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.

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 comparison 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**