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17 March 2004

Mr. James Shaffer
Pest West USA LLC
P.O. BOX 21405
Bradenton, FL 34204-1405

Re: Point source emissions assessment during fluorescent bulb recycling

Dear Mr. Shaffer:

Pest West Electronics, LTD, contracted Weston Solutions, Inc. (WESTON®) to monitor point source exhaust emissions during a test of their Mercury Vapor Vac and Bulb Compactor (Bulb Compactor). Specifically, WESTON was asked to measure mercury levels at and around the machine during and after the crushing of fluorescent light bulbs. Dr. Jeffrey Zebrowski, Ph.D., of WESTON performed the assessment using a LUMEX Mercury Vapor Meter. The LUMEX meter is most sensitive mercury vapor meter available and is capable of reading mercury vapor to 0.00002 mg/M3. Pest West Electronics personnel operated the Bulb Compactor under the direction of Dr. Zebrowski.

DESCRIPTION OF TESTING LOCATION

The test was performed on 19 February 2004 at 847 West Adams Street in Chicago, Illinois. The Bulb Compactor was placed in the basement, which was approximately 24 feet by 16 feet with a ceiling height of approximately 9.5 feet. There was a stairway leading to an exit door to the first floor and two open passageways leading to other rooms in the basement. These openings were covered with 6-millimeter-thick plastic sheets. No significant drafts were detected in the room. The tests were conducted, therefore, in a largely contained space. Room temperature at the start of the test was approximately 55°F and did not vary significantly throughout the test.

DESCRIPTION OF THE BULB COMPACTOR

The Bulb Compactor (see Photograph No. 1) consists of three main components: the crushing unit, the mercury vapor filter unit, and the waste collection drum. The crushing unit mounts directly onto the waste collection drum. A rubber gasket forms a seal around the drum and the crushing unit; thus, the crushing unit itself acts as a drum lid. A motor mounted on the top of the unit is connected to the shaft, onto which a blade (located inside the drum) is attached. Bulbs are then crushed as they are fed into the unit.

Bulbs can be added to two openings. A circular opening (approximately 2.5 inches in diameter) allows standard 2-foot, 4-foot, and 8-foot linear fluorescent bulbs to be added. Attachments (consisting of hollow metal tubes) fit over this opening and allow the bulbs to be safely fed into the machine. A second rectangular opening is approximately 2 inches by 14 inches and is raised about 14 inches above the lid (thus appearing as a metal box on top of the unit). This allows for

the addition of circline (and U-shape) fluorescent bulbs. Both of the bulb openings are sealed when not in use.

The filter unit is attached to the drum and crushing unit and is physically supported at the top of the crushing unit by a metal bracket. A 2-inch plastic accordion vacuum hose runs from the top of the crushing unit to the bottom of the filter unit. The filter unit is an off-the-shelf mercury vapor vacuum consisting of a motor attached to a canister, which contains a series of filters. When the motor is turned on, a vacuum is created, and air is drawn from the 55-gallon drum through the hose and into the filter unit. Air is expelled out the top of the filter unit after it has passed through the series of filters. A pressure gauge at the top of the crushing unit measures the extent of the vacuum created in the drum.

The entire Bulb Compactor can be placed at a 45 degree angle to allow long linear tubes to be fed into the machine. This was the position used throughout this test (see Photograph No. 2).

OCCUPATIONAL MERCURY VAPOR EXPOSURE LIMITS

Occupational exposure guidelines are designed to protect most workers under normal working conditions (i.e., 8-hour days, 5 days a week for the duration of a working lifetime). It is assumed that healthy adults, when exposed to these levels, would not suffer any harmful effects. These occupational exposure guidelines are not intended to be applied to community exposure. Typically, exposure limits are given in terms of ceiling values and time weighted average (TWA) values. A ceiling value cannot be exceeded at any time. A TWA value allows for exposures above the limit as long as they are compensated with periods of low exposure. TWA values are essentially the average concentration that a worker can be exposed to over the designated timeframe (typically 8-hour TWAs are given, though short-term limits can sometimes apply).

Exposure levels routinely are found from three sources. The Occupational Safety and Health Administration's (OSHA's) set limits set are legal requirements for occupational exposure; exceeding OSHA limits violates the law and is punishable by fines. States can, however, set their own occupational limits. The American Conference of Governmental Industrial Hygienists (ACGIH) also publishes exposure limits. These recommended limits are updated regularly and are considered the most comprehensive and influential exposure guidelines in the country. The third source for exposure limits is the National Institute of Occupational Safety and Health (NIOSH). NIOSH limits are periodically updated and are also recommended limits.

Occupational exposure limits for elemental mercury from the three sources listed above were obtained from OSHA's website (www.osha.gov). The limits posted on the site were last revised on this site on 28 July 2003 and are presumed to be the current standards. The OSHA ceiling value for elemental mercury is 100 micrograms per cubic meter ($\mu g/m^3$). OSHA does not have TWA values for mercury. ACGIH also recommends a ceiling threshold of 100 $\mu g/m^3$ and recommends an 8-hr TWA of 50 $\mu g/m^3$. NIOSH does not give a ceiling value; however, its 8-hr TWA is 25 $\mu g/m^3$. Table 1 below summarizes these standards.

Table 1
Occupational Exposure Limits for Inorganic Mercury

	OSHA*	ACGIH	NIOSH
Ceiling	100 µg/m^3	100 µg/m^3	---
8-Hr TWA	---	50µg/m^3	25 µg/m^3

* Regulatory Limit

BULB COMPACTOR TEST RESULTS

The test of the Bulb Compactor consisted of four parts: 1) an initial ambient air background check prior to operation of the Bulb Compactor; 2) measurement of mercury levels during the crushing of 2-foot and 4-foot linear fluorescent light bulbs; 3) measurement of mercury levels during the crushing of circline fluorescent bulbs; and 4) a final ambient air background check after completion.

Mercury levels were measured using a LUMEX Mercury Analyzer Model RA-915+ (serial number 00151). This instrument provides continuous readings and is able to detect levels as low as 0.002 µg/m^3. The LUMEX has an air pump that draws air through at a rate of >15 liters/minute. One mercury measurement consists of an integrated 10-second analysis. Three measurements were taken at each measurement point in order to view changes in concentration levels. A hose attached to the mercury analyzer allowed control over the precise location of the measurements.

The vapor pressure of mercury is temperature dependent and increases as the temperature rises. Measurement results obtained at higher temperatures may differ from those obtained during the test described below.

PRETEST MERCURY VAPOR MEASUREMENTS

Mercury is a naturally occurring substance that is present in very small quantities in the air due to natural processes, such as volcanoes and forest fires, and due to human industrial activities. The background levels of mercury were tested prior to crushing any bulbs. Background levels were collected at five locations in the room (four corners and at the top of the stairs) and seven locations around the Bulb Compactor. Mercury levels ranged from 0.015 µg/m^3 to 0.022 µg/m^3. Complete results can be found in Table 2.

Table 2
Initial Background Mercury Vapor Levels

Location	Mercury Concentration ($\mu g/m^3$)			Comments
	Reading 1	Reading 2	Reading 3	
SW Corner of Room	0.018	0.019	0.018	
NW Corner of Room	0.015	0.016	0.017	
NE Corner of Room	0.017	0.016	0.018	
Se Corner of Room	0.018	0.022	0.019	
Top of Stairs	0.022	0.021	0.020	
Filter Unit Exhaust	0.018	0.016	0.017	
Linear Bulb Intake	0.018	0.019	0.018	
Circline Bulb Intake	0.017	0.019	0.019	
Drum Seal	0.017	0.015	0.017	
Blade Motor	0.021	0.020	0.021	
Hose	0.016	0.018	0.020	At connection to crusher
Hose	0.016	0.017	0.014	At connection to filter

Linear Bulb Crushing Results

The Bulb Compactor was tested first with linear fluorescent bulbs. Typical linear bulbs were used for this portion of the test. These included 4-foot General Electric (GE) and Phillips bulbs and 2-foot Sylvania bulbs. An initial test with the first bulb indicated that no mercury was exhausted from the filter unit. Bulbs were then fed into the machine while additional mercury measurements were taken and recorded at locations around the Bulb Compactor. Measurements were taken at the filter canister exhaust, at the hose connections, at the bulb intake, at various points of the drum seal (where the crushing units fits onto the 55-gallon drum), and at the point where the blade motor connects to the unit. All of these locations are considered critical points on the bulb crusher.

The highest mercury levels were recorded at the drum seal with the highest measured value at 0.151 $\mu g/m^3$. While higher than background, this is significantly lower than the 100-$\mu g/m^3$ regulatory ceiling limit set by OSHA and the 8-hour TWA exposure limits recommended by ACGIH and NIOSH and (50 $\mu g/m^3$ and 25 $\mu g/m^3$, respectively). Readings recorded at the other measurement locations around the Bulb Compactor where not significantly above background levels. The highest recorded measurement in the breathing zone (at face level) was 0.033 $\mu g/m^3$. Background levels in the room were not significantly higher after this phase of the test.

Three measurements were then taken directly over the circular opening while the machine was still operating. The highest measured value at this location was 0.059 $\mu g/m^3$. In order to assess how well the vacuum system was containing the vapors, the Bulb Compactor was turned off, and measurements were again taken directly at the opening. An increase in the mercury

concentration was detected. The highest of the three measured values was 62.3 µg/m^3. This indicates that the Bulb Compactor vacuum system, when operating, was successful in retaining the mercury vapor.

Because the LUMEX is not a passive instrument, it is fitted with an air pump that draws air into it. Thus, the detected level in this instance (with no vacuum being pulled by the Bulb Compactor) may be somewhat higher than with a passive instrument. Also, while informative, this is not representative of operator exposure because it was not measured in the breathing zone. The highest level recorded is also below the 100-µg/m^3 OSHA regulatory ceiling limit. According to the Pest West Electronics representative, proper operation of the Bulb Compactor requires placing the cap on the opening prior to shutting down the equipment. Upon replacing the cap on the opening, the mercury levels right above the cap decreased rapidly to a measured value of 0.134 µg/m^3. Complete results can be found in Table 3.

Table 3
Mercury Vapor Levels Measured during
Linear Bulb Crushing

Location	Mercury Concentration ($\mu g/m^3$)			Comments
	Reading 1	Reading 2	Reading 3	
Filter Unit Exhaust	0.016	0.016	0.015	After addition of 1st bulb
Filter Unit Exhaust	0.016	0.015	0.015	After 2nd bulb addition
Drum Seal	0.064	0.048	0.035	During continuous feed
Linear Bulb Intake	0.014	0.014	0.015	
Drum Seal	0.017	0.016	0.020	Additional seal location
Filter Unit Exhaust	0.016	0.017	0.018	
Hose	0.016	0.020	0.019	At connection to crusher
Hose	0.016	0.017	0.019	At connection to filter
Drum Seal	0.088	0.094	0.089	Additional seal location
Drum Seal	0.033	0.040	0.043	Additional seal location
Drum Seal	0.110	0.132	0.124	Additional seal location
Drum Seal	0.029	0.031	0.033	Additional seal location
Breathing Zone	0.028	0.031	0.033	At face level
Filter Unit Exhaust	0.043	0.044	0.044	
Drum Seal	0.144	0.151	0.101	Additional seal location
SW Corner of Room	0.026	0.021	0.026	
NW Corner of Room	0.035	0.038	0.034	
NE Corner of Room	0.031	0.028	0.030	
SE Corner of Room	0.029	0.025	0.026	
Linear Bulb Intake	0.059	0.051	0.049	Directly at opening with compactor on and lid off
Linear Bulb Intake	38.5	62.3	59.7	Directly at opening with the compactor off and lid off
Linear Bulb Intake	0.160	0.151	0.134	Directly at opening with the compactor off and the lid on

CIRCLINE BULB CRUSHING RESULTS

The second opening on the Bulb Crusher crushes nonlinear bulbs, such as circline bulbs. This opening, as described above, is approximately 2 inches by 14 inches. An attached lid covers this port when not it use. Opening the lid causes a plate to rise at the bottom of the box, thus holding a bulb that is placed inside. Closing the lid lowers the bottom plate and drops the bulb into the crushing unit.

Levels of mercury were first measured with the Bulb Compactor turned on prior to the addition of any circline bulbs. The lid was opened, and measurements were taken directly at the opening. The highest detected level was 0.402 µg/m^3, which was higher than the value found at the linear bulb entry port. The higher value is most likely attributed to lower airflow velocity through the entrance due to the larger opening. A bulb was then added to the compactor, and the lid was shut. The highest recorded level near the lid (with the lid shut) was 0.138 µg/m^3. After crushing a bulb, the lid was opened, and measurements were taken directly at the opening with the Bulb Compactor still running. Mercury levels peaked at 55 µg/m^3; however, this value was not recorded in the breathing zone and does not represent exposure levels. Under normal operating conditions the lid is only opened to insert bulbs. During the test the lid remained open to allow for instrument readings to be conducted. The Bulb Compactor was allowed to run for approximately 15 minutes and was then shut down. Measurements were again taken at the entrance. Levels peaked at 15 µg/m^3 and decreased rapidly.

In order to obtain a more representative estimate of potential worker exposures, a series of circline bulbs were crushed. Measurements were taken (with the lid open) 1 and 2 feet above the opening while the Bulb Compactor was running. The maximum recorded mercury level was 1.3 µg/m^3, well below the 8-hour TWA exposure limits ACGIH and NIOSH recommend (50 µg/m^3 and 25 µg/m^3, respectively).

After completing the above tests, the Bulb Compactor was left running, and measurements were taken around the compactor and at the corners of the room. Mercury levels ranged from 0.027 µg/m^3 (where the blade motor connects to the crusher unit) to 0.380 µg/m^3 (in the southwest corner of the room). Complete results of the circline bulb testing can be found in Table 4.

Table 4
Mercury Vapor Measurements during
Circline Bulb Crushing

Location	Mercury Concentration ($\mu g/m^3$)			Comments
	Reading 1	Reading 2	Reading 3	
Circline Bulb Intake	0.402	0.201	0.137	Directly at opening with the compactor on and the lid off prior to crushing circline bulbs
Circline Bulb Intake	0.138	0.126	0.127	Directly at opening with the compactor on and the lid on during bulb crushing
Circline Bulb Intake	21.0	41.0	55.0	Directly at opening with the compactor on and the lid off after circline bulb crushing
Circline Bulb Intake	15.1	2.8	0.610	Directly at opening with the compactor off and the lid off – compactor was allowed to run with the lid closed prior to turning off
1 Foot Above Bulb Intake	0.647	0.585	0.922	Lid open and the compactor running
2 Feet Above Bulb Intake	1.255	1.195	1.328	Lid open and the compactor running
Drum Seal	0.105	0.117	0.108	Compactor was on for these and the following results
Drum Seal	0.208	0.229	0.223	Additional seal location
Filter Unit Exhaust	0.147	0.223	0.115	
Blade Motor	0.027	0.049	0.038	
Hose	0.103	0.106	0.124	At connection to crusher
Hose	0.109	0.115	0.120	At connection to filter
SW Corner of Room	0.326	0.369	0.380	
NW Corner of Room	0.160	0.176	0.170	
NE Corner of Room	0.181	0.196	0.173	
SE Corner of Room	0.152	0.154	0.154	

POST TEST MERCURY VAPOR MEASUREMENTS

After completing testing, the Bulb Compactor was sealed and turned off. After 20 minutes, a final set of measurements were performed around the Bulb Compactor and at the same five locations around the room. Measurements ranged from 0.066 µg/m^3 to 0.655 µg/m^3, still well below OSHA's regularoty limit and the occupational exposure limits ACGIH and NIOSH recommend. Complete results of the final background check can be found in Table 5.

Table 5
Final Background Mercury Levels

Location	Mercury Concentration (µg/m^3)			Comments
	Reading 1	Reading 2	Reading 3	
Drum Seal	0.178	0.184	0.178	All background measurements taken with the compactor off
Drum Seal	0.075	0.066	0.078	
Filter Unit Exhaust	0.245	0.230	0.202	
0.220	0.217	0.221	0.019	
Circline Bulb Intake	0.181	0.172	0.169	
Blade Motor	0.149	0.118	0.182	
Hose	0.270	0.265	0.254	At connection to crusher
Hose	0.298	0.298	0.299	At connection to filter
SW Corner of Room	0.354	0.391	0.443	
SE Corner of Room	0.364	0.369	0.366	
NW Corner of Room	0.313	0.314	0.315	
NE Corner of Room	0.334	0.338	0.336	
Top of Stairs	0.644	0.637	0.653	

CONCLUSIONS

The purpose of the test was to determine how effective the Bulb Compactor seals and vacuum systems worked at controlling ambient mercury levels around the unit during operation and, where appropriate, to identify possible sources of leaks or operating practices that could increase emissions.

Test results show that the Bulb Compactor with the vacuum system operating was capable of crushing linear bulbs without creating ambient mercury levels that approached any government-established worker exposure levels. During testing, the highest recorded values were found near the drum seal. The only significant mercury levels were recorded when the cap was off while the compactor was not running. WESTON recommends that the procedures emphasize that the cap back must be replaced on the linear bulb entrance port prior to turning the machine off.

Similar testing during the crushing of circline bulbs resulted in increased ambient vapor levels than when processing the linear bulbs; again, these values were still far below OSHA's regulatory ceiling limit and the occupational exposure limits ACGIH and NIOSH recommend. Based on the test results, vapor releases would further be decreased by opening the lid only long enough to place a bulb in the chamber and by allowing the Bulb Compactor to fully crush and compact that bulb prior to the addition of additional bulbs. As the process was explained to WESTON, crushing one circline bulb at a time would be considered standard operating procedure and normal use so opening and closing the lid, with the vacuum running should not present increased vapor levels.

WESTON noted an increase in overall mercury vapor levels in the room after completing the test. These levels, while above the initial background levels, are far below recommended occupational exposure levels. For test purposes only, the bulb ports were allowed to remain open for longer periods than required to process the bulbs. This additional time delay may have had a significant impact on raising the final background mercury vapor levels observed. According to the manufacturer, normal operating procedures all ports are sealed after bulb crushing has been completed. This procedure should reduce final background mercury vapor levels to the initial readings. For the test program, the vacuum was run at 50% capacity. According to manufacturer the normal operating range of the vacuum is 75-80%. This increased vacuum pressure should work to produce negative pressure inside of the collection drum so as not to affect ambient mercury vapor levels.

As a general practice, WESTON recommends that the Bulb Compactor be operated in a location with proper ventilation, and that bulb ports be sealed when not in use.

If you have any questions, please contact the undersigned at (312) 424-3300.

Sincerely,

WESTON SOLUTIONS, INC.

David Wojcik
Project Manager

cc: Mr. John Woodyard (WESTON)

Photograph No. 1. The Mercury Vapor Vac and Bulb Compactor at the testing location. The filter unit is in the foreground with the crushing unit on top of the 55-gallon drum. The large box-like structure is the entrance for the addition of circline bulbs. Linear bulbs are added through the circular port located in front of the mounted motor.

Photograph No. 2. The Mercury Vapor Vac and Bulb Compactor in its working position for the addition of long linear bulbs. Note the attached tube on the linear bulb entrance.