FINAL REPORT

SURVEY AND INITIAL EVALUATION

OF

SMALL ON-SITE

FLUORESCENT LAMP CRUSHERS

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INTRODUCTION

This report presents the results of a survey and initial evaluation of the different types of fluorescent lamp crushing units available on the market. Information on available fluorescent lamp crusher technology was obtained from several different sources, including a search of the Internet, review of manufacturer registries, and interviews with other regulatory agencies, manufacturers, and lamp recyclers. The survey included gathering information on unit dimensions, processing rates, emission controls, mercury emissions testing, standard operating procedures, and demonstration project reports for the small on-site fluorescent lamp crusher technologies that are commercially available. Information was also obtained on the commercial larger-scale mobile and stationary fluorescent lamp recycling systems. These larger-scale, more advanced systems illustrate the technologies that are currently used by fluorescent lamp producers, large quantity generators, and commercial lamp recycling facilities. The focus of this report, however, is mainly on the small on-site fluorescent lamp crushers, because these units may be a possible alternative for the many small- to medium-sized generators managing fluorescent lamps.

Information presented in this report on fluorescent lamp crushing and recycling systems is divided into two categories: (1) small on-site fluorescent lamp crushers; and (2) fluorescent lamp recycling equipment for commercial use. A brief overview on fluorescent lamps in general is also provided.

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Regulation of Waste Fluorescent Lamps

Under the current emergency regulations for universal waste, households and conditionally exempt small quantity generators (CESQG) generating #100 kilograms or 220 pounds per month of universal waste plus hazardous waste are allowed to dispose of their fluorescent lamps as non-hazardous waste. Small and large quantity handlers are required to ship the lamps to either another small quantity handler, a large quantity handler, a universal waste transfer station, a recycling facility, or a TSDF.

Under California's proposed universal waste rule regulations, generators will be required to send all hazardous waste lamps to an authorized recycling facility to be eligible for universal waste designation. California's proposed universal waste rule will apply to all lamps identified as hazardous waste under the California hazardous waste control law (e.g., fluorescent, high intensity discharge, neon, mercury vapor, high pressure sodium, and metal halide lamps). Households and CESQG will be allowed to dispose of hazardous waste lamps as non-hazardous waste for four years after the proposed rule is adopted. After four years, this exemption will sunset.

Composition of Fluorescent Lamps

A typical fluorescent lamp is comprised of a sealed gas tube filled with a mixture of argon and mercury vapor (generated by adding a droplet of liquid mercury to each lamp during manufacturing). The inside of this glass tube is coated with phosphor, giving off visible light when exposed to ultraviolet radiation. The visible light is emitted when the two outermost electrons of the mercury atom return to ground state after being raised to a higher level under the influence of a strong electric field[35]. The amount of mercury in fluorescent lamps manufactured prior to 1992 is > 40 mg in T12 lamps (1.5 inch diameter tube) and > 30 mg for T8 lamps (1 inch diameter tube). By 1997, fluorescent lamp manufacturers reduced this amount to < 21 mg for T12 lamps and < 10 mg for T8 lamps, respectively[30].

Fluorescent lamps are usually available as either a 4-foot or 8-foot long straight tube, a u-shaped tube, or a circular tube. The tube diameter is usually 1-inch, 1.5-inches, or 2.125-inches. Every lamp is labeled with a code containing information in the following order: lamp type (e.g., F = fluorescent), lamp length (e.g., 12", 24", or 96") or nominal wattage (e.g., 40), shape (e.g., T=tube, B or U = u-shaped, c = circular) or phosphor coating brand name (e.g., SP30, SP35), and brand designation (e.g., WM = Watt-Miser, SS = SuperSaver, EW = Econ-o-Watt, RS = Rapid Start, LW = Lite White).

Recycling Cost Comparison of Crushed Lamps to Intact Lamps

Three recycling companies on the West Coast were surveyed about the average recycling costs charged for crushed lamps versus intact lamps sent to them from generators[24,25,26]. Estimated unit costs for recycling crushed versus intact lamps for these recyclers are presented in Table 1 below. These unit costs do not include transportation or pick-up costs. To compare the

recycling costs, a 55-gallon drum was assumed to hold approximately 800 4-foot long crushed fluorescent lamps and to weigh approximately 300 lbs[25].

Table 1. Estimated Recycling Costs for Intact and Crushed Lamps

Recycler	Recycling Costs				Comments
	Crushed lamps		Intact lamps		
	$/unit	$/drum	$/ft	$/equivalent drum**	
AERC/MTI	$400/drum	$400	$0.08	$256	Average cost estimate provided. Price for crushed lamps may vary depending on amount of crushed material in drum.
EPSI	$250/drum	$250	$0.06	$192	Average cost estimate provided
EcoLights Northwest	$1.50/lb	$450*	$0.11 $0.08	$352 $256	$0.11/foot for 10,000 feet of lamps $0.08/foot for 10,000 feet of lamps

*Assumed drum weighs about 300 lbs.
**Cost based on assumption that a 55-gallon drum can hold 800 4-foot long fluorescent lamps when crushed.

It should be noted that the recycling costs listed for intact lamps may vary based on the lamp's shape (e.g., straight, U-tube, circular) and type (e.g., compact fluorescent, high intensity discharge lamps). For the crushed lamps, the number of crushed lamps contained in a 55-gallon drum will vary based on the lamp's dimensions. Based on the costs listed in Table 1, the recycling fees charged by the recycler for crushed lamps are typically higher than those for an equal amount of intact waste fluorescent lamps. Therefore, it appears that there may be no significant cost advantage with the use of on-site fluorescent lamp crushers.

Small On-Site Fluorescent Lamp Crushers (a.k.a., Fluorescent Bulb Crushers)

In general, the small on-site fluorescent lamp crusher consists of a lamp crushing unit, exhaust emission controls, and a collection container (usually a 55 gallon barrel). The fluorescent lamp is fed into the crusher one at a time and crushed by a rotating blade or flail. The crushed material drops into the collection container which is connected to the crusher. The exhaust for all units reviewed passes through an activated carbon filter to control mercury vapor prior to release into the ambient air. Frequently, mercury emissions are controlled using activated carbon impregnated with either 10-20% sulfur or 1-5% potassium iodine. Some units filter particulate matter via a particulate filter system (e.g., particulate bag filter and HEPA filter) placed before the activated carbon filter. While in operation, most systems are designed to provide a negative pressure in the collection container to prevent the release of mercury and dust into the ambient air.

For small on-site lamp crushers (barrel crushers), the three main manufacturers found are Air Cycle Corporation (Air Cycle) in Illinois, Dextrite, Inc. (Dextrite) in New York, and Environmental Disposal Concepts, Inc.(EDCI) in British Columbia. Dextrite and EDCI have distributors in the United States, Canada, Europe and Japan. Air Cycle has focused on the

U.S. market. Another manufacturer, Balcan Engineering, is located in England and has sold units mainly in Europe. Two other distributors, Wrangler Corporation in Maine and Koei in Japan, have also advertised two other types of lamp crushers, which are discussed later in this section.

Table 2 lists available information on each unit such as the dimensions, feed rate, types of lamps crushed, air flow rate, motor size, and filtration system. Table 3 indicates whether information on industrial hygiene testing, standard operating procedures (SOPs) and associated patents are available for each unit. A brief discussion on the units and associated health and safety information is provided below for each manufacturer.

Air Cycle Corporation

Air Cycle Corporation manufactures two lamp crushing units; the Bulb Eater Model 55-VRS which crushes straight lamps (Figure 1a), and the Bulb Eater 55-VRS-U which crushes straight and u-shaped lamps (Figure 1b). Both units consist of a drum-top mounted lamp crusher and a 55-gallon drum used to collect crushed material. Air Cycle sells the 55-gallon drum separately. Exhaust from the unit passes through a filter bag, HEPA filter, and activated carbon filter (laced with 15% yellow sulfur) before exiting to the ambient air. The sulfur combines with the mercury vapor to form an insoluble mercury sulfide[38]. When in use, the collection chamber is under negative pressure with

Figure 1a.
Bulb Eater Model 55-VRS

Figure 1b.
Bulb Eater Model 55-VRS-U

Table 2. Manufacturer Specifications for Small On-Site Fluorescent Lamp Crushing Units

Unit Name	Manufacturer	Dimensions	Feed Rate	Type of Lamp Crushed	Vacuum Rate	Motor Size	Filtration System			Cost ($ per unit)
							Filter Bag	HEPA Filter	Activated Carbon	
Model 55VRS Bulb Eater	Air Cycle Corporation	55 gallon drum; ~ 5 ft tall	24 lamps per minute (800-1000 lamps/drum)	Straight lamps	40 cfm	1/12 h.p.	1 micron @ 99% particle retention	0.3 micron @ 99.99%	Activated carbon impregnated with 15% sulfur	$1,900.00
Model 55VRS-U Bulb Eater	Air Cycle Corporation	55 gallon drum; ~ 5 ft tall	20 lamps per minute (800-1000 lamps/drum)	Straight lamps & U-shaped lamps	40 cfm	1/12 h.p.	1 micron @ 99% particle retention	0.3 micron @ 99.99%	Activated carbon impregnated with 15% sulfur	Not Available
HID Pro	Air Cycle Corporation	Not Available	12 lamps per minute	High intensity discharge lamps (i.e., metal halide, hi and lo sodium, and mercury vapor lamps)	Not Available	Not Available	Not Available	Not Available	Not Available	Not Available
RDA-55E Lamp Disposer	Dextrite	Ht: 100 in., W: 54 in., Dia.: 36 in.	25 4 ft lamps per min. (900 4 ft. lamps/drum)	Straight, u-shaped, and circular lamps, and bulbous lamps	Not Available	None	None	Not Available	Activated carbon impregnated with potassium iodine	Not Available
RHID-55E Lamp Disposer	Dextrite	Ht: 93 in., W: 54 in., Dia.: 36 in.	25 4 ft lamps per min. (900 4 ft. lamps/drum)	Straight lamps and bulbous lamps	Not Available	None	None	Not Available	Activated carbon impregnated with potassium iodine	Not Available
ULC-55FDA-E Lamp Disposer	Dextrite	Ht:31 in., W: 24 in., Dia.: 24 in.	25 4 ft lamps per min. (800 4 ft. lamps/drum)	Straight lamps & U-shaped lamps	140 cfm	None	None	Not Available	Activated carbon impregnated with potassium iodine	$5,335.00
RULC-55FDA-E Lamp Disposer	Dextrite	Ht: 54 in., W: 54 in., Dia.: 36 in.	25 4 ft lamps per min. (900 4 ft. lamps/drum)	Straight lamps & U-shaped lamps	140 cfm	1/6 hp	None	None	Activated carbon impregnated with potassium iodine	$7,960.00
RLC-55FDA-E Lamp Disposer	Dextrite	Ht: 54 in., W: 54 in., Dia.: 36 in.	25 4 ft lamps per min. (900 4 ft. lamps/drum)	Straight lamps	115 cfm	1/6 hp	None	None	Activated carbon impregnated with potassium iodine	$6,910.00
DC-30E Lamp Disposer	Dextrite	Ht: 12 in., W: 20 in., Dia.: 20 in.	25 4 ft lamps per min. (300 4 ft. lamps/drum)	Straight lamps	Not Available	1/14 hp	None	None	Activated carbon impregnated with potassium iodine	Not Available
LC-55FDA-E Lamp Disposer	Dextrite	Ht: 12 in., W: 24 in., Dia.: 24 in.	25 4 ft lamps per min. (800 4 ft. lamps/drum)	Straight lamps	115 cfm	1/6 hp	None	None	Activated carbon impregnated with potassium iodine	$3,760.00
BulbMaster/Bulb Eater Mark V	Environmental Disposal Concepts Inc.	Ht: 38 in., W: 22 in., L.: 22 in.	65 4ft lamps per hour (60 crushed 4 ft. lamps/ bag)	Straight lamps	Not available	Not available	Carbon particulate filter	Combination HEPA/mercury cartridge filter	activated carbon impregnated with sulfur	$2,595.00
Fluorescent Tube Recycling System	Wrangler Zone	Ht: ~6ft, Dia. ~24 in.	400 4ft lamps per drum	Straight lamps	Not available	1/4 h.p.	None	None	2 activated carbon filters	$2,234.69
Fluorescent lamp crusher	Koei	Ht: 1.7 m, collects glass in 55 gal drum	Not available	Straight lamps	Not Available	1/3 hp	Not available	Not available	separate active carbon unit	Not Available
Balcan Lampcrushers	Balcan Engineering	Not Available	Not Available	High intensity discharge lamps (i.e., metal halide, hi and lo sodium, and mercury vapor lamps)	Not Available	Not Available	Not Available	Not Available	carbon filter mounted halfway in feed chute	Not Available

Table 3. Available Sampling Results, Reports, and Patent Information

Unit Name	Manufacturer	IH Testing			SOP Available?
		Barrel Change	Operating	Idle	
Small On-site Fluorescent Lamp Crusher (a.k.a. Fluorescent Lamp Barrel Crushers)					
Model 55VRS Bulb Eater	Air Cycle Corporation	No	Yes	No	Not Available
Model 55VRS-U Bulb Eater	Air Cycle Corporation	No	Yes	Yes	Not Available
HID Pro	Air Cycle Corporation	Not Available	Not Available	Not Available	Not Available
RDA-55E Lamp Disposer	Dextrite	No	No	No	Unit operation similar to ULC-55FDA-E. Refer to SOP in Florida DEP demonstration project report for ULC-55FDA-E.
RHID-55E Lamp Disposer	Dextrite	No	Yes	No	Unit operation similar to ULC-55FDA-E. Refer to SOP in Florida DEP demonstration project report for ULC-55FDA-E.
ULC-55FDA-E Lamp Disposer	Dextrite	Florida DEP report had one direct reading and one 8-hour TWA reading taken.	Florida DEP report performed two test runs and monitored mercury vapor in breathing zone and select areas in and around the unit.	No	One developed by Florida DEP for ULC-55FDA-E available. Unit design similar to other models.
RULC-55FDA-E Lamp Disposer	Dextrite	No	No	No	Unit operation similar to ULC-55FDA-E. Refer to SOP in Florida DEP demonstration project report for ULC-55FDA-E.
RLC-55FDA-E Lamp Disposer	Dextrite	No	No	No	Unit operation similar to ULC-55FDA-E. Refer to SOP in Florida DEP demonstration project report for ULC-55FDA-E.
DC-30E Lamp Disposer	Dextrite	No	No	No	Unit operation similar to ULC-55FDA-E. Refer to SOP in Florida DEP demonstration project report for ULC-55FDA-E.
LC-55FDA-E Lamp Disposer	Dextrite	No	No	No	Unit operation similar to ULC-55FDA-E. Refer to SOP in Florida DEP demonstration project report for ULC-55FDA-E.
BulbMaster/Bulb Eater Mark V	Environmental Disposal Concepts Inc.	Yes	Yes	Not Available	Yes
Fluorescent Tube Recycling System	Wrangler Zone	Not Available	Not Available	Not Available	Not Available
Fluorescent Tube Crusher Model 92	Proveda	Not Available	Not Available	Not Available	Not Available
Fluorescent lamp crusher	Koei	Not Available	Not Available	Not Available	Not Available
Balcan Lampcrushers	Balcan Engineering	Not Available	Not Available	Not Available	Not Available

an air flow of 40 cfm. The feed chute for straight lamps has a screw-on cap to prevent fugitive emissions when the unit is off. The filter bag is changed at least every full drum while the HEPA is changed at least every 10 full drums[3]. According to the manufacturer, the activated carbon mercury filter is rated for 10 million older style lamps or 50 million newer lamps[3]. Neither models are equipped with a lamp counter system, mercury monitoring system, nor warning indicators for filter changes or full barrels. The user needs to track the number and type of lamp crushed to determine when the carbon filters need replacing. In California, the crushed material will need to be sent to an authorized recycling facility to be designated as an universal waste. If the authorized recycling facility does not accept the spent carbon and used particulate filters, then these filters should be considered hazardous and managed accordingly
Air Cycle is currently developing a unit called HID Pro, to recycle high intensity discharge (HID) lamps including metal halide, high and low pressure sodium, and mercury vapor lamps. The unit will first remove the outer glass globe on the HID lamp. Then, the mercury ampoule will be removed by hand using a special pneumatic clipping tool. No other information on the HID Pro is available at this time.

Air Cycle sampled mercury emissions while operating the Bulb Eater Model 55-VRS for two separate test runs. For the first test run, two integrated samples were collected over an 8-hour period; one sample at the unit's exhaust prior to emission control equipment and one sample at the activated carbon filter outlet. For the second test run, two integrated samples were collected over an 8-hour period; one sample between the HEPA filter and activated carbon filter and one sample after the activated carbon filter. During the second test run, two samples were also collected in the operator breathing zone for 30-minutes and for 7.5-hours using sampling sorbent tubes. All samples were analyzed per NIOSH Method 6009 for both runs. The analytical report did not contain the following information: a breakdown on the type of fluorescent lamps crushed by model number and date manufactured, condition of the filters (new or used), description of sampling train used, sampling flow rate used, sample volume collected, and the number of field and media blanks collected and analyzed per the test method. Mercury concentrations in the operator's breathing zone and after the carbon filters were below the OSHA 8-hour and 15-minute permissible exposure limits. The analytical results along with number of lamps crushed and the actual time spent crushing lamps are presented in **Table 4** below.

Air Cycle recently sampled mercury emissions while operating the Bulb Eater Model 55-VRS-U for one test run. The unit crushed 300 U-shaped lamps (Model GE F40SP30/U/6) and 150 straight lamps (Model GE F40SP35/RS/WM) during the first 90-minutes of the test run. After the crushing operation was completed, the unit was shut off but the feed chutes were not sealed. This test run consisted of four integrated samples; two collected during the crushing operation and two collected over the remaining 390-minute period. Two samples (a 90-minute and a 390-minute) were collected between the HEPA filter and activated carbon filter and after the activated carbon filter. Three samples were also collected in the operator breathing zone; one integrated sample over the first 15-minutes, one integrated sample over the last 75 minutes of the crushing operation, and one integrated sample over the remaining 390 minutes using sampling.

Table 4. Mercury concentrations for the Bulb Eater Model 55-VRS

Sample Location	Number of Lamps Crushed	Actual # of Hours Crushing Performed[a]	Sample Results (mg/m^3)
Prior to the emission control equipment[b,d]	820	4	4.0
At the activated carbon filter outlet[b,d]	820	4	0.045
	446	4	0.03
Between the HEPA filter and activated carbon filter[c,d]	446	4	0.45
Operator breathing zone for an 7.5-hour period[c]	446	4	0.002
Operator breathing zone for a 30-minute period[c]	100	0.5	0.001

OSHA Permissible Exposure Limit: (8-hour time weighted average) = 0.05 mg/m^3 (skin)
(15-minute time weighted average) = 0.1 mg/m^3 ceiling
NIOSH Recommended Exposure Limit: (8-hour time weighted average) = 0.05 mg/m^3 (skin)

[a]Unit ran for 8 hours but only performed crushing for the number of hours specified below except for the 30-minute worker breathing zone value.
[b]Correspondence between Joe Carruth at the Minnesota Pollution Control Agency and Scott Beierwaltes at Air Cycle Corporation, November 22, 2000.
[c]Air Cycle Corporation, *A Report of Air Sampling for Mercury Vapor and Particulates During Fluorescent Tubes Disposal Operation, Maywood, Illinois*, November 7, 2000.
[d]Integrated sample collected over an 8-hour period.

sorbent tubes. All samples were analyzed per NIOSH Method 6009. The analytical report did not contain the following information: description of sampling train used, sampling flow rate used, sample volume collected, and the number of field and media blanks collected and analyzed per the test method. Mercury concentrations in the operator's breathing zone and after the carbon filters were below the OSHA 8-hour and 15-minute permissible exposure limits. The analytical results are presented in **Table 5** below

Table 5. Mercury Concentrations for the Bulb Eater Model 55-VRS-U

Sample Location	Number of Lamps Crushed	Sample Results (mg/m3)		
		90-minutes	390-minutes[d]	8-hour average
Between the HEPA filter and activated carbon filter	450[a]	9.28	0.057	1.79
After the activated carbon filter	450[a]	0.00211	0.00218	0.00217
Operator breathing zone	450[a]	0.0603[b] 0.0443[c]	0.00264	0.00907

OSHA Permissible Exposure Limit: (8-hour time weighted average) = 0.05 mg/m^3 (skin)
(15-minute time weighted average) = 0.1 mg/m^3 ceiling
NIOSH Recommended Exposure Limit: (8-hour time weighted average) = 0.05 mg/m^3 (skin)

[a]300 U-shaped lamps (Model GE F40SP30/U/6) and 150 straight lamps (Model GE F40SP35/RS/WM).
[b]Sample collected over the first 15 minutes of the crushing operation.
[c]Sample collected over the last 75 minutes of the crushing operation.
[d]Samples collected while unit was shut off but feed chutes were not sealed.

Dextrite, Inc.

Dextrite manufactures seven models of lamp crushers based on the same basic design patented in 1993. The lamp crusher consists of a drum-top mounted lamp crusher with a filter attachment consisting of a "porous filter bag" and an activated charcoal filter to absorb mercury vapors[8]. Exhaust from the lamp crusher is pulled through the filter bag and the activated charcoal filter by an axial exhaust fan located at the base of the filter attachment. Negative pressure at the drum seal and the feed chute is maintained by the exhaust draw from the fan located in the filter attachment. A picture of each model is presented in Figures 2a through 2g. The PolySleeve is a polyurethane skirt with elastic ends that attach to the top of the drum and the base of the crusher outlet creating an apron. Figures 2a, 2b, 2d, and 2e show how the PolySleeve is attached. According to the manufacturer, this sleeve is designed to control dust and fumes during crushing operations and drum changes. Filter capacities are based on the number of fluorescent lamps crushed. For Models RLC-55FDA-E, DC-30E, LC-55FDA-E, RULC-55FDA-E, and ULC-55FDA-E, the filter capacity is 2,400 lamps while the filter capacity for Model RHID-55E and Model RDA-55E is 3,600 lamps[10].

To maintain an accurate count on the number of lamps crushed, the Dextrite lamp crushers are also equipped with a fluorescent lamp counter. The fluorescent lamp counter, which was modified in 1995, emits two types of timer control signals to the counter; one for either a four-foot or u-shaped lamp tube, and the other for a 8-foot lamp tube[9]. These changes were made to improve the accuracy of the lamp count and ensure filters were replaced according to manufacturer's specifications. Based on the count maintained by the lamp counter, indicator lights and a buzzer are activated to notify the user when the filters need to be replaced. Literature on Dextrite's units does not mention the proper disposal of crushed material, used particulate filters, or spent carbon filters generated by their units.

In 1995, the Florida Department of Environmental Protection (DEP) conducted a demonstration project using the Dextrite Lamp Disposer Model ULC-55FDA-E (Figure 2c) to determine whether crushing lamps was economically and environmentally sound[16]. The unit was operated by Florida DEP employees to crush a combination of straight and u-shaped fluorescent lamps which were fed into the unit via two chutes designed for each lamp shape. Florida DEP monitored mercury emissions in the operator's breathing zone using two direct reading instruments: a calibrated Bacharach Model MV2 Mercury Sniffer and a Draeger tube with mercury cartridge. Time-weighted 8-hour average concentration values were determined using OSHA Method ID-140. Mercury concentrations were also monitored at the straight lamp feed chute, at the carbon filter exhaust, and during drum changes. These monitoring results are presented in Table 6.

Figure 2a.
RDA-55E
Lamp Disposer

Figure 2b.
RHID-55E
Lamp Disposer

Figure 2c.
ULC-55FDA-E
Lamp Disposer

Figure 2d.
RULC-55FDA-E
Lamp Disposer

Figure 2e.
RLC-55FDA-E
Lamp Disposer

Figure 2f.
DC-30E
Lamp isposer

Figure 2g.
LC-55FDA-E
Lamp Disposer

Table 6. Mercury Concentrations for Crushing and Drum Changes[16]
Dextrite Lamp Crusher Model ULC-55FDA-E

Sample Location	Date Sampled	Number of Lamps Crushed	Sample results (mg/m^3)	
			Direct Reading	8-hour TWA reading
0.5" - 1" from drum to housing seal	1/18/95	214	< 0.02	---
0.5" - 1" from feed tube adaptor	1/18/95	214	0.1[a]	---
0.5" - 1" from blower exhaust (carbon filter exhaust)	1/18/95	214	<0.01	---
18" from chute tube in operator breathing zone	1/18/95	214	<0.01	---
Within the feed tube housing, between brushes and feed tube closure	1/23/95	73	0.02 - 0.40	---
0.5" to 1" from torn waste collection bag	1/23/95	73	0.02 - 0.40	---
Operator's breathing zone (1 to 2' above open waste collection bag)	1/23/95	73	0.02 - 0.60	---
During drum change	3/22/95	1000	>0.1	0.0032
At feed tube adapter (4 ft tubes)	3/22/95	1000	---	0.0481
At feed tube adapter (U-tubes)	3/22/95	1000	---	0.0081
Exhaust fan discharge (carbon filter exhaust)	3/22/95	1000	---	0.0031 0.0033
Top of drum housing	3/22/95	1000	---	0.017
Operator breathing zone	3/22/95	1000	---	0.028

OSHA Permissible Exposure Limit: (8-hour time weighted average) = 0.05 mg/m^3 (skin)
(15-minute time weighted average) = 0.1 mg/m^3 ceiling
NIOSH Recommended Exposure Limit: (8-hour time weighted average) = 0.05 mg/m^3 (skin)

[a]The high mercury concentration was attributed to particulate matter build-up in the filter assembly, which reduced the unit's ability to maintain negative pressure at the feed chute.

While the unit was operated, a few upset conditions occurred. One incident involved small releases of phosphor powder from the unit via the feed chute. The other was elevated mercury concentration detected due to a loose feed chute connection[16]. Based on the results for this project, the following standard operating procedures were recommended: (1) this unit be operated either outside or in a well-ventilated area; (2) PPE such as safety glasses or faceshields and Tyvek should be worn at all times; (3) a respirator with mercury vapor cartridges (with "end of service life" indicators) should be worn during drum change out and feed tube adapter changes; (4) an elevated platform should be used when operating and clearing occasional jams in the feed tube; (5) an accurate crushed lamp tally should be kept to ensure filters were replaced per manufacturer's specification; (6) a proper seal should be maintained between the feed tube adapter and chute; and (7) the PolySleeve should be installed correctly prior to use. Florida DEP does not recommend that generators use on-site lamp crushers based on the results of this demonstration project that show potential for increased worker exposure

due to uncontrolled mercury emissions[21], and because of the higher recycling costs charged by off-site recycling facilities for crushed fluorescent lamps.

Dextrite monitored mercury emissions during crushing operations conducted on May 25-28, 1998 using the RHID-55E lamp crusher. The unit was used to crush 100 four foot long fluorescent lamps for a previous test. A new HEPA filter was installed before conducting the May 25-28 test. During the tests, vacuum and velocity readings were measured using the Alnor AXD 550 tester and Pitot tube and mercury concentrations monitored using a Jerome mercury analyzer model 431. Vacuum readings, velocity readings and mercury concentrations for 4 separate runs are presented in Table 7 below. For each run, lamps were crushed until the barrel became full and the crusher automatically shutoff. As shown in Table 7, the exhaust velocity and the observed vacuum at the feed chutes decreased as the number of lamps crushed increased. However, the mercury concentration at the feed chute was measured or recorded only once. Therefore, it is unclear whether the vacuum at the feed chute is adequate to control potential mercury emissions at this location.

Table 7
Mercury Concentrations for Crushing Operations Using Dextrite Lamp Crusher Model RHID-55E

Sampling Location	Sample Date	No. of Tubes Crushed[a]		Number of Hours Operated	Pitot tube differential (inH_20)	Exhaust velocity (fpm)	Vacuum (inH_20)	Average Mercury Conc. (mg/m^3)	Comments
		Test Run	Running Total						
Blower exit	5/12/98	0	0	-	0.320	2266	-	-	New HEPA filter
		100	100	-	0.280	2119	-	-	
	5/2698	810	910	1.42	-	-	-	0.006	
	5/27/98	0	910	-	0.089	1195	-	-	Flail and blower on
		594	1504	1.58	0.055	935	-	0.007	
		0	1504	1.58	0.047	868	-	-	After 17 minutes
	5/28/98	0	1702	-	0.207[b]	1822[b]	-	-	Flail and blower on
		853	2555	1.95	0.039	795	-	0.004	Flail off and blower on
		0	2555	-	0.061	985	-	-	Flail and blower on
		838	3393	1.13	0.035	749	-	0.004	Flail off and blower on
Straight feed chute	5/27/98	1602	1702	1.58	-	-	-0.006	-	Average reading with flail off and blower on
	5/28/98	0	1702	-	-	-	-0.174	-	
		853	2555	1.95	-	-	-0015	0.000	
		838	3393	1.13	-	-	-0.005	-	
HID feed chute	5/27/98	1602	1702	1.58	-	-	-0.002	-	Average reading with flail off and blower on
	5/28/98	0	1702	-	-	-	-0.129	-	
		853	2555	1.95	-	-	-0.011	-	
		838	3393	1.13	-	-	-0.003	-	
Ambient Air	5/26/98	0	0	0	-	-	-	-	Not recorded
	5/27/98	810[c]	810	0	-	-	-	0.000	
	5/28/98	792[c]	1702	0	-	-	-	0.006	

[a]Number of crushed lamps are expressed as equivalent 4-foot lamps. A combination of 4-ft, 3-ft, 8-ft, and T-8 lamps were crushed for each run.
[b]The higher velocity reading is due to dust that was dislodged from the filter surface while fixing a tiny leak in the observation port.
[c]The number of tubes crushed for the ambient air location is based on the previous day's total.

Environmental Disposal Concepts, Incorporated (EDCI)

EDCI manufactures the Bulb Eater Mark V (sold as the BulbMaster in the U.S. and shown in Figure 3a) and the Bulb Eater Mark 2000 (see Figure 3b). The Bulb Eater Mark V resembles a 35-gallon plastic trash can. Fluorescent lamps are fed into the unit through a removable feed chute at the top. A pulverizing blade located below the feed chute crushes the lamp. The crushed material falls into a 6 mil plastic bag attached to the bottom of the pulverizing blade unit. A vacuum motor pulls air from the crushed material collection compartment into the exhaust compartment. Air entering the exhaust compartment passes through a 8"x 10" particulate filter. Positive pressure is maintained in the exhaust compartment which expels exhaust to the atmosphere through two combination HEPA/carbon filters (similar to a respirator cartridge) located on opposite sides of the unit[13,14]. The carbon filter used is activated carbon impregnated with sulfur. The manufacturer specifies that the particulate filter and HEPA/carbon filters be changed after 1,200 4-foot lamps have been crushed[15, 37]. Figure 3c shows the particulate filter (common "heater" filter at back of picture), and the HEPA/carbon filters (respirator cartridges in foreground), and the collection bags located beneath the HEPA/carbon filters. Since Bulb Eater Mark V is not equipped with a fluorescent lamp counter, the operator needs to record the number of lamps crushed by the unit. EDCI instructs potential buyers that crushed material and used filters need to be sent to either a hazardous waste processor for treatment or to a lamp recycling facility[13]. The Bulb Eater Mark 2000 is similar to the BulbEater Mark V except its an enclosed unit with a recirculating air system. OPPTD is waiting for additional product information requested from the manufacturer.

According to the manufacturer, testing results for mercury emissions for the Bulb Eater Mark V meets the permissible exposure limit set by OSHA and the threshold limit levels outlined by the American Conference of Governmental Industrial Hygiensts[15]. A summary of the mercury test results from EDCI's "Technology Application Analysis" report[38] is provided in Table 8 below. Their report did not include a description of the testing conditions used for each test run. OPPTD is awaiting submittal of copies of the original test run reports.

Figure 3a.
BulbEater Mark V

Figure 3b.
Bulb Eater Mark 2000

Figure 3c. Particulate Filter, Crushed Material Collection Bag, and HEPA/Carbon Cartridges

Table 8
Mercury Concentrations for the BulbEater Mark V and Mark 2000

Test Run Number[a]	Sampling Locations				
	Ambient Air		Filter Exhaust	Feed Chute Area	Operator Lapel
	Before test	During test			
BulbEater Mark V					
Test #1	0.010	0.010	0.010	0.010	NA
Test #2	0.010	0.010	0.010	0.010	NA
Test #3	NA	NA	NA	NA	0.006 0.007
Test #7	0.001 0.001	0.006 0.001	0.012 0.009	NA	0.003 0.013
Test #10	NA	0.004 0.050 0.020 0.006	0.076[b] 0.110[b] 0.016 0.010	0.085[b] 0.110[b] 0.020 0.014	0.097[b] 0.130[b] 0.043 0.048
Test #11	0.006	0.006	0.006	0.006	0.006
Test #12	0.001	0.003	0.002	0.020	0.032[c]
Average	**0.0048**	**0.0069**	**0.0133**	**0.021**	**0.0196**
BulbEater Mark 2000					
Test #13	0.001	0.005	0.006	0.010	0.005
Test #14	0.000082 0.000085 0.00031	NA	NA	NA	0.0036 0.0079 0.018 0.015
Average	**0.0002**	**-**	**-**	**-**	**0.0099**

OSHA Permissible Exposure Limit: (8-hour time weighted average) = 0.05 mg/m^3 (skin)
(15-minute time weighted average) = 0.1 mg/m^3 ceiling
NIOSH Recommended Exposure Limit: (8-hour time weighted average) = 0.05 mg/m^3 (skin)
ACGIH Threshold Limit Values: (8-hour time weighted average) = 0.025 mg/m^3

[a]Information on the testing conditions were not included in the Technology Application Analysis report. OPPTD has requested copies of the original test run reports.
[b]The elevated mercury concentrations are associated with two fluorescent lamp tubes where the aluminum caps protruding outside the feed chute came off prior to the lamp entering the crushing chamber.
[c]No unusual operating conditions are noted in the Technology Application Analysis report.

Balcan Engineering

Balcan Engineering, in Great Britain, manufactures the Balcan Lamp crusher which is available as a manually operated unit or electrically operated unit. Figure 4a shows the manually operated lamp crusher unit while Figure 4b is the electrically operated unit. The manual units available are capable of crushing 6, 20, or 30 fluorescent lamps at once. The breaking chamber is adjusted depending on the lamp's diameter and loaded. Once loaded, the safety interlocks are disengaged and the water spray is activated. The water spray is used to control dust and the "escape of harmful vapors"[4] during the crushing process. For the manual units, the operator pumps up and down on a handle that operates the crushing roller for approximately 30 seconds. The water and crushed material fall into SOAKUP Sacks located below the rollers. The SOAKUP Sacks (see Figure 4c) contain a pre-measured amount of an unidentified absorbent material[4]. Additional information on the unit is not available but at least two companies in Great Britain offer mobile on-site fluorescent lamp crushing services using the Balcan unit.

Figure 4a.
Manual
Balcan Lamp Crushers

Figure 4b.
Electric
Balcan Lamp Crushers

Figure 4c.
SOAKUP Sacks

Koei

The lamp crusher distributed by Koei is similar to the discontinued model made by Proveda (Proveda Model #92)[16]. Based on a schematic in the Florida DEP report, the Proveda Model #92 consists of a drum-top lamp crusher which exhausts to a three stage filter system. The last filter stage is a carbon filter[16]. No additional information is available on this unit.

Wrangler Corporation

The fluorescent tube recycling system distributed by Wrangler Corporation is another drum-top mounted lamp crusher (see Figure 5). No information on mercury concentrations or processing information for this unit is available. OPPTD contacted Wrangler about the unit but Wrangler has not provided any additional information on this unit (i.e., manufacturer's name). The Maine

Department of Environmental Protection (DEP) was also contacted about the unit since Wrangler Corporation is based in Maine. Maine DEP were not aware that Wrangler marketed this unit and were unable to provide any additional information.

Figure 5
Wrangler Fluorescent Tube Recycling System

Fluorescent Lamp Recycling Equipment for Commercial Operations

Larger-scale commercial fluorescent lamp separation and recycling equipment reviewed are listed in Table 9, below. A discussion of these technologies is divided into two categories, mobile versus stationary systems, and is presented below.

Mobile Recycling Units

OPPTD was able to obtain information on 3 mobile recycling units. According to the Illinois Pollution Control Board, there are two companies which offer on-site fluorescent lamp recycling services using a mobile unit: Spent Lamp Recycling Technologies, Inc. (SLRT) and National Lamp Recycling (NLR)[19].

Spent Lamp Recycling Technologies, Inc. (SLRT)

SLRT (now VX Technologies) provides on-site fluorescent lamp crushing services. Their mobile unit is subject to Illinois' universal waste rule (UWR) requirements on fluorescent lamp crushers[36]. Illinois' UWR allows universal waste handlers and transporters to crush mercury lamps only to reduce their volume, and only at the site where the lamps are generated. The Illinois UWR requires: (1) crushing to occur in a closed system that prevents mercury emissions from exceeding 0.1 mg/m3, measured on a time weighted average over an 8-hour period; (2) crushing activities to be reported quarterly to the Illinois EPA; (3) crushing to be performed in a well-ventilated and well-monitored area, to ensure compliance with applicable OSHA exposure limits; (4) crushed lamps to be stored in closed, non-leaking containers; and (5) spilled or crushed materials to be transferred immediately to closed containers. A copy of Illinois' UWR is included in Appendix A. SLRT was also granted an exemption by the Illinois Environmental Protection Agency (IEPA) to operate in the State as a mobile mercury vapor removal system[19,31] but this exemption probably pertains to their air emissions. SLRT currently provides recycling services to the Department of Energy, United Postal Service, Argonne National Laboratory, Fermi Laboratory, and Waste Management, Inc[31].

The SLRT unit uses a hydraulic crusher operating under a vacuum. The fluorescent lamps are loaded in a batch of 300 4-ft lamps and crushed in an enclosed hydraulic crusher where negative pressure is maintained during the crushing process. Exhaust from the unit passes through a particulate filter and two 55-gallons drums containing activated carbon impregnated with sulfur. Phosphor powder is collected on particulate filters located on the effluent side of the crusher and prior to the carbon filter(s). Mercury concentrations are monitored during crushing operations and 5 to 7 minutes after crushing within the van, between the particulate filter and carbon filter, and between the carbon filters. These readings are recorded using a data logger. The particulate filter is changed approximately every 5,000 lamps and reused after they are washed with water. SLRT did not provide details on wastewater management; however, TCLP testing of the phosphor powder from the particulate filters has shown mercury concentrations below the detection limit.

Table 9. Manufacturer Specifications for Commercial Fluorescent Lamp Recycling Systems

Unit Name	Manufacturer	Dimensions	Feed Rate	Type of Lamp Crushed	Vacuum Rate	Motor Size	Filtration System			Cost ($ per unit)
Commercial Off-site Fluorescent Lamp Separation or Recycling Equipment										
Model LSS1 Lamp Recycling Equipment	AERC/MTI	Ht: 11 ft 10 in, W: 11 ft 6 in, L: 30 ft	> 3,000 lamps per hour (75,000 lamps per day)	All fluorescent lamp shapes, high intensity discharge lamps (i.e., metal halide, hi and lo sodium, and mercury vapor lamps), neon lamps, ignitron tubes, arc lamps, ultra-violet lamps, & crushed lamps	Has negative vacuum (no specific data available)	Not Available	see HEPA filter	Nine baghouse cartridge filters	Carbon filtration system	$300,000.00
Fluorescent Lamp Recycling Equipment and Mercury Retort System used by Earth Protection Services Inc.	Summit Valley Equipment & Engineering, Inc.	Not Available	Not Available	Not known	Not Available	Not Available	Not Available	Not Available	Not Available	Not Available
Big Sieving Crush and Separation Plant	MRT Systems AB	Ht: ~108 in., W: ~120 in., L: 240 in.	~4000 lamps per hour	All fluorescent lamp shapes, high intensity discharge lamps (i.e., metal halide, hi and lo sodium, and mercury vapor lamps)	20 m/s (394 fpm)	Not Available	Cyclone	Dust filter	Series of carbon filters	Not Available
Mobile Fluorescent Lamp Separation Unit for Commercial Use										
Mobile Lamp Processor	Wisconsin Ballast, Inc.	Ht: 118 in, W: 102 in, L: 238 in.	1,000 lbs/hr min.	Straight, u-shaped, and circular lamps	~100 cfm	Not Available	Folded bag house w/shaker unit	Patent describes a microfilter unit	activated charcoal canister	$199,500.00
Mobile Mercury Vapor Removal System	Spent Lamp Recycling Technologies, Inc. (a.k.a. VX Technologies)	Ht:~8ft, W:~5ft, L:~15 ft	Not Available	Straight, u-shaped, and circular lamps	Not Available	Not Available	Particulate filter for phosphorous powder	Not Available	~2 -55-gallon drums of activated carbon filter	Not applicable

Carbon filters are changed approximately every 300,000 lamps. Spent carbon filters are sent to a licensed mercury retort facility for mercury recovery. Crushed glass and metal are sent off-site to manufacturers that can utilize these recyclable materials in their products.

National Lamp Recycling (NLR)

NLR's unit performs on-site fluorescent lamp crushing and material separation. The Illinois Pollution Control Board determined a hazardous waste permit was required for NLR's unit since their process includes material separation and volume reduction was not the unit's sole purpose. NLR has not applied for a permit after this determination was made[19]. No additional information on NLR is available.

Wisconsin Ballast Inc.

Wisconsin Ballast Inc. currently sells a mobile fluorescent lamp crushing and separation unit that was first patented by Budget Lamp Reclaimers, Inc. This mobile unit feeds fluorescent lamps via a feed chute into a rotating auger crusher. The crushed material is sorted into glass, metal, and phosphor dust by the air flow and deposited into hoppers. Air from the unit has to pass through a cyclone, particulate filter, HEPA filter and finally a carbon filter before it's released to the ambient air[5]. OPPTD was unable to obtain any information on maintenance requirements or purchasers of this unit.

Stationary Fluorescent Lamp Recycling Equipment

For large stationary fluorescent lamp recycling equipment, three manufacturers were identified: Advanced Environmental Recycling Company, L.L.C./Mercury Technologies International in Pennsylvania, Summit Valley Equipment & Engineering, Inc. in Utah, and MRT System AB in Sweden. These units not only crush the fluorescent lamps but also separate the crushed material into their component byproducts. Crushed material from fluorescent lamps consist of glass, metals, and phosphor powder. For spent fluorescent lamps, the lamp's total mercury content is approximately 0.2 % as mercury vapor and 2.8% in the phosphor powder[30]. Based on data from recycling operation in the State of Florida, approximately 97% of the mercury entering the facility is recovered and approximately 3% remains in the glass and metal end caps[30]. The majority of the mercury is contained in the phosphor powder that can be recovered on-site using a mercury retort system[30]. Facilities will also recover the mercury in spent carbon filters using a mercury retort system. Refer to Table 9 for specific unit information and available environmental reports and patents. A brief description of the crushing unit manufactured by each company is provided below.

Advanced Environmental Recycling Company, L.L.C./Mercury Technologies International (AERC/MTI)

AERC/MTI manufactures the Model LSS1 Lamp Recycling Equipment used by many commercial off-site lamp recyclers (Figure 6). Intact and crushed lamps are fed into the lamp

crushing unit by a open-top horizontal power conveyor belt through a negative pressure air chamber. Intact lamps undergo an initial breakage stage. The crushed lamp material is then further crushed in rotating drums and moved to a trommel system. The trommel system separates each component (glass, metal ends, and phosphor powder) into containers. Exhaust air from the unit passes through nine baghouse cartridge filters and a carbon filtration system before exiting to the ambient air[1]. MTI operates this unit along with a mercury retort system at their facility in Hayward, California[17] under a hazardous waste recycling permit.

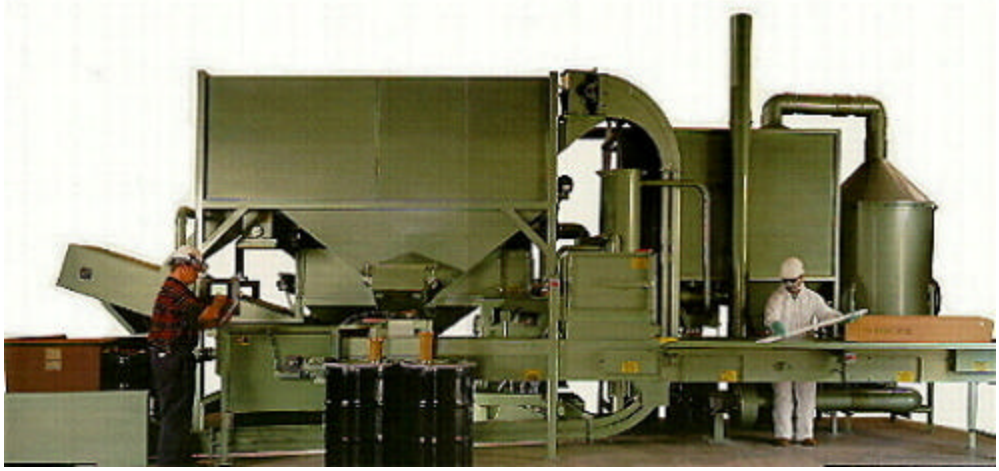

Figure 6. Model LSS1 Lamp Recycling Equipment by AERC/MTI

Summit Valley Equipment & Engineering, Inc. (SVEE)

SVEE has designed the fluorescent lamp recycling equipment including the mercury retort system used by Earth Protection Services, Inc. (EPSI) in Phoenix, Arizona[33]. The unit can recycle any fluorescent or HID lamp. Lamps are gravity fed into the crushing equipment that mechanically separates the lamp components. The aluminum end caps are removed and the crushed glass is transported to a covered container for further distribution to a glass recycling facility. A vacuum system captures all of the mercury and phosphor powder which is processed on-site by a mercury retort unit[11]. Additional information on the emission control system or process equipment was not available.

MRT System AB

MRT System AB manufactures two types of fluorescent lamp recycling units: the crush and separation plant (Figures 7a and 7b) and the end cut/air push unit[34]. OPPTD did not find patent or process information on the end cut/air punch unit, ECM 5000. The crush and separation plant comes in two basic models: the Big Sieving plant (BSP) and the Compact Crush and Separation plant (CCSP). Both plants operate by crushing the fluorescent lamps in a mill. The crushed material is separated into its glass, metal, and phosphor powder components using three separation towers (red towers in Figure 7b). Exhaust from the plant is channeled through a cyclone, dust filters and a series of carbon filters before being released into the atmosphere. The entire unit is enclosed and kept under continuous negative pressure[34]. The difference between the BSP and the CCSP is size. According to the manufacturer, the CCSP is smaller

and can be used as a mobile unit. MRT System AB has sold units to firms such as Osram/Sylvania, Recycling Technologies, Global Recycling Technologies, and Phillips Lighting.

Figure 7a.
Crushing and separation plant
MRT System AB

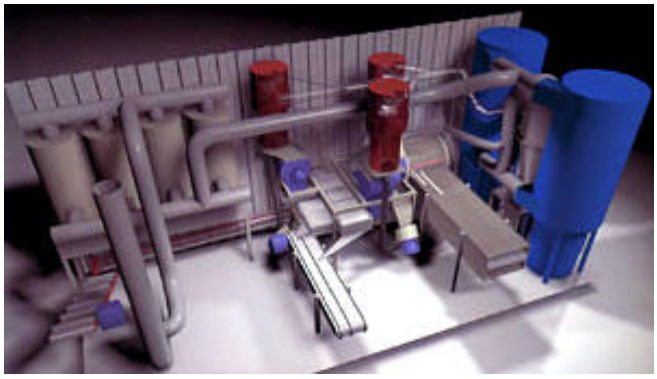

Figure 7b.
Computer representation
of crushing and separation plant
MRT System AB

Conclusions

The main advantage using small on-site fluorescent lamp crushers is that less storage space is needed for spent/used fluorescent lamps and the packaging material is not needed to prevent breakage during storage or transport. Based on a survey of 3 off-site lamp recycling facilities (see Table 1), there appears to be no significant cost advanatages in crushing lamps prior to transport and recycling at an off-site facility. Use of these units may help reduce fugitive mercury releases due to lamps broken while stored on-site or transported to a recycler. However, handling of crushed lamps may present difficulties to the off-site recycler that is set-up to take unbroken lamps.

After reviewing the available information on the small fluorescent lamp crushers, OPPTD has reservations on their ability to effectively control mercury vapor emissions and meet OSHA and CalOSHA standards. One reservation concerns the frequency which mercury filters (activated carbon) are replaced. The replacement schedule for the activated carbon filter varies greatly among the manufacturers from 1,200 lamps for ~0.002 ft^3 carbon filter to 10 million lamps for ~2 ft^3 carbon filter. Air Cycle's claim that their carbon filter will be effective after processing 10 million lamps is highly suspect when compared to a large mobile crusher which replaces two 55-gallon drum (~13 ft^3 each) carbon filters after processing 300,000 lamps.

The lamp crusher design also raises concerns about the effectiveness of mercury vapor control. For the Dextrite crushers, the seal between the crushing unit and collection container depends on the polyurethane skirt which if improperly installed or punctured may release particulates and mercury emissions into the breathing zone. A plugged particulate filter will cause a drop in

vacuum at the feed chute. Lack of proper vacuum may results in the release of particulate and mercury vapor at the feed inlet. A poor seal around the detachable feed chutes may also be a source of particulate and mercury vapor emissions into the operator's breathing zone. These conditions have been observed during independent tests conducted by Florida DEP in 1995. For the Air Cycle and Wrangler units, a warped drum may prevent the crushing unit from sealing flush with the drum top, and allow releases of particulate and mercury vapor during operation.

Available testing results for Air Cycle's and Dextrite's units are also considered inadequate. Air Cycle's tests have been conducted over an 8-hour period with the unit either operating or idle for part of the test. The test reports did not provide details on the test conditions such as whether the carbon filter was new or used, and whether the feed chute was sealed when left idle. Mercury vapor readings, monitored with a direct reading instrument for upset conditions, drum changes, and near the capacity of the carbon filter, have not been conducted. Although the STEL and PEL are based on 15-minute and 8-hour time weighted averages, respectively, these results would not assess spiked mercury vapor concentrations associated with infrequent tasks such as drum change outs or upset conditions. For Dextrite's units, mercury vapor results taken after 1995 are needed to determine if Dextrite has improved its mercury vapor control system or resolved problems reported in Florida DEP's 1995 report. Promotional literature for Dextrite's units presents a graph for mercury vapor results collected in 1994 where several peaks are attributed to fluorescent tubes broken outside the unit due to mishandling or improper packaging. For the May 25, 1998 test, only one mercury concentration was recorded at the feed chute during the test. Therefore, it is unclear whether the vacuum at the feed chute is adequate to control potential mercury emissions at this location.

It may prove difficult for on-site fluorescent lamp crushers to be operated in compliance with all federal, state and local regulations relating to the protection of worker health and safety. In California these include, but are not limited to, Cal-OSHA and OSHA requirements.

Small on-site fluorescent lamp crushers should be located either outside or in well-ventilated area where it is accessible to properly trained personnel only. Since the carbon filter replacement is dependent on the number of fluorescent lamps crushed, accurate inventories on the type and number of lamps crushed need to be kept. Mercury concentrations at the carbon filter outlet should be monitored for breakthrough using either a portable mercury vapor analyzer (e.g., Jerome 431-X Mercury Vapor Analyzer) or continuous monitoring unit (e.g., gas-phase mercury EM-4). Work such as replacing the particulate, HEPA, or carbon filters, changing the waste container, or attaching additional feed chutes should be performed by workers in PPE including full-face respirator with mercury cartridges (with "end of life" indicators), puncture resistant gloves, and Tyvek. When the unit is not in use, feed chutes need to be sealed with caps or similar devices to prevent the release of mercury emissions while idle. Used filters generated should be considered hazardous and managed accordingly unless they have been tested and determined non-hazardous based on total and soluble mercury concentrations being below the respective TTLC, STLC, and Toxicity Characteristic (TCLP) values.

OPPTD recommends independent performance testing be performed to confirm the manufacturer claims on the unit's mercury vapor control efficiency. Testing should include crushing fluorescent lamps with varying mercury content, characterizing the crushed material generated for disposal, evaluating the adequacy of the vacuum exerted, and monitoring mercury releases for different tasks (i.e., barrel changes, idle periods, attachment changes, etc.). Evaluating the adequacy of the vacuum includes monitoring the vacuum using new filters and prior to filter replacements. The manufacturer's operating procedures and maintenance requirements (i.e., filter changes) should also be evaluated as part of the performance testing. The minimum PPE requirements should be evaluated by an industrial hygienist.

For the mobile and large fluorescent lamp recycling units, the only user who would purchase these units are either very large quantity lamp generators or fluorescent lamp recycling firms. Operation of these units would require a hazardous waste recycling facility or TSDF permit, and continuous mercury monitoring in work areas and at multiple process points to meet OSHA and California regulatory standards for mercury. Characterization of the separated components (i.e., crushed glass and metal) would need to be performed on a regular basis to confirm material meets TTLC, STLC and Toxicity Characteristic standards, and can be managed as non-hazardous.

References

1. Advanced Environmental Recycling Company, L.L.C./Mercury Technologies International (AERC/MTI), Information from AERC/MTI website, November 15, 2000.

2. Air Cycle Corporation, *A Report of Air Sampling for Mercury Vapor and Particulates During Fluorescent Tubes Disposal Operation, Maywood, Illinois,* November 7, 2000.

3. Air Cycle Corporation, Information from Air Cycle Corporation website, December 5, 2000.

4. Balcan Engineering, Information listed on the Balcan Engineering website for Balcan Lamp crushers, December 6, 2000.

5. Budget Lamp Reclaimers, Inc., *U.S. Patent 5,586,730: Fluorescent Lamp Collection and Separation Method and Apparatus*, December 24, 1996.

6. Correspondence between Joe Carruth at the Minnestoa Pollution Control Agency and Scott Beierwaltes at Air Cycle Corporation, November 22, 2000.

7. Dextrite, Inc., *U.S. Patent 5,899,395: Multipurpose Fluorescent Lamp Crusher*, May 4, 1999.

8. Dextrite, Inc., *U.S. Patent 5,205,497: Fluorescent Lamp Crusher*, April 27, 1993.

9. Dextrite, Inc., *U.S. Patent 5,575,429: Control Apparatus for Fluorescent Lamp Crusher*, November 19, 1996.

10. Dextrite, Inc., Dextrite Series "E" Fluorescent Lamp Disposers with Mercury Vapor Control, Bulletin:1-7/94 "E" Series.

11. Earth Protection Services, Inc., Information from the Earth Protection Services, Inc. website, February 5, 2001.

12. EcoLights Northwest, Information from the Total Reclaim, Inc. website, November 15, 2000.

13. Environmental Disposal Concept, Incorporated, Information from the Environmental Disposal Concept, Incorporated website, January 12, 2001.

14. Environmental Disposal Concept, Incorporated, *U.S. Patent 5,769,336: Environmentally-safe Apparatus for Disposing of Light Bulbs*, June 23, 1998.

15. Environmental Disposal Concept, Incorporated, *Bulb Eater Mark V Operating Safety Procedures and Standard Operating Procedures*, October 13, 1999.

16. Florida Department of Environmental Protection, *Fluorescent Lamp and Mercury-Containing Device Management Demonstration Project: Palm Beach County Solid Waste Authority,* December 1995.

17. Sustainable Conservation, *Reducing Mercury Emissions from Fluorescent Lamps: Analysis of Voluntary Approaches*, September 27, 2000.

18. Telephone conversation with Joe Carruth, Minnesota Pollution Control Agency, December 7, 2000.

19. Telephone conversation with Mark Crites, Illinois Pollution Control Board, December 22, 2000.

20. Telephone conversation with Paul Abernathy, Association of Lighting and Mercury Recyclers, January 10, 2001.

21. Telephone conversation with John Price, Florida Department of Environmental Quality, January 10, 2001.

22. Telephone conversation with Tom Ezell, Arkansas Department of Environmental Protection, February 1, 2001.

23. Telephone conversation with Bob Hudson, Maine Department of Environmental Protection, February 2, 2001.

24. Telephone conversation with Miguel Gutierrez, AERC/MTI - Hayward Facility, February 6, 2001.

25. Telephone conversation with David Chilcott, Earth Protection Services, Inc., February 7, 2001.

26. Telephone conversation with Chris, Ecolights Northwest, Inc., February 7, 2001.

27. Thomas Register, Thomas Register 2000, Crushers, Fluorescent Tubes, Volume 6, pp. 11853.

28. Thomas Register, Thomas Register 2000, Lamps, Fluorescent (Disposal Units), Volume 12, pp. 23454.

29. U.S. EPA, *Evaluation of Mercury Emissions from Fluorescent Lamp Crushing*, February 1994.

30. U.S. EPA, *Mercury Emissions from the Disposal of Fluorescent Lamps*, June 1997.

31. VX Technologies, Information from VX Technologies website, February 2, 2001.

32. Wisconsin Ballast, Inc., Information from the Wisconsin Ballast website, December 5, 2000.

33. Summit Valley Equipment & Engineering, Inc., Information from the Summit Valley Equipment & Engineering, Inc. website, November 15, 2000.

34. MRT System AB, Information from the MRT System AB website, February 2, 2001.

35. Natural Resources Canada, R-Net Recycling Technology Newsletter, Construction and Demolition – Articles, October 1999.

36. Telephone conversation with Mark Crites, Illinois Pollution Control Board, February 22, 2001.

37. Foss Environmental, Information from the Foss Environmental website, January 8, 2001.

38. EDCI, *Technology Application Analysis, EDCI Bulb Eater Summary and Analysis of Testing Results on Fluorescent Tube Disposal* submitted to the Government of Novia Scotia Department of Environment and Labour, February 2001.

Appendix A

Illinois Universal Waste Rule

Available at : http://www.ipcb.state.il.us/Archive/dscgi/ds.py/Get/File-12254