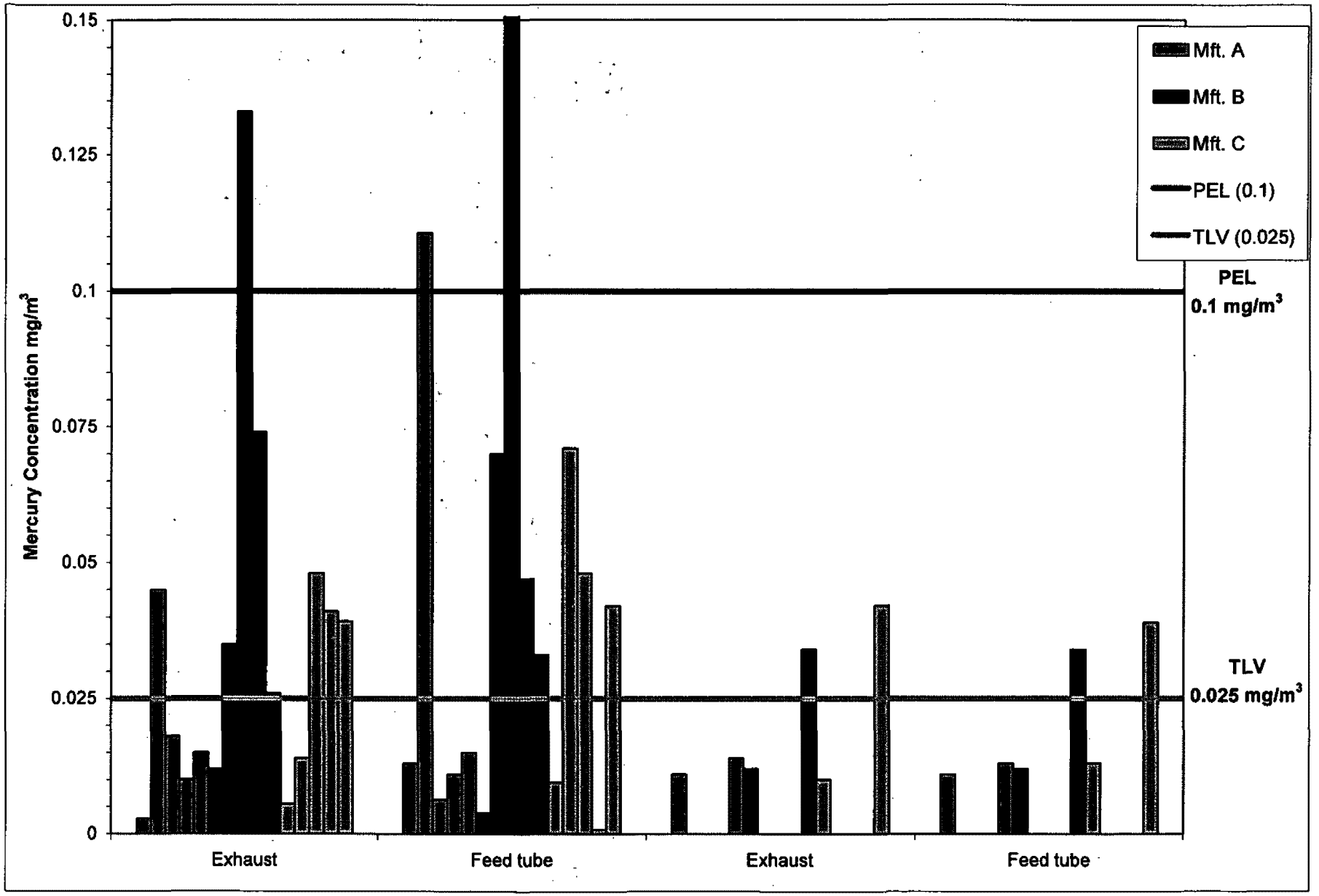
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 50: Analytical Air Results – Operator Shoulder Samples
All Devices – All Locations



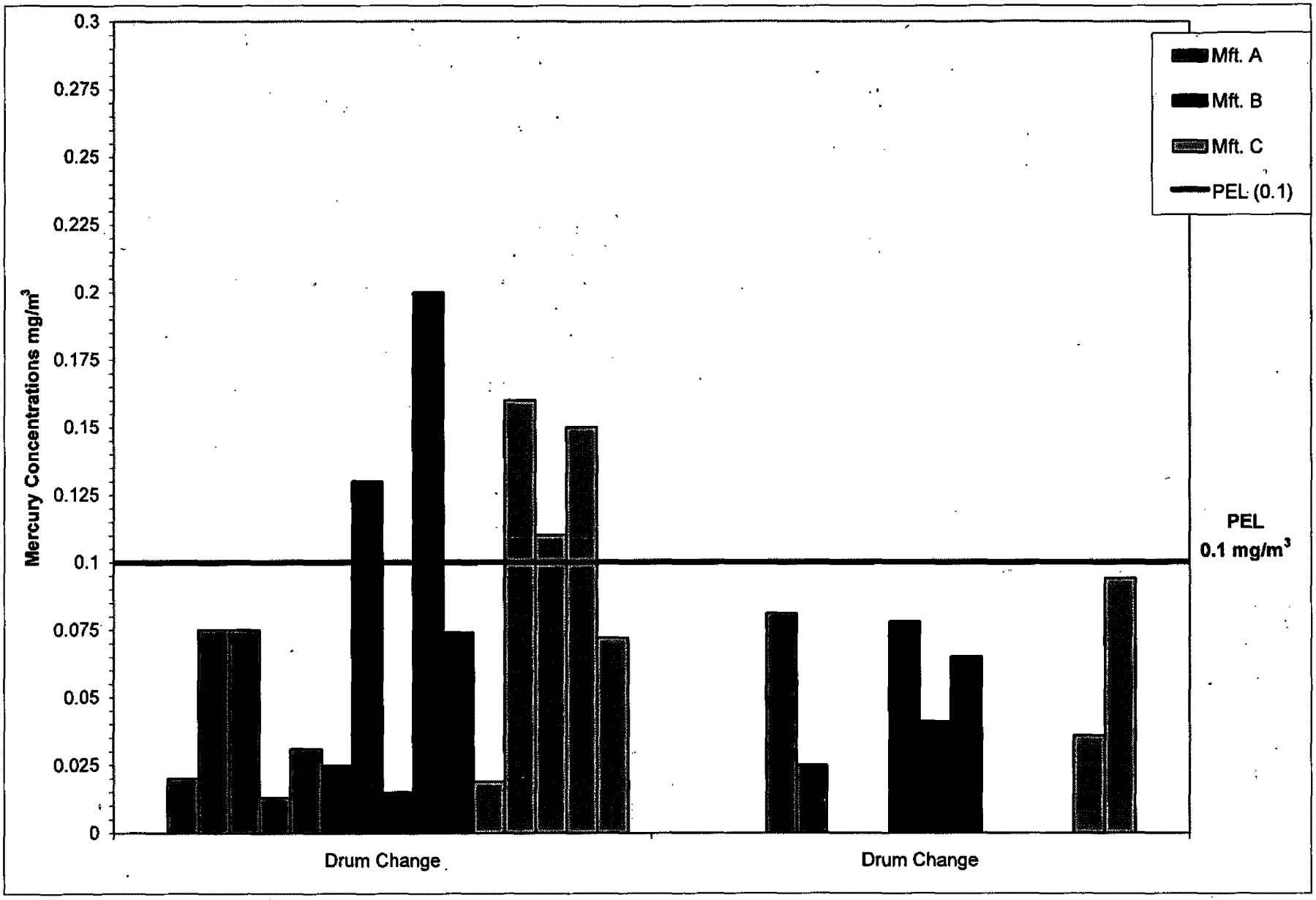
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 51: Analytical Air Results – Area Samples
All Devices – All Locations



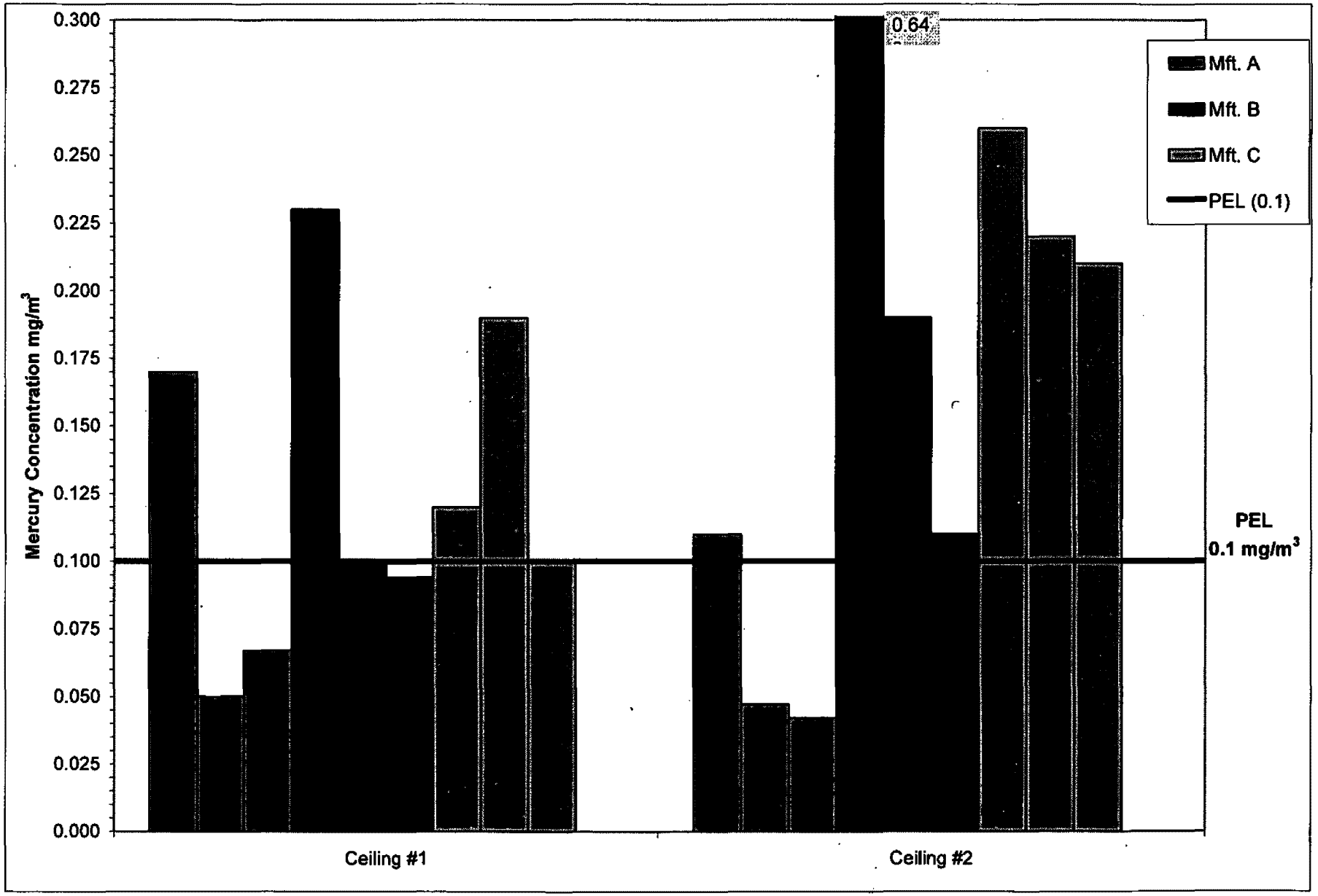
The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 52: Analytical Air Results – Drum Change Samples
All Devices – All Locations



The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Figure 53: Analytical Air Results – Ceiling Samples
All Devices – All Locations



The TLV is included on the graph as a point of reference. The results shown on this graph do not represent eight-hour, time-weighted averages.

Appendix B

Air Sampling Data Forms

Sample Shipping Information

Samples were placed in an oversized, sturdy box with packing material to fill voids and protect the samples during shipping. The sampling personnel then signed the chain-of-custody forms, and placed them in the box with the samples. Samples were shipped via Federal Express to the laboratory.

Greenwood Village, Colorado 80111
303.694.4159 FX 303.694.7367

AIR SAMPLING DATA FORM

Client EPA Date 2/25/03 Job Code

Employee SSN # Job Title

Work Description BACKGROUND

Work Location MIDDLE OF EAST BAY

Respirators/PPE

Controls

Sample # 3105-BG-2/25-01 Pump # 13027 Media MCE + HYDRO
3105-SL-2/25-01 HYDRO

Calibration: 0.212 Time: 215 min 5.94 L

Pre 201 cc/min Post On 1536 Off Volume

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: Photo 1 12

Industrial Hygienist: Reviewed by:

BOOZ ALLEN & HAMILTON
5299 DTC Blvd., Suite 840
Greenwood Village, Colorado 80111
303.694.4159 FX. 303.694.7367

AIR SAMPLING DATA FORM

Client ECA Date 2/25/05 Job Code

Employee SSN # Job Title

Work Description BACKGROUNDS

Work Location EAST BAY AT DOCK TO WEST BAY

Respirators/PPE

Controls

Sample # 3705-BG-2/25-03 Pump # 10249 Media 10CEF
3705-BG-2/25-04 HYDRAL

Calibration: Time:
Pre 205 cc/min Post 201 cc/min On 1306 Off 1549 Volume 53.24 L
205-5 278

Substance	OSHA PEL	Concentration	8 Hour TWA
Na	0.5 mg/m³		

COMMENTS: Duplicate

Industrial Hygienist: Reviewed By:

5299 DTC Blvd., Suite 840
Greenwood Village, Colorado 80111
303.694.4159 FX: 303.694.7367

AIR SAMPLING DATA FORM

Client: E PT Date: 2/26/05 Job Code:

Employee: TAD RADENSKI SSN #: Job Title:

Work Description: FEEDING TIE TUBES INTO AIRCYCLE BUBBATRS
ONE DEVICE

Work Location: E. BAY MIDDLE INSIDE CONTAINMENT

Respirators/PPE: GLOVES PSI SAFETY GLASSES TYVEK COVERALL

Controls:

Sample #: 3705-A/A-2/26/05
3705-AA-2/26-06

Pump #: 3496 Media: MCEF
HYDRIDE

Calibration: Pre: 1.5 L/m Post: 1.5 L/m Time: On: 1520 OFF: 1805 Volume: 0.2 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Ni	1 mg/m³	HYD = 0.12 mg/m³	0.0035 mg/m³
		MCE = ND	

COMMENTS: 480 MINUTES = 8 HRS
15% AUG. TWA = 2 HR 24 MIN
(2.33 HR)(0.12 mg/m³)/8 HR = 0.0035

Industrial Hygienist: Reviewed By:

Greenwood Village, Colorado 80111
303.694.4159 FX. 303.694.7367

AIR SAMPLING DATA FORM

Client: EPA Date: 2/26/03 Job Code:

Employee: TAD RADZINSKI SSN #: Job Title:

Work Description: FEEDING TO TUBES INTO AIR CYCLE BUBBATER DIC DEVICE

Work Location: E. BAY MIDALE INSIDE CONTAINMENT

Respirators/PPE: GLOVES SAFETY GLASSES TYVEK COVERALLS

Controls:

Sample #: 3705-A/A-2/26-07 / 3705-A/A-2/26-08 Pump #: 12701 Media: MCFE 47DAFF

Calibration: Pre: 151 [illegible] mL/min Post: 150.5 L/min Time: On: 1320 Off: [illegible] Volume: [illegible]

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³	HYD 0.015 mg/m³	0.0014 mg/m³
		MOE ND	

COMMENTS: 140 Min 2 Hr 20 Min 10 L/min

(2.33 HRS X 0.015) / 8 = 0.0044

Industrial Hygienist: Reviewed By:

BOOZ ALLEN & HAMILTON
5299 DTC Blvd., Suite 840
Greenwood Village, Colorado 80111
303.694.4159 FX. 303.694.7367

AIR SAMPLING DATA FORM

Client EPA Data 1/26/13 Job Code

Employee SSN Job Title

Work Description AIRCYCLE BULK EATER

Work Location DOJ FLR 2 DTC DEVICE EXHAUST

Respirators/PPE

Controls

Sample # 3705-A/A-2/26-09
3705-A/A-2/26-10 Pump # 13681 Media MCEF

Calibration: Pre 120.9 Post 9[illegible] Time: On 1320 Off 10[illegible] Volume 12[illegible]

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3	HVD 0.0035	0.0011 mg/m3
		MCE ND	

COMMENTS: 1 hr 140 min = 2.3 hr [illegible]
(233 hr)(0.0035)/8 hr = 0.0011

Industrial Hygienist: Reviewed By:

DOUG ALLEN & HAMILTON
5299 DTC Blvd., Suite 840
Greenwood Village, Colorado 80111
303.694.4159 FX. 303.694.7367

AIR SAMPLING DATA FORM

Client EPA Date 2/26/03 Job Code

Employee SSN # Job Title

Work Description AIR CYCLE BULB EMTEC

Work Location ON ELR 2 DTC DEVICE EXHAUST

Respirators/PPE

Controls

Sample # 3705-A/A-2/26-11
3705-A/A-2/26-12 Pump # 11330 Media MCEF SYDRIER

Calibration: Time:
Pre 150 cc/min Post 150 On 1320 Off 1505 Volume

Substance	OSHA PEL	Concentration	8 Hour TWA
B	0.1 mg/m³	HWD 0.010 mg/m³	0.0029 mg/m³
		MCE ND	

COMMENTS: HWD mass = 2 ug per mass increase
(2.35)(0.010)/8 = 0.0029

Industrial Hygienist: Reviewed By:

BOOZ·ALLEN & HAMILTON
5299 DTC Blvd., Suite 840
Greenwood Village, Colorado 80111
303.694.4159 FX. 303.694.7367

AIR SAMPLING DATA FORM

Client EPA Date 2/20/03 Job Code

Employee SSN # Job Title

Work Description ANCHOR BOLT EXTEL

Work Location BY DTC DEVICE FEED TUBE

Respirators/PPE

Controls

Sample # 3705 - 1A-2/20-05 (13) 3705 - 1A-2/20-04 (14) Pump # 11308 Media MCEF HYDRAR

Calibration: Pre 4%/min (155) Post (12555) Time: On 1320 Off Volume 2.5 L (10')

Substance	OSHA PEL	Concentration	8 Hour TWA
Be	0.1 mg/m³	1/2 (0.0045)	0.0027 µg/m³
		MDL = ND	

COMMENTS: 140 min × 2 L/min = 350 mL total

(2.35)(0.0045)/5 = 0.0027

Industrial Hygienist: Reviewed By:

BOOZ·ALLEN & HAMILTON
5299 DTC Blvd., Suite 840
Greenwood Village, Colorado 80111
303.694.4159 FX. 303.694.7367

AIR SAMPLING DATA FORM

Client [illegible] Date 3/23/95 Job Code

Employee SSN # Job Title

Work Description [illegible] BICYCLE AND LATER

Work Location BY DTC DEVICE FEED TUBE

Respirators/PPE

Controls

Sample # 3705-A/A-3/24-15
3705-A/A-3/24-16 Pump # [illegible] Media [illegible]

Calibration: Pre [illegible] Post [illegible] Time: On 1324 Off [illegible] Volume [illegible]

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	[illegible]	HUD 0.03	0.0038 mg/m³
		MCE = HD	

COMMENTS: [illegible] 2 Hr [illegible]
(2.5 X 0.03)/8 = 0.0038

Industrial Hygienist: Reviewed By:

Greenwood Village, Colorado 80111
303.694.4159 FX. 303.694.7367

AIR SAMPLING DATA FORM

Client EPA Date 8/24/93 Job Code

Employee TAD RADZINSKI SSN # Job Title

Work Description FOR AIRCYCE BULB EATER
FIBE FILTER CHANGE @ 502 DRUM CAPACITY

Work Location

Respirators/PPE GLOVES SAFETY GLASSES TYVEK COVERALLS

Controls

Sample # 3705-A/A-2/26-17
3705-A/A-2/26-18

Pump # 11334

Media MCE
+ PVC FILTER

Calibration:
Pre 2.7 L/min
2.7 2.65

Post 2.5
2.5 L/min

Time:
On 2140 hrs
Off 1473
12 MIN

Volume 1.81 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Asbestos	0.1 f/cc	PVD = 2 f/cc	
		MCE = ND	

COMMENTS: 12 MIN

Industrial Hygienist:

Reviewed By:

BOOZ/ALLEN & HAMILTON
5299 DTC Blvd., Suite 840
Greenwood Village, Colorado 80111
303.694.4159 FX. 303.694.7367

AIR SAMPLING DATA FORM

Client: EPA Date: 2/26/03 Job Code:

Employee: Ted Radzinski SSN #: Job Title:

Work Description: Air Cycle Bulb Later

PPE filter change in 100"L Drum Crawler

Work Location:

Respirators/PPE: Gloves Safety Glasses Tyvek Coveralls

Controls:

Sample #: 3705-A/A-3426 Pump #: 11334 Media: MCEF

3705-A/A-2,F26-26 HYDRAR

Calibration: Time:

Pre: 2.5 L/min Post: 2.5 L/min On: 1442 Off: 1500 Volume: 4.58 L

754-5 1K

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³	Hyd: ND	
		MCE: ND	

COMMENTS: 15 min

Industrial Hygienist: Reviewed By:

BOOZ-ALLEN & HAMILTON
5299 DTC Blvd., Suite 840
Greenwood Village, Colorado 80111
303.694.4159 FX: 303.694.7367

AIR SAMPLING DATA FORM

Client: EPA Date: 2/27/03 Job Code:

Employee: Ted Radzinski SSN #: Job Title:

Work Description: Feeding ~~a~~ 1 12 tubes into Aerotype 53 (Research Technology International) ~~Aerotype~~

DTC Device

Work Location: E. Bay Middle Inside Containment

Respirators/PPE: Gloves, Safety Glasses, Tyvek Coveralls

Controls:

Sample #: 3705-K-A-2/27-21 / 3705-K-A-2/27-22 Pump #: 1308 Media: MCEF 47 YOKAS

Calibration: Pre: 154 cc/min Post: 153 cc/min Time: On: 9:40 Off: 10:2[illegible] Volume: 1.[illegible]

153.5 113 (112)

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS: 113 liters

Industrial Hygienist: Reviewed by:

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303.694.4159 FX. 303.694.7367

AIR SAMPLING DATA FORM

Client: EPA Date: 2/27/03 Job Code:

Employee: Ted Radzinski SSN: Job Title:

Work Description: Feeding T-12 Tubes into Autoclave for Resource Technology Inc. OTC Device

Work Location: E. Bay Middle Inside Containment

Respirators/PPE: Gloves Safety Glasses Tyvek Coveralls

Controls:

Sample #: 3705-R-A-2/27-03 Pump #: 13027 Media: MCEF 1.4 DRAK

Calibration: Pre: ~~4.0~~ 4.1 l/min Post: 5.5 l/min Time: On: 8:30 Off: 10:23 Volume: 112.5 L

159 153 113 (112)

Substance	OSHA PEL	Concentration	8 Hour TWA
Be	0.1 mg/m³		

COMMENTS: 113 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: [illegible] Date: 2/27/93 Doc No:

Employee: [illegible] Job Title:

Work Description: [illegible]

Work Location: [illegible]

Respirator/PPE:

Controls:

Sample I: [illegible] Map I: [illegible] Media: [illegible]

Calibration: Time:
Pre: [illegible] Post: [illegible] On: [illegible] Off: [illegible] Volume: [illegible]

Substance	Corr. Fct.	Concentration	8 Hour TWA
[illegible]	[illegible]		

Comments: [illegible]

Individual Exposure: Personal ID:

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AIR SAMPLING DATA FORM

Client EPA Date 2/27/03 Job Code

Employee SSN # Job Title

Work Description ~~Area~~ Resource Technology Inc

Work Location By DTC Device Feed Line

Respirators/PPE

Controls

Sample # 3705-R-H-2/27-03 3705-R-H-2/27-03 Pump # 1249 Media MCE HYDRAR

Calibration: Pre 153 ml/min Post 154 ml/min Time: On 8 A Off 10:17 Volume 1.72 L

154.5 112

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 112 Minutes

Industrial Hygienist: Reviewed By:

[illegible]
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AIR SAMPLING DATA FORM

Client EPA Date 2/27/03 Job Code

Employee SSN # Job Title

Work Description Resource Technology, Inc.

Work Location On flow at DTC Device Exhaust

Respirators/PPE

Controls

Sample # 3701-R-11-2727-29 Pump # 13661 Media 10 HF

Calibration: Time:
Pre 15.5 Post On Off Volume 17.11 L.
15.5 12

Substance	OSHA PEL	Concentration	8 Hour TWA
Ha	[illegible]		

COMMENTS: 12 valves

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 2/27/03 Job Code:

Employee: Tal SSN #: Job Title:

Work Description: Hazardous Materials Specialist, Inc

Work Location:

Respirators/PPE:

Controls:

310-H-A-3/27-03

Sample #: 3105 H-A 2/27-3 Pump #: 11308 Media: MCEF HYDRAR

Calibration:
Pre: 153 cc/m, 153 Post: 153 cc/m.

Time:
On: 1516 Off: 1611 Volume: 8.42 L.
55

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 55 min

Industrial Hygienist: Reviewed By:

[illegible]
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AIR SAMPLING DATA SHEET

Client: EPA Inst: 21-3463 Job #/Sh:

Employee: [illegible] SSN: [illegible] Job Title:

Work Description: Residence Painted by Lead

Work Location:

Respirator(s) Type:

Controls:

Sample #: [illegible] Type: [illegible] Media: [illegible]

Calibration: Pre: [illegible] Time: On: [illegible] Off: [illegible] Volume: [illegible]

Chemical	Lab No.	Concentration	Action Lvl.
[illegible]	[illegible]	[illegible]	[illegible]

Comments:

Industrial Hygienist: Reviewed by:

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AIR SAMPLING DATA FORM

Client: EPA Date: 3/27/02 Job Code:

Employee: SSN #: Job Title:

Work Description: Hazardous Material Specialist

Work Location: Feed tube

Respirators/PPE:

Controls:

Sample #: 3X5-11-A-2127-40 3X5-11-A-2127-39 Pump #: 12708 Media: MCE F HYDRAR

Calibration: Pre: 15 cc/min Post: 15.2 cc/min Time: On: 1515 Off: 1610 Volume: 2.45 L

55

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS: 55 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 2/27/03 Job Code:

Employee: SSN #: Job Title:

Work Description: Hazardous Materials Specialist

Work Location: Feed tube

Respirators/PPE:

Controls:

Sample #: 3705-H-A-2/27-41
3705-H-A-2/27-42 Pump #: 11249 Media: MCEF Hi Vol A

Calibration: Time:
Pre: 154 cc/min Post: 156 cc/min On: 1516 Off: 1611 Volume: [illegible]
155 55 (53)

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 55 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 2/27/03 Job Code

Employee SSN # Job Title

Work Description Hazardous Materials Specialist Trainee

Work Location Exhibit

Respirators/PPE

Controls

3705-11-A-2/27-43

Sample # 3705-11-A-2/27-44 Pump # 13661 Media MCEF HYDRAR

Calibration: Time:

Pre 151 cc/min Post 150 cc/min On 1041 Off 1136 Volume 2 Liters

150.5 55

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 55 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 2/27/03 Job Code

Employee SSN # Job Title

Work Description Hazardous Materials Specialist, Inc

Work Location Exhaust

Respirators/PPE

Controls

Sample # 3705-H-A-2/27-45 / 3705-H-A-2/27-46 Pump # 11330 Media MCEF HYDRAR

Calibration: Pre ~~125~~ 253 cc/min Post 253 cc/min Time: On 1:16 Off 2:11 Volume 5.3 L

253 (253) 55

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 55 min

Industrial Hygienist: Reviewed By:

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CER EVALUATION FORM ITEM

Client: [illegible] Date: 3/6/03 Job Code:

Originator: SSN: Job Title:

Work Description: [illegible]

Work Location:

Description of Work: [illegible]

Quantities: [illegible]

Sample: [illegible] Depth: [illegible] Units: [illegible]

Calibration: Pre: [illegible] Post: [illegible] Time: On [illegible] Off [illegible] Volume [illegible]

Distance	Azimuth	Orientation	Remarks
[illegible]	[illegible]	[illegible]	

Comments: [illegible]

Reviewed by: [illegible] Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 2/28/03 Job Code

Employee Jack Ralonski SSN # Job Title

Work Description Feeding rats into ~~people~~ Ucinate DTC Devices

Work Location E Bay Middle East Containment

Respirators/PPE Gloves, Safety Glasses, Level D Overall

Controls

3702-D-A-2128-SO

Sample # 3702-D-A-2128 Pump # 1231 Media Mixed Acetate

Calibration: Time:

Pre 1.52 Post 1.52 L/min On 1130 Off 1132 Volume 13.16 L

153 SL

Substance	OSHA PEL	Concentration	8 Hour TWA
N/A			

COMMENTS: BZ mask

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 2/28/03 Job Code

Employee Ted Radzinski SSN # Job Title

Work Description Feeding fibers into Osetite in the Dome

Work Location E Bay middle Exide Containment

Respirators/PPE Gloves Safety Glasses Tyvek coveralls

Controls

Sample # 1 -52 Pump # 12.49 Media MCEF

Calibration: Pre 1.51 L/min Post 1.51 L/min Time: On 1016 Off 1034 Volume 12.99 L

Substance | OSHA PEL | Concentration | 8 Hour TWA

Asbestos | 0.1 f/cc

COMMENTS: No smoking

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 2/28/05 Job Code

Employee SSN # Job Title

Work Description Worker DEC Device

Work Location By DTC Water Feed Tube

Respirators/PPE

Controls

Sample # 3705-D-1-2/28-53 -54 Pump # 1996 Media PVC Filter

Calibration: Pre 145 Post 138 cc/min Time: On 1056 Off 1356 Volume 1247

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: Skeletons

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 2/28/03 Job Code

Employee SSN # 1316 13 Job Title

Work Description Debris DTC Drive

Work Location On floor next to DTC Drive Exhaust

Respirators/PPE

Controls

Sample # 1755-0-A-3528-57 -58 Pump # 13673 Media MCEF

Calibration: Time:
Pre: 1.52 Post: 1.54 cc/min On 10:16 Off 13:2 Volume 13.20 L
1535 8L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS: See map

Industrial Hygienist: Reviewed By:

[illegible]
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AIR SAMPLING DATA FORM

Client EPA Date 2/28/03 Job Code

Employee SSN # Job Title

Work Description Derrick DT's Heater

Work Location Dry Flow to DT's heater platform

Respirators/PPE

Controls

Sample # Pump # 17-09 Media MCEF

Calibration: Time: BY DERRICK

Pre 2.51 Post 1.52 On 1115 Off 1132 Volume 13.03 L

1515

Substance	OSHA PEL	Concentration	8 Hour TWA
Fe	3-1 mg/m³		

COMMENTS: Shiny

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 2/28/03 Job Code

Employee SSN # Job Title

Work Description Decon OF Denver

Filter Drum Change out Drum Full

Work Location

Respirators/PPE Gloves Safety Glasses Tyvek Recall

Controls

Sample # [illegible] Pump # 1930 Media MCEF

Calibration: Time:
Pre 2.5 Post 2.54 cc/m On 1119 Off 1132 Volume 3.29 L
2.53

Substance	OSHA PEL	Concentration	8 Hour TWA
Pb	0.1 mg/m³		

COMMENTS: 15 min

Industrial Hygienist: Reviewed By:

Appendix B

Air Sampling Data Forms

Sample Shipping Information

Samples were placed in an oversized, sturdy box with packing material to fill voids and protect the samples during shipping. The sampling personnel then signed the chain-of-custody forms, and placed them in the box with the samples. Samples were shipped via Federal Express to the laboratory.

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AIR SAMPLING DATA FORM

Client EPA Date 2/28/03 Job Code

Employee SSN # 1367 3 Job Title

Work Description Detroit DTE Device

Work Location on floor next to DTE Device Exhaust

Respirators/PPE

Controls

Sample # 3705-D-A-2/28-57 -58 Pump # 13673 Media MCEF HYDRAR

Calibration: Time:

Pre 153 cc/min Post 154 cc/min On 1006 Off 1132 Volume 13.20 L

153.5 EL

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: See above

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 2/20/03 Job Code

Employee SSN # Job Title

Work Description Destruct DTC Demo

Work Location On floor @ DTC device entrance

Respirators/PPE

Controls

Sample # 3705-D-A-2/28-5 -60 Pump # 12709 Media MCEF

Calibration: Time: HYDRA R

Pre 2.51 - 1 min = 151.5 Post 152 cc/min On 1015 Off 1132 Volume 13.05 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: Shannon

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 2/28/03 Job Code:

Employee: SSN #: Job Title:

Work Description: Destruct DTC Drums
Filter Drum Change out Drum Full

Work Location:

Respirators/PPE: Gloves Safety Glasses Tyvek Overall

Controls:

Sample #: INS-2-A-2/28-01 -02 Pump #: 1530 Media: MCEF HYDRA

Calibration: Time:
Pre 2.52 Post 2.54 cc/min On 1119 Off 1132 Volume 3.29 L
255

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS: 13 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 3/24/13 Job Code

Employee SSN # Job Title

Work Description Background

Work Location North of containment in Warehouse on top of Recycle Bulb Crusher Boxed crate

Respirators/PPE

Controls

Sample # 3705-B-3/24/01-02 Pump # 13684 Media Hydar MCE-F

Calibration: Pre 162 cc/min Post 148 cc/min Time: On 7.58 Off 11:23 Volume 31.78 L

~~155~~ 155 205

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 205 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 3/24/03 Job Code

Employee SSN # Job Title

Work Description Background

Work Location Each of containment in warehouse on top of boxes of gulls

Respirators/PPE

Controls

Sample # 3705-B-3/24-03-04 Pump # 800 885 Media Hydar MCEF

Calibration:
Pre 151 cc/min 136.5 Post 122 cc/min ~~157~~ Time: On 7:57 205 Off 11:23 Volume 27.98 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 208 m²

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 3/24/03 Job Code

Employee SSN # Job Title

Work Description Filter change #1 and #2 (see notes below)

Work Location Left rd cap on for first filter change - covered same media for filter change #2. only included time for 2nd filter change in total volume.

Respirators/PPE

Controls

Sample # 3705 B-A-3/24-#13 Pump # 1152 (1203 1207) Media MCEF Hydrar

=9814 #1 12:12 p.m. 12:22 p.m. (#2 reading) - did not include in L

Calibration: Time:

Pre 248 cc/min Post 266 cc/min On 11:2 7:50a.m. OFF 8:12 p.m. Volume 5.65 L

257 on 3/25/03 22

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 22 min.

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

EPA Date 7/24/03 Job Code

SSN # Job Title

escription Overnight Containment - RTI Exhaust

k Location

Respirators/PPE

Controls

Sample # 3705-R-A-3/24-15-76 Pump # 11252 ~~12705~~ Media Hydrar MCEF

alibration: Pre ~~4.0~~ cc/min 1.57 Post ~~5.0~~ 1.63 1.69 cc/min Time: 4:27pm On ~~4:57pm~~ OFF 11:35pm Volume 68.13 L ~~428~~ 418

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 428 min.

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 3/24/17 Job Code

Employee SSN # Job Title

Work Description Overnight in Containment - RTE
Fixed Wbe

Work Location

Respirators/PPE

Controls

Sample # 3705-R-A 3/24-17 -18 Pump # 11179 Media Hydra-MCEF

Calibration: Pre 157 cc/min 151.5 Post 146 cc/min Time: On 4:07pm 448 Off 11:35p 438 Volume 66.36 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS: 448 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 3/25/03 Job Code

Employee Tad SSN # Job Title

Work Description Personal - Dextrin

Work Location

Respirators/PPE Respirator, tyvek, safety goggles

Controls Terrine

Sample # 3705-B-A-3/25-19 Pump # 12713 Media Hydrar mCEP

Calibration: Time:

Pre 159 cc/min Post 301 cc/min On 9:46 Off 10:56 Volume 28,75 L

230 12:29 125 1:24

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 125 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 7/25/13 Job Code:

Employee: Ted SSN #: Job Title:

Work Description: Personal - Dextrite

Work Location:

Respirators/PPE: Respirator, tyvek, safety goggles

Controls: Fetime

Sample #: 3705-DPA-5/25-21 -22 Pump #: 13684 Media: Hydrar MCEF

Calibration: Pre: 1.42 cc/min 1355 Post: 1.29 cc/min 12:29 Time: On: 9:46 1.25 Off: 10:56 1:24 Volume: 16.94 L

Substance	OSHA PEL	Concentration	% Lower LNA
Hg	0.1 mg/m³		

Comments: 1.25 hrs

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 3/25/03 Job Code

Employee SSN # Job Title

Work Description Inside containment - nextrite
area sample on fiber drum next to exhaust

Work Location elevated

Respirators/PPE

Controls Jerome

Sample # 3705-D-A-3/25-23 -24 Pump # ~~5445~~ 800885 ~~800465~~ Media Hydrar mCEF

Calibration: 1.52 120 cc/min Time:
Pre ~~1.52 cc/min~~ ~~1.66~~ 1.7 Post 9:46 On 9:16 12:29 Off 10:56 1:24 Volume 17.0 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³	125	

COMMENTS: 125 max

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 3/25/03 Job Code

Employee SSN # Job Title

Work Description Inside containment - Dextnk
area sample on fiber drum next to inlet fed tube

Work Location

Respirators/PPE

Controls Jerome

Sample # 3705-D-A-3/25-25 Pump # 2018 Media Hydrar mcEE
-26

Calibration: Time:
Pre 156 cc/min Post 243 cc/min On 9:46 Off 10:56 Volume 24.94 L
199.5 12:29 1:24

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³	125	

COMMENTS: 125 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 3/25/03 Job Code

Employee Tad SSN # Job Title

Work Description ~~Review~~ First Draft change - Dextrik

Work Location

Respirators/PPE Respirator, tyvek, safety goggles

Controls Jerome

Sample # 3705-D-A3K5-27 -28 Pump # 14959 Media Hydra-MCEP

Calibration: Time:

Pre 253 cc/min Post 170 cc/min On 10:44 Off 10:56 Volume 2.54 L

211.5 12

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 12 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 3/25/03 Job Code

Employee SSN # Job Title

Work Description Overnight in containment - Dextile

Work Location Exhaust

Respirators/PPE

Controls

Sample # 370S-D-A-3/25-29 Pump # 2018 Media Hydrar

Calibration: Time: MCE = 0.85

Pre 153 cc/min Post 906 cc/min On 1:34pm Off 10:10pm Volume 39.7 L

-30 906 516 121.8

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 576 m.v.

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 3/25/03 Job Code

Employee SSN # Job Title

Work Description Overnight in containment - Dextrk

Work Location Reel tube

Respirators/PPE

Controls

Sample # 3705-OA-3/25-31 -32 Pump # 3715 Media Hydrar mCEF

Calibration: Time:
Pre 143 cc/min Post 126 cc/min 134.5 On 134 pm Off 10:10 pm Volume 69.40 L

514

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 576 min

Industrial Hygienist: Reviewed By:

[illegible] & ASSOCIATES
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AIR SAMPLING DATA FORM

Client: EPA Date: 3/25/03 Job Code:

Employee: SSN: Job Title:

Work Description: Second Dam Change Decline

(Amend: 3/26/03 - 8am Straight Measurements)

Work Location:

Respirator, tyvek, safety goggles

Comments:

Sample #: 103-0-A-3/26-31 = 34 Pump #: 113.2 Media: Hydrar MCEF

Calibration:
Pre: 2.5 L/m Post: 2.0 L/m Time: On: 1016 Off: 0.29 Volume: 2.96 L
227-6 13

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 13 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 3/26/03 Job Code

Employee Tad SSN # Job Title

Work Description Personal - HMS

Work Location

Respirators/PPE Respirator, tyvek, gloves, safety goggles

Controls Fans

Sample # 3705-H-A-3/26-3 tube Pump # 2517 Media Hydrar mcEF
-36 filt

Calibration:
Pre 187 cc/min Post 191 cc/min Time: On 8:13 Off 8:34 Volume 3.97 L
159 21

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m^3		

COMMENTS: 21 min.

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 3/26/93 Job Code

Employee Ted SSN # Job Title

Work Description Personal - HMS

Work Location

Respirators/PPE Respirator, truck, gloves, goggles

Controls Fenne

Sample # 3705-HA-3/26-3 two Pump # 3714 Media Hydrar MCEF

= 3 & Film

Calibration: Time:

Pre 147 cc/min Post 150 cc/min On 8:13 Off 8:34 Volume 3.12 L

148.5 21

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m^3		

COMMENTS: 21 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EIP Date: 3/26/03 Job Code:

Employee: SSN #: Job Title:

Work Description: MMS Facility Assessment - Mr. Steve Arata

Cochrel

Work Location:

Respirators/PPE:

Controls:

Sample #: 3705-H-A-2h-59 Pump #: 2018 Media: Hydro MCEF

-40

Calibration: Pre: 150 cc/min Post: 151 cc/min Time: On: 8:13 Off: 1:14 Volume: 28.92 L

1555 1546

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

Comments: 186 Bldg

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 3/24/03 Job Code:

Employee: SSN #: Job Title:

Work Description: HMS Inside containment - 330 Elec. drive motor for Fuse Hube

Work Location:

Respirators/PPE:

Controls:

Sample #: 5705-H-A 3/24-41 Pump #: 3715 Media: Hydrion MCE/F
-42

Calibration: Pre: 141 ml/min Post: 160 ml/min Time on: 5:13 off: 11:19 Volume: 21.85 L
1405 1905

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

Comments: 141 ml/min

Industrial Hygienist: Reviewed by:

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AIR SAMPLING DATA FORM

Client EPA Date 3/27/03 Job Code

Employee SSN # Job Title

Work Description Personal - Aircycle

Work Location

Respirators/PPE

Controls

Sample # 3705-A-A-3/27-43 -44-Filter Tube Pump # 80885 Media Hydrar MCEP

Calibration: Pre 158cc/min Post 145 cc/min 151.5 Time: On 10:21 1310 1650 Off 10:42 1603 1752 Volume 29.69 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 1.5 L/min.

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AIR SAMPLING DATA FORM

Client EPA Date 3/27/03 Job Code

Employee SSN # Job Title

Work Description Personal - Air Cycle

Work Location

Respirators/PPE

Controls

Sample # 3705-A-IA-3/27-45 Pump # 2517 Media Hydrar MCEF
-46

Calibration: Time:
Pre 162 cc/min Post 162 cc/min On 1021 Off 1042 Volume 31.75L
102 1310 1503
1650 1752

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³	196	

COMMENTS: Unknown

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 3/27/03 Job Code

Employee SSN # Job Title

Work Description Air Cycle - Inside containment - On floor down near exhaust

Work Location

Respirators/PPE

Controls

Sample # ~~3705-A-A-3/27-47~~ 3705-A-A-3/27-47 -48 Pump # 3719 Media Hydrar MCEF

Calibration: Pre 155 cc/min 149 Post 143 cc/min Time: On 1021 1310 1450 Off 1042 1503 1752 Volume 29.20L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1mg/m³	196	

COMMENTS: 1 x 6 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 3/27/03 Job Code:

Employee: SSN #: Job Title:

Work Description: One cycle - overnight in containment

Work Location: Let sample run throughout night. ↓ air flow, because could not get in facility to turn off in middle of night.

Respirators/PPE:

Controls: feed tube

Sample #: 3705-A-A-3/27-57 -58 Pump #: 3715 Media: Hydrar MCEF

Calibration: Pre 166 cc/min Post 164 cc/min Time: on 3/27/03 On 7:24 Off 8:20 am 8/29/07 Volume: 78.53 L

10 of 2 77c

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 71 L min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 3/27/03 Job Code

Employee SSN # Job Title

Work Description Filter Change #3 - Air Cycle
DRUM #2

Work Location

Respirators/PPE

Controls

Sample # 3DS-A-A-3/27-59 Pump # 2018 Media Hydar
60 mCEE

Calibration: Time:
Pre 248 cc/m Post 261 cc/min On 1749 Off 1801 Volume 3.05 L
254.5 12

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS: 12 min

Industrial Hygienist: Reviewed By:

U.S. EPA Headquarters Library
Mail Code 3404T
1200 Pennsylvania Avenue, NW
Washington DC 20460
202-566-0556

Appendix B

Air Sampling Data Forms

Sample Shipping Information

Samples were placed in an oversized, sturdy box with packing material to fill voids and protect the samples during shipping. The sampling personnel then signed the chain-of-custody forms, and placed them in the box with the samples. Samples were shipped via Federal Express to the laboratory.

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AIR SAMPLING DATA FORM

Client EPA Date 4/29/07 Job Code

Employee SSN # ~~12700~~ Job Title 3705

Work Description Background - East Bay 24 feet east of main dock door

Work Location

Respirators/PPE

Controls

Sample # 3705-B-4/29-01 Pump # 12708 Media Hydar MCEP
02

Calibration: Time:
Pre 207.5 cc/min Post 203 cc/min On 9:41 a.m. Off 2:39 p.m. Volume 61.16L
20525 298

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: Photo #6 on my camera was of the background sample
Photo #7 was main dock door
Photo #8 - other background -
298 minutes

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client E.P.A. Date 4/29/03 Job Code

Employee SSN # Job Title 3705

Work Description Background

Work Location East Bay 18ft North of mid dock door

Respirators/PPE

Controls

Sample # 3705-B-4/29-04 Pump # 13657 Media Hydar mCEF

Calibration: Time:
Pre 206 cc/min Post 229 cc/min On 9:41 am Off 2:31 pm Volume 64.8 L
217.5 298

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 298 minutes

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 4/29/03 Job Code

Employee Tad Radzinski SSN # Job Title

Work Description Feeding Tubes into Dextrite DTC Device
Easy Box / Inside containment

Work Location Right shoulder / chest area

Respirators/PPE

Controls

Sample # 3705-D-A-4/29-05 -06 Pump # 13682 Media Hydar MCEF

Calibration: Pre 156 cc/min (FH) Post 158 cc/min (FH) 158.3%

Time: On (H3) 3:07 161 cc/min Off 4:33 1.60 7.20 Volume 25.81 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS: 163 minutes

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 4/29/03 Job Code

Employee Tad Radzinski SSN # Job Title

Work Description Feeding tubes into Drexmit DTC Device
East Bay Inside Containment

Work Location Left Shoulder/chest area

Respirators/PPE

Controls

Sample # 3N5-0-N-4/29-07 Pump # 13914 Media Hydrar
-08

Calibration: Time: 3:07 4:33 6:03 7:20 MCE

Pre 150 cc/min Post 148 cc/min On 148 cc/min Off Volume 24.23 L

1867 #3

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 163 N.M.

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 4/29/03 Job Code

Employee SSN # Job Title

Work Description Dextrite DTC Device

Inside Containment - on fiber drum near exhaust

Work Location

Respirators/PPE

Controls

Sample # 370S-D-A-4/29-09 Pump # 1261 Media Hydrar mCEF

-TO

Calibrations: Pre 151 cc/min Post 154.2 cc/min 155 Time: On 3:07 4:35 Off 7:10 Volume 24.94 L

Substance | OSHA PEL | Concentration | 8 Hour TWA

Hg | 0.1 mg/m³

COMMENTS: Hg 3 min

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AIR SAMPLING DATA FORM

Client EPA Date 4/29/11 Job Code

Employee SSN # Job Title

Work Description Dexfrit DTC Denver

Work Location Inside containment - on 6 bbl drum near inlet feed tube

Respirators/PPE

Controls

Sample # 3705-D-A-4/29-11-12 Pump # 13673 Media Hydrar mCEF

Calibration: Pre 152 cc/min Post 154 cc/min Time: On 1 Off Volume 25.10 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 163 min-VTC

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 4/27/07 Job Code:

Employee: SSN: Job Title:

Work Description: Denver DTC Drive

Work Location: Green Chevrolet @ 168 Washington 347 311 698

Respirators/PPE:

Controls:

Sample #: 3M 5.0 L/min 15 - 19 Pump #: 1308 Media: Hydrar MCE

Calibration: Pre: 252 cc/min Post: 255 cc/min 253.5

Time: On: 4:23 Off: 14:35 Volume: 3.4 L

Substance	OSHA PEL	Concentration	8 hour TWA
Hg	0.1 mg/m³		

COMMENTS: 1 x area

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 4/29/03 Job Code

Employee SSN # Job Title

Work Description Dexrite DTC Device
Drum change 1 @ 609 bldg

Work Location

Respirators/PPE

Controls

Sample # 3705-D-A-4/29-15 Pump # 11249 Media Hydrar mCEF

Calibration: 2.58 Pre ~~50~~ cc/min 259 Post ~~259 cc/min~~ 250 cc/min Time: On ~~2:30~~ 7:00pm Off 7:20pm Volume 5.08

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1mg/m³		

COMMENTS: 20 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 4/29/03 Job Code

Employee SSN # Job Title

Work Description Dextrix DTC Device
Overnight - inside containment on

Work Location fiber draw near exhaust

Respirators/PPE

Controls

Sample # 2705-D-A-4/29-17 -18 Pump # 13914 Media Hydrar

Calibration: Time: 714 minutes MCE

Pre 2.145 Post 14.6 cc/min On 2018 Off 8:12 Volume 164.96 L

147

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 714 minutes

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 4/29/03 Job Code

Employee SSN # Job Title

Work Description Daytime DTC Demo

Work Location Overnight - inside containment @ fiber drum near Mist Feed Line

Respirators/PPE

Controls

Sample # 3705-D-A-4/29-19 -20 Pump # 12708 Media Hydrar MCEE

Calibration: Pre 153 149 Post 145 cc/min Time: On 2018 Off 8:12 714 minutes Volume 106.39 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 714 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 4/29/03 Job Code

Employee SSN # Job Title

Work Description Dextrik DTC Device
overnight - outside containment

Work Location

Respirators/PPE

Controls

Sample # 3705-D-A-4/29 -21 -22 Pump # 13657 Media Hydar mCEF

Calibration: Time:
Pre 154 153 Post 152 cc/min On 2018 Off 5:12 Volume 109.24 L

714 min

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	C .1 mg/m3		

COMMENTS: 714 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 4/29/03 Job Code

Employee SSN # Job Title

Work Description Ceiling - 4 min vtr samples - (#1)

Work Location

Respirators/PPE

Controls

Sample # 3705-D-4-4/29-23 Pump # 11308 Media Hydrox MCEF
-24

Calibration: Time:
Pre 251 cc/min Post 256 cc/min On 7:03 pm Off 7:07 pm Volume 1.01 L
253.5

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 4 min

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AIR SAMPLING DATA FORM

Client: EPA Date: 4/24/97 Job Code:

Employee: SSN: Job Title:

Work Description: Colony 4 ambient samples HD

Work Location:

Respirators/PPE:

Controls:

Sample I.D.: 3725-0-11-4/97-25 Pump I.D.: 1308 Media: Hydrocarbon/ORBO

Calibration: Pre: 2.51 cc/min Post: 2.54 cc/min Time: On 7:08 Off 7:12 Volume: 1.6 L

2555

Substance	OSHA PEL	Concentration	8 Hour TWA
Hexane	50 mg/m3		

Comments: 4 hrs

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AIR SAMPLING DATA FORM

Client EPA Date 4/30/03 Job Code

Employee Tad Radzinski SSN # Job Title

Work Description Air cycle
Feeding tubes into Air Cycle Device

Work Location Cast Bay Inside Containment
Left Shoulder this sampling Entire 2 hours (1st & 2nd Inn)

Respirators/PPE

Controls

Sample # 3705-A-A-4/30-27 Pump # 12671 Media Hydrion
-28 MCEF

Calibration: Time: On 11:15 12:36 Off 2:18 3:22
Pre 155 cc/min Post 153 cc/min Volume 22.33L
154

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 145 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 4/30/03 Job Code

Employee Tad Raczinski SSN # Job Title

Work Description On Cycle

Feeding tubes into AV Cycle Pewle

Work Location East Bay Inside Containment

Right shoulder/Chest area Sampling for first drum

Respirators/PPE

Controls

Sample # 3705-A-A-4/30-29 -30 Pump # 1249 Media Hydrar mCEF

Calibration: Pre 156 c/min Post 153 c/min 154.5 Time: On 11:15 Off 12:36 91 ~~145~~ min Volume ~~22.40 L~~ 12.51 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 91 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 11/30/03 Job Code:

Employee: Jack Balkenhol SSN: Job Title:

Work Description: Air Cycle

Work Location: Checking tubes into Air Cycle Decon
East for Fresh Contaminat
Left shoulder/chest area for 3rd set down

Respirator/PPE:

Controls:

Sample #: 3726-A-0 4/pc Pump #: 13657

Media: Hydrosorb

Calibration: Pre: 150 cc/min Post: 150 cc/min Time: On: 1315 Off: Volume: 2.39 L

Substance | OSHA PEL | Concentration | 8 Hour TWA

Hg | 0.1 mg/m³

Comments: 40 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 4/30/03 Job Code:

Employee: Tim Fairchild SSN: Job Title:

Work Description: Ov Cycle
Ensure containment on fiber drum reel trough

Work Location:

Respiratory/PPE:

Controls:

Sample #: 3105-A-M-4/30-33 -34 Pump #: 113308 Media: Hydrasorb MCEF

Calibration: Pre: 155 cc/min Post: 154 Time: On 11:15 2/9 Off 3:25 Volume: 22.79 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS: 148 m2

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 4/30/03 Job Code:

Employee: SSN #: Job Title:

Work Description: Our Cycle Inside Containment - on fiber drum area feed

Work Location: west side

Respirators/PPE:

Controls:

Sample #: 5105-A-A-4/30 35 Pump #: 11152 Media: PVC

Calibration: Pre: 155 cc/min Post: 153 cc/min 154

Time: On: 1:15 2:15 Off: 2:15 3:25 Volume: 2.772

Substance	OSHA PEL	Concentration	8 Hour TWA
U	0.1 mg/m3		

Comments: 1 of 1 pump

Industrial Hygienist: Employee #:

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AIR SAMPLING DATA FORM

Client: EPA Date: 4/30/03 Job Code:

Employee: Ted SSN #: Job Title:

Work Description: Air Cycle
Filter change #1

Work Location:

Respirators/PPE:

Controls:

Sample #: 3705-A-A-4/30-37 -38 Pump #: 13682 Media: Hydrar mcEF

Calibration: Pre 250 cc/min Post 247 cc/min 248.5 Time: On 11:40 Off 11:52 Volume 2.98 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS: 12 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 4/30/03 Job Code

Employee Tad SSN # Job Title

Work Description Arc Vale
Filter Change #2; Drum Change #1

Work Location

Respirators/PPE

Controls

Sample # 3705-A-A-4/30-3 Pump # 13682 Media Hydar mCEF
-40

Calibration: Time:
Pre 2.50 cc/min Post 2.47 cc/min On 12:19 Off 12:36 Volume 4.22 L
2.48 ✓

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 17 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 4/30/03 Job Code

Employee Tad SSN # Job Title

Work Description Air Cycle
Filter Change #3

Work Location

Respirators/PPE

Controls

Sample # 3705-A-A 4/30-41 Pump # 13682 Media Hydrar MCEP
-42

Calibration: Time:
Pre 250 cc/min Post 247 cc/min On 2:41 OFF 2:53 Volume 2.98 L
248.5

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 12 min.

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date performed: 5/2/03 Job Code:

Employee: Todd SSN #: Job Title:

Job Description: RTI Lamp change H2

Work Location:

Respirators/PPE: Contaminated used suit labels for Anticycle machine

Controls: 73 79

should be 3705

Sample #: 3705-A-A 4/30-4/7 Pump #: 11308 Media: Hydrar mcEF

Calibration: Pre 250 cc/min Post 247 cc/min Time: On 8:19 Off 8:31 Volume 3.5 L 2.98

250 cc/min 248.5

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 12 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client CPA Date 4/30/03 Job Code

Employee Tad SSN # Job Title

Work Description Ceiling #1 Air cycle
4 minute samples

Work Location done at filter change #1

Respirators/PPE

Controls

Sample # 3701-A-A-4/30-45 Pump # 13673 Media Hydar MCE
-46 4-min

Calibration: Time:
Pre 249 cc/min Post 246 cc/min On 1219 Off 1223 Volume 0.99L
247.5

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 4 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client S.P.T. Date 4/30/03 Job code

Employee Ted SSN # Job Title

Work Description Ceiling # 2 during cycle
4 minute sample

Work Location Done at Filter change #2
after ceiling #1

Respirators/PPE

Controls

Sample # 305-A-A-4/30-47 Pump # 13673 Media Hydrar MCE
-48

Calibration: Time: 4 minutes
Pre 2.44 cc/min Post 246 cc/min On 1225 Off 1229 Volume 0.99L
247.5

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1mg/m3		

COMMENTS: 4 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 4/30/03 Job Code

Employee SSN # Job Title

Work Description AM Cycle - DTC Dense Overnight - inside containment dr

Work Location Fiber drum near exhaust

Respirators/PPE

Controls

Sample # 3705-A-A-4/30-49 -50 Pump # 12708 Media Hydar MCEF

Calibration: Time: next day 991 minutes

Pre 152 cc/min Post 152 cc/min On 4:26pm Off 8:57am Volume 150.63 L

152 991

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS: 991 min

Industrial Hygienist: Reviewed By:

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Greenwood Village, Colorado 80111
303.694.4159 FX. 303.694.7367

AIR SAMPLING DATA FORM

Client EPA Date 4/30/03 Job Code

Employee SSN # Job Title

Work Description Inv Cycle Rinse
Overnight - inside containment on
Work Location Fiber drum near inlet feed tube

Respirators/PPE

Controls

Sample # 3705-AA-4/30-5 Pump # 13914 Media Hydrar MCEF
-52

Calibration: Time: next day 991 minutes
Pre 151 cc/min Post 150 cc/min On 4:26 pm Off 8:57 pm Volume 149.15 L
150.5

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS: 991

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 4/30/03 Job Code

Employee SSN # Job Title

Work Description Air Cycle Denver
overnight - outside container

Work Location

Respirators/PPE

Controls

Sample # 3705-A-A 4/30-53 -54 Pump # 13673 Media Hydrar mCEF

Calibration: Time: 491 min max + day
Pre 157 cc/min Post 154 cc/min On 4:26 pm Off 8:57 am Volume 154.10 L
155.5

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 491 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Tad F Date: 4/30/03 Job Code:

Employee: Tad Radzinski SSN #: Job Title:

Work Description: arCycle
Feeding tubes into ArCycle Device

Work Location: East Bay Inside Containment

Respirators/PPE: Right shoulder / chest area
for second drum. ~~for~~

Controls:

Sample #: 3705-A-A-4/30-55 ~56 Pump #: 11249 Media: Hydrar mCEF

Calibration: Pre 153 cc/min 155.5 Post 158 cc/min Time: On 2:18 Off 3:25 Volume 10.42 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m^3		

COMMENTS: 67 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client G & A Date 4/30/03 Job Code

Employee Ted Radzinski SSN # Job Title

Work Description Air Cycle

Feeding tubes into Air Cycle Device

Work Location East Bay Inside Containment

Respirators/PPE Left shoulder/chest area for second drum ☆

Controls

Sample # 3705-A-A-4/30-57 -58 Pump # Media Hydrar MCE

Calibration: Pre 150 cc/min Post 151 cc/min Time: On 2:18 Off 3:25 Volume 10.08 L

1:05

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 6 1 m.r

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 4/31/03 Job Code

Employee Tad SSN # Job Title

Work Description Fit Drum Change #2 + Filter change #4

Work Location

Respirators/PPE

Controls

Sample # 3705-4/31 A-A-4/31-59 -60 Pump # 1308 Media Hydrar mCEF

Calibration: Pre 255 cc/min 255.5 Post 256 cc/min Time: On ~~0819~~ 0821 Off 9:33 Volume 3.07 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1mg/m³		

COMMENTS: 12 mm

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 5/1/03 Job Code

Employee Tad Radzinski SSN # Job Title

Work Description RTI

Work Location Feeding tube into RTI device
East Bay Inside Containment
Left shoulder/chest area

Respirators/PPE Entire 1st + 2nd dress

Controls

Sample # 3705-A-A-5/1-61 Pump # 13077 Media Hydrar
=62 MCEF

Calibration: Time: 12:08 - 1:27 | 3:52 - 4:57
Pre 154 cc/min Post 154 cc/min On Off Volume 21.87 L
154

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 142 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 5/1/03 Job Code

Employee Jed Radzinski SSN # Job Title

Work Description RTI

Feeding tubes into RTI drive

Work Location East Bay inside containment

LEFT shoulder/chest area for (1st day)

Respirators/PPE

Controls

Sample # 3705-R-A-5/1-03 Pump # 13914 Media Hydrar MCEF

-44 7 hr. ea

Calibration: Time:

Pre 150 cc/min Post 149 cc/min On 1200 Off 1271 Volume 11.81 L

≈ 149.5

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 7 hr. ea

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: G&A Date: 5/1/03 Job Code:

Employee: Tad Radzinski SSN #: Job Title:

Work Description: RT 1

Feeding tubes into RT 1 Dewar

Work Location: East Bay Inside Containment

Respirators/PPE: Right shoulder / chest area sampling for (1st dewar)

Controls:

Sample #: 3705-K-A-5/1-65-66 Pump #: 12708 Media: Hydar mCEF

Calibration: Pre 1.52 c/min Post 1.51 c/min Time: On 12:08 Off 1:27 Volume 11.97L

79 min

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 79 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 5/1/03 Job Code

Employee SSN # Job Title

Work Description RTI

Work Location Inside containment - on floor drum near Exhaust

Respirators/PPE

Controls

Sample # 3705-R-A-5/1-67 -68 Pump # 1267 Media Hydrar

Calibration: Time: 1213:50-1453 mCEF

Pre 157 cc/min Post 156 cc/min 156.5 On 1209 Off Volume 2.22 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 142 m.w

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: GPA Date: 5/1/03 Job Code:

Employee: SSN: Job Title:

Work Description: RTI

Work Location: Inside containment - no fiber data was recd
outlet tube

Respirators/PPE:

Controls:

Sample #: 303-R.N-5/1-69 Pump #: 11249 Media: 1 pc
-7B 37mm

Calibration: Pre: 156.0 L/min Post: 155.0 L/min Time: On: 11:05 Off: Volume: 22.0 L
155.5

Substance	OSHA PEL	Concentration	8 Hour TWA
N/A	0.1mg/m³		

COMMENTS: 142 Mic

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 5/1/03 Job Code:

Employee: Jad SSN #: Job Title:

Work Description: ATL drum change #1

Work Location:

Respirators/PPE:

Controls:

Sample #: 3705-R-A-5/1-71 -72 Pump #: 11309 Media: Hydar mEE

Calibration: Pre 256 cc/min Post 254 cc/min 255

Time: On 1:15 Off 1:27 Volume: 3.07 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 12 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 5/1/03 Job Code

Employee Tad SSN # Job Title

Work Description Ceiling #1 KTI
4 minute samples

Work Location done at drum change for 1st drum

Respirators/PPE

Controls

Sample # 3105-R-A-5/1-75 Pump # 13682 Media Hydlon MCEF
-76

Calibration: Time:
Pre 2.5 lpm/min Post ~2.50 cc/min On 1:15 Off 1:19 Volume 1.01 L
253

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS: 4 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 5/1/03 Job Code:

Employee: Ted SSN #: Job Title:

Work Description: Cutting H2 RTI
4 minute sample

Work Location: Near + Inside Vessel for 1st time

Respirators/PPE:

Controls:

Sample #: 3703-R-A-1-1.7 Pump #: 13682 Media: Hydrocarbon
-78

Calibration: Pre: 2.56 cc/sec Post: 2.56 cc/sec
255

Time: On: 1:20 Off: 1:24 Volume: 1.6 L

Substance	OSHA PEL	Concentration	8 Hour TWA
H2	0.1 mg/m3		

COMMENTS: 4 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 5/1/03 Job Code:

Employee: Ted Radzinski SSN #: Job Title:

Work Description: RTE
Feeding Hobs

Work Location: East Bay Inside Containment
Left Shoulder / chest area for 2nd drum

Respirators/PPE:

Controls:

Sample #: 3705-RA-5/1-79 Pump #: 13914 Media: Hydrar MCEF
-80 63 mm

Calibration: Time:
Pre: 149 cc/min Post: 147 cc/min On: 8:50 Off: 4:53 Volume: 9,32 L
148

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 63 mm

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 5/1/03 Job Code

Employee Tad Radzinski SSN # Job Title

Work Description RTI
Feed wires

Work Location East Bay Inside Containment
Right shoulder/chute area for 2nd drum *

Respirators/PPE

Controls

Sample # 3705-R-A-5/1-81 Pump # 12703 Media Hydrar
-82 SKC EF

Calibration:
Pre 151 cc/min Post 149 cc/min Time: On 3:50 Off 4:53 Volume 9.45 L
150

Substance	OSHA PEL	Concentration	8 Hour TWA

COMMENTS: 93 mm

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 5/1/03 Job Code:

Employee: SSN #: Job Title:

Work Description: RTI

Work Location: overnight - inside containment on floor drum near exhaust

Respirators/PPE:

Controls:

Sample #: 3705-R-A-SU-83-84 Pump #: 13657 Media: Hydrion MCEF

Calibration: Pre: 155 cc/mm Post: 153 cc/mm 154

Time: On: 5:33pm 5/1/03 Off: 8:07am 5/2/03 874 min Volume: 134.6 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 874 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 5/1/03 Job Code:

Employee: SSN #: Job Title:

Work Description: RTI

Work Location: overnight - inside containment on Elevation near wet feed tube

Respirators/PPE:

Controls:

Sample #: 3705-R-A-C1-85 -86 Pump #: 1152 Media: Hydar mCE

Calibration: Pre 156 cc/min Post 152 cc/min 154

Time: On 5:33 pm 5/1/03 Off 8:01 am 5/2/03 Volume 134.6 C

874 min.

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 474 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 5/1/03 Job Code:

Employee: SSN #: Job Title:

Work Description: RTI

overnight = outside containment

Work Location:

Respirators/PPE:

Controls:

Sample #: 3705-RA-5/1-87-88 Pump #: Te 1120/9 Media: Hydrar

Calibration: Pre: ~~55cc/min~~ 155cc/min Post: 160cc/min Time: On: 5:33pm 5/1/03 Off: 8.07pm 5/2/03 Volume: 137.66 L

Substance | OSHA PEL | Concentration | 8 Hour TWA

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1mg/m3		

COMMENTS: 479 mw

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 5/12/89 Job Code:

Employee: Ted SSN: Job Title:

Work Description: Tech - Left shoulder - Drum #1

Work Location: Dexter Shell Only 1 drum for the test

Respirators/PPE:

Controls:

Sample #: 2365-018-5/12-89-10 Pump #: 13657 Media: Hi Vol AERP

Calibration: Pre: 153 l/min Post: 153 l/min Time: On: 1507 Off: 1557 Volume: 8.4 m³

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

Comments: Blank

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 5/2/03 Job Code

Employee Ted SSN # Job Title

Work Description Right shoulder Drum #1
Dextrite

Work Location Only 1 drum filled for this test

Respirators/PPE

Controls

Sample # 3705-D-A-5/2-91 -92 Pump # 11249 Media Hydra-mCEF

Calibration: Pre 154 cc/min Post 153 cc/min 153.5 Time: On 9:07 Off 10:03 Volume 8.60 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m^3		

COMMENTS: 56 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 5/2/03 Job Code:

Employee: SSN #: Job Title:

Work Description: Destroke - only 1 drum filled
Inside containment on fiber drum near

Work Location: exhaust

Respirators/PPE:

Controls:

Sample #: 3705-B-A-5/2-93 -94 Pump #: 1152 Media: ~~MCE~~ Hydrar MCEF

Calibration: Pre 151 cc/min Post 154 cc/min 152.5 Time: On 9:07 Off 10:04 Volume 8.69 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 57 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 5/2/03 Job Code

Employee SSN # Job Title

Work Description Dentite - only, 8 ll. one day.
Inside containment on fiber drum near
Work Location inlet feed tube

Respirators/PPE

Controls

Sample # 3705-DA-5/2-95 Pump # 1 2 7 08 Media Hydar
-96 MCE

Calibration: Time:
Pre 158 cc/min Post 151 cc/min On 9:07 Off 10:09 Volume 8.66L
152

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 57 min.

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client GIA Date 5/2/03 Job Code

Employee SSN # Job Title

Work Description Dextrite
Drumchange for 1 drum filled

Work Location

Respirators/PPE

Controls

Sample # 3705-D-A-5/2-97 Pump # 11308 Media Hydrar MCEF
-98

Calibration: Time:
Pre 25 kcc/min Post 25 kcc/min On 9:50 Off 10:02 Volume 3.07 L
256

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 12 min

Industrial Hygienist: Reviewed By:

Appendix B

Air Sampling Data Forms

Sample Shipping Information

Samples were placed in an oversized, sturdy box with packing material to fill voids and protect the samples during shipping. The sampling personnel then signed the chain-of-custody forms, and placed them in the box with the samples. Samples were shipped via Federal Express to the laboratory.

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AIR SAMPLING DATA FORM

Client EPA Date 4/29/07 Job Code

Employee SSN # ~~12708~~ Job Title 3705

Work Description Background - East Bay 24 feet east of man dock door

Work Location

Respirators/PPE

Controls

Sample # 3705-B-4/29-01 Pump # 12708 Media Hydrar MCEP

Calibration: Time:
Pre 207.5 cc/min Post 203 cc/min On 9:41 am Off 2:39 pm Volume 61.167
20525 218

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS: Photo #6 on my camera is of the background sample
Photo #7 is of man dock door
Photo #8 - Other background
298 minutes.

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 4/29/03 Job Code

Employee SSN # Job Title 3705

Work Description Background

Work Location East Bay 18 ft North of Mid Dock door

Respirators/PPE

Controls

Sample # 3705-B-4/29-03 Pump # 13657 Media Hydar MCEP

Calibration: Time:
Pre 206 cc/min Post 229 cc/min On 9:41 am Off 2:39 pm Volume 64.8 L
217.5 298

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 298 minutes

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 4/29/03 Job Code

Employee Tad Radzinski SSN # Job Title

Work Description Feeding Tubes into Dextrile DTC Device
Gas Box Inside containment

Work Location Right shoulder / chest area

Respirators/PPE

Controls

Sample # 3705-D-A-4/29-05 -06 Pump # 13682 Media Hydar MCEF

Calibration: Pre 156 cc/min (HJ) Post 158 cc/min (HJ) Time: On 3:07 167 cc/min OFF 4:35 Volume 25.81 L
158.3?

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS: 163 minutes

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 4/29/03 Job Code

Employee Ted Radzinski SSN # Job Title

Work Description Feeding tubes into Exhibit DTC Device
East Bay Inside Containment

Work Location Left + Shoulder/chest area

Respirators/PPE

Controls

Sample # 305-0-N-4/29-07 Pump # 13914 Media Hydrar
=08

Calibration: Pre 150 cc/min Post 148 cc/min Time: On 3:07 4:33 Off 6:03 7:20 MCEP Volume 24.23 L
1.867 #3

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 1 of 3 Avon

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 4/29/03 Job Code

Employee SSN # Job Title

Work Description Dextrite DTC Device

Inside Containment - on fiber drum near exhaust

Work Location

Respirators/PPE

Controls

Sample # 3705-D-A-4/29-09 -10 Pump # 1261 Media Hydar mCEF

Calibration: Pre 151 cc/min Post 154 cc/min 153 Time: On 3:07 4:45 | 1:43 Off 5:20 | 163 minutes Volume 24.94L ~~24.88L~~

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 1.3 mm

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 4/29/11 Job Code

Employee SSN # Job Title

Work Description Dextrit DTC Device

Work Location Inside containment - on floor near inlet feed tube

Respirators/PPE

Controls

Sample # 3705-D-A-4/29-11-12 Pump # 13673 Media Hydrar mCEF

Calibration: Time:
Pre 152 cc/min Post 154 1.5 l/min On 1.61 Off 163 min Volume 25.10 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 163 min VHO

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 4/27/07 Job Code:

Employee: SSN: Job Title:

Work Description: Denver DTC Office

Work Location: Drum Cleaning Area Building 347
311
658

Respirators/PPE:

Controls:

Sample #: 345-0-4/27-15 Pump #: 1308 Media: Hydrar
-15 MCE

Calibration: Time:
Pre: 2.52 cc/min Post: 2.53 cc/min On: 4:27 Off: 4:35 Volume: 3.44
2.525

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS: 12 hours

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 4/29/03 Job Code:

Employee: SSN #: Job Title:

Work Description: Dexrite DTC Device
drum change 1 @ 609 bulk

Work Location:

Respirators/PPE:

Controls:

Sample #: 3705-D-A-4/29-15 Pump #: 11249 Media: Hydnar MCEF

Calibration: 2.58 Pre: ~~5.0~~ cc/mn 254 Post: ~~2.50 cc/mn~~ 2.50 cc/mn Time: On: ~~7:30~~ 7:06pm Off: 7:20pm Volume: 5.08

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1mg/m³		

COMMENTS: 20 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 4/29/03 Job Code

Employee SSN # Job Title

Work Description Dextrie DTC Device
Overnight - inside containment on

Work Location fiber drum near exhaust

Respirators/PPE

Controls

Sample # 2705-D-A-4/29-17 -18 Pump # 13414 Media Hydrar

Calibration: Time:
Pre 2.145 Post 14.6 cc/min On 2018 Off ~~806~~ 8:12 Volume 164.96 L
714 minutes
147

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 714 minutes

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPP Date 4/29/03 Job Code

Employee SSN # Job Title

Work Description Dextrite DTC Denver

Work Location Evening+- inside containment by fiber drum near inlet feed tube

Respirators/PPE

Controls

Sample # 3705-D-A-4/29-19 -20 Pump # 12705 Media 4 glass MCEF

Calibration: Pre 153 149 Post 145 cc/min Time: On 2018 Off 8:12 714 minutes Volume 106.39 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 714 min

Industrial Hygienist: Reviewed By:

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Greenwood Village, Colorado 80111
303.694.4159 FX. 303.694.7367

AIR SAMPLING DATA FORM

Client EPA Date 4/29/03 Job Code

Employee SSN # Job Title

Work Description Dextrik DTC Device
overnight - outside containment

Work Location

Respirators/PPE

Controls

Sample # 3705-D-A-4/29-21 Pump # 13657 Media Hydar mOEP
-22

Calibration: Time:
Pre 15.4 Post 152 cc/min On 2018 Off 8:12 Volume 109.24 L
153

714 min

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	C .1mg/m³		

COMMENTS: 714 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 4/29/03 Job Code

Employee SSN # Job Title

Work Description Ceiling - 4 on outer ranges - (#1)

Work Location

Respirators/PPE

Controls

Sample # 3705-D-4-4/29-23 -24 Pump # 1308 Media Hydrar MCEF

Calibration: Pre 251 cc/min Post 256 cc/min 253.5 Time: On 7:03 pm Off 7:07 p.m. Volume 1.01 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 4 min

Industrial Hygienist: Reviewed By:

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Greenwood Village, Colorado 80111
303.694.4159 FX: 303.694.7367

AIR SAMPLING DATA FORM

Client: EPA Date: 7/24/97 Job Code:

Employee: SSN: Job Title:

Work Description: Colony Yosemite Sonora HD

Work Location:

Respirators/PPE:

Controls:

Sample I.D.: 3725-0-11-7/97-25 Time: 1130 Media: Hi-Flow

26 VACUF

Calibration: Size: 2.5 l/min Post: 2.5 l/min Time: 7:08 Out: 7:12 Volume: 1.6 L

2535

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

Comments: 4 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 4/30/03 Job Code:

Employee: Tad Radzinski SSN #: Job Title:

Work Description: Air cycle
Feeding Wires into Air Cycle Device

Work Location: East Bay Inside Containment
Left shoulder - entire 2 drums (1st & 2nd Inning) this sampling

Respirators/PPE:

Controls:

Sample #: 3705-A-A-4/30-27 Pump #: 12671 Media: Hydrar
28 MCEF

Calibration: Time: On 12:36 Off 2:18 3:22
Pre: 155 cc/min Post: 153 cc/min Volume: 22.33L
154

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 145 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 4/30/03 Job Code

Employee Tad Raczinski SSN # Job Title

Work Description QNCycle

Feeding tubes into Air Cycle Pewle

Work Location East Bay Inside Containment

Right shoulder/chest area Sampling for first drum

Respirators/PPE

Controls

Sample # 3705-A-1-4/30-29 -30 Pump # 1249 Media Hydrar MCEF

Calibration: Pre 156 c/mn Post 153 c/mn 154.5

Time: On 11:31 Off 13:31 91 +45 mn

Volume 12.51 L ~~25.40 L~~

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 91 mn

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 1/30/03 Job Code:

Employee: Ted Robinson SSN: Job Title:

Work Description: Air Cycle

Work Location: Feeding tube into Air Cycle Dewar
East for Double Containment
Right shoulder/chest area for ~~arm~~ Arm down

Respirators/PPE:

Controls:

Sample #: 3705-A-A-4118 Pump #: 13657 Media: Hydrosorb MCE

Calibration: Pre: 150 cc/min Post: 150 cc/min Time: On: 1515 Off: 1615 Volume: 2.39 L

Substance: Hg OSHA PEL: 0.1 mg/m³ Concentration: 8-Hour TWA:

Comments: 60 min/hr

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA | Date: 4/30/05 | Job Code:

Employee: [redacted] | SSN: | Job Title:

Work Description: Dust Cycle
Ensike Contaminat on fiber drum Dec 12 hour

Work Location:

Respirators/PPE:

Controls:

Sample #: 3105-A-A-4/12-33 -34 | Pump #: 11308 | Media: Hydrar MCEF

Calibration: Pre: 1.55 c/m Post: 1.52 c/m | Time: On 11:15 2:18 Off 11:46 2:25 | 1.48 m³ | Volume: 22.794

Substance:	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 1411 m²

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 4/30/03 Job Code:

Employee: SSN #: Job Title:

Work Description: Our Cycle Trade Containment - on floor above feed water tube

Work Location:

Respirators/PPE:

Controls:

Sample #: 2705-A-A-4/30-35 Pump #: 11152 Media: Mixed MCE

Calibration: Pre: 155 cc/min Post: 153 cc/min Time: On 11:15 / 2:15 Off 12:30 / 3:25 Volume: 237.6

154

Substance	OSHA PEL	Concentration	8-Hour TWA
Hg	0.1 mg/m3		

Comments: LOD 1 mg

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 4/30/03 Job Code

Employee Ted SSN # Job Title

Work Description Air Cycle
Filter change #1

Work Location

Respirators/PPE

Controls

Sample # 3705-A-A-4/30-37
-38 Pump # 13682 Media Hydrar
mcEF

Calibration:
Pre 250 cc/min Post 247 cc/min
2485

Time: On 1140 Off 1152 Volume 2.98 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS: 12 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 4/30/03 Job Code

Employee Tad SSN # Job Title

Work Description Hg Cycle
Filter Change #2; Drum Change #1

Work Location

Respirators/PPE

Controls

Sample # 3705-A-A-4/30-3 -40 Pump # 13682 Media Hydra- mCEF

Calibration: Time:
Pre 250 cc/min Post 247 cc/min On 12:19 Off 12:36 Volume 422 L
248.5

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 17 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 4/30/03 Job Code

Employee Tad SSN # Job Title

Work Description Air Cycle
Filter Change #3

Work Location

Respirators/PPE

Controls

Sample # 3705-A-H 4/30-41 -42 Pump # 1368Z Media Hydrar MCEP

Calibration: Time: 12 min

Pre 250 cc/min Post 247 cc/min 248.5 On 2:41 OFF 2:53 Volume 2.98 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS: 12 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date performed: 5/2/03 Job Code:

Employee: Tad SSN #: Job Title:

Job Description: RFI dynamic change #2

Work Location:

Respirators/PPE: (on accident used same labels for Air Cycle machine)

Controls: Glove bag 3705-A-5 1-73 -79

Sample #: 3705-A-A 4/130-43 Pump #: 11308 Media: Hydrar mcEF

Calibration: Pre: 250cc/min Post: 247cc/min Time: On: 8:19 Off: 8:31 Volume: 3.5L 2.98

250cc/min 248.5

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1mg/m3		

COMMENTS: 12 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 4/30/03 Job Code

Employee Tad SSN # Job Title

Work Description Ceiling #1 Air Cycle
4 minute samples

Work Location done at filter change #1

Respirators/PPE

Controls

Sample # 3707A-A-4/30-45 Pump # 13673 Media Hydar MCE F
=46 4 min

Calibration: Time:
Pre 249 cc/min Post 246 cc/min On 1219 Off 1223 Volume 0.99L
247.5

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 4 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: S.P.A. Date: 4/30/03 Job Code:

Employee: Tod SSN #: Job Title:

Work Description: Ceiling #2 Anycycle
4 minute sample

Work Location: Done at Filter change #2
after ceiling #1

Respirators/PPE:

Controls:

Sample #: 305-A-A-4/30-47 = 43 Pump #: 13673 Media: Hydrar mCEF

Calibration: Pre: 244 cc/min Post: 246 cc/min 747.5 Time: On: 12:25 Off: 12:29 4 minutes Volume: 0.99L

Substance	OSHA PEL	Concentration	8-Hour TWA
Hg	0.1mg/m³		

COMMENTS: 4 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 4/30/03 Job Code

Employee SSN # Job Title

Work Description Air Cycle - DTC Device
Overnight - inside containment dr

Work Location Fiber drum near exhaust

Respirators/PPE

Controls

Sample # 3705-A-A-4/30-49 Pump # 1270 Media Hydar mCEF
-50

Calibration: Time:

Pre 152 cc/min Post 152 cc/min On 4:26pm Off 8:57am Volume 150.63 L
152 991

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1mg/m3		

COMMENTS: 991 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 4/30/03 Job Code

Employee SSN # Job Title

Work Description Hot Cycle Decon
Overnight - inside containment on
Work Location Fiber drum near inlet feed tube

Respirators/PPE

Controls

Sample # 3705-AA-4/30-5 Pump # 13914 Media Hydrar MCEF
-52

Calibration: Time: workday 991 minutes
Pre 151 cc/min Post 150 cc/min On 4:26 pm Off 8:51 am Volume 149.15 L
150.5

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS: 991

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 4/30/03 Job Code

Employee SSN # Job Title

Work Description Air Cycle Denie
Overnight - outside containment

Work Location

Respirators/PPE

Controls

Sample # 3705-A-1-4/30-53 Pump # 13673 Media Hydrar
-54 MCEF

Calibration: Time: 491 mm max/day
Pre 157 cc/min Post 154 cc/min On 4:26p Off 8:57am Volume 154.10L
155.5

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 491 mm

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Tad P Date: 4/30/03 Job Code:

Employee: Tad Radzinski SSN #: Job Title:

Work Description: Air Cycle
Feeding tubes into Air Cycle device

Work Location: East Bay Inside Containment
Right shoulder / chest area

Respirators/PPE: for second drum

Controls:

Sample #: 3705-A-A-4/30-55 -56 Pump #: 11249 Media: Hydrar MCEF

Calibration: Pre 153 cc/min Post 158 cc/min Time: On 2:18 Off 3:25 Volume 10.42 L
155.5

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	C: 1 mg/m³		

COMMENTS: 67 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client GPA Date 4/30/03 Job Code

Employee Ted Radzinski SSN # Job Title

Work Description Air Cycle

Feeding tubes into Air Cycle Device

Work Location Cart Dry, Inside Containment

Respirators/PPE Left shoulder/chest area

for second drum ☆

Controls

Sample # 3705-A-A-4/30-57 Pump # 67 mm Media Hydrar MCEF

-58

Calibration: Time:

Pre 150 cc/min Post 151 cc/min On 2:18 Off 3:25 Volume 10.08L

1.05

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 67 mm

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 4/31/07 Job Code

Employee Tad SSN # Job Title

Work Description ~~Fit~~ Drum Change #2 + Filter change #4

Work Location

Respirators/PPE

Controls

Sample # 3705-4/31 A-A-4/31-59 -60 Pump # 1308 Media Hydrar mCEF

Calibration: Pre 2.55 cc/min Post 2.56 cc/min 255-5 Time: On ~~0819~~ 0821 Off 9:33 Volume 3.07 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 12 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 5/1/03 Job Code

Employee Tad Radzinski SSN # Job Title

Work Description RTI

Feeding tube into RTI device

Work Location East Bay Inside Containment

Left shoulder/chest area

Respirators/PPE Entire 1st + 2nd don

Controls

Sample # 3705-A-A-4[5/1]21-61 -62 Pump # 13 673 Media Hydrar MCEF

Calibration: Time: 12:28 - 1:27 | 3:52 - 4:57

Pre 154 cc/min Post 154 cc/min On Off Volume 21.87 L

154

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 142 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 5/1/03 Job Code:

Employee: Jed Radzinski SSN #: Job Title:

Work Description: RTI

Work Location: Feeding tubes into RTI Oven
Last Bag inside containment
LEFT shoulder/chest area for (1st draw) ★

Respirators/PPE:

Controls:

Sample #: 3705-R-A-5/1-03 Pump #: 13914 Media: Hydrar
-44 79 min MCEF

Calibration: Time:
Pre: 150 cc/min Post: 149 cc/min On: 1208 Off: 1271 Volume: 11.81 L
150.5

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 79 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: G & A Date: 5/1/03 Job Code:

Employee: Ted Redzinski SSN #: Job Title:

Work Description: RT 1

Work Location: Feeding tubes into RT 1 Device
East Bay Inside Containment

Respirators/PPE: Right shoulder/chest area sampling for (1st drum)

Controls:

Sample #: 3705-R-A-5/1-65 Pump #: 12708 Media: Hydar mCEF

-66 79 min

Calibration: Time:
Pre: 152 c/min Post: 151 c/min On: 12:08 Off: 1:27 Volume: 11.97L
151.5

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 79 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 5/1/03 Job Code

Employee SSN # Job Title

Work Description RTI

Work Location Inside containment - on floor drum near exhaust

Respirators/PPE

Controls

Sample # 3705-R-A-5/1-67 -68 Pump # 1267 Media Hydrar

Calibration: Time: mCEF

Pre 157 cc/min Post 156 cc/min 156.5 On 1208 - 1713 Off 1750-1753 Volume 22.22 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 192 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 5/1/03 Job Code:

Employee: SSN: Job Title:

Work Description: RTI

Work Location: Inside enclosure - no fiber tree used inlet tube

Respirators/PPE:

Controls:

Sample I.D.: 370-R.R.-5/1-6 Pump I.D.: 11249 Media: 37mm MCE

Calibration: Pre: 156.0 cc/min Post: 155.5 cc/min Time: On: 11:05 Off: Volume: 22.0 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1mg/m³		

COMMENTS: 192 MCE

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 5/1/03 Job Code:

Employee: Ted SSN #: Job Title:

Work Description: ATL drum change #1

Work Location:

Respirators/PPE:

Controls:

Sample #: 3705-R-A-5/1-TL-TR Pump #: 1130 Media: Hydar mcEF

Calibration: Pre 2.56 cc/min Post 2.54 cc/min Time: On 1:15 Off 1:27 Volume: 3.07 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 12 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA. Date 5/1/03 Job Code

Employee Tad SSN # Job Title

Work Description Ceiling #1 KTL
4 minute samples

Work Location done at drum change for 1st drum

Respirators/PPE

Controls

Sample # 3705-R-A-5/1-75 Pump # 13682 Media Hydrion MCEF
-76

Calibration: Time:
Pre 2.5 lpm/min Post ~2.50 lpm/min On 1:15 Off 1:19 Volume 4.01 L
753

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS: 4 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 5/1/03 Job Code:

Employee: TAJ SSN #: Job Title:

Work Description: Cutting H2 RTL
4 minute samples

Work Location: Next to Incinerator for 1st day

Respirators/PPE:

Controls:

Sample #: 3705-R-A-5/1-TA Pump #: 13621 Media: Hydrex IMCF

Calibration: Pre: 2.54 cc/sec Post: 2.53 cc/sec Time: On: 1:20 Off: 1:24 Volume: 1.01 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS: 4 hours

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 5/1/03 Job Code:

Employee: Ted Radzinski SSN #: Job Title:

Work Description: RTE
Feeding Hbrs

Work Location: East Bay Inside Containment
Left Shoulder / chest area for 2nd day

Respirators/PPE:

Controls:

Sample #: 3705-RA-5/1-79 Pump #: 13914 Media: Hydrar MCEF
-80 63 mm

Calibration: Time:
Pre: 149 cc/min Post: 147 cc/min On: 3:50 Off: 4:53 Volume: 9.32 L
148

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 63 mm

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 5/1/03 Job Code

Employee Tad Radzinski SSN # Job Title

Work Description RTI
Feeding Wire

Work Location East Bay Inside Containment
Right Shoulder/chuteway for (2nd drum) ★

Respirators/PPE

Controls

Sample # 3705-R-A-5/1-81 -82 Pump # 12708 Media Hydrex MCEF

Calibration: Pre 151 cc/min Post 149 cc/min 150 Time: On 3:50 Off 4:59 Volume 9.45 L

Substance	OSHA PEL	Concentration	8 Hour TWA

COMMENTS: 63 mm

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 5/1/03 Job Code:

Employee: SSN #: Job Title:

Work Description: RIT overnight - inside containment on fiber drum near exhaust

Work Location:

Respirators/PPE:

Controls:

Sample #: 3705-R-A-5/1-83 -84 Pump #: 13657 Media: Hydlon MCEF

Calibration: Pre: 155 cc/mm 154 Post: 153 cc/mm Time: On: 5:33pm 5/1/03 Off: 8:07am 5/2/03 874 min Volume: 134.6 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 874 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 5/1/03 Job Code:

Employee: SSN #: Job Title:

Work Description: RTI

Work Location: overnight - inside containment on Overburn near inlet feed tube

Respirators/PPE:

Controls:

Sample #: 3705-B-A-51-85 -86 Pump #: 1152 Media: Hydar mCEF

Calibration: Pre 154 cc/min Post 152 cc/min 154

Time: On 5:33 pm 5/1/03 Off 8:01 am 5/2/03 Volume: 134.60 874 min

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 874 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 5/1/03 Job Code:

Employee: SSN #: Job Title:

Work Description: RTI

overnight - outside containment

Work Location:

Respirators/PPE:

Controls:

Sample #: 3705-B-A-5/1-87 -88 Pump #: Te 1129 Media: Hydrar SPHERE

Calibration:

Pre: ~~50 cc/min~~ 155 cc/min Post: 160 cc/min Time: On 5:33pm 5/1/03 Off 8:07pm 5/2/03 Volume: 137.66 L @157.5

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1mg/m3		

COMMENTS: 879 mm

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 5/2/07 Job Code:

Employee: Ted SSN: Job Title:

Work Description: Tech — Left Shoulder — Drum #1

Work Location: Dextrite — Only 1 drum filled for this test

Respirators/PPE:

Controls:

Sample #: 225-DA-5/2-SA1 Pump #: 13657 Media: Hydar MCEF

Calibration: Pre: 1336 l/min Post: 1336 l/min Time: On: 1107 Off: 1512 Volume: 8.4 m³

Substance: Hg Calc. REL: 0.1 mg/m³ Concentration: 8 Hour TWA:

Comments: Slime

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 5/2/03 Job Code

Employee Ted SSN # Job Title

Work Description Right shoulder Drum #1
Dextrite

Work Location Only 1 drum filled for this test

Respirators/PPE

Controls

Sample # 3705-D-A-5/2-91 Pump # 11249 Media Hydrar
-92 mCEF

Calibration:
Pre 154 cc/min Post 153 cc/min Time: On 9:07 Off 10:03 Volume 8.60L
153.5

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS: 56 min

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AIR SAMPLING DATA FORM

Client: EPA Date: 5/2/03 Job Code:

Employee: SSN #: Job Title:

Work Description: Dextrite - only 1 drum filled
Inside containment on fiber drum near

Work Location: exhaust

Respirators/PPE:

Controls:

Sample #: 3705-B-A-5/2-93 -94 Pump #: 1152 Media: ~~PVC~~ Hydro MCEF

Calibration: Pre 151 cc/min Post 154 cc/min 152.5 Time: On 9:07 Off 10:04 Volume 8.69 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 57 min

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 5/2/03 Job Code

Employee Soil # Job Title

Work Description Dextrit - only, fill one drum

Work Location Inside containment on fiber drum near inlet feed tube

Respirators/PPE

Controls

Sample # 3705-DA-5/2-95 Pump # 1 2 7 08 Media Hydrar
-96 MCE

Calibration: Time:
Pre 153 cc/min Post 151 cc/min On 9:07 Off 10:09 Volume 8.66L
152

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS: 57 min.

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 5/2/03 Job Code

Employee SSN # Job Title

Work Description Dextrite
Drumchung for 1 drum filled

Work Location

Respirators/PPE

Controls

Sample # 3705-D-A-5/2-98 Pump # 11308 Media Hydrar MCEF

Calibration: Time:
Pre 25 cc/min Post 256 cc/min On 9:50 Off 10:02 Volume 3.07 L
256

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 12 min

Industrial Hygienist: Reviewed By:

Appendix B

Air Sampling Data Forms

Sample Shipping Information

Samples were placed in an oversized, sturdy box with packing material to fill voids and protect the samples during shipping. The sampling personnel then signed the chain-of-custody forms, and placed them in the box with the samples. Samples were shipped via Federal Express to the laboratory.

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AIR SAMPLING DATA FORM

Client EPA Date 6/9/03 Job Code

Employee — SSN # Job Title

Work Description Background Samples taken at AEA Facility in Ashland Virginia

Work Location

Respirators/PPE

Controls

Sample # 105-BA-6/4-01 Pump # 1368 Media Hopcal MCEF

Calibration: Pre 2.0 Post 2.2 Time: 204 min On 4:19 pm Off 9:03 pm Volume 58.3 l

2.1 cc/min 236 2.2 cc/min 2.15

Substance	OSHA PEL	Concentration	8 Hour TWA

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client CCPA Date 6/9/03 Job Code

Employee SSN # Job Title

Work Description background Samples taken at AECC Facility in Ashland Virginia

Work Location

Respirators/PPE

Controls

Sample # 345-B-A-6/9-03 Pump # R 2015 Media Hydrion MCEF

Calibration: 2.05 l/min -0.5 Time: 24hr

Pre 2.04 cc/min Post 2.07 cc/min On 4:19 pm Off 9:03pm Volume 54.1 l

Substance	OSHA PEL	Concentration	8 Hour TWA

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 6/10/03 Job Code:

Employee: Ted Radzinski SSN #: Job Title:

Work Description: RTE Denie
entire 2 drums - LEFT SHOULDER

Work Location:

Respirators/PPE:

Controls:

Sample #: 3705-RT-6/10-05 -06 Pump #: 11249 Media: Hydrar MCEF

Calibration: 1.95 l/min Time: 9:55 - 11:02 67 662

Pre: 195 cc/min Post: 196 cc/min On: 12:11 - 1:13 Off: Volume: 25.2 l
129 min

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 6/10/97 Job Code

Employee Jad Radzinski SSN # Job Title

Work Description RT E Denize
Feeding bulbs in drum #1 ONLY.

Work Location LEFT SHOULDER

Respirators/PPE

Controls

Sample # J705-R-A-66-07 Pump # 1152 Media Hydar mCEF

Calibration: 200 ml/min

Time: 9:55 11:02 67 min

Pre 201 cc/min Post 200 cc/min On Off Volume 13.4

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

lient EPA Date 6/10/03 Job Code

mployee Ted Radzinski SSN # Job Title

ork Description RI Denie
Feeding Dubs in drum #1 ONLY

ork Location RIGHT SHOULDER

espirators/PPE

ontrols

Sample # 3705-K-A-1/2-09 Pump # 11271 Media Hydrar mCEF

alibration: 0.2 L/min Time: 9:55-1 hr 07 min

Pre 203 cc/min Post 202 cc/min On Off Volume 13.5 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 6/10/03 Job Code:

Employee: SSN #: Job Title:

Work Description: RTI Demo

Work Location: Inside containment while feeding bulbs - near Exhaust

Respirators/PPE:

Controls:

Sample #: 3705-R-A-6/10-11 Pump #: 12664 Media: Hydrar mcE F

Calibration: 0.201 L/min Time: 9:39-11:02 83

Pre 202 cc/min Post 201 cc/min On 12:11-1:13 off 62 min Volume 29.1 L

45

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 6/10/03 Job Code:

Employee: SSN #: Job Title:

Work Description: RTI Device

Work Location: Inside Containment while feeding bulbs near inlet feed tube

Respirators/PPE:

Controls:

Sample #: 5705-E-A-6/10-13 -14 Pump #: 13681 Media: Hydrar. mCEF

Calibration: 0.201 Time: On 7:39-11:02 93 / 12:11-1:13 62 Volume: 29.1

Pre: 200 cc/min Post: 202 cc/min 145

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 6/10/03 Job Code

Employee Tad Rademacher SSN # Job Title

Work Description On Tad's shoulder while performing Drum change #1

Work Location

Respirators/PPE

Controls

Sample # 3705-R-A-6/10-15 Pump # R 20 15 Media Hydrion mCEP

Calibration: 0.259 lpm Time: 10:50-11:02 12 min

Pre 260 cc/min Post 259 cc/min On Off Volume 3.1 l

Substance	OSHA PEL	Concentration	8-Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

[redacted]

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AIR SAMPLING DATA FORM

lient EPA Date 6/10/03 Job Code

mployee Ted Radzinski SSN # Job Title

ork Description on Tank 5 shield while performing Drum Change # 2

ork Location

espirators/PPE

ontrols

Sample # 5705-R-A 6/10-17 -18 Pump # R2015 Media Hydar MCEF

alibration: 0.259 L/m Time: 1:01 - 1:13 12 min

Pre 260 cc/min Post 259 cc/min On Off Volume 3.1 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 6/10/03 Job Code

Employee Ted Radzinski SSN # Job Title

Work Description on Ted's shoulder during drum #1 change out sampling sample #1

Work Location

Respirators/PPE

Controls

Sample # 3705-R-A-6/10-19-20 Pump # 1270 x Media Hydrar mCEF

Calibration: 0.25l Time: 10:50-10:54 4 min

Pre 252 cc/min Post 250 cc/min On Off Volume 1.0 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 6/10/03 Job Code

Employee Tad Rudzinski SSN # Job Title

Work Description On Tad's shoulder during door #2 change ceiling Sample #2

Work Location

Respirators/PPE

Controls

Sample # 3705-R-H-6/10-21 Pump # 12708 Media Hydar MCEF

Calibration: 0.251 -22 lpm Time: 10:55-10:59 4min

Pre 252 cc/min Post 250 cc/min On Off Volume 1.0 l

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EIA | Date: | Job Code:

Employee: Tads | SSN #: | Job Title:

Work Description: On Tads LEFT Shoulder
Drum #2

Work Location:

Respirators/PPE:

Controls:

Sample #: 3705-K-A-6/10-23 | Pump #: 11308 | Media: Hydrion MCEF

Calibration: 0.198 L/min | Time: 12:11-1:13 (62 min)

Pre: 198 cc/min | Post: 199 cc/min | On: | Off: | Volume: 12.32

Substance	OSHA PEL	Concentration	8 Hour TWA

COMMENTS:

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AIR SAMPLING DATA FORM

Client: EPA Date: 6/10/03 Job Code:

Employee: Tad Radzinski SSN #: Job Title:

Work Description: On Tad's ~~shoulder [illegible] drum~~ Tad's RIGHT shoulder Drum #2

Work Location:

Respirators/PPE:

Controls:

Sample #: 3705-R-A-6/10-25 Pump #: R-2992 Media: Hydrar mCEF
-26

Calibration: 0.198 lpm Time: 12:11-1:13 62 MN

Pre: 200 cc/min Post: 197 cc/min On: Off: Volume: 12.3 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS:

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AIR SAMPLING DATA FORM

lient EPA Data 6/10/03 Job Code

mployee SSN # Job Title

ork Description Overnight Samples - inside containment
tent Dear Extractor

ork Location

espirators/PPE

ontrols

Sample # 3705-R-A-6/10-27 Pump # 11254 Media Hydrar
-28 mCEF

Calibration: 0.155 lpm Time: 6:16 - 12:11 pm
Pre 155 cc/min Post 155 cc/min On Off 360 min Volume 55.80

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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8-2

AIR SAMPLING DATA FORM

Client SVMA | Date | Job Code

Employee | SSN # | Job Title

Work Description Oxidizer Sampler - Mixed. Containment near feed table

Work Location

Respirators/PPE

Controls

Sample # 3705-R-A-610-29 Pump # ~~1354~~ 1368 Media Hydran mCEF

Calibration: 0.152 lpm 30 Time: ~~4:11pm-12:11pm~~ 6:11pm-12:11pm

Pre ~~150cc/min~~ Post 153cc/min On | Off 360 Volume 54.7 l

151 cc/min

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: GIA Date: Job Code:

Employee: SSN #: Job Title:

Work Description: overnight sample - outside containment

Work Location:

Respirators/PPE:

Controls:

Sample #: 3705-R-1-6/10-31 Pump #: 2708 Media: Hydrar MCE

Calibration: 0.150 ~~32~~ 52 lpm Time: 6:11 pm - 12:11 pm

Pre: 157cc/min Post: 156cc/min On: Off: 360 min Volume: 56.28

Substance	OSHA PEL	Concentration	8 Hour TWA

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 6/10/03 Job Code

Employee Tad Radzinski SSN # Job Title

Work Description Personal Sampling during on dem - RTI equip
Right Shoulder comparison
phase II

Work Location

Respirators/PPE

Controls

Sample # 3705-R-A-6/10-33 Pump # 11249 Media Hydar MCEF

Calibration: 0.195 Opt 34 Time: 1:16-2:20 Min

Pre 196 cc/min Post 195 On Off Volume 12.5 l

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	Max 0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 6/10/03 Job Code:

Employee: Tad Kudzinski SSN #: Job Title:

Work Description: Personal Sampling during one drum - RTI - equip. Left shoulder Comparison phase II

Work Location:

Respirators/PPE:

Controls:

Sample #: 3705-R-A-6/10-35 Pump #: K 2992 Media: Hydrar mCEF

Calibration: Pre 197 cc/min Post 195 Time: On 1:16 - 2:20 Off 64 min Volume: 12.5 Q

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

lient EPA Date 6/10/03 Job Code

mployee SSN # Job Title

ork Description RTI equip comparison phase II - filling 1 drum
Inside Containment - Exhaust

ork Location

espirators/PPE

ontrols

Sample # 3705-R-A-6/10-37 Pump # 1130 8 Media Hydrar
-38 mcf

Calibration: 0.197 lpm Time: 4:14 - 5:12 58 min

Pre 199 cc/min Post 196 On Off Volume 11.4 l

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

lient SIA Date 6/10/03 Job Code

mployee SSN # Job Title

ork Description RTD Equipment Comparison Phase II - filling 12 in Inside Containment - Exhaust

ork Location

espirators/PPE

ontrols

Sample # 3705-R-A-6/10-3 Pump # 12664 Media Hydrar mCEF

Calibration: 0.198 @ 40 Time: 4:14 - 5:12

Pre 2.0 l/min Post 1.96 On Off 58 min Volume 11.5 l

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EIA - Date 6/10/03 Job Code

Employee SSN # Job Title

Work Description RTI - Equipment Comparison Phase II - Alloy Lam
Inside Containment @ feed tube

Work Location

Respirators/PPE

Controls

Sample # 3705-R-A-6/10-1 Pump # ~~[illegible]~~ 13681 Media Hydrar

Calibration: 0.200 lpm ~42 Time: 13681 4:14 - 5:12 mCEF
Pre ~~[illegible]~~ cc/min Post 198 On Off 58 min Volume 11.6 Q
202 cc/min

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

lient GM Date 6/10/03 Job Code

mployee SSN # Job Title

ork Description RTI Equip. Comparison Phase II - filling one drum
Inside Containment @ Fuel Lab

ork Location

espirators/PPE

ontrols

Sample # 3705-R-A-6/10-43 Pump # ~~#5-2~~ 11271 Media Hg dosimeter

Calibration: 0.1960 lpm-163 ~44 Time: 4:14-5:12 On Off 58 min Volume 10.8 l
Pre ~~[illegible]~~ Post ~~[illegible]~~ mCEF

~~gr~~ ~~[illegible]~~
204 cc/min

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

lient EPA Date 6/10/03 Job Code

mployee Ted Rudzinski SSN # Job Title

ork Description Personal sampling - RTI equip compartment during drum change

ork Location

espirators/PPE

ontrols

Sample # 3705-R-A-410-45 -46 Pump # R2015 Media Hydrar MCEF

alibration: Pre 0.261pm 260 cc/min 263 Post 260 cc/min Time: On 7:56 - 8:08 Off 12 min Volume 3.1 l

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

lient CPP Date 6/10/03 Job Code

mployee SSN # Job Title

ork Description Box Test
Taken after finished filling 2 drums for RTI

ork Location

espirators/PPE

ontrols

Sample # 3705-T-A-6/10-47 Pump # 11152 Media Hydar
-48 mCEF

Calibration: 0.199 Time: 1:16 2:20
Pre 200 cc/min Post 199 cc/min On Off 64 min Volume 12.7 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client E/A Date 6/10/03 Job Code

Employee SSN # Job Title

Work Description Vac Test
Taken after finished filling 2 drums for RTI

Work Location

Respirators/PPE

Controls

Sample # 3705-T-A-6/10-49 Pump # 1127 11 Media Hydrar MCEF
-50

Calibration: ~~0.200~~ 0.203 lpm Time: 1:16-2:20 On Off 64 min Volume 13.0 l

Pre ~~200~~ 202 cc/min Post 204 cc/min

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 6/10/93 Job Order:

Employee: Todd Kotarski SSN: Job Title:

Work Description: RTE - Equip. Containment Phase II - Filling overhead Ceiling Samples #1

Work Location: 4 min. Samples

Respirators/PPE:

Controls:

Sample #: 276-1-4-4/10 Pump #: 1117 Media: Hydrion 240 SF

Calibration: 0.2470 L/min Post: 2.45 L/min Time: On 7:56 - Off 8:00 4 min Volume: 1.0 l

Pre: 2.46

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 6/10/03 Job Code

Employee Tad Radzinski SSN # Job Title

Work Description KTF - Equip Comparison Phase II - Elly Sweden
Ceiling Sample #2

Work Location

4 min sample

Respirators/PPE

Controls

Sample # 3705-R-1-6/10-~~299~~ 53 Pump # 11177 Media Hydar
256 ~~HNO3~~ CF

Calibration: 0.247 lpm Time: 9:01 - 8:05

Pre ~~250~~ cc/min Post 248 cc/min On Off 4m Volume 1.09
246

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

Appendix B

Air Sampling Data Forms

Sample Shipping Information

Samples were placed in an oversized, sturdy box with packing material to fill voids and protect the samples during shipping. The sampling personnel then signed the chain-of-custody forms, and placed them in the box with the samples. Samples were shipped via Federal Express to the laboratory.

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AIR SAMPLING DATA FORM

lient EPA Date 6/11/03 Job Code

mployee Tad SSN # Job Title

ork Description Dextrik device
Entire 2 hours - LEFT Shoulder

ork Location

espirators/PPE

ontrols

ample # 3105-D-A-611-55 Pump # 11249 Media Hydrar mCEF
-56

ibration: 0.198 lpm Time: 10:20 - 11:25 59
re 198 cc/min Post 198 cc/min On 12:41 - OFF 1:19 38 Volume 19.24
97

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

OMMENTS:

ndustrial Hygienist: Reviewed By:

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Greenwood Village, Colorado 80111
303.694.4159 FX. 303.694.7367

AIR SAMPLING DATA FORM

Client EPA Date 6/11/03 Job Code

Employee Ind SSN # Job Title

Work Description Dextrik Deuce
1st drum - LEFT Shoulder

Work Location

Respirators/PPE

Controls

Sample # 3705-D-A-6/11-57 -58 Pump # 11308 Media Hydra mCEF

Calibration: Pre 200 cc/mm 0.198 Post 196 cc/mm Time: On 10:26 - 11:25 - 59 12-41 - 1:19 - 38 Off Volume 11.78 12.2

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 6/11/03 Job Code:

Employee: Ted SSN #: Job Title:

Work Description: Death Device
1st Drum RIGHT Shoulder

Work Location:

Respirators/PPE:

Controls:

Sample #: 3705-D-A-6/11-59 Pump #: 12654 Media: Hydar MCEF

Calibration: Pre 3.02cc/min Post 1.99 cc/min Time: On 10:20-11:25 59 12:44-1019 59 Volume: 11.8 L 10+5

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

lient EPA Date 6/11/03 Job Code

mployee SSN # Job Title

ork Description Dentite Dense

Inside Containment - near exhaust on roof

ork Location fiber drum.

espirators/PPE

ontrols

ample # 3705-D-A-6/11-61 Pump # R2992 Media Hydrar MCEF

alibration: 0.203 Lpm Time: 10:20 - 11:27 61
re 203 cc/min Post 203 cc/min On 12:41 - Off 1:19 38 Volume 20.1 L
99

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

OMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

lient EPA Date 6/11/03 Job Code

mployee SSN # Job Title

ork Description Pellite Denve
Inside containment near inlet feed tube on

ork Location round fiber drum

espirators/PPE

ontrols

ample # 375-D-A-6/11-03 Pump # 11271 Media Hydrar MCEF

ibration: 0.210 Lpm Time: 10:26 – 11:27 61
re 209 cc/min Post 21 cc/min On 12:41 – off 9 38 Volume 20.8 l
99

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

OMMENTS:

dustrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: GIA Date: 6/11/05 Job Code:

Employee: Tal SSN #: Job Title:

Work Description: Dextrie Pewee
Drum Change #2

Work Location:

Respirators/PPE:

Controls:

Sample #: 3705-D-A-6/11-65 Pump #: R2015 Media: Hydar MCEF
-66

Calibration: 0-200 cc/m Time:
Pre: 260 cc/mn Post: 260 cc/mn On: 11:05 Off: 11:25 Volume: 5.2l
20

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 6/11/03 Job Code:

Employee: Tad SSN #: Job Title:

Work Description: Dextek Penile Drum change #2

Work Location:

Respirators/PPE:

Controls:

Sample #: 3705-D-A 6/11-67 -68 Pump #: R 2015 Media: Hydar MCEF

Calibration: 0.200 Qpm Time:
Pre 260 cc/min Post 261 cc/min On 1:39 Off 1:51 Volume 3.1 Q
12 min

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EIA Date: 6/11/23 Job Code:

Employee: Ted SSN #: Job Title:

Work Description: Dextrie Drive

Ceiling, Sample - taken at drum change #1

Work Location:

4 min. Sample

Respirators/PPE:

Controls:

Sample #: 3705-D-A-6/11-69 Pump #: 11177 Media: Hydrar MCEF

-78

Calibration: 0.255 lpm Time:

Pre: 254 cc/min Post: 257 cc/min On: 11:05 Off: 11:09 Volume: 1.0 L

4

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client GAA Date 6/11/03 Job Code

Employee TJ SSN # Job Title

Work Description Dextrie Device

Work Location Ceiling sample - taken at dawn change #1

Respirators/PPE 4 min sample

Controls

Sample # 3705-DA-6/11-7 Pump # 1177 Media Hydar MCEF

Calibration: 0.255-72

Pre 254 cc/min Post 257 cc/min Time: On 4:11 Off 11:15 Volume 1.02

4

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 6/11/03 Job Code

Employee TAL SSN # Job Title

Work Description Dextrik Dede
2nd Drum LEFT Shoulder

Work Location

Respirators/PPE

Controls:

Sample # 3705-D-A-6/11-73 Pump # 13681 Media Hydar mCEF

Calibration: 0.202 l/pm -74
Pre 202 cc/mn Post 202 cc/mn Time: On 12:41 Off 1:19 Volume 7.7 l
38

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 6/11/03 Job Code

Employee Ind SSN # Job Title

Work Description Dextrite Denite
2nd Drum RIGHT Shoulder

Work Location

Respirators/PPE

Controls

Sample # 3705-D-A-6/11-75 Pump # 1115 2 / 13914 Media Hydrar MCEF
76

Calibration: 0.204 Qm Time:
Pre ~~206 cc/mm~~ 202 Post 206 cc/mm On ~~11~~ 12:52 Off 1:19 Volume 5.58
27

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

lient EPA Date 6/11/97 Job Code

mployee SSN # Job Title

ork Description Dextrie Denite
Overnight air sample placed near exhaust

ork Location

espirators/PPE

ontrols

Sample # 3705-D-A-6/11-77 Pump # 1254 Media Hydrin

Calibration: Pre 158 cc/min Post 154 cc/min 0.157 ~~0.158~~ Time: On 7:15 AM Off 5:53 PM 6/11 6/12 Volume 1259.0 mCF

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client G & A Date 6/11/03 Job Code

Employee SSN # Job Title

Work Description Dextrine Dewire
Overnight Av Sample - placed near inlet feed tube

Work Location

Respirators/PPE

Controls

Sample # 3705-D-A-6/11-79 -80 Pump # 2177 Media Hydrex MCE F

Calibration: Pre 153 cc/min Post 156 cc/min Time: On 5:53 PM 6/11 Off 7:15 AM 6/12 Volume 123.50

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 360 + 420 + 7 + 15

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client GPA Date 6/11/93 Job Code

Employee SSN # Job Title

Work Description Pentrite Denite

Overnight air sample placed outside containment

Work Location

Respirators/PPE

Controls

Sample # 3705-D-A-6/11-81 Pump # 11152 Media Hydran. MCEF

Calibration: 0.141 lpm Time: 5:53 pm 6/11
Pre 142 cc/min Post 140 cc/min On 7:15 pm Off 6th 6/12 Volume 113.1 l
802 min

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

lient EPA Date 6/11/03 Job Code

mployee Ted SSN # Job Title

ork Description Dextrike device
U-TUBE Study on Teds Left Shoulder

ork Location

espirators/PPE

ontrols

ample # 3705-D A-6/11-83 -84 Pump # 12664 Media Hydrar MCEF

ibration: 0.200 lpm Time:
re 199 cc/min Post 201 cc/min On 1:23 Off 1:35 Volume 2.48
12 Min

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

dustrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 6/11/03 Job Code:

Employee: Tad SSN #: Job Title:

Work Description: Dextrite Denver
U-TUBE study on Tad's Right Shoulder

Work Location:

Respirators/PPE:

Controls:

Sample #: 3705-0-A-6/11-85 Pump #: 11308 Media: Hydrion
w/ CEF

Calibration: 0.197 l/sec (8-6)
Pre: 196 cc/min Post: 199 cc/min Time: On: 1:23 Off: 1:35 Volume: 2.4 l
12

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

lient 9+A Date 6/11/03 Job Code

mployee Tad SSN # Job Title

ork Description Dextrite Device
~~Tube Study on Lab~~

ork Location Inside Containment near Exhaust - U-TUBES

espirators/PPE

ontrols

ample # 3705-D-A-6/11-87 Pump # 11177 Media Hydrar mCEF
88

ibration: 0.198 Pre 201 cc/min Post 196 cc/min Time: On 1:23 Off 1:35 Volume 2.4 l
12

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

ndustrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 6/11/03 Job Code:

Employee: Ted SSN #: Job Title:

Work Description: Dextrite device

Work Location: Inside containment near feed tube - UTUBES

Respirators/PPE:

Controls:

Sample #: 3705-DA-6/11-89 Pump #: 12708 Media: Hydrar MCEF

Calibration: 0.205 Pre 206 cc/min Post 205 cc/min Time: On 1:23 Off 1:35 Volume 2.5 l

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

lient EPA Date 6/11/03 Job Code

mployee Tad SSN # Job Title

ork Description Dextrak Rene
Equip Comparison Phase 2 - one day

ork Location Personal sampling on R/L/HT Shoulder

espirators/PPE

ontrols

ample # 3705-D-A-6/11-91 -92 Pump # 13681 Media Hydra MCEF

ibration: Pre 202 cc/min Post 198 cc/min Time: On 4:43 Off 5:17 34 min Volume 6.8 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

OMMENTS:

dustrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 6/11/93 Job Code

Employee Ted SSN # Job Title

Work Description Vextra Demo
Equip Comparison Phase 2 - one drum

Work Location Personal sampling on LEFT shoulder

Respirators/PPE

Controls

Sample # 3705-D-A-6/11-93-94 Pump # P-2992 Media Hydrar / MCEF

Calibration: 0.200 lpm Time:
Pre 203 cc/min Post 198 cc/min On 4:43 Off 5:17 Volume 6.8 l
34

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

lient EPA Date 6/11/97 Job Code

mployee SSN # Job Title

ork Description Dextrik Denuder
Equipment Comparison Phase 2

ork Location Inside Containment at Exhaust of
fiber drum

espirators/PPE

ontrols

ample # 3705-D-A-6/11-95-96 Pump # 11271 Media Hydrar mCEF

ibration: 0.212 cm
re 211 cc/min Post 214 cc/min Time: On 4:43 Off 5:17 Volume 7.2 l
34

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

OMMENTS:

dustrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

lient EPA Date 6/11/03 Job Code

mployee SSN # Job Title

ork Description Denver Equipment Comparison Phase 2 - one day

ork Location Inside Containment near exhaust on fiberdome

espirators/PPE

ontrols

ample # 3705-0-A-6/11-97 -98 Pump # 11249 Media Hydrazine MCEF

alibration: 0.198 Lpm Time:

re 198 cc/mn Post 198 cc/mn On 4:43 Off 5:17 34 Volume 6.7 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hydrazine	0.1 mg/m3		

OMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client GPA Date 6/11/03 Job Code

Employee SSN # Job Title

Work Description Dextrik Device
Equipment Comparison Phase 2 - one drum

Work Location Inside Containment near feed inlet tube on fiber drum

Respirators/PPE

Controls

Sample # 3705-DA-6/11-99 Pump # 13914 Media Hydar MCE

-100

Calibration: 0.202 lpm

Pre 204 cc/min Post 201 cc/min Time: On 4:43 Off 5:17 Volume 6.90

34

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: Eph Date: 8/1/03 Job Code:

Employee: SSN #: Job Title:

Work Description: Destruction Device Equipment Compression phase 2 - one drum

Work Location: Inside containment access port tube on fiber drum

Respirators/PPE:

Controls:

Sample #: 370S-D-A-C/11-101 -102 Pump #: 11308 Media: Hydrar mCEF

Calibration: 0.200 lpm

Pre: 200 cc/min Post: 200 cc/min Time: On 4:43 Off 5:17 Volume: 0.82 34

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client SLA Date 6/11/03 Job Code

Employee Tad SSN # Job Title

Work Description Dextit device
Equipment configuration Phase 2

Work Location Dosing Drum Change

Respirators/PPE

Controls

Sample # 3705-D-A-6/11-103 Pump # K2015 Media Hydrar mCET
=104

Calibration: 0.257 Open
Pre 258cc/min Post 256cc/min Time: On 7:46 Off 7:58 Volume 3.10
12

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m^3		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 6/11/03 Job Code

Employee Ind SSN # Job Title

Work Description Dextrine Device

Work Location Equipment Comparison Phase 2 - Ore dryer
Personal sampling ~~for~~ during Celly #1

Respirators/PPE 4 min sample

Controls

Sample # 3705-D-A-6/11-105 Pump # 12664 Media Hydrm mCEI
-106

Calibration: 0.260 Lpm Time:
Pre 1260 cc/min Post 260 cc/min On 7:46 Off 7:50 Volume 1.0 L

Substance	OSHA PEL	Concentration	8 Hour TWA

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 6/11/08 Job Code

Employee Tuli SSN # Job Title

Work Description Dextrie Denier
Equipment Comparison Phase 2 - coating

Work Location Personal Sampling during Ceiling #2

Respirators/PPE

Controls 4 hrs sample

Sample # 3705-D-A-6/11/08 Pump # 12664 Media Hydrar MCEF

Calibration: 0.200 Qpm Time:
Pre 2 LPM Post 2 L/min On 7:51 Off 7:55 Volume 1.0 l
108 4

Substance	OSHA PEL	Concentration	8 Hour TWA

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 6/11/03 Job Code:

Employee: SSN #: Job Title:

Work Description: Box Test

Work Location: Taken after finished filling 2 drums for Doctrite and doing U-TUBE Study. last containment next to van ka

Respirators/PPE: boxes of tubes on fiber drum

Controls:

Sample #: 3705-T-A-6/11-109 -110 Pump #: 12664 Media: Hydra mCEF

Calibration: 0.201 lpm Time:

Pre	Post	On	Off	Volume
201 cc/min	201 cc/min	2:57	3:13	7.2

36

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

lient: SIA Date: 6/11/03 Job Code:

mployee: SSN #: Job Title:

ork Description: Box Test

ork Location: Taken after finished filling 2 drums for Dactik and doing U-TUBE Study
West containment near generator

espirators/PPE:

ntrols:

ample #: 3705-T-A-6/11-111 =112 Pump #: 11308 Media: Hydrar MCEF

ibration: Pre 199 cc/min Post 200 cc/min Time: On 2:37 Off 3:13 36 Volume 7.20

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1mg/m3		

OMMENTS:

dustrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 6/11/03 Job Code:

Employee: Brian SSN: Job Title:

Work Description: Test on Brian, an AERC Facility employee to wear personal air sampler while working

Work Location: LEFT Shoulder

Respirators/PPE:

Controls:

Sample #: 3705-F-A-6/11-113 -114 Pump #: 12708 Media: Hydrar mCEF

Calibration: 0.202 l/m Time:

Pre: 2.05 c/l/m Post: 1.99 c/l/m On: 2:31 Off: 4:05 Volume: 1800 l

59

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 6/11/03 Job Code

Employee Brian SSN # Job Title

Work Description Test on Brian, an AERC Facility Employee to wear personal air sample while working. RIGHT Shoulder

Work Location

Respirators/PPE

Controls

Sample # 3705-E-A-6/11-15 Pump # 1152 Media Hydar mCEP

Calibration: Pre 205cc/min Post 200cc/min 0.202 -1% Time: On 2:31 Off 4:00 Volume 1800 59

Substance	OSHA PEL	Concentration	8 Hour TWA
H3	0.1mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

Appendix B

Air Sampling Data Forms

Sample Shipping Information

Samples were placed in an oversized, sturdy box with packing material to fill voids and protect the samples during shipping. The sampling personnel then signed the chain-of-custody forms, and placed them in the box with the samples. Samples were shipped via Federal Express to the laboratory.

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AIR SAMPLING DATA FORM

Client: SAIC Date: 6/12/03 Job Code:

Employee: Tad SSN: Job Title:

Work Description: Air Cycle Decon - Port Hatch
LEFT Shoulder, enter Zdrive

Work Location:

Complications/PPE:

Controls:

Sample #: 3705-AM-4/6-117 Pump #: 11305 Media: Hydrosorb
-118 mcF

Calibration: 0.202 L/min Time: 10:05 11:29 79
Pre: 20.4 L/min Post: 20.2 L/min On: 12:15 Off: 1:17 52 Volume: 24.52
131

Substance	OSHA PEL	Concentration	8 Hour TWA
H_2	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 6/12/03 Job Code:

Employee: Ed SSN #: Job Title:

Work Description: Air Cycle Demo - Real world

LGFT Shoulder - 1st DRUM

Work Location:

Respirators/PPE:

Controls:

Sample #: 3709-AA-6/12-111 Pump #: 1249 Media: Hydrar MCEF

= 120

Calibration: 0.200 lpm Time:

Pre 203 cc/min Post 197 On 10:05 Off 11:24 Volume 15.8 l

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 6/12/09 Job Code:

Employee: Ted SSN #: Job Title:

Work Description: Anvil cycle demo - Real world
RIGHT Shoulder - 1st Dmo

Work Location:

Respirators/PPE:

Controls:

Sample #: 3705-A-A-6/12-21 -122 Pump #: 1127 (1) Media: Hydr mCEF

Calibration: 0.211 lpm Time:

Pre: 20 [illegible] Post: 211 On: 10:05 Off: 11:24 Volume: 16.7 l

212 cc/min

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

lient EPA Date 6/12/03 Job Code

mployee [illegible] SSN # Job Title

ork Description Air Cycle Device - Red World
Cleanup Inside Containment - Exhaust

ork Location

espirators/PPE

ontrols

Sample # 3705-A-A-6/12-123 Pump # R2992 Media ~~MCEF~~ Hydrar
-124 MCEF

Calibration: 0.200 lpm Time: 10:05 11:24 79
Pre 202 cc/min Post 199 cc/min On 12:25 Off 1:18 53 Volume 264 l
132

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client CPA Date 6/12/03 Job Code

Employee Twd SSN # Job Title

Work Description Air Cycle - Real World

Fissile Containment - Feed Tube

Work Location

Respirators/PPE

Controls

Sample # 3725-A-A-6/12-125 Pump # 13914 Media Hydrar. mcf

-124

Calibration: 0.201 Time: 10:05 11:24 79

Pre 204 cc/min Post 199 cc/min On 12:25 Off 1:8 52 Volume 26.5 l

132

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 6/12/03 Job Code:

Employee: Tad SSN #: Job Title:

Work Description: Air Cycle - Real World
Filter Change #1

Work Location:

Respirators/PPE:

Controls:

Sample #: 3705-A-A-6/12-127 Pump #: 12708 Media: Hydra-
-128 MCEF

Calibration: 0.255 lpm Time: 12
Pre: 256 cc/min Post: 255 cc/min On: 10:36 Off: 10:42 Volume: 3.10

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1mg/m3		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

lient EPA Date 6/13/03 Job Code

mployee Tad SSN # Job Title

ork Description Arr Cycle - Real World
Filter Change #2 / Drum D#1

ork Location

espirators/PPE

ontrols

Sample # 3705-AA-Hg-129 Pump # 12708 Media Hydrar
-130 MCEP

ibration: 0.255 lpm Time: 12

Pre 256 cc/min Post 255 cc/min On 11:12 Off 11:24 Volume 3.10

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

ndustrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 6/12/03 Job Code

Employee Tad SSN Job Title

Work Description Air Cycle Device - Real world Ceiling #1

Work Location

Respirators/PPE

Controls

Sample # 3705-A-Hg-131 Pump # 12664 Media Hydrar MCE

Calibration: 0.260 lpm-132 Time: 4

Pre 261 cc/min Post 259 cc/min On 11:12 Off 11:16 Volume 1.0 l

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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Greenwood Village, Colorado 80111
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AIR SAMPLING DATA FORM

lient EPA Date 6/12/07 Job Code

mployee Tad SSN # Job Title

ork Description Air cycle Denic - Real World Ceiling #2

ork Location

espirators/PPE

ontrols

Sample # 3705-A-A-6/12-133 -134 Pump # 12664 4 Media Hydrar MCEF

alibration: 0.200 lpm Time:

Pre 261 cc/min Post 259 cc/min On 11:17 Off 11:21 Volume 1.0 l

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

ndustrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

lient EPA Date 6/12/03 Job Code

mployee Ted SSN # Job Title

ork Description Air Cycle Device - Real world
LEFT Shoulder - 2nd day

ork Location

espirators/PPE

ontrols

Sample # 3105-A-A-6/12-135-136 Pump # 11249 Media Hydrar MCEF

Calibration: 0.198 lpm Time: 52
Pre 197cc/min Post 199cc/min On 12:25 Off 1:17 Volume 10.30

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 6/12/07 Job Code

Employee Tad SSN # Job Title

Work Description Arc Cycle Device - Real World
RIGHT SHOULDER, 2nd drum

Work Location

Respirators/PPE

Controls

Sample # 9705-AA-6/12-137 Pump # 112711 Media
-138

Calibration: 0.2120 Time: 52
Pre 211 cc/min Post 214 cc/min On 12:25 Off 1:17 Volume 1402

Substance	OSHA PEL	Concentration	8 Hour TWA

COMMENTS:

Industrial Hygienist: Reviewed By:

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Greenwood Village, Colorado 80111
303.694.4159 FX: 303.694.7367

AIR SAMPLING DATA FORM

Client: EPA Date: 6/12/03 Job Code:

Employee: SSN #: Job Title:

Work Description: 2 Air Cycle Devic - Redwood

Overnight Sample - placed near exhaust on

Work Location: fire dome

Respirators/PPE:

Controls:

Sample #: 3705-A-A-6/12-B9 Pump #: R 2992 Media: Hydrar mCEF

Calibration: Pre 146 cc/min Post 142 cc/min 0.144 lpm -140

Time: On 7:30 AM 6/12 Off 5:49 PM 6/13 821

Volume: 1182 l

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS: 11 + 30 + 420 + 36

Industrial Hygienist: Reviewed by:

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AIR SAMPLING DATA FORM

Client EPA Date 6/12/93 Job Code

Employee SSN # Job Title

Work Description ~~[illegible]~~ Arc cyclone Dewitt Real World
Overnight Sample - placed near feed tube

Work Location on fiber drum

Respirators/PPE

Controls

Sample # 3705-A-A-6/12-141 -142 Pump # 11249 Media Hydrar MCEF

Calibration: 0.157 lpm Time: 5:49 Pm 6/12
Pre 157cc/min Post 158 cc/min On 7:30 Am Off 6/13 Volume 128.9 l
521

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 6/12/03 Job Code

Employee SSN # Job Title

Work Description Air Cycle Devie - Real world

Work Location overnight sample placed on floor down outside of containment

Respirators/PPE

Controls

Sample # 3705-A-A-6/12-143 -144 Pump # 13914 Media Hydrar MCEF

Calibration: 0.150 l/m Time: 5:49 pm 6/12
Pre 150 cc/min Post 152 cc/min On 7:30 Aoff 6/13 Volume 123.12
821

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 6/12/07 Job Code

Employee Tad SSN # Job Title

Work Description Air Cycle Device - Equipment Comparison Phase II
on Tad's RIGHT Shoulder

Work Location

Respirators/PPE

Controls

Sample # 3705-A-AC/12-145 -146 Pump # 12664 Media Hydar MCEF

Calibration: 0.199 lpm Time: 37 min

Pre 200cc/min Post 199 cc/min On 4:30 Off 5:07 Volume 7.4 l

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 4/2/03 Job Code

Employee Tad SSN # Job Title

Work Description Avocyde Device Equip Comp. Phase II
On Tad's LEFT shoulder

Work Location

Respirators/PPE

Controls

Sample # 375-A-A-4/2-147 -148 Pump # 11308 Media Hydrar

Calibration: 0.203 Lpm Time: 37 min MIEF

Pre 203 cc/min Post 203 cc/min On 4:30 Off 5:07 Volume 7.5 l

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1mg/m3		

COMMENTS:

Industrial Hygienist: Reviewed By:

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JP

AIR SAMPLING DATA FORM

Client: E/A Date: 6/12/03 Job Code:

Employee: SSN: Job Title:

Work Description: Q.C. cycle demo - Equip Compressor, Pump II
Inside Containment near Exhaust

Work Location: on first floor

Respirators/PPE:

Controls:

Sample: 1370-A-A-4-2-HJ Pump: 1368 Media: Hydrion
-150 m-ERT

Calibration: 0.200 lpm Time: 5 min
Pre: 201 lpm Post: 199 cc/min On: 4:02 Off: Volume: 1 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

Comments:

Industrial Hygienist: Reviewed by:

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RMW

AIR SAMPLING DATA FORM

Client CPA Date 6/12/07 Job Code

Employee SSN # Job Title

Work Description Gas Cycle Dewax - Equip Comparison Phase II

Work Location Inside Containment near Exhaust on fiber drum.

Respirators/PPE

Controls

Sample # 3705-A-A-112-151 Pump # 11177 Media Hydrocarb 3700 F

Calibration: 0.206 l/min Time: 37 min

Pre 203 cc/min Post 229 cc/min On 4:30 Off 5:07 Volume 7.6 l

Substance	OSHA PEL	Concentration	8 Hour TWA

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 4/12/03 Job Code

Employee SSN # Job Title

Work Description Air cycle Desiccant - Equip Comparison Phase II
Inside Containment near feed inlet tube

Work Location on fiber drum

Respirators/PPE

Controls

Sample # 3705-A-A-6/12-153 Pump # 1152 Media Hydar mCEF

Calibration: 0.209 lpm -154 37

Pre 209cc/min Post ~~209~~ 209 cc/min Time: On 4:30 Off 5:07 Volume 7.7 l

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1mg/m3		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EEA Date: 6/12/07 Job Code:

Employee: SSN: Job Title:

Work Description: A.V. Cycle Equip Compartment Phase II

Double contained at feed tube inlet on

Work Location: Fiber Area

Respirators/PPE:

Controls:

Sample #: 3705-A-A-Wp-55 Pump #: 1254 Media: 1Hg

-156

Calibration: 0-205 L/m

Time: On: 4:30 Off: 5:07 37 Volume: 7.5 L

Pre: 20 L/m Post: 20 L/m

Substances	OSHA PEL	Concentration	8 hour TWA
Hg	0.1 mg/m3		

Comments:

Instrument Used: Analyst:

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AIR SAMPLING DATA FORM

Client EPA Date 6/12/03 Job Code

Employee Tad SSN # Job Title

Work Description air cycle Denver - Equipment Comparison Phase II
on Tadsh'owder for Heat Exchanger #1

Work Location

Respirators/PPE

Controls

Sample # 3705-A-A-6/12-157 Pump # 12708 Media Hydrar mCEF
-158

Calibration: 0.255 lpm Time: 12

Pre 256 Post 25 5 calm On 4:55 Off 507 Volume 3.1 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 6/12/03 Job Code

Employee Tad SSN # Job Title

Work Description Qr Cycle Verif - Equip Comparison Phase II
on Tads shoulder for Filter Δ #2 & Drum Δ #1

Work Location

Respirators/PPE

Controls

Sample # 3705-A-A-6/12-159 Pump # 12708 Media Hydrion
-160 MCEF

Calibration: 0255 lpm Time: 14
Pre 256 Post 255 cc/min On 7:46 Off 8:00 Volume 3.60

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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303.694.4159 FX 303.694.7367

AIR SAMPLING DATA FORM

Client: EPA Date: 6/15/03 Job Code:

Employee: J.S. SSN #: Job Title:

Work Description: Setting Air Cycle Equip. Compressor Plant II

Work Location: Cooling Tower Dummy Drive A

Respirator/PPE: 4 man personal respirators

Controls:

Sample #: 3705-N-1-1/4-161 -162 Pump #: 1827-11 Media: Hydrosorb MEP

Calibration: Pre 0.254 Post 0.254 lpm 25 minutes Time: On 7:46 Off 7:51 Volume: 1.0 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

Comments:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: SPP Date: 6/12/03 Job Code:

Employee: Tad SSN #: Job Title:

Work Description: Air Cycle Equip Comparison Phase II
Ceiling #2 - during demo

Work Location:

4 min personal sample

Respirators/PPE:

Controls:

Sample #: 3705-A-4-6/4-163 -164 Pump #: 112711 Media: Hydrar mCEF

Calibration: Pre 253 cc/min Post 235 cc/min Time: On 7:51 Off 7:55 4 Volume: 1.0 l

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client: EPA Date: 6/13/03 Job Code:

Employee: Tad SSN #: Job Title:

Work Description: Air Cycle - Recirculation Filter Change #3

Work Location:

Respirators/PPE:

Controls:

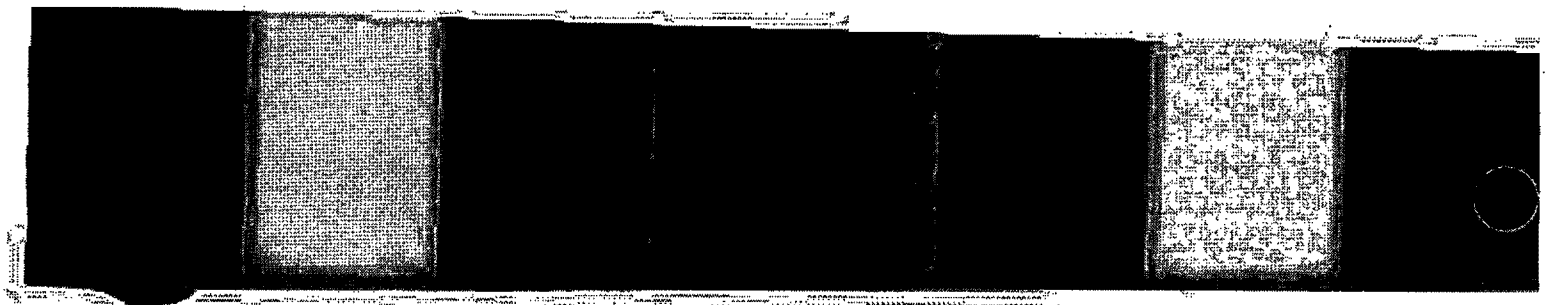
Sample #: 3705-A-A-6/12-165 -166 Pump #: 12708 12 Media: Hydrar mCEF

Calibration: Pre 0.255 lpm 2.56 cc/m Post 2.55 lpm Time: On 12:50 Off 1:02 Volume 3.1 l

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS:

Industrial Hygienist: Reviewed By:



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AIR SAMPLING DATA FORM

Client: S/A Date: 6/13/97 Job Code:

Employee: Tad SSN: Job Title:

Work Description: Asbestos Removal Work
Area #2

Work Location:

Respirators/PPE:

Controls:

Sample #: 3705-A-A-612-167 Pump #: 12708 Media: Hydro
MCE

Calibration: 0.256 L/m Time: 13:
Pre: 256 L/min Post: 255 L/min On: 1:52 Off: 2:15 Volume: 330

Substance	Conc. Est.	Correlation	8 Hour TWA
Hydro	0 fibers/cm³		

Comments:

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AIR SAMPLING DATA FORM

lient EPA Date 6/13/07 Job Code

mployee Tad SSN # Job Title

ork Description Arc Cycle = Real world
Drum #2

ork Location

espirators/PPE

ontrols

Sample # 3705-A-A-6/12-167 Pump # 12708 Media Hybrid mCEF

ibration: 0.255 167 Time: 13
re 256 cc/min Post 255 cc/min On 1:52 Off 2:05 Volume 33 l

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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1-A

AIR SAMPLING DATA FORM

Client EPA Date 6/12/03 Job Code

Employee SSN # Job Title

Work Description Box TEST in Air Cycle Containment
West containment on floor dr

Work Location

Respirators/PPE

Controls

Sample # 3705-T-A-6/12-169 Pump # 11308 Media Hydrar
=170 mCEF

Calibration: 0.201pm (45 min)
Pre 200c/min Post 203c/min Time: On 2:32 Off 3:17 3:75 Volume 9.02

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 6/12/03 Job Code

Employee Tad SSN # Job Title

Work Description UTUBES - Av Cycle

Work Location processing UTubes - on Tad's LEFT shoulder

Respirators/PPE

Controls

Sample # 3705-AA-6/12-~~45~~ 171 = 146172 Pump # 1152 Media Hydrar / mCEF

Calibration: 0.209 dpc Time: 14 min

Pre 209 cc/min Post 209 cc/min On 1:21 Off 1:35 Volume 2.9 l

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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IX

AIR SAMPLING DATA FORM

Client EPA Date 6/12/03 Job Code

Employee Tad SSN # Job Title

Work Description U TUBES Air Cycle Processing UTubes - on Tad's RIGHT Shoulder

Work Location

Respirators/PPE

Controls

Sample # 3705-A-A-6/12-173 Pump # 11254 Media Hydrar mCEF
-LS8174

Calibration: .207 lpm Time: 14 min

Pre 209 cc/min Post 206 cc/min On 1:21 Off 1:35 Volume 2.9 L

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

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AIR SAMPLING DATA FORM

Client EPA Date 6/12/03 Job Code

Employee Tad SSN # Job Title

Work Description U DUES Air Cycle
Inside Containment - Near exhaust on
Work Location fiberdrum

Respirators/PPE

Controls

Sample # 3705-A-A-6/12-HG 175 Pump # 11177 Media Hydrar
- HG 176 MCEF

Calibration: 0.205 Lpm Time: 14 min

Pre 208 cc/min Post 203 cc/min On 1:21 Off 1:55 Volume 2.8 l

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m3		

COMMENTS:

Industrial Hygienist: Reviewed By:

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Lower Level

AIR SAMPLING DATA FORM

Client: EPA Date: 6/12/03 Job Code:

Employee: Tad SSN #: Job Title:

Work Description: U TUBES Air Cycle
Inside Containment - new feed tube on
fiber drum

Work Location:

Respirators/PPE:

Controls:

Sample #: 3705-A-1 thru 4 (-1 thru -178) Pump #: 1368-1 Media: Hydrion MCEF

Calibration: Pre 2.02 l/min Post 2.01 l/min Time: On 1:21 Off 1:35 Volume: 2.8 l

Substance	OSHA PEL	Concentration	8 Hour TWA
Hg	0.1 mg/m³		

COMMENTS:

Industrial Hygienist: Reviewed By:

Appendix C

Data Chem Laboratory Reports

Sample Shipping Information

Samples were placed in an oversized, sturdy box with packing material to fill voids and protect the samples during shipping. The sampling personnel then signed the chain-of-custody forms, and placed them in the box with the samples. Samples were shipped via Federal Express to the laboratory.

DATA CHEM LABORATORIES
A Sorenson Company

ANALYTICAL REPORT

030603165721 35RX

Date MAR 0 7 2003
Laboratory Group Name 03I-0545-04
Account No. 07003

Booz Allen Hamilton
Attention: Steve Coffee
5299 DTC Blcd.
Suite 840
Greenwood Village, CO 80111

FAX (303) 694-7367
Telephone (303) 221-7559
E-mail

Sampling Collection and Shipment

Sampling Site _____ Date of Collection February 25, 2003

Date Samples Received at Laboratory March 03, 2003

Analysis

Method of Analysis NMAM 6009

Date(s) of Analysis March 06, 2003

Analytical Results

Field Sample Number	Laboratory Number	Sample Type	Mercury µg/sample	Mercury mg/m³	Air Volume L					
BG-2/25-02	03I06658	TUBE	0.23	0.0039	58.94					
BG-2/26-04	03I06659	TUBE	0.27	0.0047	58.24					
A/A-2/26-06	03I06660	TUBE	0.19	0.012	15.30					
A/A-2/26-08	03I06661	TUBE	0.23	0.015	15.05					
A/A-2/26-10	03I06662	TUBE	0.066	0.0055	12.09					
A/A-2/26-12	03I06663	TUBE	0.15	0.010	15.00					
A/A-2/26-14	03I06664	TUBE	0.12	0.0095	12.56					
A/A-2/26-16	03I06665	TUBE	0.20	0.013	15.00					
A/A-2/26-18	03I06666	TUBE	0.059	0.019	3.07					
A/A-2/26-20	03I06667	TUBE	0.088	0.019	4.58					
BLANK2/26/03	03I06668	TUBE	0.040	**	0.00					
BLANK2/26-03	03I06669	TUBE	0.041	**	0.00					
R/A-2/27-22	03I06670	TUBE	0.21	0.012	17.19					

† See comment on last page. ** See comment on last page.
ND Parameter not detected above LOD. ( ) Parameter between LOD and LOQ.
NR Parameter not requested.

Analyst: Jason D. Kim

Reviewer: Neil A. Edwards

960 West LeVoy Drive / Salt Lake City, Utah 84123-2547
Phone (801) 266-7700 Web Page: www.datachem.com
FAX (801) 268-9992 E-mail: lab@datachem.com

DATA CHEM LABORATORIES
A Sorenson Company

ANALYTICAL REPORT

03060316572135RX

Date MAR 0 7 2003
Laboratory Group Name 03I-0545-04

Analytical Results

Field Sample Number	Laboratory Number	Sample Type	Mercury µg/sample	Mercury mg/m³	Air Volume L					
R/A-2/27-24	03I06671	TUBE	0.19	0.011	17.25					
R/A-2/27-26	03I06672	TUBE	0.22	0.013	16.97					
R/A-2/27-28	03I06673	TUBE	0.19	0.011	17.30					
R/A-2/27-30	03I06674	TUBE	0.048	0.0028	16.97					
R/A-2/27-32	03I06675	TUBE	0.19	0.011	17.19					
R/A-2/27-34	03I06676	TUBE	0.061	0.020	3.03					
BLANK2/27/03	03I06677	TUBE	0.041	**	0.00					
BLANK2/27/03	03I06678	TUBE	0.038	**	0.00					
H/A-2/27-36	03I06679	TUBE	0.34	0.040	8.42					
H/A-2/27-38	03I06680	TUBE	1.1	0.13	8.58					
H/A-2/27-40	03I06681	TUBE	4.9	0.58	8.33					
H/A-2/27-42	03I06682	TUBE	5.3	0.64	8.23					
H/A-2/27-44	03I06683	TUBE	2.7	0.33	8.28					
H/A-2/27-46	03I06684	TUBE	5.1	0.36	13.92					
H/A-2-27-48	03I06685	TUBE	0.17	0.19	0.92					
D/A-2/28-50	03I06686	TUBE	0.15	0.012	13.16					
D/A-2/28-52	03I06687	TUBE	0.17	0.013	12.99					
D/A-2/28-54	03I06688	TUBE	0.049	0.0039	12.47					
D/A-2/28-56	03I06689	TUBE	0.16	0.012	13.03					
D/A-2/28-58	03I06690	TUBE	0.16	0.012	13.20					
D/A-2/28-60	03I06691	TUBE	0.16	0.012	13.03					
D/A-2/28-62	03I06692	TUBE	0.082	0.025	3.29					
BLANK2/28/03	03I06693	TUBE	0.042	**	0.00					
BLANK2/28/03	03I06694	TUBE	0.040	**	0.00					
Reporting Limit			0.01							

† See comment on last page. ** See comment on last page.
ND Parameter not detected above LOD. ( ) Parameter between LOD and LOQ.

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DATA CHEM LABORATORIES
A Sorenson Company

ANALYTICAL REPORT

030603165721 35RX

Date MAR 0 7 2003
Laboratory Group Name 03I-0545-04

General Set Comments

Method Reference: NIOSH Manual of Analytical Methods(NMAM), 4th ed., 08/15/94.
Results are not blank-corrected.
Results obtained for media blanks prepared from SKC Carulite tubes are typically found to have concentrations approximately 0.035-0.045 µg/sample above the reporting limit of 0.01 µg/sample.
Results cannot be reported in mg/m^3 or ppm for samples with no air volume.

General Lab Comments

The results provided in this report relate only to the items tested.
This page is the concluding page of the report.

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DATA CHEM LABORATORIES, INC.

ANALYTICAL REQUEST FORM

1. ☒ REGULAR Status 03I-0545-C4

☐ RUSH Status Requested - ADDITIONAL CHARGE
RESULTS REQUIRED BY _____ DATE
CONTACT DATACHEM LABS PRIOR TO SENDING SAMPLES

2. Date 2/25/03 Purchase Order No. _____

3. Company Name Booz Allen Hamilton
Address 5299 DTC Blvd. Suite 840
Greenwood Village, CO 80111
Person to Contact Steve Coffee
Telephone (303) 221-7559
Fax Telephone (303) 694-7367
E-mail Address coffee_stephen@bah.com
Billing Address (if different) on file

4. Quote No _____
DCL Project Manager Rand Potter

5. Sample Collection
Sampling Site _____
Industrial Process _____
Date of Collection 2/25/03
Time Collected _____
Date of Shipment 2/28/03
Chain of Custody No. 01

6. REQUEST FOR ANALYSES

Laboratory Use Only	Client Sample Number	Matrix*	Sample Volume	ANALYSES REQUESTED - Use method number if known	Units**
	3705-BG-2/25-01	MCEF	58.94 L	~~ID-145~~ N7103 Hg	2
03I06655	02	HYDRAR	58.94 L	~~HYDRAR~~ NAM 6009 Hg	2
	03	MCEF	58.24 L	~~ID-145~~ NAM 6009 Hg	2
03I06659	04	HYDRAR	58.24 L	HYDRAR NAM 6009 Hg	2

* Specify: Solid sorbent tube, e.g. Charcoal; Filter type; Impinger solution; Bulk sample; Blood; Urine; Tissue; Soil; Water; Other

** 1 mg/sample 2. mg/m³ 3 ppm 4 % 5 ____ (other) Please indicate one or more units in the column entitled Units**

Comments _____

Possible Contamination and/or Chemical Hazards _____

7. Chain of Custody (Optional)

Relinquished by	[signature]	Date/Time	2/25/03 1500
Received by	[signature]	Date/Time	3/3
Relinquished by	[signature]	Date/Time	3/3/03
Received by		Date/Time	

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DATACHEM LABORATORIES, INC.

DATA CHEM LABORATORIES, INC.

ANALYTICAL REQUEST FORM

1. ☑ REGULAR Status 03I-C545-04

☐ RUSH Status Requested - ADDITIONAL CHARGE
RESULTS REQUIRED BY _____ DATE
CONTACT DATACHEM LABS PRIOR TO SENDING SAMPLES

2. Date 2/28/03 Purchase Order No _____

3. Company Name Booz Allen Hamilton
Address 5299 DTC Blvd, Suite 840
Greenwood Village, CO 80111
Person to Contact Steve Coffee
Telephone (303) 221-7559
Fax Telephone (303) 694-7317
E-mail Address coffee_stephen@bah.com
Billing Address (if different) on file

4. Quote No _____
DCL Project Manager Brandi Potter

5. Sample Collection
Sampling Site _____
Industrial Process _____
Date of Collection 2/26/03
Time Collected _____
Date of Shipment 2/28/03
Chain of Custody No. 03

6. REQUEST FOR ANALYSES

Laboratory Use Only	Client Sample Number	Matrix*	Sample Volume	ANALYSES REQUESTED - Use method number if known	Units**
03I0666	3705-A/A-2/26-06	HYDRAR	15.30L	NAM 6009	2
61	" 08	HYDRAR	15.05L	NAM 6009	2
62	" 10	HYDRAR	12.09L	NAM 6009	2
63	" 12	HYDRAR	15.00L	NAM 6009	2
64	" 14	HYDRAR	12.56L	NAM 6009	2
65	" 16	HYDRAR	15.80L	NAM 6009	2
66	" 18	HYDRAR	3.07L	NAM 6009	2
67	" 20	HYDRAR	4.58L	NAM 6009	2
68	BLANK 2/26/03	HYDRAR		NAM 6009	2
69	BLANK 2/4/03	HYDRAR		NAM 6009	2

* Specify: Solid sorbent tube, e g. Charcoal; Filter type; Impinger solution; Bulk sample; Blood; Urine; Tissue; Soil; Water; Other

** 1 mg/sample 2 mg/m³ 3 ppm 4 % 5 ____ (other) Please indicate one or more units in the column entitled Units**

Comments _____

Possible Contamination and/or Chemical Hazards _____

7. Chain of Custody (Optional)

Relinquished by	[signature]	Date/Time	2/28/03 1500
Received by	[signature]	Date/Time	3/3
Relinquished by	[signature]	Date/Time	3/3/03
Received by		Date/Time	

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DATACHEM LABORATORIES, INC.

_0307121227_001.max

DATA CHEM LABORATORIES, INC.

ANALYTICAL REQUEST FORM

1. ☑ REGULAR Status 03I-C545-04

☐ RUSH Status Requested - ADDITIONAL CHARGE
RESULTS REQUIRED BY _____ DATE
CONTACT DATACHEM LABS PRIOR TO SENDING SAMPLES

2. Date 2/28/03 Purchase Order No _____

3. Company Name Booz Allen Hamilton
Address 5299 DTC Blvd., Suite 940
Greenwood Village, CO 80111
Person to Contact Steve Coffee
Telephone (303) 221-7559
Fax Telephone (303) 694-7317
E-mail Address coffee_stephen@bah.com
Billing Address (if different) on file

4. Quote No _____
DCL Project Manager Rand Pitcher

5. Sample Collection
Sampling Site _____
Industrial Process _____
Date of Collection 2/27/03
Time Collected _____
Date of Shipment 2/28/03
Chain of Custody No 17

6. REQUEST FOR ANALYSES

Laboratory Use Only	Client Sample Number	Matrix*	Sample Volume	ANALYSES REQUESTED - Use method number if known	Units**
03I0667O	3705-R/A-2/27-2	2 HYDRAR	17.19L	NAM 6009	2
71	"-24	HYDRAR	17.25L	NAM 6009	2
72	"-26	HYDRAR	16.97L	NAM 6009	2
73	"-28	HYDRAR	17.30L	NAM 6009	2
74	"-30	HYDRAR	16.97L	NAM 6009	2
75	"-32	HYDRAR	17.19L	NAM 6009	2
76	"-34	HYDRAR	3.03L	NAM 6009	2
77	Blank 2/27/03	HYDRAR		NAM 6009	2
78	Blank 2/27/03	HYDRAR		NAM 6009	2

* Specify: Solid sorbent tube, e g. Charcoal; Filter type; Impinger solution; Bulk sample; Blood; Urine; Tissue; Soil; Water; Other

** 1. mg/sample 2 mg/m³ 3 ppm 4 % 5 ____ (other) Please indicate one or more units in the column entitled Units**

Comments _____

Possible Contamination and/or Chemical Hazards _____

7. Chain of Custody (Optional)

Relinquished by	[signature]	Date/Time	2/25/03 1500
Received by	[signature]	Date/Time	3/3
Relinquished by	[signature]	Date/Time	3/3
Received by		Date/Time	

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DATA CHEM LABORATORIES, INC.

ANALYTICAL REQUEST FORM

1. ☑ REGULAR Status 03I-0515-04

☐ RUSH Status Requested - ADDITIONAL CHARGE
RESULTS REQUIRED BY _____ DATE
CONTACT DATACHEM LABS PRIOR TO SENDING SAMPLES

2. Date 2/28/03 Purchase Order No _____ 4. Quote No _____

3. Company Name Booz Allen Hamilton DCL Project Manager Randi Potter

Address 5299 DTC Blvd, Suite 940 5. Sample Collection
Greenwood Village, CO 80111 Sampling Site _____

Person to Contact Steve Coffee Industrial Process _____

Telephone (303) 221-7559 Date of Collection 2/27/03

Fax Telephone (303) 694-7367 Time Collected _____

E-mail Address coffee_stephen@bah.com Date of Shipment 2/28/03

Billing Address (if different) on file Chain of Custody No 19

6. REQUEST FOR ANALYSES

Laboratory Use Only	Client Sample Number	Matrix*	Sample Volume	ANALYSES REQUESTED - Use method number if known	Units**
03L06679	3705-IH/A-2/27-36	HYDRAR	8.42L	NAM 6009	2
80	11-38	HYDRAR	8.58L	NAM 6009	2
81	11-40	HYDRAR	8.53L	NAM 6009	2
82	11-42	HYDRAR	8.23L	NAM 6009	2
83	11-44	HYDRAR	8.28L	NAM 6009	2
84	11-46	HYDRAR	13.92L	NAM 6009	2
85	11-48	HYDRAR	0.92L	NAM 6009	2

* Specify: Solid sorbent tube, e.g Charcoal; Filter type; Impinger solution; Bulk sample; Blood; Urine; Tissue; Soil; Water; Other

** 1. mg/sample 2. mg/m³ 3. ppm 4. % 5 ____ (other) Please indicate one or more units in the column entitled Units**

Comments _____

Possible Contamination and/or Chemical Hazards _____

7. Chain of Custody (Optional)

Relinquished by	Jordan Murphy	Date/Time	2/28/03 1500
Received by	Randi Potter	Date/Time	3/3
Relinquished by	Randi Potter	Date/Time	3/3
Received by		Date/Time	

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DATA CHEM LABORATORIES, INC.

ANALYTICAL REQUEST FORM

1. ☑ REGULAR Status 03I-0545-04

☐ RUSH Status Requested - ADDITIONAL CHARGE
RESULTS REQUIRED BY _____ DATE
CONTACT DATACHEM LABS PRIOR TO SENDING SAMPLES

2. Date 2/28/03 Purchase Order No _____

3. Company Name Booz Allen Hamilton
Address 5299 DTC Blvd., Suite 940
Greenwood Village, CO 80111
Person to Contact Steve Coffee
Telephone (303) 221-7559
Fax Telephone (303) 694-7367
E-mail Address Coffee_stephen@bah.com
Billing Address (if different) on file

4. Quote No _____
DCL Project Manager Rand Potter
5. Sample Collection
Sampling Site _____
Industrial Process _____
Date of Collection 2/28/03
Time Collected _____
Date of Shipment 2/28/03
Chain of Custody No. 21

6. REQUEST FOR ANALYSES

Laboratory Use Only	Client Sample Number	Matrix*	Sample Volume	ANALYSES REQUESTED - Use method number if known	Units**
03I0668[illegible]	3705-D/A-2/28-5	HYDRAR	13.16L	NAM 6009	2
87	"-52	HYDRAR	12.99L	NAM 6009	2
88	"-54	HYDRAR	12.47L	NAM 6009	2
89	"-56	HYDRAR	13.03L	NAM 6009	2
90	"-58	HYDRAR	13.20L	NAM 6009	2
91	"-60	HYDRAR	13.03L	NAM 6009	2
92	"-62	HYDRAR	3.29L	NAM 6009	2
93	Blank 2/28/03	HYDRAR	—	NAM 6009	2
94	Blank 2/28/03	HYDRAR	—	NAM 6009	2

* Specify: Solid sorbent tube, e g Charcoal; Filter type; Impinger solution; Bulk sample; Blood; Urine; Tissue; Soil; Water; Other

** 1 mg/sample 2 mg/m³ 3 ppm 4 % 5 ____ (other) Please indicate one or more units in the column entitled Units**

Comments _____

Possible Contamination and/or Chemical Hazards _____

7. Chain of Custody (Optional)

Relinquished by	Jordan Murphy	Date/Time	2/28/03 1500
Received by	Rand Potter	Date/Time	3/3
Relinquished by	Rand Potter	Date/Time	3/3/03
Received by	_____	Date/Time	_____

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DATACHEM LABORATORIES, INC.

Appendix C

Data Chem Laboratory Reports

Sample Shipping Information

Samples were placed in an oversized, sturdy box with packing material to fill voids and protect the samples during shipping. The sampling personnel then signed the chain-of-custody forms, and placed them in the box with the samples. Samples were shipped via Federal Express to the laboratory.

DATA CHEM LABORATORIES
A Sorenson Company

ANALYTICAL REPORT

Form ARF-AL
Page 1 of 3
Part 1 of 1
040703111110402RX

Date APR 0 7 2003
Laboratory Group Name 03I-0821-01
Account No. 07003

Booz Allen & Hamilton
Attention: Jordan Murphy
5299 DTC Blvd.
Suite 840
Greenwood Village, CO 80111

FAX (303) 684-7367
Telephone (303) 221-4446
E-mail murphy_jordan@bah.com

Sampling Collection and Shipment

Sampling Site _____ Date of Collection March 24, 2003

Date Samples Received at Laboratory March 31, 2003

Analysis

Method of Analysis NMAM 6009MOD

Date(s) of Analysis April 03, 2003

Analytical Results

Field Sample Number	Laboratory Number	Sample Type	Mercury µg/sample	Mercury mg/m³	Air Volume L						
3705B324-01	03I09961	HYDRAR	0.43	0.014	31.78						
3705B024-03	03I09962	HYDRAR	0.16	0.0059	27.98						
3705RA324-05	03I09963	HYDRAR	2.0	0.074	26.49						
3705RA324-07	03I09964	HYDRAR	1.1	0.043	24.38						
3705RA324-09	03I09965	HYDRAR	1.1	0.045	25.27						
3705RA324-11	03I09966	HYDRAR	3.1	0.11	28.59						
3705RA324-13	03I09967	HYDRAR	0.43	0.075	5.65						
3705RA324-15	03I09968	HYDRAR	5.8	0.086	68.13						
3705RA324-17	03I09969	HYDRAR	1.4	0.021	66.36						
BLANK 3/24	03I09970	HYDRAR	0.078	**	0.00						
BLANK 3/24	03I09971	HYDRAR	0.086	**	0.00						
3705DA325-19	03I09972	HYDRAR	2.4	0.084	28.75						
3705DA325-21	03I09973	HYDRAR	0.27	0.016	16.94						

† See comment on last page.
ND Parameter not detected above LOD.
NR Parameter not requested.
NA Parameter not applicable.

** See comment on last page.
( ) Parameter between LOD and LOQ.

for T. C.
Analyst: Tanya Cheklin

Reviewer: Jason D. Rim

960 West LeVoy Drive / Salt Lake City, Utah 84123-2547
Phone (801) 266-7700 Web Page: www.datachem.com
FAX (801) 268-9992 E-mail: lab@datachem.com

DATA CHEM LABORATORIES
A Sorenson Company

ANALYTICAL REPORT

04070311110402RX

Date APR 0 7 2003

Laboratory Group Name 03I-0821-01

Analytical Results

Field Sample Number	Laboratory Number	Sample Type	Mercury µg/sample	Mercury mg/m³	Air Volume L					
3705DA325-23	03I09974	HYDRAR	0.60	0.035	17.00					
3705DA325-25	03I09975	HYDRAR	1.8	0.070	24.94					
3705DA325-27	03I09976	HYDRAR	0.32	0.13	2.54					
3705DA325-29	03I09977	HYDRAR	1.7	0.027	62.85					
3705DA325-31	03I09978	HYDRAR	1.8	0.026	69.40					
3705DA325-33	03I09979	HYDRAR	0.23	0.078	2.96					
BLANK 3/25	03I09980	HYDRAR	0.075	**	0.00					
BLANK 3/25	03I09981	HYDRAR	0.071	**	0.00					
3705AA327-43	03I09982	HYDRAR	0.89	0.030	29.69					
3705AA327-45	03I09983	HYDRAR	2.4	0.074	31.75					
3705AA327-47	03I09984	HYDRAR	0.40	0.014	29.20					
3705AA327-49	03I09985	HYDRAR	1.9	0.071	27.34					
3705AA327-51	03I09986	HYDRAR	0.41	0.0084	48.12					
3705AA327-53	03I09987	HYDRAR	0.53	0.16	3.40					
3705AA327-55	03I09988	HYDRAR	0.73	0.0095	77.60					
3705AA327-57	03I09989	HYDRAR	1.1	0.014	78.53					
3705AA327-59	03I09990	HYDRAR	0.065	0.021	3.05					
BLANK 3/27	03I09991	HYDRAR	0.073	**	0.00					
BLANK 3/27	03I09992	HYDRAR	0.071	**	0.00					
3705HA326-35	03I09993	HYDRAR	0.50	0.13	3.97					
3705HA326-37	03I09994	HYDRAR	0.33	0.11	3.12					
3705HA326-39	03I09995	HYDRAR	1.9	0.065	28.92					
3705HA326-41	03I09996	HYDRAR	0.66	0.022	29.85					
BLANK 3/26	03I10003	HYDRAR	0.28	**	0.00					
BLANK 3/26	03I10004	HYDRAR	0.21	**	0.00					
LAB BLK 3/24	03I10668	HYDRAR	0.056	**	0.00					
LAB BLK 3/24	03I10669	HYDRAR	0.060	**	0.00					
LAB BLK 3/24	03I10670	HYDRAR	0.065	**	0.00					
Reporting Limit			0.01							

† See comment on last page. ** See comment on last page.
ND Parameter not detected above LOD. ( ) Parameter between LOD and LOQ.
NR Parameter not requested.
NA Parameter not applicable.

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FAX (801) 268-9992 E-mail: lab@datachem.com

DATA CHEM LABORATORIES
A Sorenson Company

ANALYTICAL REPORT

04070311110402RX

Date APR 0 7 2003

Laboratory Group Name 03I-0821-01

General Set Comments

Method Reference: NIOSH Manual of Analytical Methods(NMAM), 4th ed., 08/15/94.
Results are not blank-corrected.
Results obtained for media blanks prepared from SKC Carulite tubes are typically found to have concentrations approximately the 0.035-0.045 µg/sample above the reporting limit.
Recoveries of the Laboratory Control Samples (LCS) and the Laboratory Control Sample Duplicates (LCSD) are not within the historical quality control limits.
Nonconformance/Corrective Action Report (NC/CAR) # 624 is initiated.
Results cannot be reported in mg/m^3 or ppm for samples with no air volume.

General Lab Comments

The results provided in this report relate only to the items tested.
This page is the concluding page of the report.

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FAX (801) 268-9992 E-mail: lab@datachem.com

DATA CHEM LABORATORIES, INC.

ANALYTICAL REQUEST FORM

1. ☑ REGULAR Status 03I-0821-01

☐ RUSH Status Requested - ADDITIONAL CHARGE
RESULTS REQUIRED BY _____ DATE
CONTACT DATACHEM LABS PRIOR TO SENDING SAMPLES

2. Date 3/28/03 Purchase Order No. _____

3. Company Name Booz Allen Hamilton
Address 5299 DTC Blvd., Suite 840
Greenwood Village CO 80111
Person to Contact ~~Steve~~ Jordan Murphy
Telephone (303) 221-4446
Fax Telephone (303) 694-7367
E-mail Address murphy_jordan@bah.com
Billing Address (if different) see contract

4. Quote No. _____
DCL Project Manager Rand Potter

5. Sample Collection
Sampling Site _____
Industrial Process _____
Date of Collection 3/24/03
Time Collected _____
Date of Shipment 3/28/03
Chain of Custody No. 1

6. REQUEST FOR ANALYSES

Laboratory Use Only	Client Sample Number	Matrix*	Sample Volume	ANALYSES REQUESTED - Use method number if known	Units**
03I0996[illegible]	3705-R-A-3/24-01	Hydrar	31.78L	N.C.09	2
09962	" -03	"	27.98L	"	2
09963	" -05	"	26.49L	"	2
09964	" -07	"	24.38L	"	2
09965	" -09	"	25.27L	"	2
09966	" -11	"	28.59L	"	2
09967 ~~03~~ 1C	" -13	"	5.65L	"	2
09968	" -15	"	68.13L	"	2
09969	" -17	"	66.36L	"	2
09970	Blank 3/24	"	0	"	2
09971	Blank 3/24	"	0	"	2
03I10668	Lab Blank 3/24				
" 69	Lab Blank 3/24				
" 70	Lab Blank 3/24				

* Specify: Solid sorbent tube, e.g. Charcoal; Filter type; Impinger solution; Bulk sample; Blood; Urine; Tissue; Soil; Water; Other

** 1. mg/sample (2. mg/m³) 3. ppm 4. % 5. ____ (other) Please indicate one or more units in the column entitled Units**

Comments RTT Device

Possible Contamination and/or Chemical Hazards _____

7. Chain of Custody (Optional)

Relinquished by	Jordan Murphy	Date/Time	3/28/03 11.35
Received by	Rand Potter	Date/Time	3/31/03
Relinquished by	Rand Potter	Date/Time	3/31/03
Received by	_____	Date/Time	_____

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DATACHEM LABORATORIES, INC.

DATA CHEM LABORATORIES, INC.

ANALYTICAL REQUEST FORM

1. ☑ REGULAR Status 03I-0821-01

☐ RUSH Status Requested - ADDITIONAL CHARGE
RESULTS REQUIRED BY _____ DATE
CONTACT DATACHEM LABS PRIOR TO SENDING SAMPLES

2. Date 3/28/03 Purchase Order No. _____

3. Company Name Booz Allen Hamilton
Address 5297 DTC Blvd., Suite 840
Greenwood Village, Co 80111
Person to Contact Jordan Murphy
Telephone (303) 221-4446
Fax Telephone (303) 694-7367
E-mail Address murphy_jordan@bah.com
Billing Address (if different) see contract

4. Quote No. _____
DCL Project Manager Randi Potter

5. Sample Collection
Sampling Site _____
Industrial Process _____
Date of Collection 3/25/03
Time Collected _____
Date of Shipment 3/28/03
Chain of Custody No. 3

6. REQUEST FOR ANALYSES

Laboratory Use Only	Client Sample Number	Matrix*	Sample Volume	ANALYSES REQUESTED - Use method number if known	Units**
03I09972	3705-DA3/25-19	Hydrox	28.75L	N 6009	2
09973	11-21	"	16.94L	"	2
09974	11-23	"	17.0L	"	2
09975	11-25	"	24.94L	"	2
09976	11-27	"	2.654L	"	2
09977	11-29	"	3~~9.67~~.85L	"	2
09978	11-31	"	69.40L	"	2
09979	11-33	"	2.96L	"	2
09980	Blank 3/25	"	0	"	2
09981	Blank 3/25	"	0	"	2

* Specify: Solid sorbent tube, e.g. Charcoal; Filter type; Impinger solution; Bulk sample; Blood; Urine; Tissue; Soil; Water; Other

** 1. mg/sample (2. mg/m³) 3. ppm 4. % 5. ____ (other) Please indicate one or more units in the column entitled Units**

Comments Dexfrtc Device

Possible Contamination and/or Chemical Hazards _____

7. Chain of Custody (Optional)

Relinquished by	Jordan Murphy	Date/Time	3/28/03 11:35
Received by	Randi Potter	Date/Time	3/31
Relinquished by	Randi Potter	Date/Time	3/31/03
Received by	_____	Date/Time	_____

960 West LeVoy Drive / Salt Lake City, UT 84123 800-356-9135 or 801-266-7700 / FAX: 801-268-9992
DATACHEM LABORATORIES, INC.

DATA CHEM LABORATORIES, INC.

ANALYTICAL REQUEST FORM

1. ☑ REGULAR Status 03I-0821-07

☐ RUSH Status Requested - ADDITIONAL CHARGE
RESULTS REQUIRED BY _____ DATE
CONTACT DATACHEM LABS PRIOR TO SENDING SAMPLES

2. Date 3/28/03 Purchase Order No. _____

3. Company Name Booz Allen Hamilton
Address 5299 DTC Blvd., Suite 840
Greenwood Village, CO 80111
Person to Contact Jordan Murphy
Telephone (303) 221-4446
Fax Telephone (303) 694-7367
E-mail Address murphy_jordan@bah.com
Billing Address (if different) see contract

4. Quote No. _____
DCL Project Manager Randi Potter

5. Sample Collection
Sampling Site _____
Industrial Process _____
Date of Collection ~~3/27/03~~ 3/27/03
Time Collected _____
Date of Shipment 3/28/03
Chain of Custody No. 6

6. REQUEST FOR ANALYSES

Laboratory Use Only	Client Sample Number	Matrix*	Sample Volume	ANALYSES REQUESTED - Use method number if known	Units**
03I09982	3705-A-A-3/27-43	Hydrar	29.69L	N6009	2
09983	11-45	"	31.75L	"	2
09984	11-47	"	29.20L	"	2
09985	11-49	"	27.34L	"	2
09986	11-51	"	48.12L	"	2
09987	11-53	"	3.40L	"	2
09988	11-55	"	77.6L	"	2
09989	11-57	"	78.53L	"	2
09990	11-59	"	3.05L	"	2
09991	Blank 3/27	"		N6009	2
09992	Blank 3/27	"		N6009	2

* Specify: Solid sorbent tube, e.g. Charcoal; Filter type; Impinger solution; Bulk sample; Blood; Urine; Tissue; Soil; Water; Other

** 1. mg/sample (2. mg/m³) 3. ppm 4. % 5 ____ (other) Please indicate one or more units in the column entitled Units**

Comments Air cycle Device

Possible Contamination and/or Chemical Hazards _____

7. Chain of Custody (Optional)

Relinquished by	Jordan Murphy	Date/Time	3/28/03 11:35
Received by	Randi Potter	Date/Time	3/31
Relinquished by	Randi Potter	Date/Time	3/31/03
Received by	_____	Date/Time	_____

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DATACHEM LABORATORIES, INC.

DATA CHEM LABORATORIES, INC.

ANALYTICAL REQUEST FORM

1. ☑ REGULAR Status 05I-0821-01

☐ RUSH Status Requested - ADDITIONAL CHARGE
RESULTS REQUIRED BY _____ DATE
CONTACT DATACHEM LABS PRIOR TO SENDING SAMPLES

2. Date 3/28/03 Purchase Order No. _____

3. Company Name Booz Allen Hamilton
Address 5299 DTC Blvd., Suite 940
Greenwood Village, CO 80111
Person to Contact Jordan Murphy
Telephone (303) 221-4446
Fax Telephone (303) 694-7367
E-mail Address murphy_jordan@bah.com
Billing Address (if different) SE contract

4. Quote No. _____
DCL Project Manager Randi Potter

5. Sample Collection
Sampling Site _____
Industrial Process _____
Date of Collection 3/26/03
Time Collected _____
Date of Shipment 3/28/03
Chain of Custody No. 5

6. REQUEST FOR ANALYSES

Laboratory Use Only	Client Sample Number	Matrix*	Sample Volume	ANALYSES REQUESTED - Use method number if known	Units**
05I09993	3705-H-A-3/26-35	Hydrar	3.97L	N 6009	2
09994	" - 37	"	3.12L	"	2
09995	" - 39	"	28.92L	"	2
09996	" - 41	"	29.85L	"	2
09997	3705-H-A-3/26-36	MCEF	3.97L	N 9103	2
09998	" -38	"	3.12L	"	2
09999	" -40	"	28.92L	"	2
10000	" -42	"	29.85L	"	2
10001	Blank 3/26	"	0	"	2
10002	Blank 3/26	"	0	"	2
10003	Blank 3/26	Hydrar	0	N 6009	2
10004	Blank 3/26	Hydrar	0	N 6009	2

* Specify: Solid sorbent tube, e.g. Charcoal; Filter type; Impinger solution; Bulk sample; Blood; Urine; Tissue; Soil; Water; Other

** 1. mg/sample (2. mg/m³) 3. ppm 4. % 5 ____ (other) Please indicate one or more units in the column entitled Units**

Comments HMS Denise

Possible Contamination and/or Chemical Hazards _____

7. Chain of Custody (Optional)

Relinquished by	Jordan Murphy	Date/Time	3/28/03 11:35
Received by	Randi Potter	Date/Time	3/31
Relinquished by	Randi Potter	Date/Time	3/31
Received by		Date/Time	

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DATACHEM LABORATORIES, INC.

_0407155628_001.max

Appendix C

Data Chem Laboratory Reports

Sample Shipping Information

Samples were placed in an oversized, sturdy box with packing material to fill voids and protect the samples during shipping. The sampling personnel then signed the chain-of-custody forms, and placed them in the box with the samples. Samples were shipped via Federal Express to the laboratory.

DATA CHEM LABORATORIES
A Sorenson Company

ANALYTICAL REPORT

Form ARF-AL
Page 1 of 3
Part 1 of 1
05140322400528RX

Date MAY 15 2003
Laboratory Group Name 03I-1146-06
Account No. 07003

Booz Allen Hamilton
Attention: Steve Coffee
5299 DTC Blvd.
Suite 840
Greenwood Village, CO 80111

FAX (303) 694-7367
Telephone (303) 221-7559
E-mail coffee_stephen@bah.com

Sampling Collection and Shipment

Sampling Site AERC Melbourne Date of Collection April 29, 2003

Date Samples Received at Laboratory May 05, 2003

Analysis

Method of Analysis NMAM 6009MOD

Date(s) of Analysis May 12, 2003

Analytical Results

Field Sample Number	Laboratory Number	Sample Type	Mercury µg/sample	Mercury mg/m³	Air Volume L					
3705B429-01	03I16295	HYDRAR	1.0	0.016	61.2					
3705B429-03	03I16296	HYDRAR	0.77	0.012	64.8					
3705DA429-05	03I16297	HYDRAR	3.7	0.14	25.8					
3705DA429-07	03I16298	HYDRAR	3.0	0.12	24.2					
3705DA429-09	03I16299	HYDRAR	3.3	0.13	24.9					
3705DA429-11	03I16300	HYDRAR	6.7	0.27	25.1					
3705DA429-13	03I16301	HYDRAR	0.044	0.015	3.0					
3705DA429-15	03I16302	HYDRAR	0.21	0.041	5.1					
3705DA429-17	03I16303	HYDRAR	3.7	0.035	104.9					
3705DA429-19	03I16304	HYDRAR	3.8	0.036	106.4					
3705DA429-21	03I16305	HYDRAR	2.3	0.021	109.2					
3705DA429-23	03I16306	HYDRAR	0.23	0.23	1.01					
3705DA429-25	03I16307	HYDRAR	0.65	0.64	1.01					

† See comment on last page.
ND Parameter not detected above LOD.
NR Parameter not requested.
NA Parameter not applicable.

** See comment on last page.
( ) Parameter between LOD and LOQ.

Analyst: Jason D. Kim

Reviewer: Neil A. Edwards

960 West LeVoy Drive / Salt Lake City, Utah 84123-2547
Phone (801) 266-7700 Web Page: www.datachem.com
FAX (801) 268-9992 E-mail: lab@datachem.com

DATA CHEM LABORATORIES
A Sorenson Company

ANALYTICAL REPORT

05140322400528RX

Date MAY 15 2003
Laboratory Group Name 03I-1146-06

Analytical Results

Field Sample Number	Laboratory Number	Sample Type	Mercury µg/sample	Mercury mg/m³	Air Volume L					
FLD BLK 4/29	03I16308	HYDRAR	0.046	**	0.0					
FLD BLK 4/29	03I16309	HYDRAR	0.044	**	0.0					
3705AA430-27	03I16310	HYDRAR	1.4	0.063	22.3					
3705AA430-29	03I16311	HYDRAR	0.059	0.0047	12.5					
3705AA430-31	03I16312	HYDRAR	0.87	0.070	12.4					
3705AA430-33	03I16313	HYDRAR	1.1	0.048	22.8					
3705AA430-35	03I16314	HYDRAR	1.1	0.048	22.8					
3705AA430-37	03I16315	HYDRAR	0.19	0.064	2.98					
3705AA430-39	03I16316	HYDRAR	0.45	0.11	4.22					
3705AA430-41	03I16317	HYDRAR	0.18	0.060	2.98					
3705AA430-43	03I16318	HYDRAR	0.24	0.081	2.98					
3705AA430-45	03I16319	HYDRAR	0.12	0.12	0.99					
3705AA430-47	03I16320	HYDRAR	0.26	0.26	0.99					
3705AA430-49	03I16321	HYDRAR	2.9	0.019	150.6					
3705AA430-51	03I16322	HYDRAR	3.1	0.021	149.1					
3705AA430-53	03I16323	HYDRAR	2.5	0.016	154.1					
3705AA430-55	03I16324	HYDRAR	0.35	0.034	10.4					
3705AA430-57	03I16325	HYDRAR	0.53	0.052	10.1					
3705AA431-59	03I16326	HYDRAR	0.11	0.036	3.07					
FLD BLK 4/30	03I16327	HYDRAR	0.045	**	0.0					
FLD BLK 4/30	03I16328	HYDRAR	0.048	**	0.0					
Reporting Limit			0.01							

† See comment on last page. ** See comment on last page.
ND Parameter not detected above LOD. ( ) Parameter between LOD and LOQ.
NR Parameter not requested.
NA Parameter not applicable.

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DATA CHEM LABORATORIES
A Sorenson Company

ANALYTICAL REPORT

Form ARF-C
Page 3 of 3
051403224005 28RX

Date MAY 15 2003
Laboratory Group Name 03I-1146-06

General Set Comments

Method Reference: NIOSH Manual of Analytical Methods(NMAM), 4th ed., 08/15/94.
Results are not blank-corrected.
Results cannot be reported in mg/m³ or ppm for samples with no air volume.

General Lab Comments

The results provided in this report relate only to the items tested.
This page is the concluding page of the report.

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DATA CHEM LABORATORIES
A Sorenson Company

ANALYTICAL REPORT

Form ARF-AL
Page 1 of 3
Part 1 of 1
05140323403496RX

MAY 15 2003

Date _____
Laboratory Group Name 03I-1146-07
Account No. 07003

Booz Allen Hamilton
Attention: Steve Coffee
5299 DTC Blvd.
Suite 840
Greenwood Village, CO 80111

FAX (303) 694-7367
Telephone (303) 221-7559
E-mail coffee_stephen@bah.com

Sampling Collection and Shipment

Sampling Site AERC Melbourne Date of Collection May 01, 2003

Date Samples Received at Laboratory May 05, 2003

Analysis

Method of Analysis NMAM 6009MOD

Date(s) of Analysis May 12, 2003

Analytical Results

Field Sample Number	Laboratory Number	Sample Type	Mercury µg/sample	Mercury mg/m³	Air Volume L					
3705RA501-61	03I16329	HYDRAR	0.40	0.018	21.9					
3705RA501-63	03I16330	HYDRAR	0.28	0.024	11.8					
3705RA501-65	03I16331	HYDRAR	0.31	0.026	12.0					
3705RA501-67	03I16332	HYDRAR	0.39	0.018	22.2					
3705RA501-69	03I16333	HYDRAR	0.14	0.0063	22.1					
3705RA501-71	03I16334	HYDRAR	0.23	0.075	3.07					
3705RA501-73	03I16335	HYDRAR	TBA	TBA	TBA					
3705RA501-75	03I16336	HYDRAR	0.17	0.17	1.01					
3705RA501-77	03I16337	HYDRAR	0.11	0.11	1.01					
3705RA501-79	03I16338	HYDRAR	0.16	0.017	9.32					
3705RA501-81	03I16339	HYDRAR	0.15	0.016	9.45					
3705RA501-83	03I16340	HYDRAR	1.7	0.013	134.6					
3705RA501-85	03I16341	HYDRAR	1.7	0.013	134.6					

† See comment on last page.
ND Parameter not detected above LOD.
NR Parameter not requested.
NA Parameter not applicable.

** See comment on last page.
( ) Parameter between LOD and LOQ.
TBA Parameter to be analyzed.

Analyst: Jason D. Kim

Reviewer: Neil A. Edwards

960 West LeVoy Drive / Salt Lake City, Utah 84123-2547
Phone (801) 266-7700 Web Page: www.datachem.com
FAX (801) 268-9992 E-mail: lab@datachem.com

DATA CHEM LABORATORIES
A Sorenson Company

ANALYTICAL REPORT

Form ARF-BL
Page 2 of 3
Part 1 of 1
05140323403496RX

Date MAY 15 2003

Laboratory Group Name 03I-1146-07

Analytical Results

Field Sample Number	Laboratory Number	Sample Type	Mercury µg/sample	Mercury mg/m³	Air Volume L					
3705RA501-87	03I16342	HYDRAR	2.3	0.017	137.6					
FLD BLK 5/1	03I16343	HYDRAR	0.046	**	0.0					
FLD BLK 5/1	03I16344	HYDRAR	0.049	**	0.0					
3705DA502-89	03I16345	HYDRAR	0.81	0.094	8.60					
3705DA502-91	03I16346	HYDRAR	0.76	0.088	8.60					
3705DA502-93	03I16347	HYDRAR	0.66	0.076	8.69					
3705DA502-95	03I16348	HYDRAR	0.78	0.090	8.66					
3705DA502-97	03I16349	HYDRAR	0.60	0.20	3.07					
LAB BLANK	03I16350	HYDRAR	0.046	**	0.0					
LAB BLANK	03I16351	HYDRAR	0.048	**	0.0					
LAB BLANK	03I16352	HYDRAR	0.045	**	0.0					
FLD BLK 5/2	03I16353	HYDRAR	0.049	**	0.0					
FLD BLK 5/2	03I16889	HYDRAR	0.049	**	0.0					
Reporting Limit			0.01							

† See comment on last page.
ND Parameter not detected above LOD.
NR Parameter not requested.
NA Parameter not applicable.

** See comment on last page.
( ) Parameter between LOD and LOQ.
TBA Parameter to be analyzed.

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Phone (801) 266-7700 Web Page: www.datachem.com
FAX (801) 268-9992 E-mail: lab@datachem.com

DATA CHEM LABORATORIES
A Sorenson Company

ANALYTICAL REPORT

05140323403496RX

MAY 15 2003
Date _____

Laboratory Group Name 03I-1146-07

General Set Comments

Method Reference: NIOSH Manual of Analytical Methods(NMAM), 4th ed., 08/15/94.
Results are not blank-corrected.
Results cannot be reported in mg/m³ or ppm for samples with no air volume.
Field sample 03I16335 was not submitted by the client.

General Lab Comments

The results provided in this report relate only to the items tested.
This page is the concluding page of the report.

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DATA CHEM LABORATORIES, INC.

ANALYTICAL REQUEST FORM

1. ☐ REGULAR Status 03I-11616-06

☐ RUSH Status Requested - ADDITIONAL CHARGE
RESULTS REQUIRED BY _____ DATE
CONTACT DATACHEM LABS PRIOR TO SENDING SAMPLES

2. Date 5/2/03 Purchase Order No. _____ 4. Quote No. _____

3. Company Name BOOZ ALLEN HAMILTON DCL Project Manager Rand Potter

Address 5299 DTC BLVD., STE 540 5. Sample Collection

GREENWOOD VILLAGE, CO 80111 Sampling Site AERC, MELBOURNE

Person to Contact STEVE COFFEE Industrial Process DTC DEVICE

Telephone (303) 221-7559 Date of Collection 4/29/03

Fax Telephone (303) 694-7367 Time Collected _____

E-mail Address COFFEE_STEPHEN@BAH.COM Date of Shipment 5/2/03

Billing Address (if different) REFER TO CONTRACT Chain of Custody No. 1

6. REQUEST FOR ANALYSES

Laboratory Use Only	Client Sample Number	Matrix*	Sample Volume	ANALYSES REQUESTED - Use method number if known	Units**
03I16295	3705-B-4/29-01	HYDRAR	61.2 l	NIOSH 6009	2
296	3705-B-4/29-03		64.8 l		
297	3705-D-A-4/29-05		25.8 l		
298	-07		24.2 l		
299	-09		24.9 l		
300	-11		25.1 l		
01	-13		3.0 l		
02	-15		5.1 l		
03	-17		104.9 l		
04	-19		106.4 l		
05	-21		109.2 l		
06	-23		1.01 l		
07	-25		1.01 l		
08	FIELD BLANK 4/29		—		
09	FIELD BLANK 4/29				

* Specify: Solid sorbent tube, e.g. Charcoal; Filter type; Impinger solution; Bulk sample; Blood; Urine; Tissue; Soil; Water; Other

** 1. mg/sample 2. mg/m³ 3. ppm 4. % 5. ____ (other) Please indicate one or more units in the column entitled Units**

Comments _____

Possible Contamination and/or Chemical Hazards _____

7. Chain of Custody (Optional)

Relinquished by	Stephen D. Coffee	Date/Time	5/2/03 1310
Received by	Rand Potter	Date/Time	5/5 @
Relinquished by	Rand Potter	Date/Time	5/5/03 (RP)
Received by		Date/Time	

960 West LeVoy Drive / Salt Lake City, UT 84123 800-356-9135 or 801-266-7700 / FAX: 801-268-9992
DATACHEM LABORATORIES, INC.

DATA CHEM LABORATORIES, INC.

ANALYTICAL REQUEST FORM

1. ☐ REGULAR Status 03I-1146-06

☐ RUSH Status Requested - ADDITIONAL CHARGE
RESULTS REQUIRED BY _____ DATE
CONTACT DATACHEM LABS PRIOR TO SENDING SAMPLES

2. Date 5/2/03 Purchase Order No. _____ 4. Quote No. _____

3. Company Name BOOZ ALLEN HAMILTON DCL Project Manager Rand Potter

Address 5299 DTC BLVD, STE 840 5. Sample Collection

GREENWOOD VILLAGE, CO 80111 Sampling Site AERC MELBOURNE

Person to Contact STEVE COFFEE Industrial Process DTC DEVICE

Telephone (303) 221-7559 Date of Collection 4/30/03

Fax Telephone (303 694-7367 Time Collected _____

E-mail Address COFFEE_STEPHEN@BAH.COM Date of Shipment 5/2/03

Billing Address (if different) REFER TO CONTRACT Chain of Custody No. 3

6. REQUEST FOR ANALYSES

Laboratory Use Only	Client Sample Number	Matrix*	Sample Volume	ANALYSES REQUESTED - Use method number if known	Units**
03I1631O	3705-A-A-4/30 ZA-HYDRAZ		22.3 l	NAM 6009	2
11	29.		12.5 l		
12	31.		12.4 l		
13	33.		22.8 l		
14	35.		22.8 l		
15	37.		2.98 l		
16	39.		4.22 l		
17	41.		2.98 l		
18	43.		2.98 l		
19	45.		0.99 l		
20	47.		0.99 l		
21	49.		150.16 l		
22	51.		149.1 l		
23,24	53. 55.		154.1 l 10.4 l		
25,26	57. 59.		10.1 l 3.07 l		

* Specify: Solid sorbent tube, e.g. Charcoal; Filter type; Impinger solution; Bulk sample; Blood; Urine; Tissue; Soil; Water; Other

** 1. mg/sample 2. mg/m³ 3. ppm 4. % 5. ____ (other) Please indicate one or more units in the column entitled Units**

Comments 2 FIELD BLANKS 4/30 HYRAZ NAM 6009 2
27 1 28

Possible Contamination and/or Chemical Hazards _____

7. Chain of Custody (Optional)

Relinquished by	Steve D. Coffee	Date/Time	5/2/03 1310
Received by	Rand Potter	Date/Time	5/5
Relinquished by	Rand Potter	Date/Time	5/5
Received by		Date/Time	

960 West LeVoy Drive / Salt Lake City, UT 84123.. 800-356-9135 or 801-266-7700 / FAX: 801-268-9992
DATACHEM LABORATORIES, INC.

Appendix C

Data Chem Laboratory Reports

Sample Shipping Information

Samples were placed in an oversized, sturdy box with packing material to fill voids and protect the samples during shipping. The sampling personnel then signed the chain-of-custody forms, and placed them in the box with the samples. Samples were shipped via Federal Express to the laboratory.

DATA CHEM LABORATORIES
A Sorenson Company

ANALYTICAL REPORT

Form ARF-AL
Page 1 of 3
Part 1 of 1
062303120053 98RX

Date JUN 2 4 2003
Laboratory Group Name 03I-1506-01
Account No. 07003

Booz Allen Hamilton
Attention: Steve Coffee
5299 DTC Blcd.
Suite 840
Greenwood Village, CO 80111

FAX (303) 694-7367
Telephone (303) 221-7559
E-mail coffee_stephen@bah.com

Sampling Collection and Shipment

Sampling Site AERC Ashland Trip#4 Date of Collection

Date Samples Received at Laboratory June 16, 2003

Analysis

Method of Analysis NMAM 6009

Date(s) of Analysis June 19, 2003

Analytical Results

Field Sample Number	Laboratory Number	Sample Type	Mercury ug/Sample	Mercury mg/M³	Air Volume L					
3705BA6/9-01	03I19545	TUBE	0.77	0.013	58.3					
3705BA6/9-03	03I19546	TUBE	0.46	0.0086	54.1					
LAB BLANK	03I19547	TUBE	0.040	**	0.00					
LAB BLANK	03I19548	TUBE	0.047	**	0.00					
LAB BLANK	03I19549	TUBE	0.040	**	0.00					
FB 6/10	03I19550	TUBE	0.039	**	0.00					
FB 6/10	03I19551	TUBE	0.041	**	0.00					
FB 6/11	03I19552	TUBE	0.042	**	0.00					
FB 6/11	03I19553	TUBE	0.038	**	0.00					
FB 6/12	03I19554	TUBE	0.040	**	0.00					
FB 6/12	03I19555	TUBE	0.038	**	0.00					
FB 6/13	03I19556	TUBE	0.036	**	0.00					
FB 6/13	03I19557	TUBE	0.043	**	0.00					

† See comment on last page. ** See comment on last page.
ND Parameter not detected above LOD. ( ) Parameter between LOD and LOQ.
NR Parameter not requested.
NA Parameter not applicable.

Jose G. Rocha
Analyst: Jose G. Rocha

Reviewer: Neil A. Edwards

DATA CHEM LABORATORIES
A Sorenson Company

ANALYTICAL REPORT

Form ARF-BL
Page 2 of 3
Part 1 of 1
062303120053 98RX

Date JUN 2 4 2003

Laboratory Group Name 03I-1506-01

Analytical Results

Field Sample Number	Laboratory Number	Sample Type	Mercury ug/Sample	Mercury mg/m³	Air Volume L					
3705RA6/1005	03I19558	TUBE	0.23	0.0093	25.2					
3705RA6/1007	03I19559	TUBE	0.083	0.0062	13.4					
3705RA6/1009	03I19560	TUBE	0.14	0.011	13.5					
3705RA6/1011	03I19561	TUBE	0.29	0.010	29.1					
3705RA6/1013	03I19562	TUBE	0.31	0.011	29.1					
3705RA6/1015	03I19563	TUBE	0.042	0.013	3.1					
3705RA6/1017	03I19564	TUBE	0.077	0.025	3.1					
3705RA6/1019	03I19565	TUBE	0.050	0.050	1.0					
FB FACILITY	03I19885	TUBE	0.038	**	0.00					
Reporting Limit			0.01							

† See comment on last page.
ND Parameter not detected above LOD.
NR Parameter not requested.
NA Parameter not applicable.

** See comment on last page.
( ) Parameter between LOD and LOQ.

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Phone (801) 266-7700 Web Page: www.datachem.com
FAX (801) 268-9992 E-mail: lab@datachem.com

DATA CHEM LABORATORIES
A Sorenson Company

ANALYTICAL REPORT

06230312005398RX

Date JUN 24 2003
Laboratory Group Name 03I-1506-01

General Set Comments

Method Reference: NIOSH Manual of Analytical Methods(NMAM), 4th ed., 08/15/94.
Results are not blank-corrected.
Results obtained for media blanks prepared from SKC Carulite tubes are typically found to have concentrations approximately 0.035-0.045 ug/Sample above the reporting limit.
Results cannot be reported in mg/m^3 or ppm for samples with no air volume.

General Lab Comments

The results provided in this report relate only to the items tested.
This page is the concluding page of the report.

960 West LeVoy Drive / Salt Lake City, Utah 84123-2547
Phone (801) 266-7700 Web Page: www.datachem.com
FAX (801) 268-9992 E-mail: lab@datachem.com

ANALYTICAL REQUEST FORM

DATA CHEM LABORATORIES, INC.

1. [X] REGULAR Status 03I-1506-01

[ ] RUSH Status Requested - ADDITIONAL CHARGE
RESULTS REQUIRED BY _____ DATE
CONTACT DATACHEM LABS PRIOR TO SENDING SAMPLES

2. Date 6/13/03 Purchase Order No. _____

3. Company Name Booz Allen Hamilton
Address 5299 DTC Blvd., Suite 840
Greenwood Village, CO 80111
Person to Contact Steve Coffee
Telephone (303) 221-7559
Fax Telephone (303) 694-7367
E-mail Address coffee_stephen@bah.com
Billing Address (if different from above) refer to contract

4. Quote No. _____
DCL Project Manager Rand Potter

5. Sample Collection
Sampling Site AERC Ashland Trip #4
Industrial Process DTC Device
Date of Collection 6/9 & 6/10 & 6/11 & 6/12
Time Collected _____
Date of Shipment 6/13/03
Chain of Custody No. 1

6. REQUEST FOR ANALYSES

Laboratory Use Only	Client Sample Number	Matrix*	Sample Volume	ANALYSES REQUESTED - Use method number if known	Units**
03I 19545	3705-B-A-6/9-01	Hydrar	58.3 L	NIOSH 6009	2
546	" -03		54.1 L		
547	LAB Blank		na		
548	LAB Blank		na		
549	LAB Blank		na		
550	Field Blank 6/10		na		
551	Field Blank 6/10		na		
552	Field Blank 6/11		na		
553	Field Blank 6/11		na		
554	Field Blank 6/12		na		
555	Field Blank 6/12		na		

* Specify: Solid sorbant tube, e.g. Charcoal; Filter type; Impinger solution; Bulk sample; Blood; Urine; Tissue; Soil; Water; Other

** 1. mg/sample 2. mg/m^3 3. ppm 4. % 5. ____ (other) Please indicate one or more units in the column entitled Units**

Comments _____

Possible Contamination and/or Chemical Hazards _____

7. Chain of Custody (Optional)

Relinquished by	[signature]	Date/Time	6/13/03 10:00
Received by	[signature]	Date/Time	6/14
Relinquished by	[signature]	Date/Time	6/16/03
Received by		Date/Time	
Relinquished by		Date/Time	
Received by		Date/Time	

960 West LeVoy Drive / Salt Lake City, UT 84123 800-356-9135 or 801-266-7700 / FAX: 801-268-9992
DATACHEM LABORATORIES, INC.

ANALYTICAL REQUEST FORM

DATA CHEM LABORATORIES, INC.

1. [X] REGULAR Status 03I-1506-01

[ ] RUSH Status Requested - ADDITIONAL CHARGE
RESULTS REQUIRED BY _____ DATE
CONTACT DATACHEM LABS PRIOR TO SENDING SAMPLES

2. Date _____ Purchase Order No. _____

3. Company Name Booz Allen Hamilton
Address 5299 DTC Blvd., Suite 640
Greenwood Village, CO 80111
Person to Contact Steve Coffee
Telephone (303) 221-7559
Fax Telephone (303) 694-7367
E-mail Address coffee_stephen@bah.com
Billing Address (if different from above) refer to contract

4. Quote No. _____
DCL Project Manager Rand Potter

5. Sample Collection
Sampling Site AERC Ashland Trip #4
Industrial Process DTC Device RTI
Date of Collection 6/13 & 6/10
Time Collected _____
Date of Shipment 6/13/03
Chain of Custody No. 2

6. REQUEST FOR ANALYSES

Laboratory Use Only	Client Sample Number	Matrix*	Sample Volume	ANALYSES REQUESTED - Use method number if known	Units**
03I19556	Field Blank 6/13	Hydrar	na	NIOSH 6009	2
557	Field Blank 6/13		na		
03I19886	field blank 6/13				
558	3705-R-A-6/10-05		25.2L		
559	" -07		13.4L		
560	" -09		13.5L		
561	" -11		29.1L		
562	" -13		29.1L		
563	" -15		3.1.L		
564	" -17		3.1L		
565	" -19		1.0L		

* Specify: Solid sorbent tube, e.g. Charcoal; Filter type; Impinger solution; Bulk sample; Blood; Urine; Tissue; Soil; Water; Other

** 1. mg/sample 2. mg/m³ 3. ppm 4. % 5. ____ (other) Please indicate one or more units in the column entitled Units**

Comments field Blank facility - 03I19885

Possible Contamination and/or Chemical Hazards _____

7. Chain of Custody (Optional)

Relinquished by	Steve D. Coff	Date/Time	6/13/03 10:00
Received by	R Leopold	Date/Time	6/14
Relinquished by	R Leopold	Date/Time	6/16/
Received by		Date/Time	
Relinquished by		Date/Time	
Received by		Date/Time	

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DATACHEM LABORATORIES, INC.

DATA CHEM LABORATORIES
A Sorenson Company

ANALYTICAL REPORT

Form ARP-AL
Page 1 of 3
Part 1 of 1

JUN 24 2003 0606031224475BRX

Date
Laboratory Group Name 03I-1506-02
Account No. 07003

Booz Allen Hamilton
Attention: Steve Coffee
5299 DTC Blcd.
Suite 840
Greenwood Village, CO 80111

FAX (303) 694-7367
Telephone (303) 221-7559
E-mail coffee_stephen@bah.com

Sampling Collection and Shipment

Sampling Site AERC Ashland Trip#4 Date of Collection June 10, 2003

Date Samples Received at Laboratory June 16, 2003

Analysis

Method of Analysis NMAM 6009

Date(s) of Analysis June 19, 2003

Analytical Results

Field Sample Number	Laboratory Number	Sample Type	Mercury ug/Sample	Mercury mg/m³	Air Volume L					
3705RA6/1021	03I19566	TUBE	0.047	0.047	1.0					
3705RA6/1023	03I19567	TUBE	0.19	0.015	12.3					
3705RA6/1025	03I19568	TUBE	0.19	0.015	12.3					
3705RA6/1027	03I19569	TUBE	0.37	0.0066	55.8					
3705RA6/1029	03I19570	TUBE	0.68	0.012	54.7					
3705RA6/1031	03I19571	TUBE	0.95	0.017	56.2					
3705RA6/1033	03I19572	TUBE	0.15	0.012	12.5					
3705RA6/1035	03I19573	TUBE	0.16	0.013	12.5					
3705RA6/1037	03I19574	TUBE	0.17	0.015	11.4					
3705RA6/1039	03I19575	TUBE	0.16	0.014	11.5					
3705RA6/1041	03I19576	TUBE	0.17	0.015	11.6					
3705RA6/1043	03I19577	TUBE	0.14	0.013	10.8					
3705RA6/1045	03I19578	TUBE	0.096	0.031	3.1					

† See comment on last page. ** See comment on last page.
ND Parameter not detected above LOD. ( ) Parameter between LOD and LOQ.
NR Parameter not requested.
NA Parameter not applicable.

Jose G. Rocha
Analyst: Jose G. Rocha

Reviewer: Neil A. Edwards

960 West LeVoy Drive / Salt Lake City, Utah 84123-2547
Phone (801) 266-7700 Web Page: www.datachem.com
FAX (801) 268-9992 E-mail: lab@datachem.com

DATA CHEM LABORATORIES
A Sorenson Company

ANALYTICAL REPORT

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06240312244758RX

Date JUN 24 2003
Laboratory Group Name 03I-1506-02

Analytical Results

Field Sample Number	Laboratory Number	Sample Type	Mercury ug/Sample	Mercury mg/m³	Air Volume L						
3705RA6/1047	03I19579	TUBE	0.23	0.018	12.7						
3705RA6/1049	03I19580	TUBE	1.3	0.20	13.0						†
3705RA6/1051	03I19581	TUBE	0.067	0.067	1.0						
3705RA6/1053	03I19582	TUBE	0.042	0.042	1.0						
Reporting Limit			0.01								

† See comment on last page.
ND Parameter not detected above LOD.
NR Parameter not requested.
NA Parameter not applicable.
** See comment on last page.
( ) Parameter between LOD and LOQ.

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FAX (801) 268-9992 E-mail: lab@datachem.com

DATA CHEM LABORATORIES
A Sorenson Company

ANALYTICAL REPORT

06240312244758RX

JUN 2 4 2003

Date _____

Laboratory Group Name 03I-1506-02

General Set Comments

Method Reference: NIOSH Manual of Analytical Methods(NMAM), 4th ed., 08/15/94.
Results are not blank-corrected.
Results obtained for media blanks prepared from SKC Carulite tubes are typically found to have concentrations approximately 0.035-0.045 ug/Sample above the reporting limit.

The result for sample 03I19580 exceeded the calibration range of the instrument. Due to an oversite, the sample was not diluted and reanalyzed. The reported result for this sample is therefore estimated.

Sample Comments

Laboratory Number	Comment
03I19580	See set comments.

General Lab Comments

The results provided in this report relate only to the items tested.
This page is the concluding page of the report.

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ANALYTICAL REQUEST FORM

DATA CHEM LABORATORIES, INC.

1. [X] REGULAR Status 03I-1506-02

[ ] RUSH Status Requested - ADDITIONAL CHARGE
RESULTS REQUIRED BY _____ DATE
CONTACT DATACHEM LABS PRIOR TO SENDING SAMPLES

2. Date _____ Purchase Order No. _____

3. Company Name Booz Allen Hamilton
Address 5299 DTC Blvd., Suite 840
Greenwood Village, CO 80111
Person to Contact Steve Coffee
Telephone (303) 221-7559
Fax Telephone (303) 694-7367
E-mail Address coffee_stephen@bah.com
Billing Address (if different from above) refer to contract

4. Quote No. _____
DCL Project Manager Rand Potter

5. Sample Collection
Sampling Site AERC Ashland Trip #4
Industrial Process DTC Device RTI
Date of Collection 6/10/03
Time Collected _____
Date of Shipment 6/13/03
Chain of Custody No. 3

6. REQUEST FOR ANALYSES

Laboratory Use Only	Client Sample Number	Matrix*	Sample Volume	ANALYSES REQUESTED - Use method number if known	Units**
03I19566	3705-R-A-6/10/21	Hydrar.	1.0 L	NIOSH 6009	2
567	" -23.		12.3 L		
568	" -25.		12.3 L		
569	" -27.		55.8 L		
570	" -29.		54.7 L		
571	" -31.		56.2 L		
572	" -33.		12.5 L		
573	" -35.		12.5 L		
574	" -37.		11.4 L		
575	" -39.		11.5 L		
576	" -41.		11.6 L		

* Specify: Solid sorbent tube, e.g. Charcoal; Filter type; Impinger solution; Bulk sample; Blood; Urine; Tissue; Soil; Water; Other

** 1. mg/sample 2 mg/m³ 3. ppm 4. % 5. ____ (other) Please indicate one or more units in the column entitled Units**

Comments _____

Possible Contamination and/or Chemical Hazards _____

7. Chain of Custody (Optional)

Relinquished by	[signature]	Date/Time	6/13/03 10:01
Received by	[signature]	Date/Time	6/16
Relinquished by	[signature]	Date/Time	6/16/03
Received by		Date/Time	
Relinquished by		Date/Time	
Received by		Date/Time	

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DATACHEM LABORATORIES, INC.

ANALYTICAL REQUEST FORM

DATA CHEM LABORATORIES, INC.

1. [X] REGULAR Status 03I-1506-02

[ ] RUSH Status Requested - ADDITIONAL CHARGE
RESULTS REQUIRED BY _____ DATE
CONTACT DATACHEM LABS PRIOR TO SENDING SAMPLES

2. Date _____ Purchase Order No. _____

3. Company Name Booz Allen Hamilton
Address 5299 DTC Blvd., Suite 840
Greenwood Village, CO 80111
Person to Contact Steve Coffee
Telephone (303) 221-7559
Fax Telephone (303) 694-7367
E-mail Address coffee_stephen@bah.com
Billing Address (if different from above) refer to contract

4. Quote No. _____
DCL Project Manager Rand Potter

5. Sample Collection
Sampling Site AERC Ashland Trip #4
Industrial Process DTC Device RTI
Date of Collection 6/10/03
Time Collected _____
Date of Shipment 6/13/03
Chain of Custody No. 4

6. REQUEST FOR ANALYSES

Laboratory Use Only	Client Sample Number	Matrix*	Sample Volume	ANALYSES REQUESTED - Use method number if known	Units**
03I19577	3705-R-A-6/10-43	Hydra	10.8 L	N165H 6009	2
578	" -45	↓	3.1 L	↓	↓
579	" -47		12.7 L		
580	" -49		13.0 L		
581	" -51		1.0 L		
582	" -53	↓	1.0 L	↓	✓
5/2					

* Specify: Solid sorbent tube, e.g. Charcoal; Filter type; Impinger solution; Bulk sample; Blood; Urine; Tissue; Soil; Water; Other

** 1. mg/sample 2. mg/m³ 3. ppm 4. % 5. ____ (other) Please indicate one or more units in the column entitled Units**

Comments _____

Possible Contamination and/or Chemical Hazards _____

7. Chain of Custody (Optional)

Relinquished by	Steve O. Coffee	Date/Time	6/13/03 10:00
Received by	Rand Potter	Date/Time	6/14
Relinquished by	Rand Potter	Date/Time	6/16/03
Received by		Date/Time	
Relinquished by		Date/Time	
Received by		Date/Time	

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DATACHEM LABORATORIES, INC.

DATA CHEM LABORATORIES
A Sorenson Company

ANALYTICAL REPORT

Form ARF-AL
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Part 1 of 1
062303162443O3RX

Date JUN 2 4 2003
Laboratory Group Name 03I-1506-04
Account No. 07003

Booz Allen Hamilton
Attention: Steve Coffee
5299 DTC Blcd.
Suite 840
Greenwood Village, CO 80111

FAX (303) 694-7367
Telephone (303) 221-7559
E-mail coffee_stephen@bah.com

Sampling Collection and Shipment

Sampling Site AERC Ashland Trip#4 Date of Collection June 11, 2003

Date Samples Received at Laboratory June 16, 2003

Analysis

Method of Analysis NMAM 6009

Date(s) of Analysis June 20, 2003

Analytical Results

Field Sample Number	Laboratory Number	Sample Type	Mercury ug/sample	Mercury mg/m³	Air Volume L					
3705DA61155	03I19603	TUBE	1.2	0.064	19.20					
3705DA61157	03I19604	TUBE	0.68	0.058	11.7					
3705DA61159	03I19605	TUBE	0.90	0.076	11.8					
3705DA61161	03I19606	TUBE	1.5	0.074	20.1					
3705DA61163	03I19607	TUBE	0.98	0.047	20.8					
3705DA61165	03I19608	TUBE	1.0	0.20	5.2					
3705DA61167	03I19609	TUBE	0.20	0.065	3.1					
3705DA61169	03I19610	TUBE	0.10	0.10	1.0					
3705DA61171	03I19611	TUBE	0.19	0.19	1.0					
3705DA61173	03I19612	TUBE	0.62	0.081	7.7					
3705DA61175	03I19613	TUBE	0.59	0.11	5.5					
3705AA612117	03I19615	TUBE	0.77	0.029	26.5					
3705AA612119	03I19616	TUBE	0.77	0.049	15.8					

† See comment on last page. ** See comment on last page.
ND Parameter not detected above LOD. ( ) Parameter between LOD and LOQ.
NR Parameter not requested.
NA Parameter not applicable.

Jose G. Rocha
Analyst: Jose G. Rocha

Reviewer: Neil A. Edwards

DATA CHEM LABORATORIES
A Sorenson Company

ANALYTICAL REPORT

Form ARF-BL
Page 2 of 3
Part 1 of 1
062303162443O3RX

JUN 2 4 2003

Date ___

Laboratory Group Name 03I-1506-04

Analytical Results

Field Sample Number	Laboratory Number	Sample Type	Mercury ug/Sample	Mercury mg/m³	Air Volume L					
3705AA612121	03I19617	TUBE	0.89	0.053	16.7					
3705AA612123	03I19618	TUBE	1.1	0.041	26.4					
3705AA612125	03I19619	TUBE	0.02	0.00075	26.5					
3705AA612127	03I19620	TUBE	0.17	0.055	3.1					
3705AA612129	03I19621	TUBE	0.48	0.15	3.1					
3705AA612131	03I19622	TUBE	0.19	0.19	1.0					
3705AA612133	03I19623	TUBE	0.22	0.22	1.0					
3705AA612135	03I19624	TUBE	0.40	0.039	10.3					
Reporting Limit			0.01							

† See comment on last page. ** See comment on last page.
ND Parameter not detected above LOD. ( ) Parameter between LOD and LOQ.
NR Parameter not requested.
NA Parameter not applicable.

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FAX (801) 268-9992 E-mail: lab@datachem.com

DATA CHEM
LABORATORIES
A Sorenson Company

ANALYTICAL REPORT

062303162443O3RX

JUN 2 4 2003

Date _____

Laboratory Group Name 03I-1506-04

General Set Comments

Method Reference: NIOSH Manual of Analytical Methods(NMAM), 4th ed., 08/15/94.
Results are not blank-corrected.
Results obtained for media blanks prepared from SKC Carulite tubes are typically found to have concentrations approximately 0.035-0.045 ug/Sample above the reporting limit.
Samples 03I19603,606 required a 10X dilution.

General Lab Comments

The results provided in this report relate only to the items tested.
This page is the concluding page of the report.

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FAX (801) 268-9992 E-mail: lab@datachem.com

ANALYTICAL REQUEST FORM

DATA CHEM LABORATORIES, INC.

1. [X] REGULAR Status 03I-1506-04

[ ] RUSH Status Requested - ADDITIONAL CHARGE
RESULTS REQUIRED BY _____ DATE
CONTACT DATACHEM LABS PRIOR TO SENDING SAMPLES

2. Date 6/13/03 Purchase Order No. _____

3. Company Name Booz Allen Hamilton
Address 5299 DTC Blvd., Suite 840
Greenwood Village, CO 80111
Person to Contact Steve Coffee
Telephone (303) 221-7559
Fax Telephone (303) 694-7367
E-mail Address coffee_stephen@bah.com
Billing Address (if different from above) refer to contract

4. Quote No. _____
DCL Project Manager Rand Potter

5. Sample Collection
Sampling Site AERC Ashland Trip #4
Industrial Process DTC Device Dextrit
Date of Collection 6/11/03
Time Collected _____
Date of Shipment 6/13/03
Chain of Custody No. 9

6. REQUEST FOR ANALYSES

Laboratory Use Only	Client Sample Number	Matrix*	Sample Volume	ANALYSES REQUESTED - Use method number if known	Units**
03I19603	3705-D-A-6/11-55	Hydrar	19.2 L	NIOSH 6009	2
604	" -57		11.7 L		
605	" -59		11.8 L		
606	" -61		20.1 L		
607	" -63		20.8 L		
608	" -65		5.2 L		
609	" -67		3.1 L		
610	" -69		1.0 L		
611	" -71		1.0 L		
612	" -73		7.7 L		
613	" -75	↓	5.5 L	↓	↓

* Specify: Solid sorbent tube, e.g. Charcoal; Filter type; Impinger solution; Bulk sample; Blood; Urine; Tissue; Soil; Water; Other

** 1. mg/sample 2. mg/m^3 3. ppm 4. % 5. ____ (other) Please indicate one or more units in the column entitled Units**

Comments _____

Possible Contamination and/or Chemical Hazards _____

7. Chain of Custody (Optional)

Relinquished by	Steve D. Coffee	Date/Time	6/13/03 10:00
Received by	Rand Potter	Date/Time	6/14
Relinquished by	Rand Potter	Date/Time	6/16
Received by		Date/Time	
Relinquished by		Date/Time	
Received by		Date/Time	

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DATACHEM LABORATORIES, INC.

ANALYTICAL REQUEST FORM

DATA CHEM LABORATORIES, INC.

1. ☒ REGULAR Status 03I-1506-04

☐ RUSH Status Requested - ADDITIONAL CHARGE
RESULTS REQUIRED BY _____ DATE
CONTACT DATACHEM LABS PRIOR TO SENDING SAMPLES

2. Date 6/13 Purchase Order No. _____

3. Company Name Booz Allen Hamilton
Address 5299 DTC Blvd., Suite 840
Greenwood Village, CO 80111
Person to Contact Steve Coffee
Telephone (303) 221-7559
Fax Telephone (303) 694-7367
E-mail Address coffee_stephen@bah.com
Billing Address (if different from above) refer to contract

4. Quote No. _____
DCL Project Manager Rand Potter

5. Sample Collection
Sampling Site AERC Ashland Trip #4
Industrial Process DTC Device AIR CYCLE
Date of Collection 6/12/03
Time Collected _____
Date of Shipment 6/13/03
Chain of Custody No. _____

6. REQUEST FOR ANALYSES

Laboratory Use Only	Client Sample Number	Matrix*	Sample Volume	ANALYSES REQUESTED - Use method number if known	Units**
~~03I-1961A~~	~~5705-A-A-6/12~~	HYBRAR		NAM (600)	2
615	117.		26.5 l		
616	119.		15.8 l		
617	121.		16.7 l		
618	123.		26.4 l		
619	125.		26.5 l		
620	127.		3.1 l		
621	129.		3.1 l		
622	131.		1.0 l		
623	133.		1.0 l		
624	135.		10.3 l		

* Specify: Solid sorbent tube, e.g. Charcoal; Filter type; Impinger solution; Bulk sample; Blood; Urine; Tissue; Soil; Water; Other

** 1. mg/sample 2. mg/m^3 3. ppm 4. % 5. ____ (other) Please indicate one or more units in the column entitled Units**

Comments _____

Possible Contamination and/or Chemical Hazards _____

7. Chain of Custody (Optional)

Relinquished by	[signature]	Date/Time	6/13/03 10:01
Received by	Rand Potter	Date/Time	6/04/
Relinquished by	Rand Potter	Date/Time	6/16/03
Received by		Date/Time	
Relinquished by		Date/Time	
Received by		Date/Time	

960 West LeVoy Drive / Salt Lake City, UT 84123 800-356-9135 or 801-266-7700 / FAX: 801-268-9992
DATACHEM LABORATORIES, INC.

DATA CHEM LABORATORIES
A Sorenson Company

ANALYTICAL REPORT

Form ARF-AL
Page 1 of 3
Part 1 of 1
06240312455882RX

JUN 2 4 2003

Date

Laboratory Group Name 03I-1506-03

Account No. 07003

Booz Allen Hamilton
Attention: Steve Coffee
5299 DTC Blcd.
Suite 840
Greenwood Village, CO 80111

FAX (303) 694-7367
Telephone (303) 221-7559
E-mail coffee_stephen@bah.com

Sampling Collection and Shipment

Sampling Site AERC Ashland Trip#4 Date of Collection June 11, 2003

Date Samples Received at Laboratory June 16, 2003

Analysis

Method of Analysis NMAM 6009

Date(s) of Analysis June 19, 2003

Analytical Results

Field Sample Number	Laboratory Number	Sample Type	Mercury ug/Sample	Mercury mg/m³	Air Volume L					
3705DA61199	03I19583	TUBE	0.23	0.033	6.9					
3705DA611101	03I19584	TUBE	0.23	0.034	6.8					
3705DA611103	03I19585	TUBE	0.23	0.074	3.1					
3705DA611105	03I19586	TUBE	0.094	0.094	1.0					
3705DA611107	03I19587	TUBE	0.11	0.11	1.0					
3705DA611109	03I19588	TUBE	0.89	0.12	7.2					
3705DA611111	03I19589	TUBE	0.85	0.12	7.2					
3705DA611113	03I19590	TUBE	1.6	0.089	18.0					
3705DA611115	03I19591	TUBE	1.3	0.073	18.0					
3705DA61177	03I19592	TUBE	0.065	0.00052	125.9					
3705DA61179	03I19593	TUBE	6.0	0.049	123.5					
3705DA61181	03I19594	TUBE	0.059	0.00052	113.1					
3705DA61183	03I19595	TUBE	0.24	0.10	2.4					

† See comment on last page.
ND Parameter not detected above LOD.
NR Parameter not requested.
NA Parameter not applicable.

** See comment on last page.
( ) Parameter between LOD and LOQ.

Jose G. Rocha
Analyst: Jose G. Rocha

Reviewer: Neil A. Edwards

DATA CHEM LABORATORIES
A Sorenson Company

ANALYTICAL REPORT

Form ARF-BL
Page 2 of 3
Part 1 of 1
06240312455882RX

JUN 24 2003

Date _____

Laboratory Group Name 03I-1506-03

Analytical Results

Field Sample Number	Laboratory Number	Sample Type	Mercury ug/Sample	Mercury mg/m³	Air Volume L					
3705DA61185	03I19596	TUBE	0.044	0.018	2.4					
3705DA61187	03I19597	TUBE	0.20	0.083	2.4					
3705DA61189	03I19598	TUBE	0.23	0.092	2.5					
3705DA61191	03I19599	TUBE	0.23	0.034	6.8					
3705DA61193	03I19600	TUBE	0.23	0.034	6.8					
3705DA61195	03I19601	TUBE	0.19	0.026	7.2					
3705DA61197	03I19602	TUBE	0.23	0.034	6.7					
Reporting Limit			0.01							

† See comment on last page.
ND Parameter not detected above LOD.
NR Parameter not requested.
NA Parameter not applicable.

** See comment on last page.
( ) Parameter between LOD and LOQ.

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DATA CHEM LABORATORIES
A Sorenson Company

ANALYTICAL REPORT

Form ARF-C
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062403124558B2RX

JUN 2 4 2003

Date _____

Laboratory Group Name 03I-1506-03

General Set Comments

Method Reference: NIOSH Manual of Analytical Methods(NMAM), 4th ed., 08/15/94.
Results are not blank-corrected.
Results obtained for media blanks prepared from SKC Carulite tubes are typically found to have concentrations approximately 0.035-0.045 ug/Sample above the reporting limit.
Samples 03I19590, 91 and 93 required a 10X dilution.

General Lab Comments

The results provided in this report relate only to the items tested.
This page is the concluding page of the report.

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ANALYTICAL REQUEST FORM

DATA CHEM LABORATORIES, INC.

1. [X] REGULAR Status 03I-1506-03

[ ] RUSH Status Requested - ADDITIONAL CHARGE
RESULTS REQUIRED BY _____ DATE
CONTACT DATACHEM LABS PRIOR TO SENDING SAMPLES

2. Date 6/13/03 Purchase Order No. _____ 4. Quote No. _____

3. Company Name Booz Allen Hamilton DCL Project Manager Rand Potter

Address 5299 DTC Blvd., Suite 840 5. Sample Collection

Greenwood Village, CO 80111 Sampling Site AERC Ashland Trip #4

Person to Contact Steve Coffee Industrial Process DTC Device Dextrite

Telephone (303) 221-7559 Date of Collection 6/11/03

Fax Telephone (303) 694-7367 Time Collected _____

E-mail Address coffee_stephen@bah.com Date of Shipment 6/13/03

Billing Address (if different from above) refer to contract Chain of Custody No. 11

6. REQUEST FOR ANALYSES

Laboratory Use Only	Client Sample Number	Matrix*	Sample Volume	ANALYSES REQUESTED - Use method number if known	Units**
03I 19583	3705-D-A 6/11-99	Hydrar	6.9 L	N105H 6009	2
584	" -101	"	6.8 L		
585	" -103	"	3.1 L		
586	" -105	"	1.0 L		
587	" -107	"	1.0 L		
588	" -109		7.2 L		
589	" -111		7.2 L		
590	" -113		18.0 L		
591	" -115	↓	18.0 L	↓	↓

* Specify: Solid sorbent tube, e.g. Charcoal; Filter type; Impinger solution; Bulk sample; Blood; Urine; Tissue; Soil; Water; Other

** 1. mg/sample 2. mg/m^3 3. ppm 4. % 5. _____ (other) Please indicate one or more units in the column entitled Units**

Comments _____

Possible Contamination and/or Chemical Hazards _____

7. Chain of Custody (Optional)

Relinquished by	Steph. (FF)	Date/Time	6/13/03 10:00
Received by	Rand Potter	Date/Time	6/14
Relinquished by	Rand Potter	Date/Time	6/16/03
Received by		Date/Time	
Relinquished by		Date/Time	
Received by		Date/Time	

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DATACHEM LABORATORIES, INC.

ANALYTICAL REQUEST FORM

DATA CHEM LABORATORIES, INC.

1. [X] REGULAR Status 03I-1506-03

[ ] RUSH Status Requested - ADDITIONAL CHARGE
RESULTS REQUIRED BY _____ DATE
CONTACT DATACHEM LABS PRIOR TO SENDING SAMPLES

2. Date 6/13/03 Purchase Order No. _____

3. Company Name Booz Allen Hamilton

Address 5299 DTC Blvd., Suite 840

Greenwood Village, CO 80111

Person to Contact Steve Coffee

Telephone (303) 221-7559

Fax Telephone (303) 694-7367

E-mail Address coffee_stephen@bah.com.

Billing Address (if different from above) refer to contract

4. Quote No. _____

DCL Project Manager Rand Potter

5. **Sample Collection**

Sampling Site AERC Ashland Trip #4

Industrial Process DTC Device Destrike

Date of Collection 6/11/03

Time Collected _____

Date of Shipment 6/13/03

Chain of Custody No. 10

6. **REQUEST FOR ANALYSES**

Laboratory Use Only	Client Sample Number	Matrix*	Sample Volume	ANALYSES REQUESTED - Use method number if known	Units**
03I19592	3705-D-A-6/11-77	Hydrar	125.9L	N105H 6009	2
593	" -79.		123.5L		
594	" -81.		113.1L		
595	" -83.		2.4L		
596	" -85.		2.4L		
597	" -87.		2.4L		
598	" -89.		2.5L		
599	" -91.		6.8L		
600	" -93.		6.8L		
601	" -95.		7.2L		
602	" -97.	↓	6.7L	↓	↓

* Specify: Solid sorbent tube, e.g. Charcoal; Filter type; Impinger solution; Bulk sample; Blood; Urine; Tissue; Soil; Water; Other

** 1. mg/sample 2. mg/m^3 3. ppm 4. % 5. ____ (other) Please indicate one or more units in the column entitled Units**

Comments _____

Possible Contamination and/or Chemical Hazards _____

7. **Chain of Custody (Optional)**

Relinquished by	[signature]	Date/Time	6/13/03 10:00
Received by	Rand Potter	Date/Time	6/14
Relinquished by	Rand Potter	Date/Time	6/16/03
Received by		Date/Time	
Relinquished by		Date/Time	
Received by		Date/Time	

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ANALYTICAL REPORT

Form ARF-AL
Page 1 of 3
Part 1 of 1
062303162530 74RX

Date JUN 2 4 2003
Laboratory Group Name 03I-1506-05
Account No. 07003

Booz Allen Hamilton
Attention: Steve Coffee
5299 DTC Blcd.
Suite 840
Greenwood Village, CO 80111

FAX (303) 694-7367
Telephone (303) 221-7559
E-mail coffee_stephen@bah.com

Sampling Collection and Shipment

Sampling Site AERC Ashland Trip#4 Date of Collection June 11, 2003

Date Samples Received at Laboratory June 16, 2003

Analysis

Method of Analysis NMAM 6009

Date(s) of Analysis June 20, 2003

Analytical Results

Field Sample Number	Laboratory Number	Sample Type	Mercury ug/Sample	Mercury mg/m³	Air Volume L					
3705AA612137	03I19626	TUBE	0.43	0.039	11.0					
3705AA612139	03I19627	TUBE	6.8	0.057	118.2					
3705AA612141	03I19628	TUBE	7.4	0.058	128.9					
3705AA612143	03I19629	TUBE	5.5	0.044	123.1					
3705AA612145	03I19630	TUBE	0.13	TBA	TBA					
3705AA612147	03I19631	TUBE	0.29	TBA	TBA					
3705AA612149	03I19632	TUBE	0.29	TBA	TBA					
3705AA612151	03I19633	TUBE	0.32	TBA	TBA					
3705AA612153	03I19634	TUBE	0.32	0.042	7.7					
3705AA612155	03I19635	TUBE	0.29	0.039	7.5					
3705AA612157	03I19637	TUBE	0.12	0.039	3.1					
3705AA612159	03I19638	TUBE	0.26	0.072	3.6					
3705AA612161	03I19639	TUBE	0.10	0.10	1.0					

† See comment on last page. ** See comment on last page.
ND Parameter not detected above LOD. ( ) Parameter between LOD and LOQ.
NR Parameter not requested. TBA Parameter to be analyzed.
NA Parameter not applicable.

Jose G. Rocha
Analyst: Jose G. Rocha

Reviewer: Neil A. Edwards

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ANALYTICAL REPORT

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062303162530 74RX

JUN 2 4 2003

Date _____

Laboratory Group Name 03I-1506-05

Analytical Results

Field Sample Number	Laboratory Number	Sample Type	Mercury ug/Sample	Mercury mg/m³	Air Volume L					
3705AA612163	03I19640	TUBE	0.21	0.21	1.0					
3705AA612165	03I19641	TUBE	0.54	0.17	3.1					
3705AA612167	03I19642	TUBE	0.31	0.094	3.3					
3705TA612167	03I19644	TUBE	0.45	0.050	9.0					
3705TA612169	03I19645	TUBE	0.13	0.014	9.0					
3705AA612145	03I20063	TUBE	0.33	TBA	TBA					
3705AA612147	03I20064	TUBE	0.075	TBA	TBA					
3705AA612149	03I20065	TUBE	0.13	TBA	TBA					
3705AA612151	03I20066	TUBE	0.14	TBA	TBA					
Reporting Limit			0.01							

† See comment on last page.
ND Parameter not detected above LOD.
NR Parameter not requested.
NA Parameter not applicable.

** See comment on last page.
( ) Parameter between LOD and LOQ.
TBA Parameter to be analyzed.

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A Sorenson Company

ANALYTICAL REPORT

Form ARF-C
Page 3 of 3
062303162530 74RX

JUN 2 4 2003

Date _____

Laboratory Group Name 03I-1506-05

General Set Comments

Method Reference: NIOSH Manual of Analytical Methods(NMAM), 4th ed., 08/15/94.
Results are not blank-corrected.
Results obtained for media blanks prepared from SKC Carulite tubes are typically found to have concentrations approximately 0.035-0.045 ug/Sample above the reporting limit.
Samples 03I19627, 28 and 29 required a 10X dilution.

General Lab Comments

The results provided in this report relate only to the items tested.
This page is the concluding page of the report.

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ANALYTICAL REQUEST FORM

DATA CHEM LABORATORIES, INC.

1. [X] REGULAR Status 03I-1506-05

[ ] RUSH Status Requested - ADDITIONAL CHARGE
RESULTS REQUIRED BY _____ DATE
CONTACT DATACHEM LABS PRIOR TO SENDING SAMPLES

2. Date 6/13 Purchase Order No. _____ 4. Quote No. _____

3. Company Name Booz Allen Hamilton DCL Project Manager Rand Potter

Address 5299 DTC Blvd., Suite 840 5. Sample Collection

Greenwood Village, CO 80111 Sampling Site AERC Ashland Trip #4

Person to Contact Steve Coffee Industrial Process DTC Device AIR CYCLE

Telephone (303) 221-7559 Date of Collection 6/12/03

Fax Telephone (303) 694-7367 Time Collected _____

E-mail Address coffee_stephen@bah.com Date of Shipment 6/13/03

Billing Address (if different from above) refer to contract Chain of Custody No. _____

6. REQUEST FOR ANALYSES

Laboratory Use Only	Client Sample Number	Matrix*	Sample Volume	ANALYSES REQUESTED - Use method number if known	Units**
~~03I-1962S-2~~	3705-A-A-6/12	MYORAL		NAM 6009	2
626	137.		11.0 l		
627	139.		118.2 l		
628	141.		128.9 l		
629	143.		123.1 l		
630	145.		~~7~~ l		
631	147.				
632	149.				
633	151.				
634	153.		7.7 l		
635	155.		7.5 l		

* Specify: Solid sorbent tube, e.g. Charcoal; Filter type; Impinger solution; Bulk sample; Blood; Urine; Tissue; Soil; Water; Other

** 1. mg/sample 2. mg/m^3 3. ppm 4. % 5. ____ (other) Please indicate one or more units in the column entitled Units**

Comments _____

Possible Contamination and/or Chemical Hazards _____

7. Chain of Custody (Optional)

Relinquished by	Steve D. Coffee	Date/Time	6/13/03 10:00
Received by	Rand Potter	Date/Time	6/14
Relinquished by	Rand Potter	Date/Time	6/16
Received by		Date/Time	
Relinquished by		Date/Time	
Received by		Date/Time	

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ANALYTICAL REQUEST FORM

DATA CHEM LABORATORIES, INC.

1. [X] REGULAR Status 03I-1506-05

[ ] RUSH Status Requested - ADDITIONAL CHARGE
RESULTS REQUIRED BY _____ DATE
CONTACT DATACHEM LABS PRIOR TO SENDING SAMPLES

2. Date 6/13 Purchase Order No. _____

3. Company Name Booz Allen Hamilton
Address 5299 DTC Blvd., Suite 840
Greenwood Village, CO 80111
Person to Contact Steve Coffee
Telephone (303) 221-7559
Fax Telephone (303) 694-7367
E-mail Address coffee_stephen@bah.com
Billing Address (if different from above) refer to contract

4. Quote No. _____
DCL Project Manager Rand Potter

5. Sample Collection
Sampling Site AERC Ashland Trip #4
Industrial Process DTC Device AIR CYCLE
Date of Collection 6/12/03
Time Collected _____
Date of Shipment 6/13/03
Chain of Custody No. _____

6. REQUEST FOR ANALYSES

Laboratory Use Only	Client Sample Number	Matrix*	Sample Volume	ANALYSES REQUESTED - Use method number if known	Units**
~~03I~~ 19636	3705-A-A-6/12	HYDRAZ		NAM 6009	2
19637	157.		3.1 l		
19638	159.		3.6 l		
19639	1601.		1.0 l		
19640	1603.		1.0 l		
19641	1605.		3.1 l		
19642	1607.		3.3 l		
19643	3705-T-A-6/12-				
19644	167.		9.0 l		
19645	169.		9.0 l		

* Specify: Solid sorbent tube, e.g. Charcoal; Filter type; Impinger solution; Bulk sample; Blood; Urine; Tissue; Soil; Water; Other

** 1. mg/sample 2. mg/m^3 3. ppm 4. % 5. _____ (other) Please indicate one or more units in the column entitled Units**

Comments _____

Possible Contamination and/or Chemical Hazards _____

7. Chain of Custody (Optional)

Relinquished by	Steve Coffee	Date/Time	6/13/03 10:00
Received by	R. Potter	Date/Time	6/14
Relinquished by	R. Potter	Date/Time	6/16/03
Received by		Date/Time	
Relinquished by		Date/Time	
Received by		Date/Time	

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DATACHEM LABORATORIES, INC.

Appendix D

Drum-Top Crushing Device
Sampling and Study Plan

Mercury Lamps Drum-Top Crushing (DTC) Device
Sampling and Study Plan

February 4, 2003
REPA3-0305-001v1

Objective

The basis of this study is to collect reliable measurements to document the potential release of mercury and human exposure to mercury during the processing of fluorescent lamps in a drum top crusher (DTC) device. Four manufacturers will provide DTC devices for evaluation and comparison. The data collected from the measurements will be used by EPA to assist in the development of a national policy for the use of DTC devices to process mercury containing fluorescent lamps. Part of the objectives are to be in compliance with and by the plans REPA Quality Management Plan (QMP), REPA Region 3 Quality Assurance Project Plan, and the Region 3 Health and Safety Program. For all sampling, analysis and handling procedures, where applicable, Booz Allen staff will follow REPA3 Standard Operating Procedures (SOPs).

Scope

Two different studies will be completed as part of the overall DTC device study. The detail methods for conducting each study are documented in this Sampling and Study Plan. The first study is the environmental validation study and is divided into two phases: Equipment comparison phase and mass balance phase. The second, real world study, is real world testing of the devices. A brief description of the tests for the DTC device study include:

Environmental Validation Study

- Equipment Comparison - Quantify mercury vapor emissions and measure personal mercury exposure during the operation of new devices provided by the manufacturer. Compare the emissions of mercury from the DTC devices, when new, to emissions after the DTC devices have filled a number of 55-gallon drums.
- Mass Balance - Conduct a mass balance study to quantify the mercury released during the processing of fluorescent lamps compared to the estimated quantity of mercury contained in the fluorescent lamps.

Real World Study

- Real World Testing - Conduct field sampling to quantify mercury vapor emissions and worker exposure during the operation of four different DTC devices at three locations in the continental United States.

Schedule

Four manufacturers will provide DTC devices for inclusion in this DTC device study. The following devices will be included in the study:

- Air Cycle Bulb Eater Model 55 VRS
- Resource Technology, Inc. (RTI) Model DTP
- The Hazardous Materials Specialist, Inc. (HMS) Fluorescent Lamp Disposal and Mercury Vapor Recovery System
- Dextrite Model ULC-55 FDA-E

Each manufacturer will provide one new DTC device for the DTC device study. Each of the four devices will be used for the validation testing and real world testing.

Biological monitoring will be incorporated into the study to further define potential mercury exposure. Each DTC device operator will participate in the biological monitoring process. Before the DTC device study begins, **the operators will provide urine samples to a medical clinic to establish background mercury levels**. The operators will submit urine samples at the conclusion of the study to determine whether there is a increase in mercury due to exposure while operating the DTC devices. Mercury levels will be examined and tested to ensure that they are not above acceptable bodily concentrations. All samples will be collected after operators have completed a 24 hour fasting.

Sample collection for the first stages of the equipment comparison phase and the mass balance study will be performed concurrently. The proposed site for these studies is the AERC facility in Ashland, Virginia. The expected time to complete the validation testing includes one day to set up and two days to complete the studies. **Once the results of the samples from these two phases are received and reviewed by Booz Allen, the proposed methods for sampling during the real world testing will be evaluated and modified as necessary by Booz Allen with assistance from the EPA WAM.** Once the methods for the real world testing are determined, Booz Allen and EPA (the team) will conduct tests starting at the Earth Protection Services Inspection (EPSI) facility in Arizona. Next, the team will travel to the Fluorocycle facility in Ingleside, IL. Finally, the team will conduct real world testing back at the AERC facility in Ashland. The real world testing at each location is expected to last the entire week. After completing the real world testing at the Ashland facility, the second stage of the equipment comparison phase will be conducted at this facility.

Sampling Strategy
ENVIRONMENTAL VALIDATION STUDY: Equipment Comparison

The purpose of the equipment comparison phase is to evaluate the potential release of mercury from new DTC devices compared to the same DTC devices after the devices have processed enough fluorescent lamps to have completed a number of drum and filter changes. The equipment comparison phase will be conducted in two stages. The first stage will be conducted before the real world sampling and the second stage will occur at the conclusion of the real world sampling. This will allow each device to have processed enough lamps to completely fill eight drums. Booz Allen will collect wipe samples from various surfaces and collect air samples to measure the concentration of mercury in the air. The first stage of the equipment comparison phase will be conducted concurrently with the mass balance study and some of the sample results will be incorporated into the mass balance equation.

All operations, for each of the devices, will be conducted as directed by the user manual and instructions. This includes the operation of the devices as well as scheduling filter changes and drum changes. Each DTC device will be operated for the time it takes to completely fill one 55-gallon drum. Filters and drums will be changed according to the manufacturer's recommendations. It is estimated that the typical device can fill the drum in 3.5 hours. Based on information provided by the manufacturers, a full drum may hold from 400 to 1,200 lamps depending on the device. Once the drum is full, the next device from another manufacturer will be tested in the same manner. During the operation of all DTC devices only 4-foot Alto T12 lamps by Philips Lighting will be processed. These lamps were chosen because T12 lamps are still the predominant lamps used today compared to the T8 lamps. The Philips Lighting Alto lamps were selected because the Alto lamps are more consistent in the quantity of mercury used in each lamp, although Alto lamps typically contain less mercury. EPA personnel and a Booz Allen Hamilton (Booz Allen) employee will operate and feed the lamps into the DTC devices.

EPA and Booz Allen personnel, with assistance from facility personnel, will build a containment constructed from a rigid tube frame and polyethylene (plastic) sheeting to isolate each DTC device during testing and assist in reducing potential interferences. The containment dimensions will be 12 feet by 12 feet in order to accommodate for the unique sizes of the different DTC devices. Each device will be operated in a containment with new plastic on the walls, floor, and ceiling. Therefore, once each drum has been filled and all samples have been collected, all the plastic sheets from the containment will be removed and new plastic sheets will be installed on the floor, walls, and ceiling before operating the next device. The old plastic will be decontaminated by washing with a water solution containing HGX compound. An appropriate portion of the plastic (determined by testing requirements), will then be tested and disposed of based on the results of the test by the team. **If the results indicate the plastic is contaminated with mercury that is above acceptable levels, the levels of mercury on the sheeting will be recorded and the plastic will be disposed of as mercury contaminated waste according to mercury disposal standards.**

Prior to the start of both the first and second stages of the equipment comparison phase, two background air samples will be collected by Booz Allen staff in the immediate location where the DTC

devices will be operated. Additionally, Booz Allen will use the Jerome Mercury Vapor Analyzer to collect direct measurements and data log the results. The Jerome Analyzer will be operated in accordance with Region 3 SOPs for calibration and measuring. Results of the air monitoring will identify background mercury concentrations that may need to be accounted for in the results and analysis of the study to be performed by Booz Allen.

During the operation of the DTC devices, air samples will be collected, by the team, in specified areas inside the containment and on the operator. All air sampling will be performed in accordance with acceptable industrial hygiene air monitoring procedures. Air samples will be collected in each containment in the following areas (see attached Table-1 for further detail). Booz Allen will perform all air monitoring according to Booz Allen SOPs:

- Two samples (one on each shoulder) will be collected on the operator for the entire duration of the device operation, including filter changes and the drum change.
- Two concurrent samples will be collected at each DTC device exhaust for the duration of the device operation. The results of this sampling during the first stage will be used in the mass balance study.
- Two concurrent samples will be collected at the DTC device feed tube for the duration of the device operation. The results of this sampling during the first stage will be used in the mass balance study.
- One sample will be collected on each operator during the change-out of the filters and drum. Particulate filter changes will occur based on manufacturer's recommendations. It is anticipated that the filter change and drum change will only take a few minutes to complete. In order to ensure a detection limit of less the 0.1 mg/m^3 the sample pumps will operate after the filter change and drum change is complete in order to achieve sufficient air **volume, as was determined by EPA and Booz Allen. The schedule for each device's** filter change and subsequent air sample is as follows:

    - HMS–every 300 lamps = three samples/drum
    - Air Cycle–every drum change = one sample/drum
    - RTI–No filter changes, system back purges the filter every 15 minutes
    - Dextrite–every 2400 lamps = approximately every third drum.

- Two field blanks will be prepared for each day of sampling.
- One set of three laboratory blanks will be prepared for each stage of the equipment comparison study.

Air samples will be collected to measure airborne mercury concentrations in the vapor phase and aerosol phase. Air samples to measure mercury in the aerosol phase will be collected and analyzed in accordance with the Occupational Safety and Health Administration (OSHA) analytical method ID-145. Air samples to measure mercury in the vapor phase will be collected and analyzed in accordance with the National Institute for Occupational Safety and Health (NIOSH) analytical method 6009. The samples will be collected on a 37-mm mixed cellulose ester filter to capture aerosols connected to a

Hopcalite sample media or an equivalent sample media to capture vapors. The sample pump for every air sample will be pre-calibrated and post-calibrated against a primary standard to adjust the air flow to the proper flow rate.

U.S. EPA Headquarters Library
Mail Code 3404T
1200 Pennsylvania Avenue, NW
Washington DC 20460
202-566-0556

Information to document each air sample will be recorded on air monitoring forms. The information required on each form includes:

- A sample number unique to that air sample
- Specific details of the sample location or name of the operator wearing the samples
- Pre-calibration and post-calibration results
- Time on and time off of the sample pump
- Volume of air collected–duration of the sampling multiplied by the air flow rate (average of the pre- and post-calibration)
- Number of fluorescent lamps processed during the sampling and categorized by wattage
- Other notable conditions that may effect the sample results.

In addition to air samples, the equipment comparison phase will also include wipe samples collected inside the containment on numerous surfaces. A set of wipe samples will be collected prior to the start of the DTC device operation and a set will be collected at the conclusion of the DTC device operation. A set of pre- and post-operation wipe samples will be collected for each of the manufacturer's devices. The wipe samples will be collected and analyzed in accordance with the NIOSH draft analytical method N9103 for wipe samples. Under this procedure, a 100 cm^2 wipe sample will be collected using a "Wash-n-Dry" towelette and placed into a vial provided by the laboratory. For each location two side-by-side wipe samples will be collected. The nine locations for the wipe samples inside each containment include:

- Floor–two feet from the device
- Floor–five feet from the device
- Floor–at the device exhaust
- Drum side
- DTC device
- Feed tube inlet exterior
- Ceiling
- Wall
- Wall

At the end of the each equipment comparison stage, the air samples and wipe samples will be collected, packaged, and submitted by the team to DataChem Laboratories, Inc. (DataChem) located in Salt Lake City, Utah, along with completed chain-of-custody forms. DataChem is an American Industrial Hygiene Association (AIHA) accredited laboratory. Samples will be placed in an oversized sturdy box with packing material to fill voids and protect the samples. The Booz Allen person shipping the samples will sign the chain-of-custody forms and will place the forms in the box with the samples. Samples will be submitted via Federal Express to the laboratory.

During the process of measuring mercury concentrations in the air using sampling pumps, two factory calibrated mercury vapor analyzers will be employed by the team to measure real-time mercury concentrations in the air. At least one of the mercury vapor analyzers will be equipped with a data logger to measure and record the mercury concentrations throughout the day. The analyzers, one stationary and one mobile, will be used to identify fluctuations in concentrations while the DTC devices operate and will also measure for leaks in the seals of the DTC devices.

At the conclusion of the device operations for the day, each DTC device will be placed on a drums containing crushed debris and be allowed to set for the night. Any operation of the devices will be performed in accordance with manufacturer instructions. Air samples will be collected next to the DTC device/drum assemblies during the night in between equipment comparison studies. The air samples will measure for any escaping mercury off-gassing that may occur when the devices are not in operation. Air sample pumps with in-line collection media will be set next to each device and the mercury vapor analyzer will log the concentrations throughout the night.

After completion of the first stage of the equipment comparison phase, the new devices will be shipped to the EPSI facility in Arizona. To prepare the devices for shipping the team, with assistance from facility personnel, will be wipe down each device, wrap each device in plastic, and place each device in the crates provided by the manufacturers. Plastic sheet roles and framing will not be shipped but will be purchased separately at each location. Upon receipt of the devices at each of the testing sites, the team will perform an inspection of the devices for damages that resulted from the transport.

In order to test the efficiency of the DTC devices and their performance in use with "U" shaped tubes, a study will take place at the completion of the validation phase. A defined number of lamps will be determined based on amount available at the AERC facility in Ashland, Virginia and used for testing in a final study and the required amount to gain an accurate sample collection. The "U" shaped lamps will be crushed using the devices provided by Air Cycle, Dextrite, and HMS. The RTI device is not equipped with an attachment for feeding "U" shaped tubes and therefore will not be included in this portion of the study. Air samples and wipe samples as described in Table-1 will be collected during the operation of the devices until tubes have been crushed.

ENVIRONMENTAL VALIDATION STUDY: Mass Balance Study

The mass balance study is intended to determine the capture efficiency of mercury vapors during the operation of the DTC devices. Only Alto T12 lamps will be used in the mass balance study. The study will take into account the different wattages of the T12 lamps (wattage 34/40 and 39/60). This study will incorporate the results of the air samples and wipe samples collected during the first stage of the equipment comparison phase. In addition, the team will collect bulk material samples and have them analyzed for mercury by DataChem. The bulk samples will be collected from the DTC devices after the devices have completely filled one drum during the equipment comparison phase prior to removing the device from the containment. The bulk samples will be collected and analyzed in accordance with EPA method SW-846 method 7471A and sampling directions provided by the analytical laboratory (DataChem).

The bulk samples to be collected from the each of the four DTC devices include:

- Three samples from the particulate pre-filters from the HMS device, Air Cycle device and Dextrite device. The RTI device is not equipped with a particulate pre-filter.
- Three samples from the HEPA filters from all four devices.
- Three samples from the carbon filters from all four devices.
- Three samples from the crushed material in the drums. This sample will include representative amounts of broken glass, metal end caps, and phosphor powder.

Before the DTC devices are operated, the filters and empty drums will be tared, to measure the weight of the filters and drum before crushing the lamps. After crushing enough lamps to fill a drum, the filters will be accessed with support from the device manufacturer's representatives and the bulk samples will be collected by cutting out portions of the particulate filters or removing the loose carbon from the top of the carbon filter container. The bulk material will be placed into collection vessels provided by the laboratory. Next, the devices will be removed from the drum, and bulk samples will be collected from the crushed debris below the top surface of debris. The debris samples will be placed in collection vessels provided by the laboratory.

In addition, five Alto T12 lamps (wattage 34/40 and 39/60) will be submitted to the analytical laboratory to confirm the quantity of mercury contained in the lamps. DataChem will crush the lamps in a similar manner as occurs in the devices to ensure that the measurement for mercury is accurate. These results will be used to confirm the amount of mercury reported by the manufacturer. These results will be used to calculate the quantity of mercury based on the number of lamps processed. The bulk samples and intact lamps will be submitted to DataChem for analysis along with completed chain-of-custody forms.

Booz Allen will select, based on accuracy determinations, wipe samples and air samples collected during the equipment comparisort phase on the DTC devices will be incorporated into the mass balance study. These select samples include:

- Wipe samples from the exterior drum surface
- Wipe samples from the DTC device
- Air samples collected at the DTC device exhaust
- Air samples collected at the DTC device feed tube.

Upon return of the laboratory results for mercury, the data will be plugged into the mass balance equation by Booz Allen to determine the mercury capture efficiency of the DTC devices. The mass balance equation is:

Total Hg = Hg retained in the DTC device + Hg released from the DTC device

Total Hg is the quantity of mercury calculated by the quantity of mercury contained in a fluorescent lamp multiplied by the number of lamps processed. Hg retained is determined by the results of the bulk samples collected from the crushed debris in the drum and the bulk filter samples. Hg released is determined by the results of the air samples and wipe samples. Using the equation, the percent recovery of mercury can be calculated. The mass balance study is contained in Attachment 1.

REAL WORLD STUDY: Real World Testing

The real world testing phase will determine the release of mercury vapors and human exposure to mercury vapors during the normal operation of the DTC devices. The same DTC devices used in the equipment comparison phase will be evaluated in a real world industrial setting. The DTC devices will process a variety of four foot T12 lamps for an entire work shift. For this study, a work shift will include the time needed to completely fill two 55-gallon drums. The real world testing will be repeated at three separate locations. The DTC devices will be operated inside a containment equivalent to the containment used in the equipment comparison phase. Each device will be operated in a containment with new plastic on the walls, floor, and ceiling. Therefore, once the work shift has been completed and all samples have been collected, all the plastic sheets from the containment will be removed and new plastic sheets will be installed on the floor, walls, and ceiling before operating the next device. The old plastic will be decontaminated by washing with a water solution containing HGX compound. An appropriate portion of the plastic (determined by testing requirements), will then be tested and disposed of based on the results of the test by the team. **If the results indicate the plastic is contaminated with mercury that is above acceptable levels, the levels of mercury on the sheeting will be recorded and the plastic will be disposed of as mercury contaminated waste according to mercury disposal standards.**

Air samples will be collected over the entire work shift (two drum changes). The operation of the DTC device over the work shift will be performed by EPA and Booz Allen staff. The first person will operate the DTC device until the first drum is filled, including the filter changes and drum change. The second person will operate the DTC device until the second drum is filled, including the filter changes and changing the drum at the end of the day.

During the operation of the DTC devices, air samples will be collected in specified areas inside the containment and on the operator by the team. All air sampling will be performed in accordance with acceptable industrial hygiene air monitoring procedures as well as the Region 3 SOPs. Air samples will be collected in each containment in the following areas (see Attached Table-1 for more detail):

- Two samples (one on each shoulder) will be collected by the operator while they operate the device and completely fill the drum, including filter changes and the drum change.
- Two samples will be collected inside the containment at locations that will be determined based on the results from the equipment comparison phase.

- One sample will be collected on each operator during the change-out of the filters and drum. Particulate filter changes will occur based on manufacturer's recommendations. It is anticipated that the filter change and drum change will only take a few minutes to complete. In order to ensure a detection limit of less the 0.1 mg/m^3 the sample pumps will operate after the filter change and drum change is complete in order to achieve sufficient air volume. The schedule for each device's filter change and subsequent air sample is as follows:

    - HMS - every 300 lamps = eight samples
    - Air Cycle - every drum change = two samples
    - RTI - no filter changes, system back-purges the filter every 15 minutes
    - Dextrite - every 2400 samples = one sample

- Two field blanks will be prepared for each day of sampling.
- One set of three laboratory blanks will be prepared for each location.

Air samples will be collected to measure airborne mercury concentrations in the vapor phase and aerosol phase. Air samples to measure mercury in the aerosol phase will be collected and analyzed in accordance with the OSHA analytical method ID-145. Air samples to measure mercury in the vapor phase will be collected and analyzed in accordance with the NIOSH analytical method 6009. The samples will be collected on a 37-mm mixed cellulose ester filter to capture aerosols connected to a Hopcalite sample media or an equivalent sample media to capture vapors. The sample pump for every air sample will be pre-calibrated and post-calibrated against a primary standard to adjust the air flow to the proper flow rate.

Information to document each air sample will be recorded on air monitoring forms by Booz Allen. The information required on each form includes:

- A sample number unique to that air sample
- Specific details of the sample location or name of the operator wearing the samples
- Pre-calibration and post-calibration results
- Time on and time off of the sample pump
- Volume of air collected–duration of the sampling multiplied by the air flow rate (average of the pre- and post-calibration)
- Number of fluorescent lamps processed during the sampling and categorized by type of lamp and wattage
- Other notable conditions that may effect the sample results.

In addition to air samples, the equipment comparison phase will also include wipe samples, collected by Booz Allen, inside the containment on numerous surfaces. A set of wipe samples will be collected prior to the start of the DTC device operation and a set will be collected at the conclusion of the DTC device operation. A set of pre- and post-operation wipe samples will be collected for each of the manufacturer's devices. The wipe samples will be collected by Booz Allen and analyzed by DataChem in accordance with the NIOSH draft analytical method N9103 for wipe samples. Under this

procedure, a 100 cm^2 wipe sample will be collected using a "Wash-n-Dry" towelette and placed into a vial provided by the laboratory. For each location two side-by-side wipe samples will be collected. The nine locations for the wipe samples inside each containment include:

- Floor–two feet from the device
- Floor–five feet from the device
- Floor–at the device exhaust
- Drum side
- DTC device
- Feed tube inlet exterior
- Ceiling
- Wall
- Wall

At the end of the each real world testing location, the air samples and wipe samples will be collected, packaged, and submitted by the team to DataChem located in Salt Lake City, Utah, along with completed chain-of-custody forms. DataChem is an AIHA accredited laboratory. Samples will be placed in an oversized sturdy box with packing material to fill voids and protect the samples. The chain-of-custody forms will be signed by the Booz Allen person shipping the samples and the form placed in the box with the samples. Samples will be submitted via Federal Express to the laboratory.

During the process of measuring mercury concentrations in the air using sampling pumps, two factory calibrated mercury vapor analyzer will be employed to measure real-time mercury concentrations in the air. At least one of the mercury vapor analyzers will be equipped with a data logger to measure and record the mercury concentrations throughout the day. The analyzers, one stationary and one mobile, will be used to identify fluctuations in concentrations while the DTC devices operate and will also measure for leaks in the seals of the DTC devices.

After completion of real world testing at each location, the DTC devices will be shipped to the next location by the team with assistance from facility personnel. The device surfaces will be wiped clean using a water solution containing the HGX compound. The cleaned devices will be capped or plugged at the feed tube intake and at the exhaust wrapped in plastic. The devices will then be placed in the crates or packaging provided by the manufacturers and prepared for transportation.

ATTACHMENT 1

Lamp Crusher Hg Mass Release/Mass Balance Study

Total Hg = Hg retained in crusher unit + Hg released from unit

Where:

Hg_T = Total Hg
Hg_U = Hg retained in crusher unit
Hg_R = Hg released from unit

1. Hg_T = Total Hg

   = Total # lamps crushed X Hg/lamp

   Hg/lamp based on: 1) manufacturer's claims/estimates; and/or
   2) testing of 5 lamps for total Hg

2. Hg_U = Hg retained in crusher unit

   = Hg in crushed lamps + Hg retained in HEPA filter + Hg retained in carbon filter + Hg residual on interior surface of crusher

3. Hg_R = Hg released from unit

   Hg_R = Hg released at exhaust port + Hg fugitive release

   $Hg_{(EP)}$ = Hg exhaust conc X air flow rate X air flow duration

   $Hg_{(F)}$ = (Hg conc. at fugitive release sites X est. air leakage rate) + (drum change air conc X est. air release at drum change)

   And/Or,

   $Hg_{(R)}$ = (chamber ambient air Hg conc X chamber volume) + (wipe sample Hg conc (in mass/SA) X surface area of chamber)

Field Monitoring, Sampling, and Analytical Methods

Sample Type	Location	Frequency	Number of samples				Limit of Detection	Analytical Method
			Vapor	Aerosol	Per Unit	Total		
Equipment Comparison Phase 1 (consists of comparing four new units made by HMS, Air Cycle, RTI, and Dextrite) **3 DAYS**								
Wipe samples (2 samples each)[1]	Floor – 2 feet from device	Pre & post samples	N/A	N/A	4	16	0.01 ug/sample	NIOSH N9103
	Floor – 5 feet from device	Pre & post samples	N/A	N/A	4	16	0.01 ug/sample	NIOSH N9103
	Floor – at device exhaust	Pre & post samples	N/A	N/A	4	16	0.01 ug/sample	NIOSH N9103
	Ceiling	Pre & post samples	N/A	N/A	4	16	0.01 ug/sample	NIOSH N9103
	Wall	Pre & post samples	N/A	N/A	4	16	0.01 ug/sample	NIOSH N9103
	Wall -	Pre & post samples	N/A	N/A	4	16	0.01 ug/sample	NIOSH N9103
	Exterior drum surface - side	Pre & post samples	N/A	N/A	4	16	0.01 ug/sample	NIOSH N9103
	DTC device	Pre & post samples	N/A	N/A	4	16	0.01 ug/sample	NIOSH N9103
	DTC device feed tube Inlet Exterior	Pre & post samples	N/A	N/A	4	16	0.01 ug/sample	NIOSH N9103
	Lab Blanks	Prior to each equipment run	N/A	N/A	2	6	0.01 ug/sample	NIOSH N9103
	Wipe sample subtotal					**150**		
Air samples	Both shoulders of operator[2]	During test run including drum and filter changes (all four units)	2	2	4	16	0.01 ug/sample	NIOSH 6009; OSHA ID-145
	DTC Exhaust[2]	During test run including drum and filter changes	2	2	4	16	0.01 ug/sample	NIOSH 6009; OSHA ID-145
	DTC Feed Tube[2]	During test run including drum and filter changes	2	2	4	16	0.01 ug/sample	NIOSH 6009; OSHA ID-145
	On operator[4]	During drum and filter change	1	1	2	8	0.01 ug/sample	NIOSH 6009; OSHA ID-145
	On operator[3]	During additional filter changes for HMS = every 300 lamps crushed	3	3	6	6	0.01 ug/sample	NIOSH 6009; OSHA ID-145
	Laboratory Blank	Prior to study	3	3	N/A	6	0.01 ug/sample	NIOSH 6009; OSHA ID-145

	Field Blanks	Prior to study	2	2	N/A	12	0.01 ug/sample	NIOSH 6009; OSHA ID-145
	Background	On each sampling day	2	2	N/A	4	0.01 ug/sample	NIOSH 6009; OSHA ID-145
	Air sample subtotal					**84**		
Bulk samples	Pre-filter for particulates	Air Cycle = every drum change	N/A	N/A	3	3	0.01 ug/in^2	EPA Method 7471A
		Dextrite = every 2,400 lamps crushed	N/A	N/A	3	3		
		HMS = every 300 lamps crushed	N/A	N/A	3	3		
		RTI = no filter change; filter back-purged every 15 minute	N/A	N/A	N/A	N/A		
	HEPA filter	For this demonstration, change filter when drum changed for HMS, Air Cycle, & Dextrite units	N/A	N/A	3	12	0.01 ug/in^2	EPA 7471A
	Carbon filter	For this demonstration, change filter when drum is changed for all units	N/A	N/A	3	12	0.02 ug/g	EPA 7471A
	Drum contents (crushed material)	When drum is full for each unit	N/A	N/A	3	12	0.02 ug/g	EPA 7471A
	Bulk sample subtotal					**45**		
~~**Air Samples**~~	~~DTC Exhaust and Feed Tube~~	Use results from Equipment Comparison Phase 1	N/A	N/A	N/A	N/A		
~~**Wipe Samples**~~	~~Drum side and DTC Device~~	Use results from Equipment Comparison Phase 1	N/A	N/A	N/A	N/A		
Alto lamps	Alto T12 (34/40)	N/A	N/A	N/A	3	3	0.1 ug/Lamp	EPA 7470
	Alto T12 (39/60)	N/A	N/A	N/A	3	3	0.1 ug/Lamp	EPA 7470
	Alto lamp subtotal					**6**		
Air samples	Both shoulders of operator[6] (2 operators per unit)	During test run including drum and filter changes (All 4 units)	4	4	8	96	0.01 ug/sample	NIOSH 6009; OSHA ID-145
	Inside the containment[7]	During test run including drum and filter changes (All 4 units)	2	2	4	48	0.01 ug/sample	NIOSH 6009 ; OSHA ID-145
	Inside the containment[7]	Overnight next to DTC unit (ONE LOCATION)	2	2	4	16	0.01 ug'sample	NIOSH 6009; OSHA ID-145
	On operator[9]	During drum and filter change (2 events per unit): HMS, Air Cycle, RTI, Dextrite	2	2	4	48	0.01 ug/sample	NIOSH 6009; OSHA ID-145
	On operator[8]	During additional filter changes for HMS = every 300 lamps crushed	6	6	12	36	0.01 ug/sample	NIOSH 6009; OSHA ID-145

	Laboratory Blank	Prior to study	3	3	6	18	0.01 ug/sample	NIOSH 6009; OSHA ID-145
	Background	Prior to start of study at each facility	2	2	N/A	12	0.01 ug/sample	NIOSH 6009; OSHA ID-145
	Field Blanks[11]	At the start of each test day at each facility	2	2	N/A	48	0.01 ug/sample	NIOSH 6009; OSHA ID-145
	Air sample subtotal					**322**		
Wipe samples (2 samples each)[12]	Floor – 2 feet from device	Pre & post samples	N/A	N/A	4	48	0.01 ug/sample	NIOSH N9103
	Floor – 5 feet from device	Pre & post samples	N/A	N/A	4	48	0.01 ug/sample	NIOSH N9103
	Floor – at device exhaust	Pre & post samples	N/A	N/A	4	48	0.01 ug/sample	NIOSH N9103
	Ceiling	Pre & post samples	N/A	N/A	4	48	0.01 ug/sample	NIOSH N9103
	Wall	Pre & post samples	N/A	N/A	4	48	0.01 ug/sample	NIOSH N9103
	Wall	Pre & post samples	N/A	N/A	4	48	0.01 ug/sample	NIOSH N9103
	Exterior drum surface - side	Pre & post samples	N/A	N/A	4	48	0.01 ug/sample	NIOSH N9103
	DTC device	Pre & post samples	N/A	N/A	4	48	0.01 ug/sample	NIOSH N9103
	DTC device feed tube Inlet Exterior	Pre & post samples	N/A	N/A	4	48	0.01 ug/sample	NIOSH N9103
	Field Blanks	Start of each day	N/A	N/A	2	24	0.01 ug/sample	NIOSH N9103
	Wipe sample subtotal					**456**		
Air samples At end of Phase II	Both shoulders of operator	TBD	2	2	4	12	0.01 ug/sample	NIOSH 6009; OSHA ID-145
	Inside the containment	TBD	2	2	4	12	0.01 ug/sample	NIOSH 6009; OSHA ID-145
	On operator[13]	During drum and filter change (1 event per unit): HMS, Air Cycle, Dextrite	1	1	2	6	0.01 ug/sample	NIOSH 6009; OSHA ID-145
	On operator[3]	During additional filter changes: HMS = every 300 lamps crushed	3	3	6	6	0.01 ug/sample	NIOSH 6009; OSHA ID-145
	Field Blanks[5]	At the start of each day	2	2	N/A	8	0.01 ug/sample	NIOSH 6009; OSHA ID-145
	Air sample subtotal					**44**		

Wipe samples (2 samples each)[14]	Floor – 2 feet from device	Pre & post samples	N/A	N/A	4	12	0.01 ug/sample	NIOSH N9103
	Floor – 5 feet from device	Pre & post samples	N/A	N/A	4	12	0.01 ug/sample	NIOSH N9103
	Floor – at device exhaust	Pre & post samples	N/A	N/A	4	12	0.01 ug/sample	NIOSH N9103
	Ceiling	Pre & post samples	N/A	N/A	4	12	0.01 ug/sample	NIOSH N9103
	Wall	Pre & post samples	N/A	N/A	4	12	0.01 ug/sample	NIOSH N9103
	Wall	Pre & post samples	N/A	N/A	4	12	0.01 ug/sample	NIOSH N9103
	Exterior drum surface - side	Pre & post samples	N/A	N/A	4	12	0.01 ug/sample	NIOSH N9103
	DTC device	Pre & post samples	N/A	N/A	4	12	0.01 ug/sample	NIOSH N9103
	DTC device feed tube Inlet Exterior	Pre & post samples	N/A	N/A	4	12	0.01 ug/sample	NIOSH N9103
	Field Blanks	Prior to each equipment run	N/A	N/A	2	4	0.01 ug/sample	NIOSH N9103
	Wipe sample subtotal					**112**		
Wipe samples (2 samples each)	Floor – 2 feet from device	Pre & post samples	N/A	N/A	4	16	0.01 ug/sample	NIOSH N9103
	Floor – 5 feet from device	Pre & post samples	N/A	N/A	4	16	0.01 ug/sample	NIOSH N9103
	Floor – at device exhaust	Pre & post samples	N/A	N/A	4	16	0.01 ug/sample	NIOSH N9103
	Ceiling	Pre & post samples	N/A	N/A	4	16	0.01 ug/sample	NIOSH N9103
	Wall	Pre & post samples	N/A	N/A	4	16	0.01 ug/sample	NIOSH N9103
	Wall	Pre & post samples	N/A	N/A	4	16	0.01 ug/sample	NIOSH N9103
	Exterior drum surface - side	Pre & post samples	N/A	N/A	4	16	0.01 ug/sample	NIOSH N9103
	DTC device	Pre & post samples	N/A	N/A	4	16	0.01 ug/sample	NIOSH N9103
	DTC device feed tube Inlet Exterior	Pre & post samples	N/A	N/A	4	16	0.01 ug/sample	NIOSH N9103
	Field Blanks	Prior to each equipment run	N/A	N/A	2	4	0.01 ug/sample	NIOSH N9103
	Wipe sample subtotal					**148**		

Air samples	Both shoulders of operator	During test run including drum and filter changes (all four units)	2	2	4	16	0.01 ug/sample	NIOSH 6009; OSHA ID-145
	DTC Exhaust	During test run including drum and filter changes	2	2	4	16	0.01 ug/sample	NIOSH 6009; OSHA ID-145
	DTC Feed Tube	During test run including drum and filter changes	2	2	4	16	0.01 ug/sample	NIOSH 6009; OSHA ID-145
	On operator	During filter changes: HMS = every 300 lamps crushed	3	3	6	6	0.01 ug/sample	NIOSH 6009; OSHA ID-145
	On operator	During drum and filter change	1	1	2	8	0.01 ug/sample	NIOSH 6009; OSHA ID-145
	Laboratory Blank	Prior to study	3	3	6	6	0.01 ug/sample	NIOSH 6009; OSHA ID-145
	Field Blanks Background	Prior to study	2	2	4	4	0.01 ug/sample	NIOSH 6009; OSHA ID-145
	Field Blanks	On each sampling day	2	2	4	8	0.01 ug/sample	NIOSH 6009; OSHA ID-145
	Air sample subtotal		17	17	34	**80**		

[1]Number of wipe samples = number of samples per location (2) x number of sampling events (2) x number of devices tested (4) = 2 x 2 x 4 = 16 samples

[2]Number of air samples calculated using the following formula and assumptions:

Assumptions: Two air samples (a vapor and aerosol sample) are collected at each shoulder. Therefore, 4 air samples (2 vapor and 2 aerosol) will be collected for each unit tested.

Number of samples to be collected = number of samples per unit (4) x number of units to be tested (4) = 4 x 4 = 16 samples

[3]Based on manufacturer's specs, the particulate filter is changed every 300 lamps. Assumed the HMS DTC drum could hold 1200 crushed lamps so the unit would require 4 filter changes. Assumed one filter change will coincide with the drum change. Sampling plan text (page 4) indicates one sample will be collected during filter change out.

Number of air samples collected = number of samples per event (2 = one aerosol and one vapor) x number of filter changes (3) x number of units tested (1 – HMS unit) = 3 x 2 x 1 = 6 samples

[4]Assumed one drum and filter change per unit.

Number of samples collected = number of samples per event (2 = one vapor and one aerosol) x number of drum changes per unit (1) x number of units tested (4) = 2 x 1 x 4 = 8 samples

[5]Used assumption on page 2 of the sampling plan that the test would take 2 days. Assumed two sets of field blanks are collected per day as listed on page 4 of sampling plan. One set of field blanks consists of a vapor and an aerosol blank.

Number of samples collected = number of samples per day (4 = 2 vapor and 2 aerosol) x number of test days (2) = 4 x 2 = 8 samples

[6]Number of air samples calculated using the following formula and assumptions:

Assumptions: Two air samples (a vapor and aerosol sample) are collected at each shoulder. 2 operators crushing lamps on each unit. Therefore, 8 air samples (4 vapor and 4 aerosol) will be collected for each unit tested.

Number of samples to be collected = number of samples per unit (8) x number of units to be tested (4) x number of test facilities (3) = 8 x 4 x 3 = 96 samples

[7]Number of samples = number of samples per unit (4 = two vapor and two aerosol) x number of units tested (4) x number of test facilities(3) = 4 x 4 x 3 = 48 samples

[8]Based on manufacturer's specs, the particulate filter is changed every 300 lamps. Assumed the HMS DTC drum could hold 2400 crushed lamps so the unit would require 8 filter changes. Assumed two filter changes will coincide with two drum changes. Sampling plan text (page 4) indicates one sample will be collected during filter change out.

Number of air samples collected = number of samples per event (2 = one aerosol and one vapor) x number of filter changes (6) x number of units tested (1 – HMS unit) x number of test facilities = 3 x 6 x 1 x 3 = 36 samples

[9]Assumed two drum and filter changes per unit.

Number of samples = number of samples per unit (2 = one vapor and one aerosol) x number of drum changes per unit (2) x number of units tested (4) x number of test facilities (3) = 2 x 2 x 4 x 3 = 48 samples

[10]Assumed a field blank sample would be collected at each test facility prior to the start of the real world testing. Assumed two sets of field blanks are collected per day as listed on page 4 of sampling plan. One set of field blanks consists of a vapor and an aerosol blank.

Number of samples collected = number of samples per day (4 = 2 vapor and 2 aerosol) x number of test facilities (3) = 4 x 3 = 12 samples

[11]Used assumption on page 2 of the sampling plan that the test would take one week and that field blanks would be needed for four days. Assumed two sets of field blanks are collected per day as listed on page 4 of sampling plan. One set of field blanks consists of a vapor and an aerosol blank.

Number of samples collected = number of samples per day (4 = 2 vapor and 2 aerosol) x number of test days (4) x number of test facilities (3) = 4 x 4 x 3 = 48 samples

[12]Number of wipe samples = number of samples per location (2) x number of sampling events (2) x number of devices tested (4) x number of test facilities (3) = 2 x 2 x 4 x 3 = 48 samples

[13]Assumed one drum and filter changes per unit.

Number of samples = number of samples per unit (2 = one vapor and one aerosol) x number of drum changes per unit (1) x number of units tested (3) = 2 x1 x 3 = 6 samples

[14]Number of wipe samples = number of samples per location (2) x number of sampling events (2) x number of devices tested (3) = 2 x 2 x 3 = 12 samples

[15]The same assumptions used under Equipment Comparison Phase 1 are used to calculate the number of samples for Phase 2.

Summary of Samples:

Project Phase	# of Wipe Samples	# of Air Samples	# of Bulk Samples	# of Alto Lamps
Equipment Comparison Phase 1	150	84		
Mass Balance Study			45	6
Real World Testing	456	322		
U-Shaped Tube Testing	112	44		
Equipment Comparison Phase 2	148	80		
Total	**866**	**530**	**45**	**6**

Total All Samples: 1,447

Mercury Lamps DTC Device Sampling and Study Plan

Table 1 - Sampling Table

				Four Devices						
Sample Number	Location	Duration/Time of Sample	General	Air Cycle Bulb Eater	Resource Technology, Inc. (RTI) Model DTP	The Hazardous Materials Specialist Inc. (HMS) VRS	Dextrite	Aerosol Sample	Vapor Sample	Total Samples (By Line Item)
Equipment Comparison										
Air Samples	One on each shoulder of operator	Entire study including Drum and Filter Changes		2	2	2	2	8	8	24
	DTC Device Exhaust	Entire study including Drum and Filter Changes		2	2	2	2	8	8	24
	DTC Device Feed Tube	Entire study including Drum and Filter Changes		2	2	2	2	8	8	24
	On Operator	During Drum and Filter Change		1	1	1	1	4	4	12
	Field Blanks	Prior to Study	2					2	2	6
	Laboratory Blanks	Prior to Study	3					3	3	9
Wipe Samples (2 Each)	Floor - 2 feet from Device	Pre and Post Operation		4	4	4	4			16
	Floor - 5 Feet from Device	Pre and Post Operation		4	4	4	4			16
	Floor - at the device Exhaust	Pre and Post Operation		4	4	4	4			16
	Drum Side	Pre and Post Operation		4	4	4	4			16
	DTC Device	Pre and Post Operation		4	4	4	4			16
	Feed Tube Inlet Exterior	Pre and Post Operation		4	4	4	4			16
	Ceiling	Pre and Post Operation		4	4	4	4			16
	Wall	Pre and Post Operation		4	4	4	4			16
	Wall	Pre and Post Operation		4	4	4	4			16
Mass Balance Study										
Bulk Samples	Particulate Pre Filters	Per Device Instructoins		3	3	3	0			9
	HEPA Filters	Per Device Instructoins		3	3	3	3			12
	Carbon Filters	Per Device Instructoins		3	3	3	3			12
	Crushed Materials from Drums (Includes broken glass, metal end caps, and phosphor powder)	Upon completion of filling drum		3	3	3	3			12
Alto Lamps tested	Alto T12	N/A	5							5
Air Samples	DTC Device Exhaust	Entire study including Drum and Filter Changes		2	2	2	2	8	8	24
	DTC Device Feed Tube	Entire study including Drum and Filter Changes		2	2	2	2	8	8	24
Wipe Samples (2 Each)	Drum Side	Pre and Post Operation		4	4	4	4			16
	DTC Device	Pre and Post Operation		4	4	4	4			16
Real World Testing	(To be performed at 3 Locations)									
Air Samples	One on each shoulder of operator	Entire Work Shift (2 Drum Changes)		6	6	6	6	24	24	72
	Inside the containment	Entire Work Shift (2 Drum Changes)		6	6	6	6	24	24	72
	On Operator.	During Drum and Filter Change		3	3	3	3	12	12	36
	Field Blanks	Prior to Study	2					2	2	6
	Laboratory Blanks	Prior to Study	3					3	3	9
Wipe Samples (2 Each)	Floor - 2 feet from Device	Pre and Post Operation		12	12	12	12			48
	Floor - 5 Feet from Device	Pre and Post Operation		12	12	12	12			48
	Floor - at the device Exhaust	Pre and Post Operation		12	12	12	12			48
	Drum Side	Pre and Post Operation		12	12	12	12			48
	DTC Device	Pre and Post Operation		12	12	12	12			48
	Feed Tube Inlet Exterior	Pre and Post Operation		12	12	12	12			48
	Ceiling	Pre and Post Operation		12	12	12	12			48
	Wall	Pre and Post Operation		12	12	12	12			48
	Wall	Pre and Post Operation		12	12	12	12			48

Mercury Lamps DTC Device Sampling and Study Plan
Table 1 - Sampling Table

				Four Devices						
Sample Number	Location	Duration/Time of Sample	General	Air Cycle Bulb Eater	Resource Technology, Inc. (RTI) Model DTP	The Hazardous Materials Specialist Inc. (HMS) VRS	Dextrite	Aerosol Sample	Vapor Sample	Total Samples (By Line Item)
U-Shaped Tube Testing	(To be performed at 1 Location)									
Air Samples	One on each shoulder of operator	TBD		2	N/A	2	2	6	6	18
	Inside the containment	TBD		2	N/A	2	2	6	6	18
	On Operator	During Drum and Filter Change		1	N/A	1	1	3	3	9
	Field Blanks	*Prior to Study*	2					2	2	6
	Laboratory Blanks	Prior to Study	3					3	3	9
Wipe Samples (2 Each)	Floor - 2 feet from Device	Pre and Post Operation		4	N/A	4	4			12
	Floor - 5 Feet from Device	Pre and Post Operation		4	N/A	4	4			12
	Floor - at the device Exhaust	Pre and Post Operation		4	N/A	4	4			12
	Drum Side	Pre and Post Operation		4	N/A	4	4			12
	DTC Device	Pre and Post Operation		4	N/A	4	4			12
	Feed Tube Inlet Exterior	Pre and Post Operation		4	N/A	4	4			12
	Ceiling	Pre and Post Operation		4	N/A	4	4			12
	Wall	Pre and Post Operation		4	N/A	4	4			12
	Wall	Pre and Post Operation		4	N/A	4	4			12
TOTAL SAMPLES			20	231	190	231	228	134	134	1168

Appendix E

Laboratory Methods and Modifications

NIOSH Draft Method 9103 – Modified: Analysis of MCE Filter

1. Transferred each filter sample to pre-cleaned individual 250-mL HDPE bottles.
2. Added 10 mL of concentrated nitric acid to each sample and gently swirled until the filter was completely saturated.
3. Placed caps loosely on the bottles and then set samples in a water bath maintained at 90 to 92 °C. After 2 minutes in the water bath, removed samples and cooled bottles to room temperature.
4. Added 50 mL of ASTM Type II water to each sample and gently swirled to mix thoroughly.
5. Added 25 mL of 5% potassium permanganate to each sample and gently swirled to mix thoroughly.
6. Added 8 mL of 5% potassium persulfate to each sample and gently swirled to mix thoroughly.
7. Placed caps loosely on the bottles and then set samples in a water bath maintained at 90 to 92 °C. After 30 minutes in the water bath, removed samples and cooled bottles to room temperature.
8. Immediately prior to analysis, added 7 mL of 20% hydroxylamine hydrochloride to each sample, replaced and tightened caps, and shook the bottles to mix samples thoroughly. Allowed bottles to cool to room temperature and proceeded to analysis.

- All standards were prepared the same manner as the sample except no filter media was present.
- One set of QC samples (QB, LCS, and LCSD) were prepared using MOE filter at the rate of 1 set per 20 field samples. (LCS & LCSD samples were prepared using 0.5 mL of 1.0 µg/mL Hg standard, yielding a spike target at 0.5 µg/sample.)

NIOSH Method 6009 - Modified: Analysis of Carulite (Hydrar) Tube

1. Carefully broke the edge of the sampling tube adjacent to sorbent material, and carefully transferred only the sorbent material of each sample to pre-cleaned individual 50-mL volumetric flasks.
2. Added 2.5 mL of concentrated nitric acid to each sample and gently swirled until the sample was completely saturated.
3. Added 2.5 mL of concentrated hydrochloric acid to each sample and gently swirled until the sample became dark. Placed the sample in a hood at least for 1 hour and swirled occasionally.
4. Diluted each sample to 50 mL volume with ASTM Type II water and shook the flasks to mix thoroughly.
5. Allowed samples to settle and proceeded to analysis.

- All standards were prepared the same manner as the sample except no sorbent media was present and no 1 hour waiting time was needed.
- One set of QC samples (QB, LCS, and LCSD) was prepared using SKC Carulite (Hydrar) tubes at the rate of one set per 20 field samples. (LCS and LCSD samples were spiked using 0.5 mL of 1.0 μg/mL Hg standard, yielding spike targets at 0.5 μg/sample.)

NIOSH Draft Method 9103: Analysis of Wash'n Dri Wipe

1. Transferred each wipe sample to pre-cleaned individual 250-mL HDPE bottles.
2. Added 5 mL of concentrated nitric acid to each sample and gently swirled until the wipe was completely saturated.
3. Added 5 mL of concentrated sulfuric acid to each sample and gently swirled until the wipe was dissolved. Placed samples in a hood until all acid fumes were evolved and no further reaction was observed.
4. Added 50 mL of ASTM Type II water to each sample and gently swirled to mix thoroughly.
5. Added 10 mL of 10% potassium permanganate to each sample and gently swirled until purple color disappeared. Added another 10 mL of 10% potassium permanganate to each sample, gently swirling until the reaction subsided. Added an additional 30 mL of 10% potassium permanganate to each sample and gently swirled to mix thoroughly.
6. Added 8 mL of 5% potassium persulfate to each sample and gently swirled to mix thoroughly.
7. Placed caps loosely on the bottles and then set samples in a water bath maintained at 90 to 92 °C. After 30 minutes in the water bath, removed samples and cooled bottles to room temperature.
8. Immediately prior to analysis, added 7 mL of 20% hydroxylamine hydrochloride to each sample, replaced and tightened caps, and shook the bottles to mix samples thoroughly. Allowed bottles to cool to room temperature and proceeded to analysis.

- All standards were prepared the same manner as the sample except no wipe media was presented.
- One set of QC samples (QB = quality control blank = media blank, spiked LCS = laboratory control sample, and LCSD = duplicate spiked laboratory control sample) was prepared using Wash'n Dri wipes at the rate of one set per 20 field samples. (LCS and LCSD samples were spiked using 0.5 mL of 1 .0 μg/mL Hg standard, yielding a spike target at 0.5 μg/sample.)

EPA Method 7470 - Modified/Phillips Lab Procedure - Modified: Analysis of Unbroken, Spent Lamp

1. Each entire lamp was cooled with dry ice for 1 hour and one end of the lamp was carefully broken.
2. Inner contents of the lamp was washed out with 200 mL of concentrated nitric acid and mixed well.
3. 1 mL of the acid leached sample was transferred to pre-cleaned 250-mL HDPE bottles.
4. Added 99 mL of ASTM Type II water, 5 mL of concentrated sulfuric acid, 2.5 mL of nitric acid, 15 mL of 5% potassium permanganate, and 8 mL of potassium persulfate, then mixed well.
6. Placed caps loosely on the bottles and then set samples in a water bath maintained at 90 to 92 °C. After 2 hours in the water bath, removed samples and cooled bottles to room temperature.
7. Immediately prior to analysis, added 5 mL of 20% hydroxylamine hydrochloride to each sample, replaced and tightened caps, and shook the bottles to mix samples thoroughly. Allowed bottles to cool to room temperature and proceeded to analysis.

- All standards were prepared the same manner as the sample except no acid leaching was involved.
- One set of QC samples were prepared using ASTM Type II water at the rate of one set per 20 field samples. (LCS and LCSD samples were spiked using 0.5 mL of 1.0 µg/mL Hg standard, yielding spike targets at 5.0 µg/L.)

EPA Method 7470 - Modified/Phillips Lab Procedure - Modified: Analysis of Lamp Debris (including glass, metal endcaps, and fines)

1. The lamp debris samples were preserved in a cooler and each sample was weighed (total weight – bottle weight = sample weight).

2. Each sample was leached with 200 mL of concentrated nitric acid for 1.5 hours.

3. 2 mL of homogeneous representative aqueous sample was transferred into pre-cleaned 250-mL HDPE bottles.

4. Added 98 mL of ASTM Type I water, 5 mL of concentrated sulfuric acid, 2.5 mL of nitric acid, 15 mL of 5% potassium permanganate, and 8 mL of potassium persulfate, then mixed well.

5. Placed caps loosely on the bottles and then set samples in a water bath maintained at 90 to 92 °C. After 2 hours in the water bath, removed samples and cooled bottles to room temperature.

6. Immediately prior to analysis, added 5 mL of 20% hydroxylamine hydrochloride to each sample, replaced and tightened caps, and shook the bottles to mix samples thoroughly. Allowed bottles to cool to room temperature and proceeded to analysis.

• All standards were prepared the same manner as the sample except no acid leaching was involved.

• One set of QC samples (LCS, and LCSD) were prepared using EPA reference soil at the rate of one set per 20 field samples. LCS and LCSD samples were obtained by leaching 0.5 g of EPA reference soil (target concentration of 12.3 µg/g) in 20 mL of concentrated nitric acid. 2 mL of the leachate solution was used to prepare the QCs.

NIOSH Draft Method 9103 – Modified: Analysis of HEPA Filter

1. Each HEPA filter container was opened and a representative portion of the main filter membrane was cut by 5 cm x 5 cm (= 25 cm^2).
2. Transferred each filter sample to pre-cleaned individual 250-mL HDPE bottles.
3. Added 5 mL of ASTM Type II water to each sample and gently swirled until the filter was saturated.
4. Added 5 mL of aqua regia to each sample and gently swirled until the filter was saturated.
5. Added 50 mL of ASTM Type II water to each sample and gently swirled to mix thoroughly.
6. Added 30 mL of 5% potassium permanganate to each sample and gently swirled to mix thoroughly.
7. Added 8 mL of 5% potassium persulfate to each sample and gently swirled to mix thoroughly.
8. Placed caps loosely on the bottles and then set samples in a water bath maintained at 90 to 92 °C. After 30 minutes in the water bath, removed samples and cooled bottles to room temperature.
9. Immediately prior to analysis, added 7 mL of 20% hydroxylamine hydrochloride to each sample, replaced and tightened caps, and shook the bottles to mix samples thoroughly. Allowed bottles to cool to room temperature and proceeded to analysis.

- All standards were prepared the same manner as the sample except no filter media was present.
- One set of QC samples (QB, LCS, and LCSD) were prepared using Whatman filters at the rate of 1 set per 20 field samples. (LCS and LCSD samples were spiked using 0.5 mL of 1 .0 µg/mL Hg standard, yielding a target at 0.5 µg/sample.)

EPA Method 7470 – Modified: Analysis of Carbon Pellets, Fines from Lamp Debris Samples, and Pre-filter Samples

1. Weighed 0.5 g of each representative sample and transferred the sample to pre-cleaned individual 250-mL HDPE bottles.
2. Added 5 mL of ASTM Type II water to each sample and gently swirled until the sample was wetted.
3. Added 5 mL of aqua regia to each sample and gently swirled until the sample was fully wetted.
4. Placed caps loosely on the bottles and then set samples in a water bath maintained at 90 to 92 °C. After 2 minutes in the water bath, removed samples and cooled bottles to room temperature.
5. Added 50 mL of ASTM Type II water to each sample and gently swirled to mix thoroughly.
6. Added 15 mL of 5% potassium permanganate to each sample and gently swirled to mix thoroughly.
7. Placed caps loosely on the bottles and then set samples in a water bath maintained at 90 to 92 °C. After 30 minutes in the water bath, removed samples and cooled bottles to room temperature.
8. Immediately prior to analysis, added 50 mL of ASTM Type II water and 5 mL of 20% hydroxylamine hydrochloride to each sample, replaced and tightened caps, and shook the bottles to mix samples thoroughly. Allowed bottles to cool to room temperature and proceeded to analysis.

- All standards were prepared the same manner as the sample except no bulk or soil media was present.
- One set of QC samples (LCS and LCSD) were prepared using EPA reference soil at the rate of 1 set per 20 field samples. (LCS and LCSD samples were prepared using 0.5 g of EPA reference soil, which has a targeted mercury concentration at 12.3 µg/g.) Also, one matrix spike sample (MS) and one matrix spike duplicate sample (MSD) was prepared at the rate of one per 20 field samples by spiking 0.1 mL of 1.0 µg/mL Hg onto the field samples, yielding spike targets at 1 .0 µg/L.

Appendix F

Wipe Sample Data and Discussion

Wipe Sampling Results

Wipe samples were collected from various surfaces to evaluate the deposition of mercury condensate and mercury-contaminated particulates on surfaces inside the containment. A set of wipe samples from nine different locations was collected prior to testing each DTC device (pre-test wipes), and another set was collected near the same nine locations at the conclusion of the test for each device (post-test wipes). Refer to Section 3.3 for wipe sample locations. These analyses were conducted as part of the Mass Balance Study to help quantify the mass of mercury released (i.e., not captured by the DTC device).

The results of the pre-test wipes and the post-test wipes were compared to each other. Pre-test and post-test wipes were collected from approximately the same general locations within the containment, to account for any spatial variation in ambient conditions (e.g., sampling location relative to the crusher, difference in local ventilation patterns).

To review the individual wipe sample results, refer to Appendix A, Table 2.

Wipe Sample Results – PVS Phase I

The wipe sample analytical results from Phase I of the Performance Validation Study (PVS) indicated that baseline mercury concentrations were present inside the AERC Ashland facility prior to initiation of this study. The ranges of results for each device are listed in Table 1 below.

Table 1: Phase I Performance Validation Study Wipe Sample Results

Device	Wipe Sample Results (µg/100 cm²)	
	Pre-Test	Post-Test
Manufacturer A	0.016 – 0.49	0.013 – 0.19
Manufacturer B	ND – 0.17	ND – 0.64
Manufacturer C	ND – 0.71	0.021 – 3.1
Manufacturer D	0.028 – 0.40	ND – 0.1

Detectable concentrations of mercury were noted on pre-test wipes when testing all four devices. Approximately 44 percent of the total post-test wipes exhibited higher levels of mercury than the pre-test wipes.

Wipe Sample Results – EFT#1

The wipe sample analytical result indicated that baseline mercury concentrations were present during Extended Field Test (EFT) #1 in the EPSI facility. The ranges of results for each device are presented in Table 2.

Table 2: Extended Field Test #1 Wipe Sampling Results

Device	Wipe Sample Results (µg/100 cm²)	
	Pre-Test	Post-Test
Manufacturer A	ND - 9.40	0.058 - 5.0
Manufacturer B	0.088 - 0.800	0.050 - 1.60
Manufacturer C	0.019 - 0.17	0.14 - 2.7
Manufacturer D	0.034 - 5.30	0.038 - 4.5

Detectable concentrations of mercury were noted on pre-test wipes when testing all four devices. Approximately 75 percent of the total post-test wipe results exhibited higher levels of mercury than the pre-test wipes.

Wipe Sample Results - EFT #2

Upon review of the wipe sample results collected during PVS Phase I and EFT #1, it was apparent that the baseline level of mercury contamination already present at the recycling facilities had the potential to confound the study results. One possible source of this contamination was the practice of measuring and cutting the polyethylene sheeting on the (contaminated) work area floor.

The team worked to reduce the interference from this contamination at the AERC Melbourne facility by measuring and cutting the polyethylene outdoors, in the parking lot behind the facility. A clean sheet of polyethylene was first laid on the ground to create an uncontaminated work surface. The polyethylene sheeting for the containment structure was cut and stored outside the facility on the clean, polyethylene work surface.

To further evaluate baseline the high levels of mercury found in pre-test wipes, it was also decided to collect two additional wipe samples inside the containment area the morning after the DTC devices were left idle in the containment overnight. One of the additional wipe samples was taken from the floor approximately two feet away from the device, and the other additional wipe sample was taken from the east wall of the containment. Field personnel attempted to collect these samples from approximately the same location as the earlier wipe samples.

Levels of mercury were still detected on the pre-test wipes collected for all three devices during EFT #2. The ranges of results for each device are presented in Table 3 below.

Table 3: Extended Field Test #2 Wipe Sampling Results

Device	Wipe Sample Results (µg/100 cm²)	
	Pre-Test	Post-Test
Manufacturer A	0.015 - 0.860	0.052 - 3.6
Manufacturer B	0.035 - 0.63	0.050 - 1.60
Manufacturer C	0.08 - 0.25	0.02 - 0.49

Approximately 70 percent of the total post-test wipes exhibited higher detected levels of mercury than the pre-test wipes, which was similar to the EPSI facility.

Wipe Sample Results - EFT #3

As in EFT #2, to reduce the level of mercury contamination on the polyethylene used to construct the containment, the procedure of measuring and cutting the polyethylene sheeting was performed outdoors in the parking lot behind the Ashland AERC Facility. In addition, a separate piece of polyethylene was measured, cut, and placed on the facility floor beneath each prepared containment structure. This task was performed to attempt to further reduce the effects of the ambient level of mercury contamination on test results.

The wipe sample results indicate that there was a level of background contamination present in the AERC Ashland facility during EFT #3. The ranges of results for each device are presented in Table 4 below.

Table 4: Extended Field Test #3 Wipe Sampling Results

Device	Wipe Sample Results (µg/100 cm²)	
	Pre-Test	Post-Test
Manufacturer C	0.020 - 0.17	0.092 - 2.8
Manufacturer B	0.024 - 0.23	0.055 - 3.8
Manufacturer A	ND - 0.73	0.11 - 1.7

All three DTC device studies resulted in the detection of mercury on pre-test wipes. Approximately 89 percent of the total post-test wipes exhibited higher detected levels of mercury than the pre-test wipes.

Wipe Sample Results - PVS Phase II

The ranges of wipe sampling results for each device are presented in Table 5.

Table 5: Phase II Performance Validation Study Wipe Sample Results

Device	Wipe Sample Results (pg/100 cm²)	
	Pre-Test	Post-Test
Manufacturer A	0.011 - 1.7	0.024 - 1.1
Manufacturer B	0.039 - 0.98	0.043 - 0.45
Manufacturer C	0.016 - 0.98	0.019 - 0.43

As during the Phase I test, the wipe sampling results from PVS Phase II indicated a baseline level of airborne mercury present in the AERC Ashland facility, most likely caused by the routine lamp crushing operations. All three DTC device tests resulted in the detection of mercury on pre-test wipes. Only 48 percent of all post-test wipes exhibited higher concentrations of mercury than the pre-test wipes.

Conclusions

Mercury was detected in the pre-test wipes, regardless of testing location. The higher mercury concentrations on pre-test wipes were not anticipated when the sampling and study plan was finalized. These elevated results indicated contamination prior to the operation of the DTC devices. Thorough review of the sampling and study plan by an individual with experience measuring mercury in field conditions would likely have helped the study team avoid or minimize these complications.

The mercury contamination on the polyethylene containment surfaces may have had several different sources. The ambient mercury vapor in the facilities may have deposited/sorbed onto on the polyethylene before the pre-test wipes were collected. Cross-contamination of the polyethylene sheeting may have occurred when it was sized and cut on the warehouse floor of the facility.

As described above, at the AERC Melbourne facility and the AERC Ashland facility (EFT #2, EFT #3, and PVS Phase II), the polyethylene sheeting was measured and cut outside the facility. Even after this methodology was adopted, many of the pre-test wipes were higher than the post-test wipes (during EFT #2, 30 percent were higher; during EFT #3, 11 percent were higher, and during PVS II, 52 percent were higher). This indicates that cutting the polyethylene sheets outdoors, away from the warehouse and on top of another polyethylene sheet, did not significantly decrease mercury contamination during construction of the containment.

In general, the two additional post-test wipes taken the day after testing at the AERC Melbourne facility and the AERC Ashland facility were higher than the corresponding post-test wipes taken the same day that the DTC device was

operated. This indicates that the ambient mercury most likely contributed to the high mercury levels detected for most of the pre-test wipes.

The wipe samples provided inconclusive data due to contamination. The study team determined that the wipe sample results would not be used as part of the Mass Balance Study.

Appendix G

Sampling Error and Correction Efforts For Mass Balance Study

Mass Balance Sampling Error

The initial sample results from the drum debris samples reported by the laboratory were much higher than the results used in the mass balance equation in Chapter 5. These higher concentrations were scrutinized by the team and upon further discussion with the laboratory, an error in the analytical method for the drum debris bulk samples was discovered. Table 1 presents the results from the initial analysis that was used in the original mass balance equation.

Table 1: Initial Drum Debris Bulk Sample Analytical Results

Device	Sample #	Result	Average Concentration
MFG A	R/B-2/27-16	160 µg/g	123.3µg/g
MFG A	R/B-2/27-17	100 µg/g	
MFG A	R/B-2/27-18	110 µg/g	
MFG B	D/B-2/28-35	140 µg/g	180.0 µg/g
MFG B	D/B-2/28-36	130 µg/g	
MFG B	D/B-2/28-37	270 µg/g	
MFG C	A/B-2/26-07	150 µg/g	145.3 µg/g
MFG C	A/B-2/26-08	200 µg/g	
MFG C	A/B-2/26-09	86 µg/g	

The quantity of mercury in the drum debris was calculated by multiplying the average of the drum debris results by the weight of the debris in the drum. The weight of the drum debris for the Mfg C device was 436 pounds that converts to 197766.3 grams. The weight of the drum debris for the Mfg A device was 466 pounds that converts to 211374 grams. The weight of the drum debris of the Mfg B device was 331 pounds that converts to 150139.1 grams. Based on the drum debris analytical results and debris weight the quantity of mercury in the debris for each device is:

- Mfg C 28,735.4 mg
- Mfg A 26,062.4 mg
- Mfg B 27,025.0 mg

When these quantities are added into the table presenting all the mass balance quantities, a large difference between the quantity of mercury processed Hg_T and the quantity of mercury in the drum debris is notable. Table 2 presents the results of the mass balance equation using the values presented for Hg_T, Hg_U, and Hg_R. Refer to Chapter 5 of the report for a description of how the other quantities were derived.

Table 2: Mass Balance Results

Device	Hg_T	Hg_U				Hg_R
		Drum Debris	Pre-filter	HEPA filter	Carbon filter	
MFG A	2675.4 mg	26,062.4 mg	NA	2.659 mg	1015.5 mg	0.38 mg
MFG B	2307.6 mg	27,025.0mg	12.45 mg	NA	7.3 mg	0.41 mg
MFG C	2934.5 mg	28,735.4 mg	47.35 mg	0.029 mg	57.9 mg	0.39 mg

Upon reviewing results in Table 3 below, the amount of mercury recovered is significantly greater than the calculated quantity of mercury processed in the study.

Table 3: Percentage of Mercury Recovery

Device	Hg Processed (HgT)	Hg Recovered (HgU+HgR)	% Recovery
MFG A	2675.4 mg	27080.8 mg	1012.2 %
MFG B	2307.6 mg	27045.0 mg	1172.0 %
MFG C	2934.5 mg	28841.0 mg	982.8 %

Due to significant error in the results of the Mass Balance Analysis, the study team re-evaluated the entire original mass balance study including the laboratory results to identify discrepancies in the study to account for the errors when balancing the equation. Upon further discussion with the laboratory it was discovered that the when preparing the drum debris sample for analysis, only the "fines" were removed from the bulk sample for analysis. The "fines" consisted of the fine phosphor powder and possibly the very small pieces of glass. However, the content of the drum debris samples also consisted of larger glass pieces and metal end caps, which could also contain some of the unaccounted mercury and contributed mass to the calculation of the total mercury concentration. In an effort to obtain more accurate bulk sample results and account for mercury post crushing, the remainder of the original drum debris bulk samples were analyzed and the results were combined with the results from the first analysis.

The second analysis of the drum debris involved weighing the entire remaining content of the samples and digesting the entire sample. The results from the original analysis and the second analysis were combined mathematically and presented as µg/sample. The weights in grams from the original analysis and the second analysis were added together to get the total weight of the drum debris bulk samples. The final reported results shown below in Table 4, in µg/g, are a combination of the analytical results and the weights from the original and second analyses. The following table presents the drum debris bulk sample results from the second analysis and shows a comparison to the original analysis.

Table 4: Drum Debris Bulk Sample Results (2nd Analysis)

Sample #	Device	Combined Wt. [1]	Corrected Result	Original Result	% Difference
A/B-2/26-07	MFG C	74.8 g	6.07 µg/g	150 µg/g	- 95.9 %
A/B-2/26-08	MFG C	56.6 g	5.58 µg/g	200 µg/g	- 97.2 %
A/B-2/26-09	MFG C	95.2 g	2.43 µg/g	86 µg/g	- 97.2 %
R/B-2/27-16	MFG A	72.9 g	5.84 µg/g	160 µg/g	- 96.4 %
R/B-2/27-17	MFG A	79.2 g	2.70 µg/g	100 µg/g	- 97.3 %
R/B-2/27-18	MFG A	86.4 g	2.57 µg/g	110 µg/g	- 97.7 %
D/B-2/28-35	MFG B	67.7 g	5.17 µg/g	140 µg/g	- 96.3 %
D/B-2/28-36	MFG B	85.2 g	4.59 µg/g	130 µg/g	- 96.5 %
D/B-2/28-37	MFG B	79.0 g	5.56 µg/g	270 µg/g	- 97.9 %

1. The combined weight presented in the table was reported in the final analytical report as measured by the laboratory.

Analyzing the results between the original analysis and the corrected analysis has identified an approximate 96 % difference in the concentration of mercury in the drum debris bulk samples. This significant change in values is due to the significant increase in sample weight when the larger pieces of debris are included in the analysis. When the analysis included only the "fines", where mercury is expected to be concentrated, it resulted in biased results and increased the concentration.

Table 5 presents the recalculated quantity of mercury in the drums compared to the original quantity:

Table 5: Re-calculated Mercury Amounts

Device	Total Weight Crushed Material and Drum Weight (Net)	Total Mass of Hg Corrected	Total Mass of Hg Original
MFG C	197,765 g	927.5 mg	28,735.3 mg
MFG A	211,373 g	782.1 mg	26,062.3 mg
MFG B	150,138 g	767.2 mg	27,024.8 mg

The new drum debris results above are inputted into the mass balance table to replace the original results. Refer to Chapter 5 of the report presents the mass balance study using the correct drum debris bulk sample results.

Appendix H

Procedures for Collection of Samples From Pollution Control Media

Samples were collected from the pollution control media for each device using the following procedures:

Manufacturer A

- The HEPA filter, located inside the filter canister, was accessed after the system had performed a filter purge where the device reverses the airflow to blow the collected particulates (purge) off the filter and back into the drum. Three bulk samples were collected from the filter by cutting approximately 100 cm^2 portions per sample out of the filter using a razor knife. The samples were folded in half, with any bulk material on the inside, and placed into separate sample containers.

- The top of the carbon filter canister was opened to access the carbon. The carbon filter consisted of three bags of carbon stacked on top of each other inside the canister. The top two bags were removed and opened. The carbon from each of the two bags was transferred to a separate generic plastic trash bag of sufficient size to accommodate its volume and each plastic bag of carbon was composited. Three bulk samples of carbon (approximately three ounces per sample) were collected from the top carbon bag, and three bulk samples of carbon (approximately 3 ounces per sample) were collected from the middle carbon bag using a clean plastic spoon. The samples were placed in separate sample containers.

Manufacturer B

- The pre-filter and carbon filter were all contained in a single cartridge. One bulk sample was collected from particulate contained in the pre-filter and placed in a sample container (there was only sufficient amount of particulate for one sample). Three carbon bulk samples (approximately two ounces per sample) were taken directly from the carbon container within the cartridge and placed into separate sample containers.

Manufacturer C

- Three samples of bulk particulate were collected inside the filter bag using a clean plastic spoon and placed in separate sample containers.

- The HEPA filter was removed, placed into a plastic Ziploc bag, and sealed.

- The top of the carbon filter canister was removed to access the loose carbon. The carbon was transferred to a generic plastic trash bag of sufficient size to accommodate its volume. The carbon was composited inside the bag, and

three bulk samples (approximately three ounces per sample) were collected using a clean plastic spoon and placed in separate sample containers.

Manufacturer D

- Three samples of bulk particulate were collected inside the filter bag using a clean plastic spoon and placed in separate sample containers.

- The HEPA filter was removed, placed into a plastic Ziploc bag, and sealed.

- The carbon filter bag was removed and cut open, and the carbon was transferred to a generic plastic trash bag of sufficient size to accommodate its volume. The carbon was composited in the bag, and three bulk samples (approximately three ounces per sample) were collected Using a clean plastic spoon and placed in separate sample containers.

Appendix I

Letter from EPA Documenting Problems with Manufacturer D Device

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

May 8, 2003

Mr. Edward J. Domanico
The Hazardous Materials Specialist, Inc
3200 S. Andrews Avenue
Suite 110
Fort Lauderdale, FL 33316

Dear Mr. Domanico:

The purpose of this letter is to document EPA's observations and provide Hazardous Material Specialist, Inc. (HMS) with a copy of the sampling data collected during testing of the Hazardous Material Specialist Fluorescent Lamp Disposal and Mercury Vapor Recovery System in Ashland, Virginia on February 27, 2003 and Phoenix, Arizona on March 26, 2003. The Equipment Validation Phase I and Real World Testing tasks in the Mercury Lamps Drum Top Crushers (DTC) Study are designed to evaluate how efficiently DTC devices capture mercury vapors emitted while crushing fluorescent lamps. Airborne mercury samples were collected and measured per the Sampling and Study Plan and following the NIOSH analytical methods. Furthermore, two Jerome mercury vapor analyzers were employed to collect and measure real-time airborne concentrations. Once the data has been collected, the results of the two studies are reviewed and compared against published mercury exposure limits. The results from the DTC device study are compared against the Occupational Safety and Health Administration (OSHA) regulated Permissible Exposure Limit (PEL) for mercury of 0.10 mg/m^3, and the American Conference for Governmental Industrial Hygienists (ACGIH) recommended Threshold Limit Value (TLV) for mercury of 0.025 mg/m^3.

EPA detected elevated levels of mercury vapor during testing of the HMS machine on February 27, 2003 during the Equipment Validation Phase I testing in Ashland, VA. Jerome readings collected during the operation of the HMS device measured a continuous increase in concentration that exceeded nominal limits. The operation of the HMS device was suspended when the readings measured 0.44 mg/m^3 (after crushing approximately 25- 30 bulbs) to allow for the operator to put on respiratory protection. Operation of the HMS device continued for approximately 45 minutes, where readings increased to measurements of 0.89 mg/m^3. At this time the study was concluded. The HMS device exceeded the OSHA PEL within a short period of time from the start of the operation. Note that when comparing the Jerome reading to the analytical air sample measurements, the Jerome is providing real-time data at the specific point in time. The analytical air sample measurements are collected over a period of time at specified

locations, and represent a timed average exposure concentration. This accounts for differences in the results between the Jerome and analytical air samples.

Analysis of the analytical air sample results indicate that the HMS device was not efficient in capturing and retaining mercury vapor, and exceeded OSHA PEL and ACGIH TLV exposure limits. Out of eight samples collected during the operation of this device, one sample did not exceed the OSHA PEL, while the remaining seven samples did exceed the OSHA PEL (reference the "Ashland, VA AERC Facility Analytical Air Results February 2003" graph.)

At the conclusion of the HMS machine test in Ashland, HMS requested that EPA ship the unit back to the HMS facility in Fort Lauderdale, Florida so an evaluation into the cause of the elevated mercury readings could be determined. The unit was returned to HMS during the week of March 10, 2003. EPA requested a written report detailing the cause of the elevated mercury emissions and confirmation of the adequacy of the repairs by conducting an analysis for mercury vapors by a qualified industrial hygienist. See attached e-mail from Mr. Tad Radzinski to Mr. Ed Domanico outlining this request dated March 7, 2003. EPA had requested that HMS complete the evaluation and issue a report by March 17, 2003. However, due to shipping delays and problems reported by HMS in regard to obtaining a Jerome mercury analyzer, EPA received a fax summary of "Findings on the Malfunctioning Bulb Machine" on March 19, 2003, followed by a written report (dated December 17, 2002) on the HMS findings via fax on March 24, 2003, and a fax of Jerome Mercury Analyzer results on March 22, 2003. The Jerome data provided by HMS indicated several readings on hose connections that exceeded the OSHA PEL after processing only 30 lamps as well as elevated mercury levels from the charcoal discharge.

The HMS device that arrived to the Earth Protection Services Inc. facility in Phoenix, Arizona on March 25, 2003 was damaged. The vacuum assembly had a large crack, which appeared to be either shipping damage, or damage that occurred when the unit was packed by HMS for shipping. The unit received in Phoenix appeared to be a redesigned model from the unit originally tested in Ashland, Virginia. The unit tested in Ashland contained 24 ounces of carbon in a vacuum bag inside the activated charcoal canister. The unit received in Phoenix had an activated charcoal canister that was noticeably larger with the canister packed full of activated carbon estimated to be 40+ pounds. In addition the feed tube design appeared to be different and the drum to hand cart-mounting system was redesigned. EPA notified HMS regarding the equipment differences and the explanation was that the unit sent to Phoenix was a "field unit". EPA did not understand why HMS would send a different unit for testing and when asked for clarification, the response was that HMS had to build a unit quickly for the Ashland, Virginia test which had a different carbon system then field models.

To meet testing protocols established for this study each DTC device vendor was required to provide one machine that would be used throughout the entire test. Changing the design of the machine not only violated the testing protocol, which would make HMS ineligible to continue participation in the study, but also eliminated an opportunity to verify that repairs to the machine originally tested in Ashland, Virginia had corrected the mercury vapor release problem. Since the unit was damaged when received in Phoenix, EPA could not perform the complete "Real World" testing of the unit. However, EPA decided to take some Jerome readings and air samples of the HMS device with the cracked filter assembly. With this type of damage mercury levels

exceeded the OSHA PEL after processing only 16 lamps (see attached "Phoenix, AZ EPSI Facility Jerome Hg Vapor Analyzer Direct Reading Air Results March 2003" graph and "Phoenix, AZ EPSI Facility Analytical Air Results March 2003" graph.)

EPA recommends that HMS conduct an independent test of a machine that is identical to models that are in use in the field. This test should include processing of enough lamps to fill a drum in order to determine if the machine is operating in a manner to effectively control mercury emissions. If elevated mercury levels are detected, then HMS will need to take appropriate action to correct the problem and notify all facilities that are utilizing this equipment as outlined in Item (4) of the HMS fax from Mr. Edward Domanico to EPA (Subject: Findings on Malfunctioning Bulb Machine Tested in 1st EPA Validity Test") dated March 19, 2003.

Please contact me at 215-814-2394 if you have any questions.

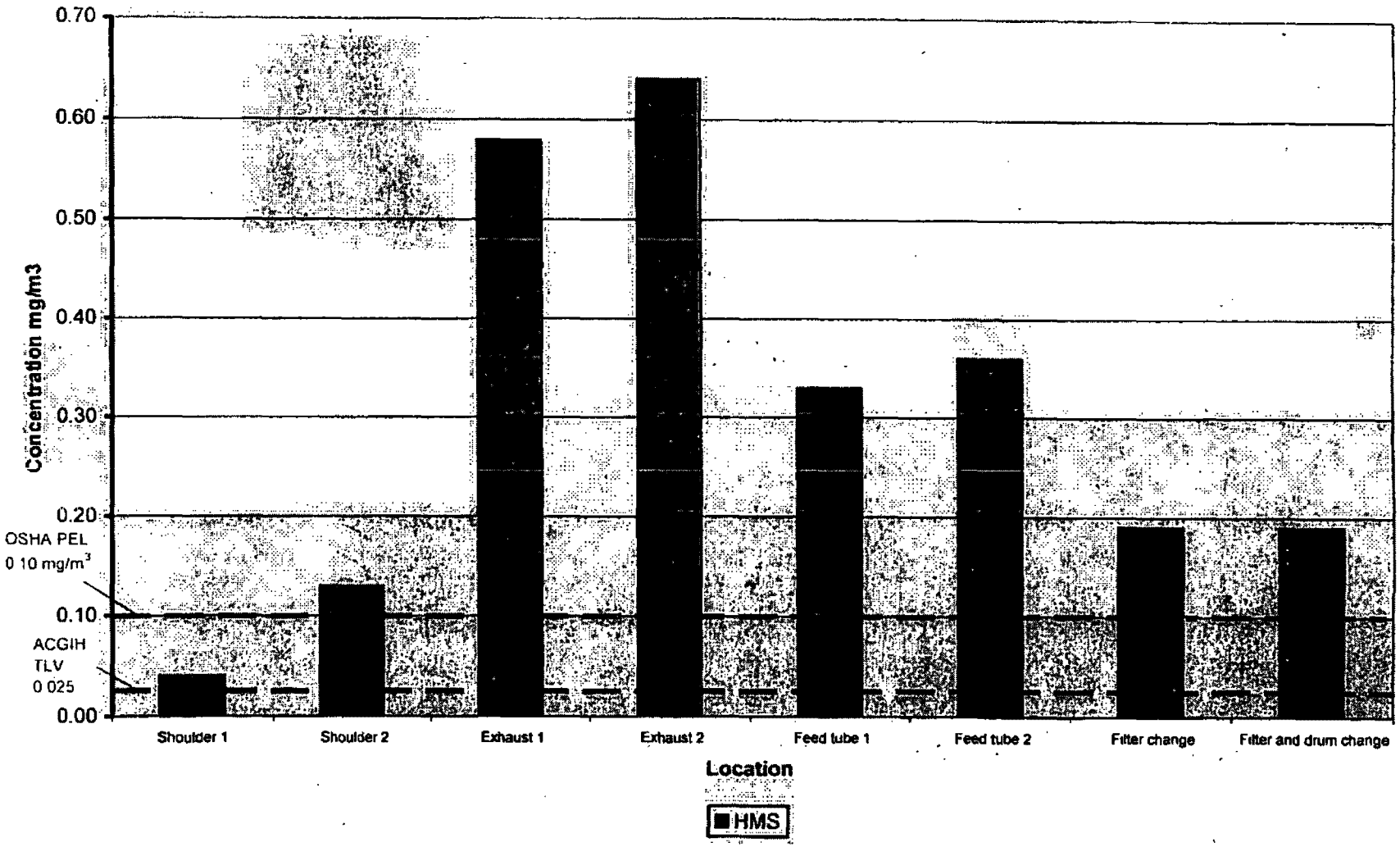
Sincerely,

Tad Radzinski, P.E.

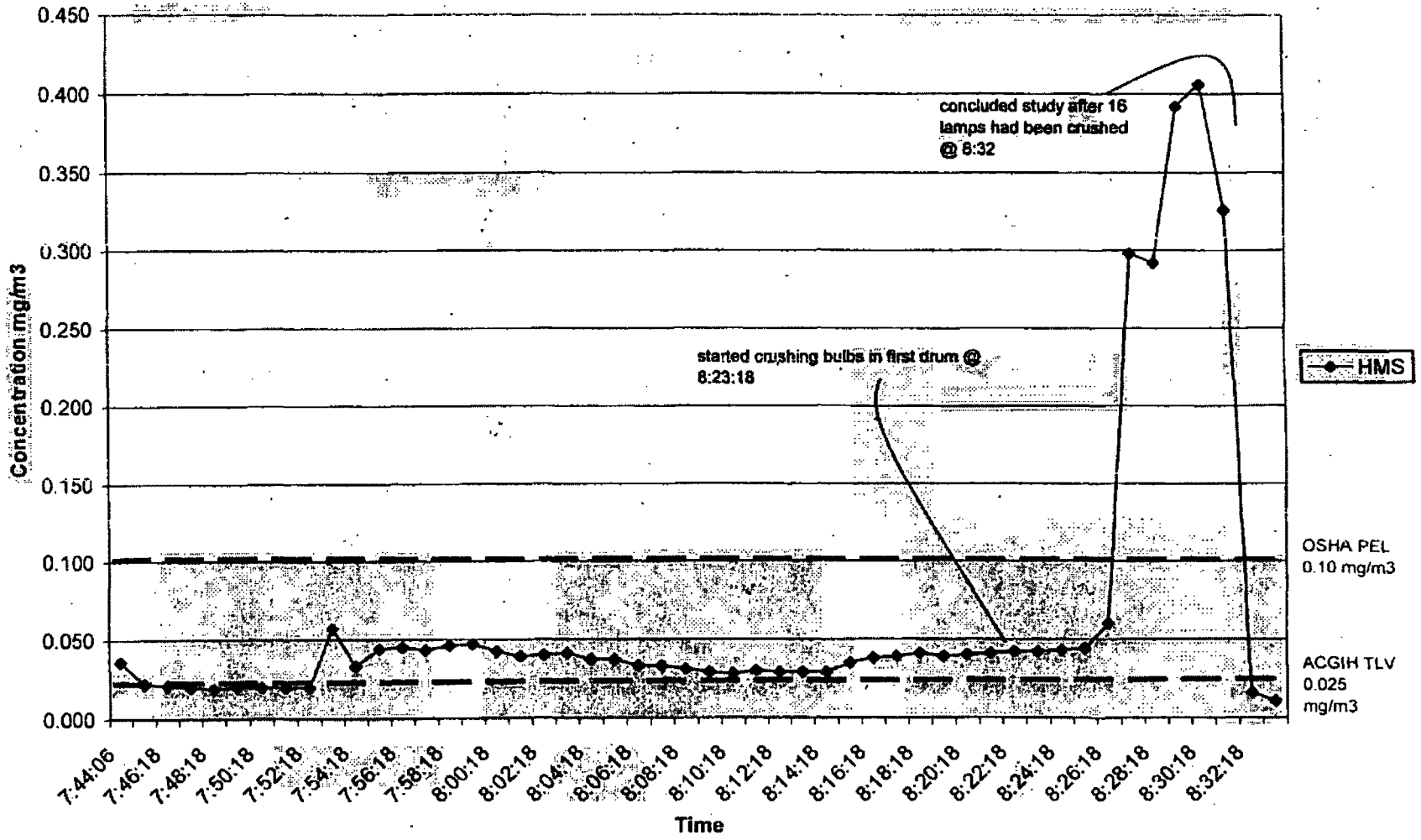
DTC Device Study Project Manager

Attachments

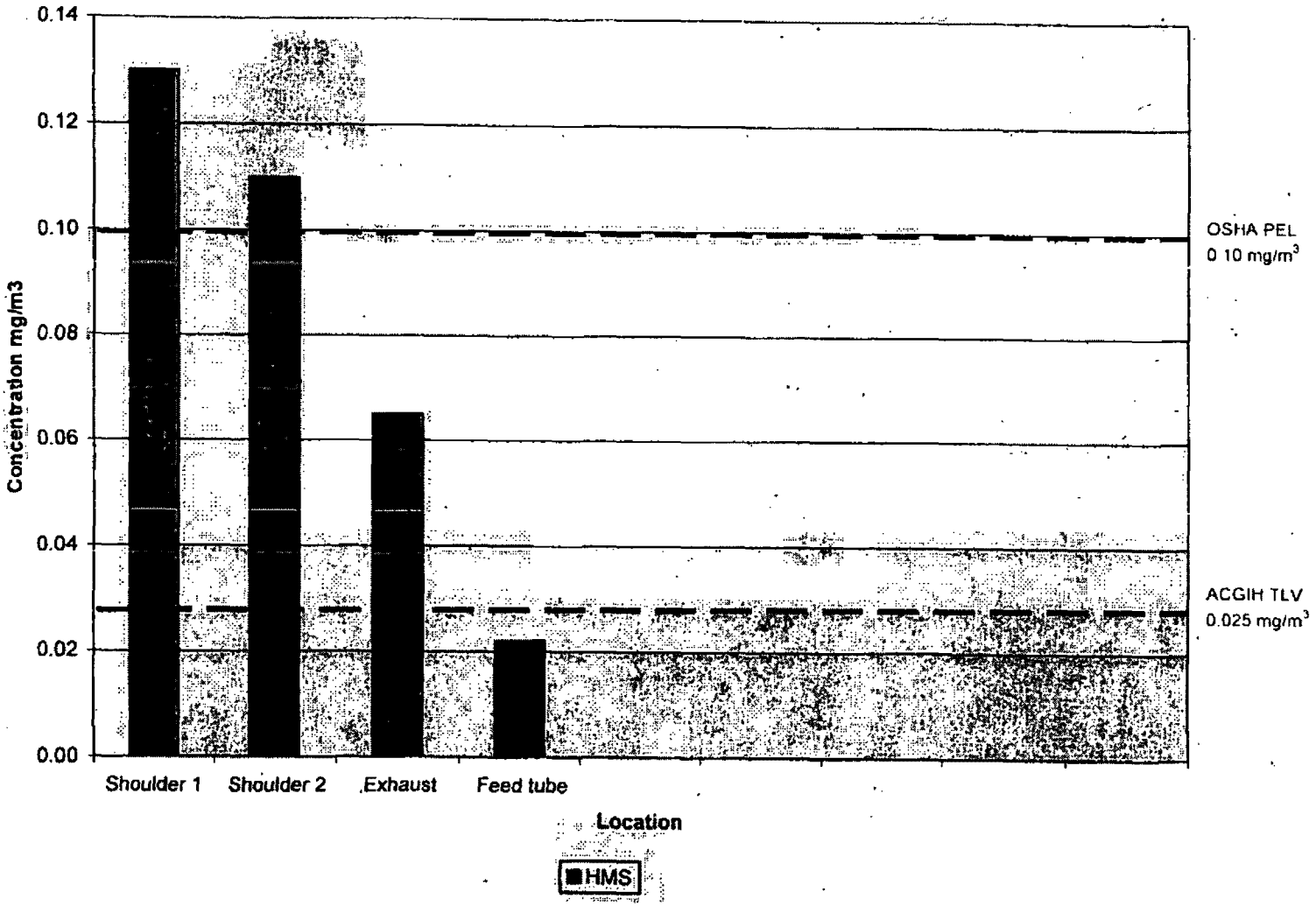
Ashland, VA AERC Facility Analytical Air Results February 2003



Phoenix, AZ EPSI Facility Jerome Hg Vapor Analyzer Direct Reading Air Results March 2003



Phoenix, AZ EPSI Facility Analytical Air Results March 2003



Tad Radzinski
03/07/2003 10:01 AM

To: hazmatspex@aol.com
cc:
Subject: Return of Your Equipment and Next Steps

Ed,

As we discussed today I have made arrangements for AERC to ship your DTC unit back to you COD via their freight company. When you receive the machine please evaluate to determine the cause of the elevated mercury emissions from your machine during the testing in Ashland, VA on February 27, 2003. I will need you to submit a written report to me with the results of your assessment. Once the machine is repaired you will need to test the machine including an analysis for mercury vapors using a Jerome or other mercury monitoring device by a qualified industrial hygienist. Please include the results of this test with your written report. We are planning to conduct the next round of testing in Phoenix, AZ during the week of March 24, 2003. I will need your report and testing results as soon as possible but no later than March 17 in order to confirm your continued participation in this study.

The contact for the Earth Protection Services Facility in Phoenix, AZ is Mr. John Chilcott and the shipping address and phone are listed below:

10 S. 48th Ave., Suite #4
Phoenix, AZ 85063-3820
Phone: 800-414-0443 - Fax: 602-353-9285
http://www.earthpro.com/

Please let me know if you have any questions. For shipping questions please contact Mr. Tom Downing of AERC at 804-798-9295.

Thank You,

Tad Radzinski
EPA Region III
Waste Minimization Team Leader
215-814-2394

THE HAZARDOUS MATERIALS SPECIALIST, INC.

ENVIRONMENTAL TRAINING, CONSULTING AND COMPLIANCE
INDUSTRIAL • CRUISE • MARINE

December 17, 2002

Mr. Tad Radzinski
Waste Minimization Team Leader
U.S. EPA Region 3
1650 Arch Street
Mail Stop 3WC11
Philadelphia, PA 19101-2029

REF: Equipment Comparison Phase I Sampling Results of THMSI Bulb Crushing Unit

Dear Tad,

Pursuant to our conversations, I apologize for the delay in providing you with this report. However, there have been several obstacles we have had to overcome. First, our unit did not arrive back here until March 13th late in the day. This was 2 full weeks from the test date in Virginia of February 27th. Once we received the unit the problem was quickly identified. However, lining up the test proved to be another challenge because of the unavailability of the Jerome 431X Meter. This combined with trucking companies not guaranteeing arrival times has made it a tough week. As you might recall, our unit did not arrive in Virginia until 1 hour before the test was to be performed. We landed at the airport when I phoned you and you said the unit had not even arrived yet and then it came in while were on the phone. Regardless of these obstacles, I am providing the following report for you and your colleagues to review.

1) At the Virginia test site, after initializing our unit it was clear to Mike and I that something was wrong. When you were feeding bulbs into the machine they were not going in smoothly and Mike determined that the feeder tube was slightly bent. Apparently, this happened during shipping or unpacking. Mike bent it back a little and the feeder tube performed more normally. It wasn't perfect but it was better. This kind of a crate for us was new and both feeder tubes will be secured in a stronger manner so this doesn't happen again.

2) Unnecessarily High Readings of Mercury. As you might recall, just prior to starting the test on our unit you and your associates switched out the drum that came

3200 S. Andrews Ave. • Suite 110 • Fort Lauderdale, FL 33316, U.S.A. • Phone: 954.527.5135 • Toll Free: 1.800.886.3531 • Fax: 954.527.5137

Recieved Time Mar. 24. 10:03AM

with our unit. As explained by you, this was because we had used our unit prior to shipping it and you needed a "clean" drum for the test. In placing the unit on top of the new drum we are not clear as to whether or not the side bolts were tightened down sufficiently. We do not believe they were and I will explain why.

a) When your initial readings were coming up high we could not understand why, especially based on other tests that we did independently. At the time of the first HEPA Filter change it became obvious to us that something was wrong because the HEPA filter was almost "clean" with no powder. The bag was almost clean and light. Again, normally the bag would be filled up, especially after 150 bulbs and it would be fully expanded, which it was not.

As you continued with the test and mercury levels rose, we were almost positive there was a vacuum or seal leak in the system somewhere. At that point, we left and as you might imagine, feeling very perplexed. Tad, I'm sure you realize we spent a lot of time and money to participate in this study and feel it is very useful and necessary. I consider myself one of the pioneers regarding this technology in making it a "real world product" and in no way want you or your management to think that think this malfunction represents our standards.

3) Review of Unit Upon its Return to Florida for Evaluation. When the returned crate was opened we immediately observed the following:

a) The side set bolts were missing and the unit sitting on the drum had a good ¾" play in it. When the unit was tilted on its side, it is our finding that it slipped off the upper seal that sits on the rolled metal edge of the drum. This would cause a vacuum leak allowing the unit to draw clean air allow mercury to escape.

Corrective Action: Replace and evenly tighten unit to top of drum. Increase seal size width at inner top of unit that sits on drum. Even if the screws were not put in it could not shift far enough to split off the seal.

In addition to this, we feel that the charcoal filter my have somehow lost connection to the exhaust canister. This would account for the high readings at the exhaust point.

In addition to these corrective items we checked our CFM flow on the vacuum with and without the HEPA Filter. With the HEPA Filter removed, it is 55 cfm. With the HEPA Filter in place it drops to 30 cfm. This is considered normal. Also, the charcoal filter medium is the EPA recommended product in accordance with EPA method 245.1 specially treated charcoal #580-13.

Recieved Time Mar.24. 10:03AM

We will provide you, by fax, late this afternoon, the field test results from our unit. Also, it will be arriving in Phoenix on Monday according to Delta Freight.

If you require any additional details please advise me accordingly.

Thank you for your patience and best regards.

Edward J. Domanico
Senior Certified Hazardous Materials Manager

cc: Mike Britton

Recieved Time Mar.24. 10:03AM

TOTAL P.05

To: TAD

From: ED

Hazardous Materials Specialist, Inc.
3200 S. Andrews Avenue
Fort Lauderdale, Florida
Mercury Testing

EHE Project # 03-023
Date: March 22, 2003

Test Location: Spray Booth

Test Run Quantity: 30 Bulbs

Sample Location	Hg (mg/m3) During Process	Hg (mg/m3) After 30 Bulbs Processe with Unit running
Booth Background-	.000	.000
Charcoal Discharge-	.000-.022	.059
Hose Connections:		
Charcoal Supply-	.160	.075
Vacuum Exhaust-	.207	.159
Vacuum Suction-	.062	.059
Vacuum Hose at Drum-	.070	.052
Seals:		
Drum Seal-	.056	.055

Testing Device: Jerome 431-X Mercury Analyzer

OSHA ceiling level for Mercury is 0.1mg/m3.

Appendix J

Peer Review of Mercury Lamp Drum-Top Crusher Study: Response to Comments

Background

The universal waste regulations, set forth in 40 CFR 273, were formulated in order to ease the regulatory burden associated with the collection of universal waste and to thereby facilitate the entry of these hazardous wastes into the RCRA hazardous waste management system. The original federal list of universal wastes included certain hazardous waste batteries, pesticides, and mercury-containing thermostats. Hazardous waste fluorescent lamps were added to the federal list of universal wastes on January 6, 2000 (64 FR 36465). One of the issues raised during the notice and comment period of this rulemaking was the use of Drum Top Crusher (DTC) devices for lamp management. A DTC device fits over the top of a standard 55-gallon drum and crushes the spent lamps into the drum. The DTC device is used to simplify handling of the spent lamps by reducing their volume.

At the time that hazardous waste lamps were added to the universal waste list, some states already allowed the use of DTC devices. EPA provided some general guidance to states with regard to the appropriate use of DTCs for lamp management (64 FR 36477) and determined that further, more detailed information or guidance regarding the use of DTC devices needed to be informed by an assessment of DTC device performance. Therefore, in 2003, EPA performed a study assessing the performance of DTC devices.

EPA prepared a draft report for the DTC Device Study (the Study), *Mercury Lamps Drum-Top Crusher Study Report*. RTI International (RTI), under contract to EPA, arranged for an independent review of the draft report, dated September 20, 2004, by recognized technical experts. This review was conducted by letter format in a manner consistent with EPA's Office of Research and Development and Science Policy Council *Peer Review Handbook* (December, 2000). The peer review was sought so that EPA may benefit from additional viewpoints and perspectives. Each reviewer certified that they had no actual or potential conflicts of interest; therefore, these reviews provided impartial evaluations of the scientific information and study findings. The following experts served as reviewers of the report:

- Carl Herbrandson, Ph.D., Minnesota Department of Health
- Steven Lindberg, Ph.D., Corporate Fellow Emeritus (retired) Environmental Sciences Division, Oak Ridge National Laboratory
- Michael McLinden, M.S., C.I.H., New Jersey Department of Environmental Protection

This report presents a compilation of the reviewers' verbatim comments on the draft report and the Agency's responses to these comments. Many substantive comments were made by the reviewers. As a result of these comments, EPA extensively revised the study report. Many sections of the report were rewritten, expanded upon, or moved in order to address the concerns of the commenters and provide a clear, thorough discussion of the DTC Device Study. Because of this extensive revision, several of the specific statements that the reviewers quoted and commented on are not in the revised report. Agency responses to these comments explain why the text was changed and addresses the substantive portions of the comments. The comments and responses are grouped by subject and generally follow the order of the report.

Comments Answering Questions Posed to the Reviewers by EPA

EPA posed the following specific questions to the reviewers:

1. General Design/Execution of the Study: Is the design and execution of the Study appropriate for evaluating the likely Hg releases from DTCs in use?
2. Laboratory Methods/QA/QC: Are the laboratory analytical methods and QA/QC procedures appropriate and adequate to generate reliable data?
3. General Results/Conclusions: Do the data generated by the Study support the conclusions presented in the report? If not, in what regard? Are other conclusions supported by the data generated?
4. Effects of Temperature and Humidity: DTC operations were performed at three locations under temperature and humidity conditions that varied at the different sites. The report does not attempt to quantify the effects of temperature and humidity on mercury releases from DTC devices in operation. Are the data generated by the Study adequate to assess the impacts of temperature and humidity on Hg release from DTCs in operation?
5. Background Hg: The DTC Study was conducted at operating commercial lamp recycling facilities. As a result, background mercury levels in the areas of the Study were much higher than would be expected to occur in buildings that do not use Hg in routine operations. How should the background levels of mercury be considered in assessing DTC releases of Hg?
6. Mass Balance Study: One portion of the Study consisted of a Mass Balance Study of mercury being put into the DTC devices, and the mercury released from the devices (Chapter 5). Estimated recoveries ranged from 34% to 67%. A number of possible reasons for the low recovery rates are discussed in the report. Do the sources of error described in the report adequately address the low recoveries? Are other sources of error plausible (and should be considered in any subsequent Mass Balance Study)?
7. Operator Observations: Are the operator observations presented in chapters 6 and 7 appropriate?
8. Study Limitations: Does the discussion of study limitations (Chapter 8) identify all important weaknesses in the Study not elsewhere identified in the report?

The reviewers' answers and the corresponding responses are presented below.

1. <u>General Design/Execution of the Study</u>: Is the design and execution of the Study appropriate for evaluating the likely Hg releases from DTCs in use?

Carl Herbrandson's Comment: Mercury emissions from DTCs, as mass of mercury released or as a fraction of mercury released from each fluorescent bulb, were not characterized in this study. The study was not designed appropriately for evaluating likely mercury releases during DTC use. The study measured containment area air concentrations, which was also an objective of the study. "The objective of the project was to evaluate the performance of the DTC devices in terms of mercury emissions and potential for worker exposure to adverse levels of mercury releases due to the operation of these devices." The potential for worker exposure to adverse levels of mercury releases due to operation of DTCs was effectively evaluated.

Response: EPA agrees that mercury emissions from DTCs in use were not measured in this Study. The discussion presented in this report has been modified to more clearly state that the Study was designed to evaluate DTC device performance in terms of worker exposure.

Steven Lindberg's Comment: No. The study was flawed, resulting in serious contamination which makes it difficult to quantify actual Hg releases.

Response: Mercury releases from DTC devices were not quantified in the Study. The Study was designed to evaluate mercury exposures that could result from the use of DTC devices and changes in mercury exposure over time. The data collected during the Study provide information about which activities involved in DTC device operation are associated with the highest mercury exposure and about how devices perform over time, in terms of their ability to prevent mercury exposure. Contamination, due to mercury present in the testing environment, was an issue. The limitations due to background mercury are discussed in Chapter 6 of the revised report, and background air sampling data (Jerome analyzer readings and analytical air samples) are presented in Chapter 4 of the revised report.

Steven Lindberg's Comment: Statements made in Section 7 suggest that the design was compromised to decrease costs of the study.

Response: The reviewer did not specify what statements in Section 7 suggest that cost concerns caused the study team to compromise the study design. However, one of the major concerns expressed was that the testing was conducted at lamp recycling facilities and thus, high background concentrations of mercury were present. (See next comment and response for specific response to this concern.) In addition, the study team made many ad hoc decisions in response to data that was collected during the early phases of the Study. A thorough review of the original study design by researchers more experienced in mercury sampling would most likely have lead to an improved study design. As with any large-scale study, cost and time considerations were important because inattention to these constraints (i.e., planning more sampling than could be completed in the amount of time allotted for a given test) would have made it difficult or impossible to complete the Study. However, the primary concern in designing the DTC Device Study was to assess the performance of the four DTC devices tested, and concerns about the cost of the testing were secondary to completing the objectives of the Study.

Steven Lindberg's Comment: The notion that these devices might be used at major existing recycling facilities seems poor justification for the chosen sampling locations. My experience in seeing these devices in the field is that they are used primarily at small to moderate-sized generators of used bulbs, such as small industries and hospitals.

Response: There were several reasons why lamp recycling facilities were used as the sites for the Study. Not all of these reasons were clearly explained in the draft study report. The revised report includes the following, more detailed explanation as to why the Study was conducted at lamp recycling facilities:

- These facilities possessed the appropriate permits to process mercury-containing fluorescent lamps.

- These facilities had ample supplies of lamps that were provided at no cost to the study team.
- The facilities had the capacity to process and dispose of the drums of lamp debris, with no shipping, manifesting, or disposal arrangement required of the study team.

The study team made every effort to isolate the study area from normal lamp processing operations. **(pg. 78)**

The study team considered other locations for the Study. However, some states require permits for the operation of a DTC device, and it was not feasible to obtain state permits within the timeframe of the Study.

The containment structure used for testing the DTC devices was constructed in order to simulate field conditions for DTC use by creating a small, confined space, similar to a boiler room or janitor's closet. The containment structure was also intended to isolate the test area from the rest of the lamp recycling facility, as best as possible.

Steven Lindberg's Comment: Perhaps the only questions these data could answer are "Do the tested DTC's have serious operating problems [yes], and do they capture all of the Hg from the feed lamps [no]?"

Response: EPA agrees that the data collected for this report should primarily be used to answer qualitative questions. The purpose of this Study was to provide information regarding possible worker exposures due to DTC device use. The agency believes that there are many insights that can be gained from the data collected in the Study. Chapter 7 of the revised report discusses the study results.

- *Laboratory Methods/QA/QC: Are the laboratory analytical methods and QA/QC procedures appropriate and adequate to generate reliable data?*

Carl Herbrandson's Comment: Generally, yes. The use of a realtime monitor (Jerome) also provided supporting confirmation of the analytical results. The effectiveness of the MCE filters, as the first stage of the sample collection train, to capture and retain aerosol Hg could be suspect and was not demonstrated.

Response: The effectiveness of the mixed cellulose ester (MCE) filters is discussed at the beginning of Chapter 4 of the revised report. It is possible that the MCE filters were not effective for capturing aerosol mercury; however, the total amount of mercury in the air sampled was effectively measured because any aerosol that was not captured in the MCE filter was captured by the Hydrar tubes (the second stage in the sample collection train).

Carl Herbrandson's Comment: Jang et al., 2005 shows an HCl / nitric acid solution removes a maximum of 36% of the Hg from bulb waste. Therefore, the effectiveness of the methods employed in this study to measure the amount of Hg in spent bulbs should be confirmed.

Response: In the revised report, a reference to Jang et al., 2005 is included in the section describing the extraction (in Chapter 5). Additionally, the need for a valid laboratory method

for quantifying the amount of mercury in spent lamps, with appropriate QA/QC procedures, is suggested in Section 7.4 as an area where further work is needed.

Steven Lindberg's Comment: In 3 decades of working with Hg I have never heard of Hydrar solid sorbent tubes. This does not mean they are unacceptable, but in the absence of strenuous QA tests, I was unable to verify the validity of data generated by this approach. My group has sampled Hg at levels in air and solids from background (pg of Hg) to highly enriched (mg of Hg), and or approaches have involved various sorbent traps (activated iodated C, gold), automated instruments (Jerome, Tekran, Lumex) and chemical extraction methods (such as for methylmercury). I found no QA testing of these tubes that provided any evidence of their ability to quantitatively collect Hg under conditions encountered. I would describe the methods as less than adequate (Appendix D titled Data Chem Methods was blank in my copy).

Response: According to OSHA's *Occupation Safety and Health Guideline for Mercury Vapor*, which can be found at http://www.osha.gov/SLTC/healthguidelines/mercuryvapor/recognition.html, "Determination of a worker's exposure to airborne mercury vapor is made using a Hydrar or Hopcalite tube (200 mg section), SKC brand with a prefilter/cassette." (The prefilter used in the Study was a mixed cellulose ester filter.) In addition to the OSHA guideline, Hydrar tubes are an acceptable medium for sampling mercury vapor in an industrial setting according to the National Institute for Occupational Safety and Health (NIOSH [1994]. NIOSH manual of analytical methods, 4th ed. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94–113.).

Steven Lindberg's Comment: I was surprised that readily available, widely used and accepted methods were not employed. Although the Lumex data could have been very valuable, the users seemed to have encountered several problems deploying this instrument, which many others have used successfully.

Response: EPA agrees that the Lumex data would have been very valuable. The study team attempted to record data with the Lumex but was unable to do so because the instrument was not functioning properly.

Steven Lindberg's Comment: The Jerome is a valuable instrument when properly used. However, there seemed to be no serious attempt to perform a sampling or analytical intercomparison between these two methods (see comment on Section 4 below). This would have proved useful in evaluating the Hydrar method. Also, the most interesting Jerome data were relegated to the Appendices and the trends not discussed (see below).

Response: The study team found that the Jerome data were valuable, and EPA agrees with the reviewer that the importance of the Jerome data was understated in the draft report. Unfortunately, because of problems with the data loggers, there were not enough Jerome data for each device at each location to perform any rigorous statistical analyses. The revised report highlights the Jerome data. Also, averages of the Jerome data and the analytical air

sample (Hydrar tube) data were graphed together to better facilitate comparison of the results from the two air sampling methods; these graphs are in .Appendix A, Figures 26, 35 and 43, of the revised report.

Steven Lindberg's Comment: The supplied raw analytical data tables suggested that up to half of the samples were below detection. This seemed odd given the enriched background under which the study was performed.
Also, I noted that the detection limits seem to have varied by over an order of magnitude (<0.1 to <1.1 ug) which is worrisome.

Response: Aside from the blank Hydrar tube samples, the samples that were below the detection limit were the MCE filter samples. The report was revised to highlight the fact that the majority of the MCE filter results were below the detection limit. (See earlier comment and response under "Laboratory Methods/QA/QC" for specific response to this concern.) The actual detection limits were based on the actual sampling media (0.1 µg per Hydrar tube or MCE filter). The "less than" values in the raw data tables vary because the total volume of air sample varied for each MCE filter/Hydrar tube. The units used for the final reporting value reported were mg/m^3, so the volume of air affected the "less than" value for each individual sample.

– *General Results/Conclusions: Do the data generated by the Study support the conclusions presented in the report? If not, in what regard? Are other conclusions supported by the data generated?*

Carl Herbrandson's Comment: Generally, the data supported the results and the conclusions of the report. With the following exceptions:

- There is no analysis of data showing that Manufacturer A's device performed better than the other devices in the PVS. While data from Phase 2 suggests this to be true, data from Phase 1 are equivocal.
- Data available are not sufficient to allow a mass balance calculation. Therefore, mentioning "a large fraction unaccounted for" may be misleading.

Response: An analysis was performed to support the assertion that there was a decrease in the performance of the devices from Manufacturer B and C but not the device from Manufacturer A. This is discussed in Chapter 4 of the revised report.

EPA agrees with the commenter regarding the Mass Balance Conclusions so the report was revised to eliminate the Conclusions section. The Mass Balance Study discussion was revised so that no definitive statements based on the data were made. Instead, the problems with the Mass Balance Study were presented along with the data so that this information could be used by future researchers.

Steven Lindberg's Comment: It would be difficult to draw any quantitative conclusions from the data presented in the report.

Response: EPA agrees, and thus, the conclusions presented in the report are primarily qualitative.

- *Effects of Temperature and Humidity: DTC operations were performed at three locations under temperature and humidity conditions that varied at the different sites. The report does not attempt to quantify the effects of temperature and humidity on mercury releases from DTC devices in operation. Are the data generated by the Study adequate to assess the impacts of temperature and humidity on Hg release from DTCs in operation?*

Carl Herbrandson's Comment: NO. There are too many variables. Differences between sites include: building configurations, proximity to industrial crushers, air currents within the buildings, potential changes in DTCs as a result of shipping, as well as seal leakage and potential maintenance issues could also confound a relationship. Differences between PVS phases 1 and 2 in Virginia may show a temperature/humidity effect, and some site related variables may be controlled, but showing a relationship between temperature/humidity and emissions would require showing that differences are outside any expected variability (i.e., multiple tests would be needed, at different times, and with cold temperature tests both before and after warm temperature tests).

Steven Lindberg's Comment: No, the data are not adequate. This question required a systematic approach under controlled conditions.

Michael McLinden's Comment: I expect temperature would directly influence the amount of mercury released from crushed/broken lamps as well as the amount escaping from the DTC devices, higher temperatures would volatilize more mercury. As for relative humidity, my guess is that since mercury is thirteen times as dense as water, it would not have a significant affect on mercury volatilization. As for your question "Are the data generated by the study adequate to assess the impacts of temperature and humidity on Hg release from DTCs in operation?" It may be helpful to graph results of a particular sampling location (e.g., all area air sample taken at feed tube) for all three Extended Field Tests. You could then compare the graph with ambient air temperatures to see if temperature affected the results.

Response: The Study was not designed to evaluate the effects of temperature on the measured mercury concentrations. After the Study began, the study team recognized that ambient temperature could significantly impact the amount of mercury that volatilized when the lamps were crushed, so temperature data was collected. The peer reviewers were specifically asked to comment on the adequacy of the temperature and humidity data for the purposes of assessing any possible effects that environmental conditions may have had on the results of the Study. Based on the comments made by the reviewers, no attempt was made to assess the impacts of temperature and humidity on DTC performance in the revised report.

- *Background Hg: The DTC Study was conducted at operating commercial lamp recycling facilities. As a result, background mercury levels in the areas of the Study were much higher than would be expected to occur in buildings that do not use Hg in routine operations. How should the background levels of mercury be considered in assessing DTC releases of Hg?*

Carl Herbrandson's Comment: High background mercury in the testing areas was handled properly in the report: background Hg was recorded and reported. Certainly if longterm testing had occurred in a pristine setting, wipe samples could have provided some useful data about the potential for DTCs to contaminate work areas. However, it is not clear how the background concentrations may have impacted the mercury vapor data acquired during the reported experiments. Background mercury vapor concentrations could be subtracted from the test data, but this would have required substantial data supporting the use of specific background concentrations.

Response: In the revised report, more complete background data are presented in the results section (Section 4.2). The background air sample data was compared to the air samples taken during testing to show that the mercury concentrations measured during testing were significantly higher than the background levels at each facility.

Carl Herbrandson's Comment: Data from Jerome #2 is not shown in the figures. As noted in the report, air leaks and exchanges occurred whenever the bay doors at the testing facilities were open. The readings from Jerome #2 could provide useful information for evaluating the variability of background mercury vapor concentrations.

Response: EPA agrees that the data from the Jerome Mercury Vapor Analyzer that was used to sample the air outside the containment structure during testing would have enhanced the analysis and discussion of the background data. Unfortunately, due to problems with the Jerome data loggers, the real-time background data is not available.

Carl Herbrandson's Comment: The report should note that the background concentrations in locations at some distance from the 'industrial' crushers suggest that exposures near operating industrial crushers may be above levels of concern for the general public; and that Hg contamination on floors near the containment areas suggests that tracking of mercury from facilities like these may be significant.

Response: The potential for exposure to the general public is discussed in Chapter 7 and several other sections of the revised report. The Study was not designed to measure possible migration of mercury off site from the lamp recycling facilities, so the report does not make any statement about the possibility of significant amounts of mercury being released due to tracking from the facilities.

Steven Lindberg's Comment: The decision to perform these tests under the chosen conditions represents a fatal flaw in this study. The problems of such serious contamination cannot be overcome without a revised study design. Since the background was never adequately controlled, or even quantified (too few samples, too much variability), I don't see how any quantitative conclusions can be drawn from the study as designed and performed.

Response: As stated above, there were many reasons that the lamp recycling facilities were chosen as the sites for this Study. EPA agrees that the background mercury is a serious confounding factor in the Study, and the majority of the conclusions drawn in the report are

qualitative. In response to the reviewers' concerns about the low number of background samples, a more thorough presentation of all available background mercury samples measured using the Hydrar tubes and using the Jerome Mercury Vapor Analyzer is included in the results section (Chapter 4) of the revised report, and the chapter about limitations (Chapter 6) discusses several ways in which the background samples may bias the results.

- *Mass Balance Study: One portion of the Study consisted of a Mass Balance Study of mercury being put into the DTC devices, and the mercury released from the devices (Chapter 5). Estimated recoveries ranged from 34% to 67%. A number of possible reasons for the low recovery rates are discussed in the report. Do the sources of error described in the report adequately address the low recoveries? Are other sources of error plausible (and should be considered in any subsequent Mass Balance Study)?*

  Carl Herbrandson's Comment: Calculations and estimates used in the "mass balance" should not be reported. Instead, for the benefit of future investigators, the problems with attempting to show a mass balance with the available data should be detailed. Other potential sources of mass balance loss are described in accompanying comments.

  Steven Lindberg's Comment: Considering all of the assumptions, analytical errors, and background problems, I would not accept that even the stated range of recoveries is accurate. Given the analytical and sampling errors, and the flawed design, it is not surprising that correction factors as large as 95% were applied in an attempt to close the mass balance. It is never explained why there was no attempt to quantify the losses based on the air concentration data.

  Response: EPA agrees that the uncertainty in the Mass Balance Study is too high to estimate the different fractions of mercury. The discussion of the Mass Balance Study was revised to present the data collected, the calculations, and the problems encountered. The air concentration data was used to calculate the amount of mercury released; however, there was a significant mass of mercury unaccounted for.

- *Operator Observations: Are the operator observations presented in chapters 6 and 7 appropriate?*

  Carl Herbrandson's Comment: Yes. Inclusion of operator observations can provide important subjective information and insight.

  Steven Lindberg's Comment: These were possibly the most useful contribution. The DTC's as a whole seemed poorly designed, and the problems encountered were not surprising. The safety suggestions offered are valuable, although several were also noted in the manufacturer's guidelines. It is interesting to note that these manuals contained misinformation concerning Hg.

  Response: The operator observations are included in Chapter 7 of the revised report.

– *<u>Study Limitations</u>: Does the discussion of study limitations (Chapter 8) identify all important weaknesses in the Study not elsewhere identified in the report?*

Carl Herbrandson's Comment: Additional study limitations are discussed in the accompanying comments.

Steven Lindberg's Comment: In general, the major limitations were noted, but several more could be listed, as noted both above and below.

Response: The study limitations are discussed in Chapter 6 of the revised report. EPA has responded to all comments in this document.

Additional Comments of Peer Reviewers and Agency Responses

The additional comments provided by the reviewers follow. General comments are presented first, and specific comments are organized to follow the order of the report.

General Comments

Carle Herbrandson's Comments: This study was a very good initial study of DTCs. The study showed operator exposures to mercury vapor may regularly be above the TLV (for the duration of operation) and often above the PEL. Adverse health effects are consistently seen in studies of workers exposed at the TLV (0.025 mg/m3 for 8-hour day). Therefore as a scientist in the field of public health, I would recommend to my state environmental agency that additional study should be conducted prior to allowing the use of DTCs. These studies should answer the following questions:

a. Can contamination accumulate in areas where DTCs are used? Can this contamination be tracked? Is there a need to establish decontamination areas and procedures for operators?
b. Can the circumstances of use of DTCs be controlled so that the general public is not exposed to potentially hazardous levels of mercury?
c. What fraction of the mercury in a fluorescent bulb is emitted from DTCs, in all phases of operation?
d. Are there regulations that will ensure control and proper disposal of full drums?
e. How do emissions from currently operated 'industrial' recycling processors and DTC emissions compare? Can the use of DTCs reduce the overall emissions from spent fluorescent bulbs to the environment?
f. Can we objectively evaluate the apparent tradeoff between potential decreased environmental emissions and the potential for significant exposures to more individuals – individuals exposed to emissions or contamination associated with DTCs?

I would hope that, without answers to the above questions, DTC usage does not increase.

Response: The questions posed by the reviewer are excellent research questions. While the Agency is not suggesting that DTC devices not be used until these questions are answered, EPA agrees that regulators should carefully consider the possible effects to human health and the environment that would come from allowing the use of DTC devices. This then can be compared to continuing to have the majority of mercury containing fluorescent lamps disposed of in MSW landfills.

Carle Herbrandson's Comments: The order of presentation of data on DTC devices in all tables and figures should be A, B, C, D. Data are always more confusing when they are listed in different order in different places. If the actual sampling order was different than the reporting order (A,B,C,D), then the sampling order should be noted in table/figure footnotes.

Response: The presentation of the data has been changed to A, B, C, D order.

Carle Herbrandson's Comments: Pg 92 last line – there is no section 3.6.2.1.

Michael McLinden's Comment: There is no Section 3.7, perhaps it should read Section 3.5.2.1. There is no section 3.9.1.

Response: All references within the report were checked and revised to ensure that they were correct.

Steven Lindberg's Comments: Although the nature of this project led to moderately difficult objectives, they should have been achievable by an experienced research group with sufficient planning. In my opinion, this project and the report do not meet the stated objectives. The primary reasons relate to the apparent inexperience of the project team in working with Hg and an inability to anticipate potential problems. Detailed comments follow the questions below.

Response: While some objectives of the Study were not met, the data collected in this Study provide valuable information to regulators and users of DTC devices. EPA agrees however, that a more thorough review of the sampling and study plan by researchers more experienced with mercury monitoring would have been beneficial to the study team to avoid some of the problems encountered during the Study.

Executive Summary

Note to the reader: The Executive Summary that was included in the draft report given to the reviewers was extensively revised. The Executive Summary in the revised report provides the reader with the background of the Study and the results of the Study, in a concise form. Many of the comments made by the reviewers are not directly relevant to the revised report; however, responses to the concerns raised by these comments are provided below.

Carl Herbrandson's Comment: The executive summary introduction says that the use of DTCs "will likely increase." This will certainly be true, in the absence of regulatory action. Does this report assume that there will be no regulatory action taken? Or that additional testing will not occur before DTC-use increases?

Response: EPA is not proposing any changes in regulations; the purpose of this Study was to provide information about the use of DTC devices. The statement that DTC use "will likely increase" is no longer in the Executive Summary. The issue of the use of DTC devices was discussed in the final notice for the addition of hazardous waste lamps to the federal list of universal waste (64 FR 36477). Authorized state programs have the authority to make regulatory decisions about the use of DTC devices as part of their universal waste management programs.

Carle Herbrandson's Comment: Pg 5 (TLV) of 0.25 mg/m^3 - - should read 0.025 mg/m^3

Response: The TLV listed in the Executive Summary now reads 0.025 mg/m^3.

Carl Herbrandson's Comment: The conclusions and recommendations section of the Executive Summary includes the statement that "Additional recommendations for engineering controls, PPE, equipment isolation, and worker medical monitoring may apply in site-specific situations." Does this suggest a different level of regulation than is typically seen

in Haz Waste regulations? Are equipment isolation, PPE, ...controls EPA wants to, recommend only at certain sites?

Response: EPA is not proposing any changes in regulations; the purpose of this Study was to provide information about the use of DTC devices. The statement quoted by the reviewer, which is no longer in the Executive Summary, reflects the fact that EPA expects that there will be a broad range of conditions under which DTC devices will be used. The members of the operator and operator's assistant wore Tyvek® coveralls, Kevlar® gloves, safety glasses, and, at times, full-face respirators while conducting the Study.

Michael McLinden's Comment:

Report Text:

The Manufacturer D device was removed from the study after the second round of testing due to its inability to control mercury emissions below Occupational Health and Safety Administration (OSHA) and the American Council of Governmental and Industrial Hygienists (ACGIH) standards.

Comment (Suggested Text Changes Highlighted): The Manufacturer D device was removed from the study after the second round of testing due to its inability to control mercury emissions below Occupational Safety and Health Administration (OSHA) and the American Conference of Governmental Industrial Hygienists (ACGIH) standards.

Response: The correction suggested in the above comment was made in the revised report.

Steven Lindberg's Comment: The accuracy and precision of the data are never mentioned. There seems to be a lack of any serious attempt to reproduce these results, and no replicates are discussed.

Response: There is no longer a discussion of the data in the Executive Summary. The study design did not call for replicate testing because one of the basic assumptions of the Study was that there would be changes in device performance over time. Multiple air samples were collected during each test. The variability between air samples collected for each device during a specific testing event were used to determine the variance associated with the measured mercury concentrations.

Steven Lindberg's Comment: Phrases suggesting that emissions were measured are inaccurate. There were no measurements of emissions performed in this Study, only estimates made, based on concentration data.

Response: The report has been revised to make it clear that emissions were not measured. The concentrations near the feed tube and exhaust port were measured.

Michael McLinden's Comment: Although this is a good recommendation [*medical monitoring program for device operators*], OSHA does not require specific biological monitoring in order to use respiratory protection, only a questionaire and/or physical exam. I agree that respiratory protection should be used, however based on established industrial hygiene hierarchy to control workplace contaminants respiratory protection would be

recommended only after engineering and administrative controls were explored. Engineering controls should be instituted first in order to reduce employee exposure below the PEL. If engineering controls are not feasible (and I believe they would be feasible in this case) then administrative controls would be explored. Repiratory protection is used as a last resort or while instituting engineering controls.

Response: These recommendations are not in the Executive Summary, but some of the issues are discussed in Chapter 7 of the revised report. The revised report mentions the established industrial hygiene hierarchy (Chapter 7).

Michael McLinden's Comment: In order for an air purifying respirator to work (and be certified by NIOSH) it must have adequate warning properties to indicate when the filter/cartridge has reached break-through. Mercury cartridges do not have adequate warning properties; however, some manufacturers (e.g., MSA mersorb cartridge) have received approval for cartridges equipped with an end of service life indicator (ESLI) so employee can check for break through. Special SOPs (e.g., wearing a belt-mounted cartridge so employee can see the ESLI, or providing mirrors so a worker could see ESLI on his full-face APR) would have to be developed for using APR with Hg.

Response: This fact was not addressed in the revised report; however, EPA will consider this point in drafting additional guidance.

Scope of Study

Carl Herbrandson's Comment: The study objective was to evaluate the performance of DTCs with respect to potential mercury emissions and potential exposures to workers operating DTCs. The study does provide useful data and information on the potential exposures to DTC operators. However, mercury emissions from DTCs, as mass of mercury released or as a fraction of mercury released from each fluorescent bulb, were not characterized in this study.

Response: EPA agrees that the Study was designed to assess worker exposure due to operation of DTC devices and not to measure mercury emissions. The revised report reflects this point – that is, the fact that mercury emissions from DTC devices were not characterized in this Study.

Steven Lindberg's Comment: Several design decisions mentioned in this section are hard to reconcile with an assumed experience of working with environmental or occupational levels of Hg. The decision to locate the study at recycling facilities is surprising and suggests a lack of understanding of (or experience with) the behavior of elemental Hg vapor. It's surprising that someone didn't realize the impact of this decision sooner.

Response: There were several reasons why lamp recycling facilities were used as the sites for the Study. Not all of these reasons were clearly explained in the draft study report. The revised report includes the following, more detailed explanation as to why the Study was conducted at lamp recycling facilities:

- These facilities possessed the appropriate permits to process mercury-containing fluorescent lamps.
- These facilities had ample supplies of lamps that were provided at no cost to the study team.
- The facilities had the capacity to process and dispose of the drums of lamp debris, with no shipping, manifesting, or disposal arrangement required of the study team.
  The study team made every effort to isolate the study area from normal lamp processing operations. (pg. 78)

The study team considered other locations for the Study; however, it was not feasible to obtain permits for each site within the timeframe of the Study. The most important reason for using the lamp recycler facilities for the Study was the fact that they had permits for lamp crushing.

The containment structure used for testing the DTC devices was constructed in order to simulate field conditions for DTC use by creating a small, confined space, similar to a boiler room or janitor's closet, and also to isolate the test area from the rest of the lamp recycling facility.

EPA also agrees that future studies conducted in a testing environment with very low background mercury levels, involving the measurement of emissions, would be helpful in evaluating the effectiveness of DTC devices.

Data Collection Methodology

Michael McLinden's Comment: Which model, Jerome-411 or newer model?

Response: The model for the Jerome was 431-X. This information is included in the revised report.

Michael McLinden's Comment: Were any background samples collected at the end of the week to determine if background Hg levels had risen during the week due to normal facility processing of lamps? It may be possible that background levels on Monday are lower than Friday levels if the facility is shut down for the weekend.

Response: Background samples were not specifically taken at any point after the first day at each facility. However, during EFT #2, EFT #3, and PVS-II, one overnight air sample was taken outside of the containment structure after each day of testing. These air sample results are presented Table 4.1 and Table 4.2 in the revised report along with the other background sample data and the Jerome background sample data that was manually recorded throughout the Study. Based on this limited sampling, there was no observable trend indicating an increase in background concentrations throughout the week.

Carl Herbrandson's Comment: Table 3.1 is poorly designed – not very understandable.

Response: Table 3.1 in the draft report described the types of analytical air samples that were taken during each portion of the Study. This table has been replaced by four distinct

tables – Tables 3.1, 3.2, 3.3, and 3.4 – in the revised report, which describe the samples for each portion of the Study (the Performance Validation Study, Extended Field Test #1, Extended Field Test #2 and #3, and "U"-tube Test).

Carl Herbrandson's Comment: Last sentence on page 26 – not clear. 2 samples "in sequence, for a total duration of 4 minutes per sample." Does that mean a total duration of 8 minutes?

Steven Lindberg's Comment: The intent of ceiling samples was never clearly described, but they seem to be interpreted as representative of maximum exposure. Why?

Response: The description of the ceiling samples that were described on page 26 of the draft report was clarified in the final report. The original description was:

> Short-term ceiling samples were air samples collected over a short duration in time (for this study the sample period was 12 minutes) in order to evaluate the airborne concentration at a specific time. These samples were collected to attempt to quantify airborne concentrations at the estimated time of maximum exposure determined to be during the drum changes. Readings taken on the Jerome Mercury Vapor Analyzer indicated that maximum exposure conditions most probably occurred during drum changes. Thus, the ceiling samples were collected during one of the drum changes for each device. Two samples were collected on the operator's shoulder, in sequence, for a total duration of four minutes per sample.

The revised description is:

> The ceiling samples were another set of personal air samples, which were collected to attempt to quantify airborne mercury concentrations at the estimated time of maximum exposure. Readings taken on the Jerome analyzer indicated that maximum exposure conditions most probably occurred during drum changes. Thus, the ceiling samples were collected during one of the drum changes for each device during PVS-Phase II, EFT #2, and EFT #3. Two samples were collected on the operator's shoulder, in sequence; each ceiling sample was collected for 4 minutes. **(pg. 18)**
>
> ***
>
> Short-term ceiling air samples were introduced into the Study during this round of testing. As described above, ceiling samples were air samples collected over a short duration in time in an attempt to quantify airborne concentrations at the estimated time of maximum exposure.
>
> Readings taken on the Jerome analyzer indicated that maximum exposure conditions most probably occurred during drum changes. Drum change sample results from EFT #1 showed that the ambient concentration of mercury is sufficiently high during drum changes such that the samples did not need to be 12 minutes in order to exceed detection limits. Thus, two short-term, personal air samples were collected in sequence during one of the drum changes for each device. The sampling time was four minutes per sample, for a total duration of eight minutes. **(pg. 21)**

Steven Lindberg's Comment: The decision to cut the plastic on the floor was a fatal flaw.

Response: The study team attempted to rectify the problem with the contaminated wipes samples. Because many of the pre-test wipe results were higher than the post-test wipe

results, the wipe sample data were not used in the report and were only included in the Appendix. Later, the plastic was cut outside in the parking lot; however, the number of pre-wipe samples exhibiting high amounts of mercury did not decrease.

Steven Lindberg's Comment: The Lumex was "written off" with a brief comment regarding inoperability. Were any attempts made to rectify the problems?

Response: EPA agrees that the real-time data would have been an asset to the Study; however, although the study team attempted to correct the problems with the Lumex, the device obtained for the Study did not operate correctly.

Michael McLinden's Comment: Was the DTC decontaminated between EFT #3 and PVS-Phase II? Would contaminated DTC indicate lower performance when compared to Phase I using a clean DTC device?

Response: The DTC devices were not decontaminated between EFT #3 and PVS-II. This may have slightly elevated the results from PVS-II. This is discussed in the revised report.

Steven Lindberg's Comment: The NIOSH methods applied are never described in detail, but are simply defined as being unpublished. The normal set of QA tests one would expect are missing.

Response: Due to an error in distributing the report to reviewers, Appendix D was omitted, so the reviewers did not receive a copy of the analytical methods. The National Institute for Occupational Safety and Health (NIOSH) method for sampling mercury vapor in air, Method 6009, and the draft NIOSH method for sampling mercury aerosol in air, Method 9103, were used in the Study. Copies of all NIOSH methods and laboratory methods used are contained in Appendix E of the revised report. Method 6009 is published, and Method 9103 is unpublished. Field QA/QC samples results (i.e., trip blanks and field blanks) are in Chapter 4 of the revised report. All laboratory QA/QC procedures specified in the methods were followed by the laboratory analyzing the samples (Data Chem Laboratories), and, as is standard procedure for commercial analytical laboratories, the laboratory QA/QC data should be on file at Data Chem.

Steven Lindberg's Comment: The duration of the samples is not discussed, but the number of samples "below detection" suggests they were too short. Why was this not resolved with a simple change in design?

Response: The duration of the sample and the volume of air sampled are listed along with the raw data in Appendix A, Table 1. As discussed above, the majority of "below detection" samples were the MCE filter samples. This is discussed in the report in Chapter 4, footnote 12. The purpose of the MCE filter samples was to measure the concentration of mercury aerosols inside the containment structure during operation of the DTC device; the "below detection" results may indicate that no aerosols were formed or that the MCE filters were not the most appropriate media for the detection of mercury aerosols. The Study was not designed to make evaluate the likelihood of either possibility. Further study of this question

is suggested in Section 7.4 of the final report. The Hydrar tube samples were not "below detection".

Steven Lindberg's Comment: Hydrar tubes are never defined. Were the air flows checked during sampling? Were they recorded continuously?

Response: Hydrar tubes are one of the acceptable media for sampling mercury vapor in NIOSH Method 6009. Each air pump was calibrated before and after sampling. The two calibration values were averaged to determine the approximate velocity at which air was being drawn through the pump. The air flows on the pumps were not checked during sampling or continuously recorded.

Steven Lindberg's Comment: The reliance on sorbent tubes for much of the data biased the concentrations measured to temporal means. Spikes in exposure were generally not detected unless the Jerome was being used.

Response: EPA agrees that the use of sorbent tubes resulted in measurements that did not allow for the measurement of spikes in exposure. The Jerome Mercury Vapor Analyzer was included in the study design to identify spikes in exposure; unfortunately, problems with the Jerome data-loggers prevented the study team from collecting Jerome data for every device at every location. In general, the Study was designed to measure worker exposure during device operation; this evaluation was best served by collecting samples that were a temporal average of mercury concentrations that the operator of a DTC device would be exposed to under test conditions.

Steven Lindberg's Comment: Swipe samples are never quantitatively defined (surface area wiped, duration of wipe, composition of solvent, etc). Why were the pre/post swipe samples not collected at the same locations? How can they be quantitative? The extreme variability reflects these problems. The statement at the end of p. 29 regarding replicate sampling is wrong. Upon encountering high variability, one should attempt to increase the number of replicate samples, not decrease it.

Response: The wipe samples were moved from the main report to Appendix F in the revised report. The method for collection and the wipes used for sampling (Clorox® Wash N Dri) are described in greater detail in the revised report. The reviewer is correct in noting that the number of replicates should have been increased instead of decreased to account for sample variability.

Steven Lindberg's Comment: Was any attempt made to sample the air in the drum headspace? The elevated concentrations one would expect to find there suggest a considerable Hg pool, unless the volume was very small.

Response: The air in the headspace of the drum was tested during EFT #1 and EFT #2 using the Jerome Mercury Vapor Analyzer. The results are given in Chapter 4.

Carl Herbrandson's Comment: It would be helpful to include, in the section on wipe samples and perhaps in the section on study limitations, some discussion of the Hg permeability of polyethylene. Hg can permeate through polyethylene. Polyethylene cannot be used for taking water-Hg samples because the water will take up some Hg from air, through the container. Does a wipe sample from the polyethylene containment wall take Hg that has permeated the material? Does it only take Hg that is oxidized, complexed or bound and cannot pass through the material? Or is it likely that this permeability is not significant enough to affect these data?

Steven Lindberg's Comment: The choice of polyethylene film was also a serious flaw. Most people experienced with sampling for Hg in air are aware of the well-known ability of Hg vapor to both penetrate through and sorb onto polyethylene, rendering any conclusions regarding the behavior of Hg within these enclosures highly uncertain and subject to considerable error. It is difficult to understand why these problematic approaches continued to be applied for so long before drawing attention.

Michael McLinden's Comment: Plastic absorbs mercury vapor, might this bias your results low due to Hg absorbtion by the plastic? It would have been helpful to collect a bulk sample of polyethylene before arriving at the facility to set up the containment and a bulk sample of the plastic containment wall just prior to dismantelling to see how much Hg was absorbed by the plastic.

Response: EPA agrees that use of polyethylene most likely biased the measured mercury concentration in the air samples and in the wipe samples due to mercury's ability to permeate through and sorb onto polyethylene. Vinyl sheeting would have most likely been a better choice of materials for the containment structure. This issue is discussed in Chapter 6 in the revised report.

Michael McLinden's Comment:

Report Text:

Bulk samples were collected from the particulate filters and carbon filters for each device at the following frequencies:

Comment (Suggested Text Changes Highlighted): Bulk samples were collected from the particulate filters and carbon filters for each device using the following procedures:

Response: The wording was changed as suggested. The description of the collection of samples from the pollution control media for each device was moved to Appendix H in the revised report.

Michael McLinden's Comment: Were any bulk samples collected and analyzed prior to the start of Phase I to detect background Hg contamination of the filter media (similar to hydrar Hg background contamination)?

Response: Blank samples of the pollution control media were taken and analyzed. The results are presented in Chapter 5. There was some background mercury in some of the pollution control media, but the mercury levels were quite low.

Michael McLinden's Comment: Please elaborate on what this "mercury absorbing powder" [*that was used to decontaminate the sampling spoons prior to* use] is.

Response: The "mercury absorbing powder," a product called "Hg-X," is described in the revised report. Hg-X reacts with elemental mercury to form HgS, a reaction that occurs readily under ambient indoor conditions.

Michael McLinden's Comment: Please elaborate a bit more on the condition of Manufacturer D DTC and any damage or modifications made to the device by the manufacturer. Sections 4.2.1 and 4.3.1 both give a bit more information but it is difficult to visualize the condition of the device and possible reason for such poor performance.

Response: Information about the problems with the Manufacturer D DTC device can be found in Section 3.5.3 and Appendix I of the revised report. There is a more detailed description than that presented in the draft report

Data Presentation and Evaluation

After reading the comments from the reviewers, EPA determined that the draft report contained insufficient data analysis. In order to answer many of the questions posed by the reviewers, the data collected during the DTC Device Study were reanalyzed, and the discussion of the data was expanded. Two significant changes to Chapter 4 of the report were the addition of background and blank data to this chapter (initially, this information was only presented in Chapter 8: Limitations) and the use of simple statistical comparisons, whenever possible, to evaluate study objectives.

Michael McLinden's Comment: I agree with your conclusion [regarding whether the OSHA PEL is a ceiling or TWA], however, the regulated community will most likely disagree. The Ceiling limit is more difficult to comply with since a short (15 minute) excursion above the ceiling would indicate an over-exposure and violation where as when calculating the 8 hr TWA for the PEL a short excursion would be averaged out over the eight hour shift resulting in no violation. Critics will discount the argument that the PEL has been exceeded arguing that OSHA policy and intent is to enforce the standard as an eight hour TWA. It may be wise to also present a calculated/estimated 8 hr TWA based on Jerome readings. Either extrapolate to 8 hrs using an "average" Jerome Hg reading thought to be representative of the entire 480 minute workday or calculate the concentration (C1) during the actual duration of Jerome sampling (T1) and add to background dose (C2) for the remainder of the shift (T2).

$$8\text{ hr TWA} = \frac{C1\ T1 + C2\ T2}{480\text{ minutes}}$$

Response: The OSHA exposure limit for mercury is published in the CFR as a ceiling limit, so the PEL was treated as a ceiling limit for the purposes of this Study. It would be inappropriate for EPA to comment on the discretion that OSHA uses or may use when implementing its own regulations. Also, there is not sufficient Jerome data to perform TWA

calculations for each device. EPA did not extrapolate the data to 8 hours because of the potentially widely varying use patterns for DTC devices.

Michael McLinden's Comment: FYI while the TLV is an 8 hour TWA over a 40 hour week, the REL is a TWA based on a 10 hr workday in a 40 hr week to allow for extended work shifts such as overtime). Recommended exposure level (REL) should be recommended exposure limit.

Response: The REL was not used for evaluation in the Study, so the description of the REL was removed from the revised report.

Steven Lindberg's Comment: Background values are often mentioned, but rarely defined as to location. It is never quite clear how any "background or blank" data were treated. What is the meaning of values such as 0.0059/0.014 in Table 4.18? Are these reps? Is this a range? Was N=2?

Response: In the revised report, there is a more complete discussion of blank and background samples in both the data collection section (Chapter 3) and the results section (Chapter 4). The table is not in the revised report. The results for the background air samples can be found in Table 4.1 and Table 4.2.

Carl Herbrandson's Comment: Discussion of the implications of the vapor phase and aerosol data would be helpful. Does the very low level detected in only 7 of about 177 MCEF samples suggest that only Hg vapor is emitted from the DTCs? Or is Hg aerosol that sticks to the MCEF volatilized by the sampling vacuum pump? Does this study help to answer these questions? Should future studies assume that there is no aerosolization?

Response: The draft report did not discuss the low number of the MCE filter samples that had detectable levels of mercury. The revised report contains the following discussion to address this:

> It is important to note that, out of the 199 analytical air samples collected, only eight mercury aerosol (MCE filter) samples had values above the detection limit, and all blank MCE filter samples were below the detection limit. Because the amount of mercury aerosol was not high enough to measure, the air results discussed in this chapter only address the mercury vapor (Hydrar tube) samples. The results for the MCE filters can be found in Appendix A, Table 1. Future research may be necessary to determine whether aerosols were not detected because no aerosolization occurred or because any aerosol mercury collected on the MCE filter was vaporized by the sampling vacuum pump and subsequently sorbed onto the Hydrar tubes.
>
> **(footnote 12, pg. 21)**

The DTC Device Study was not designed to answer the questions posed by the reviewer. EPA agrees that these questions are important and that could be considered for future study.

Steven Lindberg's Comment: Comparisons with the Jerome are mentioned, but never discussed in detail or presented quantitatively. Was there a systematic approach to performing a method intercomparison? It would have been useful to see overlain plots of the Hydrar and Jerome data for periods both were used at the same location. The data

"comparison" is inadequate for evaluation of the validity of the airborne Hg data (see above). The only mention of the results of any method comparisons on p. 58 is inadequate ("analysis of Jerome...indicate a similar pattern..."), especially given the objective of the study (to evaluate performance, to quantify emissions, mass balance determination, etc.). The numbers of replicate samples collected was similarly inadequate.

Response: In the revised report, averages of the Jerome data and the analytical air sample (Hydrar tube) data were graphed together to better facilitate comparison of the results from the two air sampling methods. The Jerome data was not complete (due to the malfunctioning data loggers) and did not include enough sampling events to create an overlay plot or to justify statistical comparisons between the two types of data. The language in the report has been revised to reflect the fact that no quantitative comparisons between the Jerome data and the Hydrar data were made. Graphical comparisons of the data are presented in Appendix A, Figures 26, 35 and 43, of the revised report.

As noted above, the study design did not call for replicate testing because one of the basic assumptions of the Study was that there would be changes in device performance over time. Multiple air samples were collected for each device during each test.

Michael McLinden's Comment: After being in the containment for such a long time I'm supprised the gold foil [*on the* Jerome] didn't get overload/over-ranged. Did you have any "over-ranging" problems which necessitated purging the foil??

Response: The model 431-X Jerome analyzer has an improved film regeneration circuit, which makes the sensor last longer than earlier models. When the sensor became saturated while the Jerome analyzer (model 431-X) was attached to the data logger or computer, the analyzer automatically regenerated the sensor and then resumed sampling. The Jerome graphs in Appendix A note when the Jerome was regenerating.

Michael McLinden's Comment: Why were the results inside containment lower than TLV while results outside containment were occassionally above the TLV? – is it due to data logger failing and no data gathered? Which Jerome data-logger failed? Please clarify.

Response: The results inside the containment structure that were lower than the TLV were collected at a different time than the results outside the containment structure that were above the TLV. Thus, there is no data suggesting that the mercury concentration was higher outside the containment structure than inside the containment structure at any point in time. These different Jerome analyzer readings do show that there was variability in the mercury levels. This is clearer in the revised report. Both Jerome data-loggers failed at different points during the Study.

Steven Lindberg's Comment: The statement on p. 47 "as measured by the ambient airborne emissions" is in error. There were no measurements of emissions performed in this study, only estimates based on concentration data.

Response: The report has been revised to make it clear that emissions were not measured.

Michael McLinden's Comment: What size & wattage lamps were processed in Phase II, T-8, T-12? You provide the number of lamps but not the number of each size lamp and wattage of each lamp processed as you did in Table 4.1. In Phase II did you use all Phillips Lighting "Alto" lamps? If you used lamps other than Phillips "Alto" you would have processed more mercury, also if you processed larger lamps you would again process more mercury (in Phase I Manufactruer B device processed 611 T-8 lamps). This seems more likely to contribute to higher phase II result than the higher Phase II background levels.

Response: There were not sufficient Phillips Lighting "Alto®" lamps for use in PVS-II. Because the waste lamps were from different manufacturers, and therefore did not contain a standard amount of mercury, the types of waste lamps processed were not recorded during PVS-II. The possible effects of crushing waste lamps other than Alto® lamps could have impacted the results during PVS-II, and the possible impacts are discussed in the revised report.

Michael McLinden's Comment: Were these low results [*in PVS-phase* I] due to colder temperature resulting in less Hg being volatalized ?.

Response: The temperature most likely had some affect on the amount of mercury that was volatilized during the different parts of the Study; although, this could not be quantified. This is discussed in Section 6.2 of the revised report.

Carl Herbrandson's Comment:

- Location of background, TLV and/or PEL lines on figures 4.2; 4.3, 4.4 and 4.5 aren't at the correct locations. (no background line for Fig 4.1) Similarly, these lines in Appendix A don't always line up right.
- Table 5.2 – Is the "measured mercury" the "average mercury quantity"? Aren't you really reporting the mean of the measured values? Means and averages are confused in this table and others (e.g. Table 5.5).
- %CV is more informative than Std Dev in many of the tables, especially where the means have large ranges (e.g. Table 5.5). What, actually, does the "Standard Deviation" in Table 5.8 describe? This standard deviation may provide some (poor) measure of the mixing between a few locations in the containment area, but still, this column should be omitted. The column contains the standard deviation of measurements that are not realistically comparable. Each measurement describes a unique volume of the containment area. It isn't known if the air at these various locations was moving or quiescent, or if the volume that the concentration described was large or small.
- Appendix A, Table 2-5 label box described as "% valid data" should be renamed something like "% locations with increase".

Steven Lindberg's Comment:

- The term NA is not defined or explained (why not analyzed, or not attempted, or not applicable?).

- The % difference numbers in Table 4.6 are in error based on the definition of the validation (if the Phase II results are > Phase I, the differences would normally be expressed as + values, not -).
- Table 4.9 would have benefited by an inclusion of the corresponding Hydrar trap data.
- Several tables express data with a greater number of significant digits than are justified.
- Several tables show ranges in data, but means and SD would also be useful.
- The Figures (here and in App's) are inconsistently labeled.

Michael McLinden's Comment:

- TABEL ENTRY [*Table 4.6*]: MANUFACTURER C, On Operator during Filter Changes -118%/105% Should 105% be a negative number?

Response: There were several errors on the labels for the figures and tables throughout the draft report. These errors have been corrected, and the titles for the figures and tables have been changed to provide a more detailed description of the data being presented.

- The PEL and TLV lines were corrected for all figures, and lines for background concentrations were added.
- The "average mercury" actually is the calculated mean. The labels in the tables were corrected. Standard deviations were calculated to describe many means, but this statistic is only presented if it is valid for the measurements being averaged.
- The column describing "% valid data" was removed from the table in Appendix A.
- All notations in tables, such as NA or ND, are now defined in the revised report.
- The % differences column was deleted from Table 4.6 (Table 4.9 in the revised report). Other statistics were used to compare phase I and phase II of the PVS.
- Averages of the Jerome data and the analytical air sample (Hydrar tube) data were graphed together to better facilitate comparison of the results from the two air sampling methods.
- Means and standard deviations are included wherever these descriptive statistics are appropriate and valid.

Michael McLinden's Comment:

Report Text:

As noted in the table, the Hydrar sorbent tube appeared to capture a greater amount of ambient mercury during the sample acquisition period (i.e., when the sample pump was in operation). Furthermore, two of the operator breathing zone samples (one for the Manufacturer C and one for the Manufacturer B) equaled or slightly exceeded the PEL. **The remaining results** for both devices **were above the TLV** and below the PEL. No U-tube tests were performed using the Manufacturer A or Manufacturer D devices. ***Comment:*** In Table 4.19 the results for "Manufacturer B, Operator's right shoulder" indicate 0.018 mg/m3 which is lower than the 0.025 mg/m3 TLV.

Response: The text was corrected to reflect the fact that one of the operator shoulder samples for Manufacturer B was below the TLV. The table is not in the revised report (air sampling results can be found in Appendix A, Table 1).

Carl Herbrandson's Comment: Wipe sample results should be reported as µg/100 cm^2, not µg/sample.

Steven Lindberg's Comment: Was any attempt made to wipe the insides of the drums to determine the sorbed Hg? Was wipe efficiency/extraction/analysis ever determined with knowns? Was the parking lot "wiped" to determine if this approach was an improvement? The other problems with the study design mentioned above would still apply however.

Response: Due to difficulties with contamination, the wipe sample data was not used in the report to support any of the findings or observations; therefore, wipe sample data is presented in Appendix F in the revised report, instead of Chapter 4. The wipe sample results are reported as $\mu g/100cm^2$ in the revised report in Appendix F. The insides of the drums were not wiped. The wipe sample extraction method was developed by Data Chem as a NIOSH method and has been tested by Data Chem. The parking lot was not wiped, and there is no evidence that the change from cutting the polyethylene on the facility floor to cutting the polyethylene outside in the parking lot decreased contamination of the plastic sheeting.

Carl Herbrandson's Comment: Manufacturer A's device was run in ventilation mode throughout the course of the tests – including over night. Is it possible to estimate the mass of overnight emissions from available data? While these emissions are likely to be only a small fraction of the overall emissions for B and C, it is unclear what fraction of A's emissions occur in the ventilation mode.

Response: The data collected for overnight samples is shown in the revised report in Figure 4.15: Overnight Test Sample Results (pg. 63). There is not sufficient data to estimate the mass of overnight emissions.

Steven Lindberg's Comment: The problem of atmospheric contamination ("background") due to broken bulbs in bulb boxes should have been anticipated, or at least recognized sooner. The "box test" is not clearly defined until after the data are presented.

Response: EPA agrees that a more thorough review of the sampling and study plan by researchers more experienced with mercury monitoring would have been beneficial to the study team. The study team added the "Box Test" to the Study in order to quantify the atmospheric contamination due to broken bulbs in bulb boxes; the revised report more clearly defines the Box Test.

Michael McLinden's Comment: Can you elaborate on what happened [*in Figure 4.6*] during the 6^{th} minute and again at the 28^{th} minute to explain these spikes? Was the spike at the 6^{th} minute due to handling and opening the top of the boxes? Also, can you explain why the concentration levels off from about the 8th minutes to the 19^{th} minute but then begins a steady rise? Was the DTC in operation at any point during the test (e.g., from the 8^{th} to the 19^{th} minute) to influence the results shown in Figure 4.6? It may be helpful to explain the box test in more detail, this data alone may have important implications regarding Hg concentrations in and around storage locations of spent/broken lamps in general industry as

well as at lamp recycling facilities. Were the air sampling results collected with the Jerome or with sampling pumps?

Response: There is not sufficient data to speculate about the cause of the spikes in measured mercury concentration in Figure 4.6 (Figure 4.14 in the revised report). There is a general increase in the ambient mercury concentration, which may be due to mercury release from the broken lamps in the boxes; however, there is not enough data to fully substantiate this hypothesis. The DTC device was not operated during the box test. The air sampling results for the box test in Table 4.17 (same table number in draft report and in revised report) were collected using the Hydrar tubes and sampling pumps.

Steven Lindberg's Comment: The phrase "outside the containment" is used, but never defined specifically. Some observations seem trivial (e.g. that the Hg sorbent is more efficient when the pump is running).

Response: The phrase "outside the containment" generally referred to the area that was not inside the containment structure but was inside the room in the facilities in which the Study was being conducted. Wherever possible, the revised report specifically describes the locations "outside the containment" where samples were taken.

Mass Balance

One of the questions posed to the peer reviewers by EPA concerned the validity of the discussion of the error associated with the Mass Balance Study. The reviewers generally commented that the amount of uncertainty in the Mass Balance Study was too high to draw any conclusions from that portion of the Study. Therefore, the revised report concentrates on presenting the data collected during the Mass Balance Study, explaining the difficulties encountered during the Study, and providing suggestions for future mass balance studies involving DTC devices.

Carl Herbrandson's Comment: The tenor of the mass balance discussion should be changed to focus on why available data can't provide the necessary information for a mass balance. Estimates and calculations should not be reported. A mass balance would be useful for determining the fraction of fluorescent bulb mercury that escapes into the environment from DTCs. However, even as a range estimating tool, this mass balance is not instructive.

Steven Lindberg's Comment: The issue of quantitative uncertainty must be addressed for all of these measurements. This is especially true for the mass balance. The uncertainties and assumptions of the mass balance computations must be clearly stated. A serious and critical assessment of uncertainties involved in this particular study might indicate the impossibility of drawing any quantitative conclusions.

Response: EPA agrees that the uncertainty in the Mass Balance Study is too high to estimate the different fractions of mercury. The discussion of the Mass Balance Study was revised to present the data collected, the calculations, and the problems encountered. While the high degree of uncertainty does limit the types of analyses that can be performed to evaluate the study results, the data were collected in the field under conditions that were as close to a

probable management scenario as possible. The revised report acknowledges the limitations of this set of data.

Michael McLinden's Comment: I agree with your decision not to use Jerome readings for this portion on the study [*Mass Balance Study*].

Michael McLinden's Comment: Hgu [the amount of mercury captured by the device] missing the amount of Hg adhering to the inside of the DTC device. Hg may have been bound to interior metal and plastic parts of the DTC, this may lower your recovery. Mercury may have been absorbed by plastic containment, lowering your Hgr [the amount of mercury released by the device] result. It might have been wise to collect a pre and post bulk sample of the plastic containment.

Response: These factors are discussed in the revised report in Chapter 5 and Chapter 6. (Note: Hg_U was changed to Hg_C in the revised report. Hg_C is the amount of mercury captured by the device.)

Steven Lindberg's Comment: How much Hg was added to these lamps during manufacturing? The amounts analyzed seem low, depending on date of manufacture.

Response: Table 5.1 in the report lists the amount of mercury added to each type of lamp. The Phillips Lighting Alto® lamps are specifically manufactured to avoid adding excessive amounts of mercury by precisely dosing each lamp.

Carl Herbrandson's Comment: The study design optimized the ability to measure potential exposure concentrations, not the mass emitted from the DTCs. These are two very different goals and require different tools. Attempts to calculate the mass emitted from many different air-Hg concentrations assumes each sample location represents a volume of air in the containment area that is characteristically similar to the other sample locations in: virtual volume, air flow, mixing, replacement rate (or containment area input rate) and removal rate (or containment area exhaust rate). It is likely that each measurement location was very different, and weighting of individual sample results would be necessary to calculate a reasonable emission rate/mass – an impossible task given the study design.

Steven Lindberg's Comment: Why was no attempt made to estimate the gaseous loss based on the air concentration measurements?

Response: EPA recognizes that the Mass Balance Study was not properly designed to achieve the goals stated in the study plan. Mercury emissions were not measured during the DTC Device Study. The air concentration data was used to estimate the amount of mercury released; however, because the study design was not optimal for precise measurement of mercury emissions, there was a significant mass of mercury unaccounted for.

Steven Lindberg's Comment: Given the uncertainties in all the raw data, the SD's shown in Table 5.8 seem much too low. What do they represent?

The number of air exchanges was never measured, but can have an important effect on the calculations. How was this evaluated?

Michael McLinden's Comment: Looking at Figures 27 and 28 in Appendix A it indicates that it took over four hours to fill two drums. Two air changes seems very low for this time period. Making an air tight containment, even sealing plastic with duct tape, is difficult to achieve as demonstrated in asbestos abatement containments which are similar in design and generally tighter than your containment. I suspect you are under estimating the air changes and under estimating fugitive emissions through the door and walls of the containment.
As per Appendix C, [*Manufacturer A*] Drum Top Crusher process description - the fan draws 25 CFM:
25 CFM = (1,440 CF) / (57.6 Minutes)
One Air Change in Minutes = (CF) / (CFM)
(1,440 CF) / (25 minutes) = 57.6 Minutes for one air change
(60 minutes) / (57.6 minutes) = 1.04 Air Changes per hour
(1.04 ACH) X (4 hours) = 4.16 Air Changes over the four hour it takes to fill two drums.
Please elaborate on how you estimated the number of air changes.

Response: The averages shown in Table 5.8 of the draft report were the averages of the air samples from the Performance Validation Study – Phase I. This portion of the Study had the lowest amount of variability between the air samples. The standard deviation is no longer included in this table.
Table 5.8 now includes the data used for the calculation of the number of air exchanges, in addition to the values for the amount of mercury released from the devices.
In the draft report, the numbers of air changes were estimated based on general knowledge. In the revised report, the volumetric flow rate of the DTC device fan was used to estimate the number of air exchanges, following the suggestion of one of the reviewers.
The Mass Balance Study only involved filling one drum per device, so the duration ranged between 86 and 112 minutes. The calculations used to estimate the number of air exchanges for each device are explained in Chapter 5 of the revised report.

The assumption that the Manufacturer A device released a similar amount of mercury as the Manufacturer B and Manufacturer C devices is based on the calculations described in Chapter 5. While this assumption is most likely not correct, additional attempts were not made to correct the estimate for Hg_R because the amount of mercury estimated as being released was very small as a percentage of the total mercury processed through each DTC Device (Hg_R).

Carl Herbrandson's Comment: Problems in estimating barrel content. These problems are well documented in the report and appendix.

Response: As discussed in the limitations section (Chapter 6), the phosphor powder, which tends to contain the largest fraction of the mercury in the drum, sifts to the bottom due to the vibration of the drum in operation. Therefore, any sample taken from a full 55-gallon drum of crushed lamps would likely not be representative of the contents of the drum. Based on

such a sample, a determination, that the waste contained in such a drum is not hazardous, may be questionable.

Steven Lindberg's Comment: I could not find any blank data for the contents and components of the DTCs.

Michael McLinden's Comment: New drum filters may be contaminated with background Hg, did you test a filter for backgound?

Response: The blank data for the components of the DTC devices were presented in Table 5.11 in the draft report. These data are presented earlier in Chapter 5 (in Table 5.6) in the revised report.

Steven Lindberg's Comment: Detailed method descriptions for obtaining representative samples of any substrate are lacking.

Response: The description of the collection of samples from the pollution control media of the DTC devices is included in the revised report in Appendix H.

Carl Herbrandson's Comment: Problems with measuring filter/carbon content (e.g. high %CV in carbon samples implies non-uniform capture and poor capture/mass estimate).

Carl Herbrandson's Comment: Errors on the order of 2400, 1100 and 1800 times the estimated mercury vapor emissions; 2, 0.5 and 2 times the calculated barrel contents; or 18, 0.9 and 78 times the calculated filter/carbon mercury could account for the discrepancies in the quantitative mass balance. There is no apparent consistency to the possible error.

Steven Lindberg's Comment: Given the gross differences among the activated C weights used in each DTC, the conclusion that Mfg A device "released" about the same amount of Hg as DTC's B & C seems in error.

Carl Herbrandson's Comment: Jang et al. Waste Management 25 (2005) 5–14 showed a maximum of 36% recovery with an acid extraction of Hg from fluorescent bulbs. Can additional mercury can be released from the bulbs by heating them (part of QA/QCing the methods?)? (This could increase the discrepancy in the attempted mass balance.)

Steven Lindberg's Comment: Did the team attempt to test the method for measuring Hg in lamps? Although some Hg may condense, quantitative condensation seems unlikely.

Response: The study team did not test the method for measuring mercury in spent lamps. The values measured in the spent lamps were slightly lower than the amounts of mercury reported to be added to each Phillips Lighting, Alto® lamp as discussed in Section 5.2 and shown in Table 5.1 and Table 5.2 of the revised report. A reference to Jang et al., 2005 is also included in Section 5.2. Additionally, at the end of Chapter 5 of the revised report, EPA suggests that any future research quantifying the amount of mercury in spent lamps should develop and test a laboratory method with appropriate QA/QC procedures.

Steven Lindberg's Comment: The recovery data in Table 5.11 suggest serious analytical problems which could have influenced much of the other data. Where are similar data for the other sample types and analytical methods?

Response: The recovery data in Table 5.11 for the matrix spikes of the pollution control media do suggest serious analytical problems. These data were presented to help explain the problems with the mass balance. Data Chem Laboratories followed the appropriate QA/QC described in the analytical methods, which are included in Appendix E of the revised report. All QA samples met the criteria specified by the test method being used. The Data Chem Laboratory reports are included in Appendix B.

Operator Observations and Safety Concerns

Steven Lindberg's Comment: Statements made here, and elsewhere, refer to data which are not clearly identified as to their source (Table or Fig. #).

Response: The reviewer did not list specific instances in which data were not clearly identified; however, in the revised report, the actual table and/or figure numbers were included whenever a reference was made to specific data.

Michael McLinden's Comment:

Report Text:

Lamp breakage was a common issue for all devices. The fragile lamps often broke before they could be fed into the devices, causing, in some instances, visible release of mercury-containing phosphor powder. The ergonomic orientation of the feed tubes on several devices also exacerbated this problem, where, for example, the operator either had to lower the lamps to waist level or raise them up to shoulder level in order to insert them into the feed tube.

Comment: I'm not sure ergonomic is the best/correct word for this situation.

Response: "Ergonomic" was changed to "configuration". **[pg. 86]**

Lessons Learned

Steven Lindberg's Comment: One is left with the impression that the study and sampling design was compromised to decrease costs.

Response: As discussed above, the study team made every effort to carefully collect field data that represented possible mercury exposures associated with DTC device operation. The primary concern in designing and conducting the DTC Device Study was to assess the performance of the four DTC devices tested with regard to operator exposure, and concerns about the cost of the testing were secondary to completing the objectives of the Study. Nevertheless, EPA recognizes that certain decisions made regarding the design of the Study do present problems in analyzing the data.

Limitations

Steven Lindberg's Comment: A statement such as "each facility had a measurable concentration of mercury in ambient air" misrepresents the severity of existing and ongoing contamination encountered during this study, and the degree to which this problem compromised this study and its conclusions. Blanks defined as containing "trace amounts of Hg" but in actuality containing microgram amounts of Hg are also misleading.

Response: The two statements commented on by the reviewer, as well as several other statements on the same topic, were changed in the revised report to better emphasize the degree to which background mercury levels may have impacted the study results. Background mercury concentrations are discussed in Chapter 6 of the revised report.

Steven Lindberg's Comment: Many comments in this section indicate that a thorough design evaluation should have been conducted prior to the study. Surely, some, if not many, of the problems encountered in the field could have been anticipated.

Response: EPA agrees that a review of the original study design by researchers more experienced in mercury sampling would likely have lead to an improved study design.

Steven Lindberg's Comment: Given the degree of variability noted in many of the samples, the assumption that each milliliter of air contains approximately the same concentration of mercury as the adjacent milliliter seems subject to large uncertainty.

Response: The analytical air samples collected thousands of milliliters of air under several different operating and non-operating conditions. These data provide information about possible worker exposure to mercury, as opposed to the specific concentration of mercury in each milliliter of air.

Steven Lindberg's Comment: The data in Table 8.3 should include the appropriate statistical summaries. These data do not support the conclusion drawn below the table regarding concurrence between lab and field blanks (e.g. data from 3/26).

Response: Table 4.4 contains the field blank data. This data was moved to Chapter 4 so that the blank data and the air sampling data could be discussed together. The averages and standard deviations are now presented with these data.

Michael McLinden's Comment: I agree with your conclusion, sample volume is the critical value for calculating concentration, flow rates need to be within the range specified by the analytical method.

Response: The discussion as to whether variations in air sampling pump flow rates may have affected the study results was removed from the revised report.

Conclusions and Recommendations

Carl Herbrandson's Comment: Data from this study shows: high mercury vapor concentrations in existing facilities; high levels of removable (trackable) mercury on floors of existing bulb recycling facilities; and, high mercury vapor concentrations near bulb-transport boxes containing broken bulbs. These data suggest that bulb transport containers and currently operating recycling facilities should be studied for ways to improve their mercury retention and control.

Response: This is an area where further study would be helpful. Some of these topics where included in Section 7.4 (Future Areas for Study).

Steven Lindberg's Comment: As discussed above, the application of any, much less several, correction factors adds significant uncertainty in any conclusions drawn from these data. This results in an inability to draw firm conclusions in my opinion. The study should have encouraged support for the design of improved DTC's, as those tested left much to be desired. The misinformation on Hg included in the manufacturer's manuals should also have been noted.

Response: The correction factors applied to the mass balance data are no longer included in the main body of the revised report. This information is included in Appendix G. The uncertainty associated with the data does limit the information and knowledge that can be drawn from this study; however, a significant amount of relevant information was gained in performing this study. The discussion presented in the revised report was written to provide information about DTC device performance. The report is not a guidance document; however, it provides observations noted in conducting the Study.

Michael McLinden's Comment: Venting outdoors would defeat the purpose of using the DTC device to control emission, suggest venting to a pollution control device rather than simply to outside air.

Response: The revised report does not suggest venting outdoors. The Study was not designed to make specific recommendations or determinations about the most appropriate ventilation for a room in which a DTC device is operated.

Appendices

Steven Lindberg's Comment: As mentioned above, these tables and figures relate poorly to the text, carrying in many cases different and undefined labels compared to comparable items in the main text. There were also no captions. Several experiments are illustrated here which are never described elsewhere (e.g. real world tests).

Response: The tables and figures in the appendices were extensively revised in the final report, including adding captions, to make them clearer and more consistent. The use of terminology such as "real world tests" was removed. The names used for the study

components in the original sample and study plan (now contained in Appendix D) were not the names that were used in the report. These inconsistencies have been corrected.

Steven Lindberg's Comment: The scale chosen for the Y axis (Hg concentration in mg/m3) would have been more readable if converted to ug/m3.

Response: The units of mg/m^3 were chosen for the y-axis of the graphs because the OSHA PEL is reported as $0.1 mg/m^3$.

Steven Lindberg's Comment: The Jerome data were buried in the appendices, with no discussion, despite the capture of several interesting temporal trends in airborne Hg. Why were these never compared directly to the Hydrar data?

Response: In the revised report, wherever possible, the Jerome data were highlighted, discussed, and compared to the Hydrar data. Due to problems with the data loggers, there were significant gaps in the Jerome data, making the uncertainty of the data too high to make quantitative comparisons.

Michael McLinden's Comment: Appendix C – initial paragraph and paragraph below Table AE both reference "the mass balance equation in section 6.0," perhaps this should be Section 5.0.

Response: The discussion regarding the sampling errors and corrections for the Mass Balance Study is now in Appendix G; references to the Mass Balance Study in Appendix G were corrected in the revised report.

Steven Lindberg's Comment: Finally, Appendix D titled Data Chem Methods was blank.

Response: There was an error in distributing the report, and Appendix D was not included in the draft report received by the reviewers. All of the analytical methods and any modifications are included in Appendix E of the revised report.

Mercury Lamp Drum-Top Crusher Study Peer Reviewers:

- Carl Herbrandson, Ph.D., Minnesota Department of Health
- Steven Lindberg, Ph.D., Corporate Fellow Emeritus (retired)
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1996 – present ***Research Scientist 3***, Minnesota Department of Health, St. Paul, MN

- Toxicologist and Health Assessor for Site Assessment and Consultation Unit, a cooperative partner grantee of the Agency for Toxic Substances and Disease Registry, Center for Disease Control, Atlanta GA
- Review health hazards and risks associated with exposure to chemicals in the environment; evaluate data and conduct health assessments; model potential human exposures; investigate biomarkers which may indicate exposures; and determine the likelihood of conducting successful exposure or health investigations.
- Focus is currently on complex multimedia evaluations with an emphasis on environmental chemistry. Two focus areas of work are fate, exposure and toxicity of heavy metals (primarily mercury and arsenic) and quantitative evaluation of the six potential routes of exposure to organic and inorganic compounds in sediments.
- Recommend sampling and remediation criteria for environmental media.
- Write technical evaluations of potential health impacts of environmental exposures to toxic chemicals for U.S. Agency for Toxic Substances and Disease Registry concurrence.
- Write public health information sheets for affected communities about potential effects of exposure to environmental chemicals and procedures for prudent avoidance or reduction of exposure.
- Represent the Minnesota Department of Health in meetings with responsible parties, state and federal agencies, in interviews with news media, and in interactions with the public.

1996 ***Research Associate***, University of Minnesota, St. Paul, MN

- Design and perform experiments to identify a sex pheromone from Eurasian Ruffe (*Gymnocephalus cernuus)*.
- Endocrine manipulation of fish reproductive cycle; extraction of steroids, prostaglandins and bile acids excreted by fish; *in vitro* receptor binding studies; and *in vivo* electrophysiological studies.

1992 - 1996 ***Graduate Research Assistant***, University of Minnesota, Minneapolis, MN

- Develop laboratory model for investigating toxicodynamic and toxicokinetic interactions of a chemical and a physical stressor on a whole organism in an aquatic environmental system.
- Thesis: Toxicological Effects of Suspended Solids and Carbofuran on *Daphnia magna*, Graduate School of the University of Minnesota, February 1996

1984 – 1991 ***Engineering Research Specialist***, Unisys, Eagan, MN

- Invented and developed a system for passively monitoring the growth rate of YIG crystals which are used as the active element in solid state magnetooptical switches and optical isolators.
- Designed and developed a system for mounting lasers into connectorized fiber optic packages while maintaining laser coupling efficiency into a 6 μm core over a 75° C temperature range.
- Designed and developed a computer automated station for testing superconducting tunnel junctions to be used as sensors.

Invited Lecturer/Instructor

2005 ***Seminar***, University of Minnesota Duluth Medical School: Toxicology/Public Health response to a recent mercury spill. Public health concerns coupled with an emergency response incident required rapid development of public health clearance criteria, modeling likely juvenile exposure, and development of new biomarkers of exposure.

2004 ***Grand Rounds***, Minnesota Poison Control System, Hennepin County Medical Center: Rosemount Woods Mercury Incident. The behavior of a chemical in the environment is important when evaluating exposures and undertaking a successful cleanup.

2004 ***Grand Rounds***, Regions Hospital Department of Emergency Medicine: Rosemount Woods Mercury Incident. Problems related to understanding chemical exposures during an emergency incident: biomarkers, kinetics, analytical issues, and people.

2004 ***Grand Rounds***, University of Minnesota School of Public Health: Public Health and a mercury spill. The responsibility of public health experts in an emergency is to support local officials, communities and medical practitioners.

2003 ***Guest Lecturer,*** Toxicology Program, University of Minnesota Graduate School: Toxicology in State Government. When and how we evaluate exposures and assess health.

2003 ***Guest Lecturer,*** University of Minnesota School of Public Health: Mercury. The environmental chemistry of mercury: sources, exposures, fate and toxicity.

2003, 2001 ***Guest Lecturer,*** Toxicology Program, University of Minnesota Graduate School: Aquatic Toxicology. An introduction to chemicals in the aquatic environment and how they affect aquatic species.

2002 ***Guest Lecturer,*** University of Minnesota School of Public Health: Mercury and Arsenic - two toxic heavy metals. How do they behave in the environment and why are we concerned about them?

2001 ***Grand Rounds,*** Minnesota Poison Control System, Hennepin County Medical Center: Mercury and Chromated Copper Arsenate. Presentation to poison control specialists, toxicologists and medical practitioners on the environmental chemistry, bioavailability, kinetics and toxicity of mercury and CCA. Included measuring mercury volatilization from the amalgam fillings of audience volunteers with a realtime mercury vapor analyzer and a discussion of the data.

2000 ***Invited Presentation,*** Minnesota Metal Finishers Association, Minneapolis, MN: Health concerns associated with metal finishing operations. A review of current epidemiology and toxicology related to aerosols and vapors emitted by metal finishing companies.

2000 ***Invited Presentation,*** Minnesota Environmental Health Association Annual Meeting, Brainerd, MN: Clandestine methamphetamine labs. A discussion of potential meth lab exposures and the cleanup criteria derived by the Minnesota Department of Health.

1999 ***Invited Presentation,*** Bi-National Forum Meeting, Thunder Bay, Ontario, Canada: Issues related to improving and assuring air quality. Air monitoring, dispersion modeling, chemical reactions in the troposphere, health effects, risk assessment and current regulations were discussed.

1996, 1998 ***Assistant Professor / Instructor,*** Department of Fisheries and Wildlife, University of Minnesota. FW 5460: Pollution Impacts on Aquatic Systems. Course was offered during the winter quarter every other year on the principles and experimental techniques for investigating the impacts of chemical pollutants in aquatic environments.

Presentations at ATSDR Partners in Public Health Meetings

2001 **Evaluating sediments at contaminated sites.** What do we know about the behavior of chemicals in sediments? How do groundwater and freeze-thaw cycles affect the integrity of large volumes of chemical wastes in sediments?

2001 **Are clandestine methamphetamine laboratories a public health concern?** Evaluating potential exposures to hazardous chemicals in Clan labs.

2001 **Air modeling or air monitoring?** While ambient air monitoring data are often requested by health assessors, dispersion modeling of stack testing data is typically more useful in evaluating potential hazards from facility emissions.

1999 **Weight of evidence in health assessments.** When quantitative health assessments cannot be performed it is often necessary to use a weight of evidence approach to qualitatively evaluate a potential public health hazard.

Peer reviewed / refereed publications

- Baker, B., C. Herbrandson, T. Eshenaur and R. Messing (2005). Measuring Exposure to an Elemental Mercury Spill — Dakota County, Minnesota, 2004. Morbidity and Mortality Weekly Reports 54(6): 146-149.
- Herbrandson, C., Bradbury, S.P., and Swackhammer, D.L. (2003). Influence of suspended solids on acute toxicity of carbofuran to Daphnia magna: I. Interactive effects. Aquatic Toxicology, 63(4):333-42
- Herbrandson, C., Bradbury, S.P., and Swackhammer, D.L. (2003). Influence of suspended solids on acute toxicity of carbofuran to Daphnia magna: II. An evaluation of potential interactive mechanisms. Aquatic Toxicology, 63(4):343-55
- Herbrandson, C., Bradbury, S.P., and Swackhammer, D.L, (1999) New Testing Apparatus for Assessing Interactive Effects of Suspended Solids and Chemical Stressor on Plankton Invertebrates. Environmental Toxicology and Chemistry, 18:4 679-684.

Selected, authored ATSDR Health Assessment Reports on mercury

2005 **Rosemount Woods mercury incident**. Report includes discussion of: decontamination; the need for exposure and medical screening during the incident; methods of evaluating individual exposures; the environmental chemistry of mercury; quality assurance and control issues related to the use of real-time mercury vapor analyzers; evacuation criteria; re-occupation criteria; vehicle clearance criteria; discussion on the clearance of personal property, and risk communication.

2003 **Drum-top bulb crusher demonstration at the Minneapolis-St. Paul International Airport**. Report reviews published information about mercury contained in and released from fluorescent light bulbs when they are discarded, as well as data acquired during a demonstration of a fluorescent bulb crusher. Regulatory restrictions on the use of this machine in Minnesota are discussed.

2003 **Onyx Special Services, Incorporated**. Report is a review of issues related to human health following attempts to cleanup a mercury recycling facility.

2002 **Chemically contaminated South Minneapolis residence**. Report reviews mercury vapor data acquired using hopkalite tubes (1998) and 2 different realtime monitors (2000, 2001) to evaluate indoor contamination in a house where an amateur chemist used many processes to reclaim precious metals from disposed products.

2001 **Mercury from a gas regulator spill**. Mercury in a low-pressure gas regulator was spilled in the basement of a residence. This report evaluates exposures that may have resulted from the spill and the cleanup.

2001 **Mercury in a Marine residence**. Report evaluates the potential exposures that may occur when thermometers (4) are broken in a home.

Steven E. Lindberg

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Education

Duke University	**B.S.**	1969	Chemistry
Florida State University	**M.S.**	1973	Chemical Oceanography
Florida State University	**Ph.D.**	1979	Geochemistry

Professional Experience

1971-1974	**Graduate Fellow**, Florida State University Department of Oceanography, Tallahassee.
1974-1986	**Research Associate and Staff Member**, Oak Ridge National Laboratory, Oak Ridge, TN.
1987	**Visiting Professor,** Institute of Bioclimatology, University of Göttingen, Germany.
1994	**Visiting Scientist**, Swedish Environmental Research Institute, Göteborg, Sweden.
1995	**Visiting Professor**, University of Stockholm and University of Lund, Sweden
1996-1997	**Visiting Scientist**, Institute of Hydrophysics, GKSS Fed. Laboratory, Geestacht, Germany
1995-*present*	**Adjunct Professor**, School of Public Health, University of Michigan, Ann Arbor, MI; Dept. of Ecology and Evolutionary Biology, The University of Tennessee, Knoxville, TN
1987-1999	**Senior Research Staff Member**, and Group Leader for Atmospheric and Biogeochemical Cycling
2000-*present*	**ORNL Corporate Research Fellow**, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN.
2002	**Visiting Scientist,** Institute of Ecosystem Studies, NY

Honors and Awards

- Alexander von Humboldt Foundation Fellowship Award, 1986-1987
- Elected Fellow, American Association for the Advancement of Science, 1992
- Lab-wide Publication and Technical Achievement Awards, 1985, 1986, 1997, and 2001
- Nominated for Ernest Orlando Lawrence Award, 1990, and ORNL Scientist of the Year, 2001
- American Men and Woman of Science, Who's Who in Science and Technology
- Environmental Sciences Scientific Achievement Award, 1984
- Oak Ridge National Laboratory Significant Achievement Awards: 1983, 1985, 1992, 1995

Professional Activities

- Associate Editor, Environmental Reviews, Science of the Total Environment, Tellus (Sweden)
- Member, Review Boards: EPA Science Advisory Board for Mercury, Swedish EPA Mercury Panel
- Chairman, International Conference on Mercury as A Global Pollutant, 1995-1996; 1999-2001
- Director for Atmospheric Research, Integrated Forest Study, 1986-1990
- Chairman, United States National Atmospheric Deposition Program; 1988-1989
- Conference Chairman (1986-87) and Member of Conference Honorary Committee (since 1983) for the International Conference on Heavy Metals in the Environment

Publications

Six books edited, and over 200 publications authored in the open literature, with more than 110 in refereed journals in the fields of atmosphere/surface exchange, trace metal chemistry, and biogeochemical cycling. Invited lecturer or plenary speaker on atmospheric deposition, mercury, and canopy interactions at more than 100 institutes and conferences in North America, Europe, South America, and Asia.

Funded Proposals, Contracts, and Grants (with ORNL collaborators unless otherwise noted):

1970-1979

- 1975-1976, "Trace Element Emissions from Coal Fired Power Plants" (with A Andren). US Dept. of Energy (DOE) ($50,000).
- 1975-1976, "Geochemical Cycling of Hg in a River-Reservoir System" (with R Turner). NSF-RANN ($90,000).
- 1978, "Mercury Emissions from Mine Spoils" (with D Jackson). NSF-RANN ($75,000).
- 1977-1980, "Trace Element Deposition, Stream Chemistry, and Cycling in Forest Watersheds" (with R. Turner). US DOE ($1,000,000).

1980-1989

- 1981-1982, "Dry Deposition to Petri Dish and Foliar Surfaces" (with C Davidson, CMU). US Environmental Protection Agency (EPA) ($30,000).
- 1981-1983, "Acid Deposition/Forest Canopy Interactions: Mechanisms of Sulfur and Nitrogen Deposition to Forests." Electric Power Research Institute (EPRI) ($675,000).
- 1981-1984, "Atmosphere/Canopy Interactions: Wet Deposition and Rain Chemistry." US DOE ($900,000).
- 1985-1989, "Integrated Forest Study (IFS) of the Effects of Atmospheric Deposition on Forest Nutrient Cycles" (with D Johnson) EPRI (total project $11,600,000).
- 1985-1989, "Atmosphere/Canopy Interactions: Development of Surface Analysis Methods for Dry Deposition." US DOE ($920,000).
- 1987, "Deposition and Atmospheric Chemistry of Nitrogen Compounds" (with G. Gravenhorst, U. Gottingen). West German Federal Ministry for Technology and Alexander von Humboldt Foundation ($45,000).
- 1989, "Atmospheric Deposition and Red Spruce Nutrition in the Great Smoky Mountains National Park" (with D Johnson and H Van Miegroet). USDA Forest Service ($225,000).

1990-1999

- 1990, "A Soft Ionization Mass Spectrometer for the Simultaneous, Real-time Analysis of Biogenic Non-
- methane Hydrocarbons in the Forest Canopy Airspace" (with M Payne, W Chen, and P Hansen). ORNL Seed Money Committee ($100,000).
- 1990, "Integrated Forest Study of the Effects of Atmospheric Deposition on Forest Nutrient Cycles: Synthesis of Results." (with D Johnson) EPRI ($198,000).
- 1990, "Atmospheric Deposition and Red Spruce Nutrition in the Great Smoky Mountains National Park-Testing the Al Hypothesis" (with H Van Miegroet). USDA Forest Service (total project $235,000).
- 1990-1991, "Development of Methods for Network Sampling of Air Toxics in Precipitation" (with S. Vermette, ISWS) USGS ($70,000).

- 1991-1994, "Atmosphere/Canopy Interactions: Surface Analysis of Dry Deposition in Complex Terrain". US DOE ($700,000).
- 1992-1996, "Air/Surface Exchange of Mercury (MASE): Development of Flux Methods and Models". EPRI ($1,195,000).
- 1993-1995, "Elevational Trends in Deposition in the Smoky Mountains" (with S. Nodvin, USBS). NPS ($150,000).
- 1994-1995, "Aerosols at the Sea/Land Interface". (with B Wiman, U Lund) Swedish NFR (NSF) (30,000Kr).
- 1996, "Emission of Mercury from Freshwater Lakes". USEPA ($18,000).
- 1996-1997, "Emission of Mercury from soils in the Elbe River Floodplain". (with R. Ebinghaus, GKSS) German BMFT (15,000DM).
- 1996-1999, "Mercury Emissions from Wetlands in the Florida Everglades". South Florida Water Management District ($400,000).
- 1997-1998, "Mercury Fluxes and Exposure over Contaminated Industrial Soils". ABB Engineering ($32,000).
- 1997-2000, "Mercury Emissions from Landfills in Florida". Florida DEP ($190,000).
- 1997-2000, "Natural Mercury Emission Study (NaMES): Their Role in the Global Cycle". (with M. Gustin, UNR) EPRI (total project $580,000).
- 1997-2000, "Air/Surface Exchange of Mercury in the Lake Superior Watershed". Lake Superior Trust ($250,000).
- 1998-1999, "Intercomparison of Speciation Methods for Reactive Gaseous Mercury in Ambient Air". (with
- W. Stratton, Earlham College) Florida DEP ($20,000).
- 1998-2000, "Air Mass Trajectories of Mercury Transport in the Arctic Environment" (with T. Meyers, ATDD) NOAA ($100,000).
- 1998-2003, "Atmospheric Deposition in Mountainous Terrain: Scaling up to the Landscape". (with K Weathers and G Lovett, IES) USEPA and NPS (total project $580,000).
- 1999, "Pilot Studies with Stable Isotopes to Quantifying Air/surface Exchange Rates of Hg, USDOE ($280,000).
- 1999-2000, "Dry Deposition of Mercury in the Florida Everglades". (with G. Keeler, UMAQL) Florida DEP (total project $200,000).
- 1999-2000, "Emission of Mercury from Chlor-alkali Plants". (with J. Kinsey, NERL) USEPA (total project $200,000).
- 1999-2000, "Chlor-alkali wastes: Assessing their Role as a Mercury Source in the Great Lakes". (with J. Nriagu, UM) Great Lakes Protection Fund (total project $225,000).
- 1999-2000, "Evaluating a reactive gaseous mercury sampler for the Arctic". USEPA and Florida DEP ($65,000).

2000

- 2000-2002, "The role of plants & soils in the biogeochemical cycling of Hg on an ecosystem level, (with UNR/DRI), EPA EPSCOR, ($60,000).
- 2000-2002, "Mercury transport and fate through a watershed: The role of Hg reduction reactions, (with J. Nriagu), USEPA STAR Grant, ($260,000).
- 2000-2004, "Applications of Stable Isotopes to Quantifying Air/surface Exchange Rates of Hg in Whole-ecosystem Manipulation Studies at the ELA, Canada, USDOE ($1,270,000).
- 2000-2004, "Fugitive Mercury Emissions from Non-combustion Sources in the Great Lakes Region, (with Frontier Geosciences), USEPA, GLNPO, ($200,000).

- 2001-2002, "Methylmercury Production in Florida Landfills". Florida DEP ($140,000).
- 2001-2003, "Mercury Emissions from Natural Processes: Scaling to the Landscape". (with M. Gustin, UNR) EPRI ($170,000).
- 2001-2004, "Dynamic Oxidation of Mercury in the Arctic Environment" (with S. Brooks, ATDD) NOAA ($295,000).
- 2002-2005, "Assessment of Natural Source Mercury Emissions" (with UNR/DRI), EPA STAR, (total project $891,500).

[grants last updated in Dec; 2002]

Students Supervised:

Advisor to ORNL Student Interns

- S. Henry, B.S., Chemistry, Earlham College (1976)
- S. Kimbrough, B.S., Biology, College of the South (1976)
- W. Petty, B.S., Biology, Grinnell College (1986)
- A. Pendergrass, B.S., Civil Engineering, Auburn University (1993)
- T. Kuiken, B.S., Chemistry, Rochester State (1999)
- J. Ramierez, Chemistry, U. Puerto Rico (2000)

Advisor to Postdoctoral Researchers at ORNL

- Dr. G. Lovett (Ph.D., Ecology, University of New Hampshire), ORAU Postdoctoral Fellow (1982–1984) (currently Sr. Scientist, Institute of Ecosystem Studies, NY)
- Dr. D. Schaefer (Ph.D., Biogeochemistry, University of New Hampshire), ORAU Postdoctoral Fellow (1986– 1988, currently Asst. Prof., University of Puerto Rico)
- Dr. K.-H. Kim (Ph.D., Marine Chemistry, University of South Florida), ORNL Postdoctoral Fellow (1992– 1994, currently Asst. Prof., University of Seoul, Korea)
- Dr. Hong Zhang (Ph.D., Soil Chemistry, University of Vermont), ORNL Postdoctoral Fellow (1998–2001, currently Assoc. Prof., Tennessee Tech. University, Cookeville)
- Dr. Weijin Dong (Ph.D., Plant Physiology, Tulane University), ORNL Postdoctoral Fellow (2000–2002, currently Assoc. Prof., McNeese State University)

Adjunct Faculty Committee Member for Graduate Students

- C. Potter, Ph.D. in Ecology, Emory University (1983–1985)
- M. Hoyer, Ph.D. in Atmospheric Chemistry, Air Toxics Laboratory, School of Public Health, University of Michigan (1992–1995)
- A. Rea, Ph.D. in Air Quality, Air Quality Measurements Laboratory, School of Public Health, University of Michigan (1994–1998)
- J. Shubzda, M.S. in Forestry, School of Fisheries, Forestry, and Wildlife,
- The University of Tennessee (1995–1999)
- A. Carpi, Ph.D. in Environmental Toxicology, Cornell University (1994–1996).
- A. Vette, Ph.D. in Air Quality, Air Quality Measurements Laboratory, School of Public Health, University of Michigan (1996–1999).
- M. Goodsite, Ph.D. in Atmospheric Chemistry, Department of Chemistry, University of Copenhagen, Denmark (2000-present).

Invited Faculty Opponent for Ph.D. Defense

- W. Ivens, Ph.D. in Biogeochemistry, University of Utrecht, The Netherlands
- (1989–1991)
- Z. Xiao, Ph.D. in Inorganic Chemistry, Chalmers University of Technology, Göteborg, Sweden (1994–1995)
- M. Coggin, Ph.D. in Atmospheric Chemistry, University of Galway, Ireland (1999-2000)
- J. Benesch, M.S. in Environmental Science, University of Nevada, Reno (2001-2002)

Expert External Reviewer for Habilitation to Professor

- Dr. D. Godbold, Habilitation candidate, University of Göttingen, Germany (1990)
- Dr. R. Ebinghaus, Habilitation candidate, University of Lüneberg, Germany (2002)

Informal PhD Advisor

- D. Walschlager, Ph.D. in Geochemistry, University of Hamburg, Germany (1995-1996)
- T. Frescholtz, M.S. in Environmental Science, University of Nevada, Reno (2001-2002)
- K. Scott, Ph.D. in Microbiology, University of Manitoba, Winnipeg, Canada (2001-2002)

Publications-*(in prep and submitted)* *[updated Apr 2003, published list starts below]*

Lindberg, S.E., G. Southworth, E.M. Prestbo, D. Wallschläger, M. A. Bogle, J. Price. Gaseous methyl-and inorganic mercury in landfill gas from landfills in Florida, Minnesota, and California. Atmos. Envir. (in prep).

Schroeder, W.H., A. Steffen, K. Scott, T. Bender, E. Prestbo, R. Ebinghaus, J.Y. Lu and S. E. Lindberg. First International Arctic atmospheric mercury research workshop. Atmos. Envir. (submitted).

Amyot, M., G. Southworth, S.E. Lindberg, H. Hintelmann, J.D. Lalonde, C. Gilmour, J.W.M. Rudd, C.A. Kelly, R. Harris, F.M.M. Morel, A.Poulain, Ken Sandilands. Evolution of dissolved

gaseous mercury in large lake enclosures amended with $^{200}HgCl_2$. Can J. Fish Aq Sci (submitted).

Southworth, G. R., S. E. Lindberg, H. Zhang, J. S. Kinsey, F. Anscombe, and F. Schaedlich. Fugitive mercury emissions from a chlor-alkali facility: sources and fluxes to the atmosphere. Atmos. Envir. (submitted).

Kinsey, J. S., Swift, J., Bursey, J., Lindberg, SE, and Southworth, G. Characterization of mercury emissions from the cell building at a U. S. chlor-alkali plant. Atmos. Envir. (submitted).

Lindberg, S., G. Southworth, M. Bogle, T. Blasing, H. Zhang, T. Kuiken, D. Wallschlaeger, J. Price, D. Reinhart, H. Sfeir, J. Owens, and K. Roy. Airborne emissions of mercury from municipal solid wasteNew measurements from three landfills in Florida. JAWMA, (submitted).

W. Dong, S.E. Lindberg, T. Meyers, and J. Chanton. A proposed mechanism of gaseous mercury emission mediated via aquatic plant in the Florida Everglades. Atmos. Envir. (in prep.)

Brooks, SB, K. Scott, and SE Lindberg. Surface Mercury Hg(0) Emissions during Annual Snowmelt at Barrow, Alaska. J. Geophys. Res. (in prep. 5/02).

Brooks, SB, M. Goodsite, SE Lindberg, M Landis, and R. Stevens. Aircraft Studies of Atmospheric Mercury Conversion in the Arctic Marine/Coastal Boundary Layer. Nature (in prep. 6/02).

Tate, Scherbatskoy, Donlon, Keeler, Shanley, Lindberg. Dry Deposition of Hg to a Northern Hardwood Forest (in prep 5/02).

Brooks S., and S. E. Lindberg. Estimates of Springtime Atmospheric Mercury Deposition rates at Barrow, Alaska from Stable Boundary Layer Inverse Method. J. Geophys. Res. (in revision).

Publications (in print) *[updated Apr 2003, new submissions listed above]*

Books and Whole Journal Issues:

L. Levin, D. S. E.Lindberg, and D. Porcella (Guest Eds.). 2000. Special Issue on Mercury Biogeochemistry. Science of the Total Environment: Vols. 259-260-261, 511 pp. Elsevier Publ., N.Y.

Gustin, M-S., S. E. Lindberg, and M. A. Allan (Guest Eds.). 1999. Special Issue: Nevada SToRMS mercury flux intercomparison study: Constraining mercury emissions from naturally enriched surfaces: Assessment of methods and controlling parameters. J. Geophys. Res: 104, No. D17, pp. 21829-21896. American Geophysical Union Publ., Washington.

Lindberg, S. E. (Sr. Guest Ed.). 1998. Special Issue: Atmospheric Transport, Chemistry and Deposition of Mercury. Atmospheric Environment: 32, No. 5, 134 pp. (807-940). Pergamon Press, U.K.

Johnson, D.W., and S.E Lindberg (Eds.). 1992. Atmospheric Deposition and Forest Nutrient Cycling, Ecological Studies Vol. 91, Springer-Verlag, New York, 707 pp.

Norton, S., S. E. Lindberg, and A. L. Page. (Eds.) 1990. Soils, Aquatic Processes, and Lake Acidification, Advances in Environmental Sciences Series Acidic Precipitation, Vol. 4. Springer Verlag, NY., 293 pp.

Lindberg, S. E., A. L. Page, and S. Norton. (Eds.) 1990. Sources, Deposition, and Canopy Interactions, Advances in Environmental Sciences Series Acidic Precipitation, Vol. 3. Springer Verlag, NY., 332 pp.

Lindberg, S. E. and T. C. Hutchinson (Eds.). 1987. Proceedings of the Sixth International Conference on Heavy Metals in the Environment, New Orleans, LA, September 15-18, 1987, CEP Limited Publishers, Edinburgh, UK.

Shriner, D. S., C. R. Richmond, and S. E. Lindberg (Eds.) 1980. Atmospheric Sulfur Deposition. Ann Arbor Science Publishers, Ann Arbor, MI, 568 pp.

Journal Papers and Book Chapters:

In Press

Gustin, M-S., and S.E. Lindberg. Understanding the role of natural ecosystems in the biogeochemical cycle of Hg. Proc. Air Quality-III (in press).

2000's

Johnson, D.W., Benesch, J.A., Gustin, M.S., Schorran, D.E., Coleman, J., and Lindberg, S.E. 2003. Soil gaseous Hg and CO2 concentrationsresponse to watering, plants, and evidence against diffusion control of Hg flux, Science of the Total Environment 304: 175-184.

Gustin, M.S, M. Coolbaugh, M. Engle, B. Fitzgerald, R. Keislar, S. Lindberg, D. Nacht, J. Quashnick, J. Rytuba, C. Sladek, H. Zhang, R. Zehner. 2003. Atmospheric Mercury Emissions from Mine Wastes and Surrounding Geologically Enriched Terrain. Envir. Geol. 43:339-351.

J. Ericksen, M.S. Gustin, D. Schorran, D. Johnson, S. Lindberg, and J. Coleman. 2003. Accumulation of atmospheric mercury in forest foliage, Atmos. Envir. 37:1613-1622.

Hintelmann, H., V. St.Louis, K. Scott, J.Rudd, S. E. Lindberg, D. Krabbenhoft, C. Kelly,A. Heyes, R. Harris, and J. Hurley. Reactivity and mobility of newly deposited mercury in a Boreal catchment, 2003. Envir. Sci. & Technol. 36:5034-5040.

Lindberg, S. E., W. Dong, and T. Meyers. 2002. Transpiration of gaseous mercury through vegetation in a subtropical wetland in Florida. Atmos. Envir. 36: 5200-5219.

Zhang, H, Lindberg, S, Gustin, M, and Xu, X. Towards A Better Understanding of Mercury Emissions from Soils. IN Cai, Y, and Braids, O. C. Eds., Biogeochemistry of Environmentally Important Trace Elements, ACS Symposium Series 835, American Chemical Soc, Washington.

Wallschlèger, D., Kock, H.H., Schroeder, W.H., Lindberg, S.E., Ebinghaus, R. and Wilken, R.D. 2002. Estimating gaseous mercury emissions from contaminated floodplain soils to the atmosphere with simplified field measurement techniques. Water, Air, Soil, Pollut. 135: 39-54.

Van Miegroet, H. I.F. Creed, N.S. Nicholas, D.G. Tarboton, K.L. Webster, J. Shubzda, B. Robinson, J. Smoot, D.W. Johnson, S.E. Lindberg, G. Lovett, S. Nodvin, S. Moore. 2001. Is there synchronicity in N input and output fluxes at the Noland Divide Watershed, a small N-saturated forested catchment in the Great Smoky Mountains National Park? In Optimizing Nitrogen Management in Food and Energy Production and Environmental ProtectionProceedings of the 2nd International Nitrogen Conference on Science and Policy: TheScientificWorld 1 (S2), 480-492.

Lindberg, S. E., Brooks, S.B., C-J. Lin, K. J. Scott, M. S. Landis, R. K. Stevens, M. Goodsite, and A. Richter. 2002. The Dynamic Oxidation of Gaseous Mercury in the Arctic Atmosphere at Polar Sunrise, Envir. Sci. & Technol. 36: 1245-1256.

Zhang, H, Lindberg, SE, Barnett, MO, Vette, AF, Gustin, MS. 2002. Dynamic flux chamber measurement of gaseous mercury emission fluxes over soils, Part 1 Simulation of gaseous mercury emissions from soils measured with dynamic flux chambers using a two-resistance exchange interface model. Atmospheric Environment 36: 835-846.

Lindberg, SE, Zhang, H, Vette, AF, Gustin, MS, Barnett, MO, and Kuiken, T. 2002. Dynamic flux chamber measurement of gaseous mercury emission fluxes over soils, Part 2 Effect of flushing flow rate and verification of a two-resistance exchange interface simulation model. Atmospheric Environment 36: 847-859.

Zhang, H., and S.E. Lindberg. 2002. Dissolved gaseous mercury in Whitefish bay and the Taquemenon River watershed in the Michigan Upper Peninsula: Distribution and dynamics. Water, Air, Soil, Pollut. 133: 379-389.

Rea, A.W.; Lindberg, S.E.; Scherbatskoy, T. 2002. Mercury accumulation in foliage over time in two northern mixed-hardwood forests. Water, Air, Soil, Pollut. 133: 49-67.

Lindberg, S. E., S. Brooks, C-J Lin, K. Scott, T. Meyers, L. Chambers, M. Landis, and R. Stevens. 2001. Formation of reactive gaseous mercury in the arcticevidence of oxidation of Hg° to gas-phase Hg-II compounds after arctic sunrise Water, Air and Soil Pollution: Focus, 1: 295-302.

Lindberg, S.E., S.B. Brooks, M. Landis, and R. Stevens. 2001. Comments on atmospheric mercury species in the European Arctic: Measurements and modeling, Atmospheric Environment 35:5377-5378.

Levin, L., Lindberg, S. and Gustin, M. 2001. Uncertainties in Mass Balance of U.S. Atmospheric Mercury Emissions. IN *Air-Surface Exchange of Gases and Particles Poster Proceedings* (D. Fowler,

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Research Scientist I (Industrial Hygienist) (8/04 - Present)
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Senior industrial hygienist responsible for the development and implementation of occupational health policies, procedures and health and safety programs throughout the Department. Performed workplace exposure evaluations, air monitoring and training in order to maintain compliance with applicable regulations. Major projects included work on asbestos management, bloodborne pathogens, chemical hygiene plans, confined space entry, ergonomics, indoor air quality, mercury and other metals, noise, nuclear emergency preparedness, pesticides and respiratory protection.

Research Scientist I (5/98 – 8/04)
Office of Pollution Prevention & Right to Know
New Jersey Department of Environmental Protection
Promote pollution prevention initiatives in an effort to reduce environmental and occupational health exposures. Provide regulatory and technical assistance to industrial facilities to help increase efficiency and reduce the quantity of toxic (TRI) substances used, generated as waste and released to the environment. Represent the Office of Pollution Prevention on the DEP Mercury Workgroup. Former co-chair of the Pollution Prevention workgroup for the National Environmental Performance Partnership System (NEPPS) Steering Committee. Under an EPA grant, provide industrial hygiene technical assistance to the Office of Occupational Training and Education Consortium (OTEC) at Rutgers University. This project develops training programs designed to integrate pollution prevention and occupational health. Chairmen of the health & safety committee for the Division of Environmental Safety and Health (DESH).

Research Scientist II (8/96 - 9/98)
Division of Environmental and Occupational Health
New Jersey Department of Health and Senior Services
Working as a Health Assessor in the Hazardous Site Health Evaluation Program, performed health hazard investigations to evaluate potential public exposure to chemical and physical hazards associated with National Priority List (NPL) sites in New Jersey. Working with the

Agency for Toxic Substances and Disease Registry (ATSDR) reviewed environmental, demographic and public health data and evaluated potential human exposure pathways. Primary responsibilities included assisting with the development of a dose reconstruction model of a municipal water distribution system and the development of the occupational exposure portion of an epidemiological case-control study in support of a childhood cancer cluster investigation in Toms River, NJ.

Research Scientist III (7/94 - 7/96)
Office of Air Quality Management
New Jersey Department of Environmental Protection
Acted as project manager for a team of administrators, engineers and scientists developing State air Pollution control regulations for stationary sources. Major rules included Mercury Emissions from MSWIs, VOC-RACT, and Architectural and Industrial Maintenance Coatings Rules. Member of the Air Toxics Steering Committee providing advice to the Department concerning health exposure issues.

Research Scientist II (Industrial Hygienist) (9/89 - 7/94)
Center for Occupational Medicine
New Jersey Department of Environmental Protection
Senior industrial hygienist responsible for the development and implementation of occupational health policies and program specific health and safety programs for approximately 4,000 employees throughout the Department. Performed workplace exposure evaluations, air monitoring and training in order to maintain compliance with applicable regulations. Major projects included work on asbestos management, bloodborne pathogens, chemical hygiene plans, confined space entry, ergonomics, indoor air quality, mercury and other metals, noise, nuclear emergency preparedness, pesticides and respiratory protection.

Occupational Health Consultant (12/87 - 9/89)
Division of Environmental and Occupational Health
New Jersey Department of Health and Senior Services
Responsible for industrial hygiene activities related to asbestos including review and approval of asbestos management plans, abatement project inspections and air monitoring, and emergency response activities. Participated in various NJDHSS / EPA research projects concerning environmental exposure to asbestos.

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Outer Continental Shelf Oil & Gas Leasing Program

2007-2012 Draft Environmental Impact Statement (updated July 2006)

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    - **Figures III-1 through III-6** *(6054 KB)*
    - **Figures III-7 through III-12** *(6617 KB)*

- **Figures III-13 through III-24** *(6410 KB)*
- **Figures III-25 through III-38** *(6238 KB)*
- **Figures III-39 through IV-1** *(4421 KB)*

- **Tables:**
  - **Tables III-1 through III-17** *(3107 KB)*
  - **Tables III-18 through III-25** *(4916 KB)*
  - **Tables III-26 through III-45** *(7516 KB)*
  - **Tables III-46 through III-52** *(771 KB)*
  - **Tables III-53 through III-56** *(649 KB)*
  - **Tables III-57 through III-63** *(264 KB)*
  - **Tables IV-1 through IV-28** *(444 KB)*