



January 4, 2017

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Via e-mail: Tim@aircycle.com

Bureau Veritas Project No. 07016-000101.00

Subject: **Mercury Emission Sampling and Noise Exposure
Monitoring for the *Bulb Eater® 3L***

Dear Mr. Racke:

Bureau Veritas North America, Inc., (Bureau Veritas) Health Safety and Environmental Services, is pleased to provide you with a copy of the **revised final** Industrial Hygiene report from the September 8, 2016 assessment at the Air Cycle Corporation facility located at 2200 Ogden Avenue, Suite 100 in Lisle, Illinois. This assessment was conducted by Ms. Alma R. Herrera, Industrial Hygienist with Bureau Veritas.

Should you have questions in regard to the enclosed report, or need assistance with other industrial hygiene issues, please feel free to contact me at 630.536.5901.

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Very truly yours,

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Mercury Emission Sampling and Noise Exposure Monitoring for the *Bulb Eater® 3L*

Completed At: Air Cycle Corporation
2200 Ogden Avenue, Suite 100
Lisle, Illinois 60532

Bureau Veritas Project Number: 07016-000101.00

Report Date: January 4, 2017

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REVISED FINAL REPORT



Move Forward with Confidence

The purpose of this Industrial Hygiene assessment and report is to assist you, the client, in your responsibility to establish and maintain a loss control program to prevent illness and injury to your employees and others. Our activities and recommendations are a supplement to and not a substitute for, any part of your own responsibilities and activities. These services are based upon information supplied by client management and conditions that are readily observable, and should not be relied upon exclusively to prevent all possible illnesses, injuries or losses.



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1.0 INTRODUCTION

Mr. Tim Racke, Chief Operating Officer with Air Cycle Corporation, retained Bureau Veritas North America, Inc. (Bureau Veritas / BUREAU VERITAS) to conduct an industrial hygiene assessment on the *Bulb Eater® 3L* at the Air Cycle Corporation facility located at 2200 Ogden Avenue, Suite 100 in Lisle, Illinois. The scope of work for this project was described in Bureau Veritas' Proposal No. 0709.16.093 dated April 18, 2016 and addressed to Mr. Racke. The project was completed in accordance with Bureau Veritas Standard Terms and Conditions dated July 1, 2013.

Ms. Alma R. Herrera, Industrial Hygienist with Bureau Veritas, completed the industrial hygiene assessment on September 8, 2016. Messrs. Mike Tuymmer and Ged Zukas were Bureau Veritas' primary contacts while on-site.

2.0 BACKGROUND

2.1 PURPOSE OF TEST

The *Bulb Eater® 3L* tests were performed to quantify airborne concentrations of mercury vapor emissions at various points around the machine, at the operators breathing zone, and at several locations in the lamp staging areas during the crushing operations, filter replacements, and drum change-outs. All the data was compared to the Occupational Health and Safety Administration (OSHA) Permissible Exposure Limit (PEL) and the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) for mercury.

2.2 BULB EATER® 3L

The *Bulb Eater®* drum-top lamp crushing machine has been in practical usage as a volume reduction method to aid in the recycling of fluorescent lamps since 1998. To date there are approximately 12,000 *Bulb Eaters* in service worldwide. With increased interest in operational safety and operator exposure to mercury vapor, Air Cycle Corporation developed the next generation machine, the *Bulb Eater® 3L*. The *Bulb Eater® 3L* includes the following design features that achieve these goals:

- Single model that crushes linear, CFL, and U-bend lamps
- Lower angle entry tube (lower entry height - easier to use)
- Four stage filter system:
 - 1 High Volume Cartridge Filter
 - 2 High Efficiency Particulate Air (HEPA) Filter
 - 3 Activated Carbon Filter
 - 4 Final HEPA Filter

- Only two hose connections, no casual connections of hoses
- On-board controls with Intelli Technology
 - Additional sensing points that assist with machine diagnostics and maintenance/filter change-outs
 - LCD display that advertises which mode the machine is in and any defaults that might occur

Bureau Veritas performed the following tasks during two test cycles:

- Performed wipe tests on drum top before and after lamp crushing sessions. These were collected and analyzed in accordance with the OSHA ID-145 method.
- Measured vapor concentrations with Air Cycle Corporation's direct-reading instrument (Mercury Instruments [MI] Mercury Tracker 3000 IP, calibrated on 5/23/2016) and hopcalite tubes designed for mercury vapor collection (NIOSH 6009) during the two test cycles. One of the test cycles was conducted while workers crushed one drum full in an open warehouse area and the second test was conducted while workers crushed one drum full in an office space. During the first crushing session, 1,325 lamps were crushed in 106 minutes and 1,200 lamps were crushed during the second crushing session over a 99 minute period.
 - For each test cycle Bureau Veritas collected: six (6) samples, including two (2) personal samples on each operator (one stopped after approximately 200 lamps, with no drum/filter change-out) while the other ran for the duration of the test and included the drum/filter change out, one (1) on a separate operator that assists with the drum change out; one (1) at the exhaust of the carbon filter; one (1) approximately 10 feet away from the Bulb Eater® 3L; and one (1) in the lamp staging area.
 - Collected direct readings using the Mercury Tracker in the locations specified by Air Cycle Corporation. A diagram with the sample locations is provided in Table B, Figure 4 of this report. Readings were collected in 10- 20 minute intervals until the drum was full. A detailed description of the test procedure is provided in Appendix C.
- Measured personal noise exposure levels on the person operating the Bulb Eater® 3L and on the person assisting with the drum and filter change-outs.

- Measured general sound levels utilizing a Sound Level Monitor during the operation of the Bulb Eater® 3L.
- Submitted the collected air samples (along with quality control blank samples) to the Bureau Veritas American Industrial Hygiene Association (AIHA) accredited laboratory in Novi, Michigan for analysis. The Laboratory is accredited by the American Industrial Hygiene Association (AIHA), Laboratory # 100967. To review the scope of accreditation, visit the accreditation organization website at www.aiha.org.
- Prepared this written report documenting Bureau Veritas' evaluation. The report will include a description of sampling and analytical methods, interpretation of the analytical results, a discussion of findings, and conclusions.

The following appendices supplement the results of the industrial hygiene assessment discussed in this report:

- Appendix A Data Tables
 - Table 1 Results of Personal Air Monitoring and Analysis for Mercury
 - Table 2 Results of Area Air Monitoring and Analysis for Mercury
 - Table 3 Results of Surface Wipe Sampling and Analysis for Mercury
 - Table 4 Noise Dosimeter Measurements Compared to the OSHA PEL
 - Table 5 Noise Dosimeter Measurements Compared to the OSHA AL
 - Table 6 Results of Short Term Area Noise Level Measurements
 - Table 7 Direct Reading Measurements for Mercury
- Appendix B Bureau Veritas Laboratory Report
- Appendix C Equipment and Assessment Procedures
- Appendix D Equipment Calibration Certificates
- Appendix E Abbreviations and Glossary
- Appendix F References

3.0 DESCRIPTION OF OPERATIONS

Air Cycle Corporation is a sustainable solutions and technologies company developing tools and services to help clients implement a comprehensive environmental program at their facilities. The tools and services include fluorescent lamp, ballast, battery, e-waste recycling, and food waste diversion. Bureau Veritas performed this assessment on Air Cycle Corporation's Bulb Eater® 3L fluorescent lamp crushing machine.

3.1 BULB EATER® 3L OVERVIEW

Air Cycle Corporation manufactures the Bulb Eater® 3L line of drum-top fluorescent lamp crushing machines. The Bulb Eater® 3L mounts on top of a 55-gallon drum as shown in Figure 1. The spent linear fluorescent lamp is fed through a 30 degree entry tube connected to the Bulb Eater® 3L lid assembly. An electric motor spins a chain inside the unit breaking each inserted lamp. Entry tubes for linear lamps are available in 48-in lengths. Each entry tube connects to the top of the unit by a threaded connection. The system also includes a feed chute that accommodates the crushing of Compact Fluorescent Lamps (CFLs) and U-tube lamps. A vacuum pump pulls the mercury vapor through the unit's four-stage filtration system. The first two stages consist of a filter cartridge followed by a HEPA filter to remove particulates. The cartridge and HEPA filters are contained together in a single housing and followed by an activated carbon filter which is the mercury vapor removal system. Lastly, another HEPA filter follows the carbon filter.

Depending on the lamp type and cleanliness, the filter cartridge should be replaced after filling approximately six 55-gallon drums with crushed lamp waste. The first HEPA filter should be replaced approximately every 15 drums of lamp waste. The activated carbon filter, which is contained in a metal housing, has a calculated life of approximately 1500 hours of running time (approximately 1,000,000 fluorescent lamps). The Bulb Eater® 3L system will crush approximately 850 or more T-12 / 1400 or more T-8 4-foot spent fluorescent lamps into a 55-gallon drum. The average weight of a full drum of crushed fluorescent lamps is approximately 530 pounds (including weight of drum). With trained, experienced operators the unit is capable of processing 30 lamps per minute.

The Bulb Eater® 3L is a simplified version of the Bulb Eater® 3 model. It is the same machine without the first-stage cyclone filter and rotary airlock assembly. The end result is a lower price point, high performance, drum-top lamp crushing machine: the Bulb Eater® 3L.

Figure 1 depicts the Bulb Eater® 3L mounted to a 55-gallon drum.

**Figure 1
 Bulb Eater® 3L**



3.2 LAMP TEST INVENTORY SELECTION

Spent 4-foot (ft) T-8 lamps and 4-ft T-12 lamps were crushed during the tests. Each 4-foot lamp contains on average a concentration of mercury ranging from 3 to 10 milligrams. Table A contains a breakout of the type and number of lamps crushed.

Table A: Test Lamp Inventory		
Lamp Types	Approximate Number of Lamps Collected	Percentage of Total
4-ft, T-8	2,258	89%
4-ft, T-12	267	11%
Total	2,525	100%

Note: The majority of the spent lamps that were crushed were the standard efficiency type. Approximately 10% were green-tip, low mercury type.

3.3 TEST SITE PREPARATION

The Bulb Eater® 3L was tested in two separate areas within Air Cycle Corporation's headquarters facility in Lisle, Illinois. The first test was conducted in an open warehouse area (14 foot ceiling height) which

was equipped with ceiling fans creating some downward air flow. Lamps were staged for crushing in fiber drums within 10 feet of the machine tested. See Figure 2 for photo of the warehouse test area.

The second test was conducted in an open office area. The heating, ventilation, and air conditioning (HVAC) system to this area supplies make-up air, but does not have a return vent.

The Bulb Eater® 3L unit was assembled on a 55-gallon waste drum in the respective test areas by the operator and helper prior to testing in accordance with Air Cycle Corporation Bulb Eater® 3L owner's manual instructions. All fittings, clamps, and fasteners were put in place and inspected to ensure proper attachment, tightness, and seals prior to each test cycle.

Figure 2
Bulb Eater® 3L in Warehouse Area – Test 1



Figure 3
Bulb Eater® 3L in Office Area – Test 2



3.4 SAFETY PRECAUTIONS

The Bulb Eater® 3L operator, operator assistant, and Industrial Hygienist wore personal protective equipment (PPE) during crushing operations. The PPE worn included neoprene-coated, chemical, and cut-resistant gloves; chemical safety glasses, and earplugs.

The warehouse floor area and the open office floor area were periodically checked using the Mercury Tracker 3000 IP for mercury contamination during the test operations and prior to clean-up after each test.

3.5 MERCURY EMISSIONS SAMPLE LOCATIONS

The Bulb Eater® 3L primary sample locations were measured with a factory calibrated (on 5/23/2016) mercury vapor meter, Mercury Tracker 3000 IP direct reading instrument (DRI). The DRI sample locations are presented in Figure 4 and the descriptions of each sample point are provided in Table B.

Figure 4
Bulb Eater® 3L Sample Locations

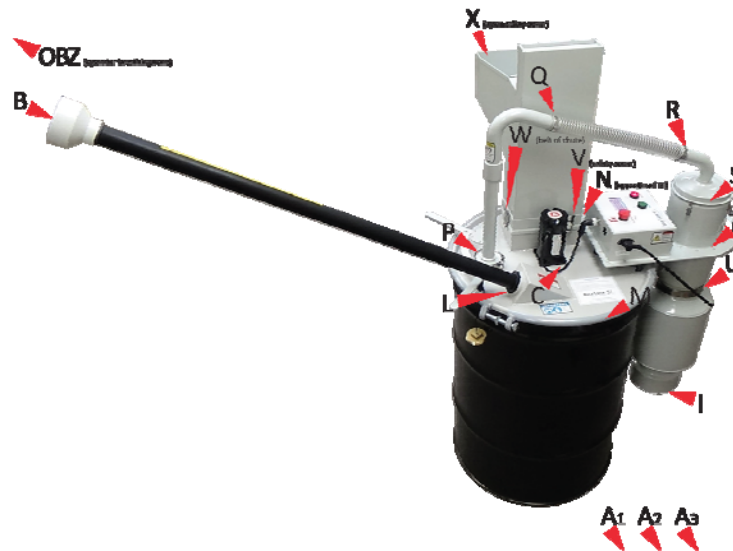


Table B: The Bulb Eater® 3L Sample Points

Sample Point	Description
A1	Ambient Hg concentration before test cycle (4-6 " above floor, 5-6 ft. from drum)
A2	Ambient Hg concentration 30 min. into test cycle, motor on (4-6" above floor, 5-6 ft. from drum)
A3	Ambient Hg concentration after test cycle, motor off (4-6" above floor, 5-6 ft. from drum)
B	Fluorescent lamp chute entry point
C	Motor housing area
I	Filter air exit
L	Fluorescent lamp chute entry connection to drum top
M	Drum lid rim area near chute entry connection to drum top
N	Drum lid rim area near safety cover (opposite of M)
OBZ	Operator breathing zone
P	Outlet tube to lid assembly
Q	Cyclone filter connection to flexible hose
R	Flexible hose connection to filter lid
S	Filter lid connection to filter housing
T	Filter housing connection to vacuum
U	Vacuum connection to carbon canister
V	Safety cover
W	Belt of all-in-one chute
X	Compact fluorescent lamp hopper (open safety cover)
Y1	Fluorescent lamp chute entry point (full drum, machine not running) (not shown in figure)
Y2	Filtered air exit (full drum, machine not running) (not shown in figure)
Y3	Max reading from drum lid rim area circumference (full, sealed drum) (not shown in figure)
Z1	Operator breathing zone (during filter replacement) (not shown in figure)
Z2	Operator breathing zone (during drum change-out) (not shown in figure)

4.0 STANDARDS AND GUIDELINES

4.1 AIRBORNE CONTAMINANTS

Results of air samples collected during this assessment are compared against the OSHA PEL established in 29 CFR 1910.1000 Table Z-2 and the ACGIH TLVs - 2016 Edition. The OSHA PELs are enforceable as a governmental regulation while the ACGIH TLVs are not. Bureau Veritas' considered both the OSHA PELs and the ACGIH TLVs in forming conclusions. Specific exposure limits are provided in Table C and in Tables 1 – 2 in Appendix A.

Table C: OSHA and ACGIH Exposure Limits		
Substance	OSHA PEL 8-hour TWA (mg/m³)	ACGIH TLV 8-hour TWA (mg/m³)
Mercury	0.1	0.025, Skin

OSHA: Occupational Safety and Health Administration

PEL: Permissible Exposure Limit

ACGIH: American Conference of Governmental Industrial Hygienists

TLV: Threshold Limit Value

TWA: Time Weighted Average

mg/m³: Milligrams per cubic meter of air

Skin: Skin, eye and mucous membrane contact as a significant pathway of absorption

4.2 NOISE

OSHA mandates limits for personal noise exposure that are based on the period of time the employee is exposed to noise at a specific intensity, measured in decibels using the "A"-weighting scale (dBA). The OSHA PELs for noise are provided in Table D.

Duration Per Day (hours)	OSHA PEL (dBA)
16	85
12	87
10	88
8	90
4	95
2	100
1	105
0.5	110
0.25	115

^a: Measured in decibels using, a 5dB exchange rate, an "A" weighted filter, 80 to 130 dBA range, and slow response mode.

The OSHA Noise Standard (29 CFR 1910.95) specifies a PEL of 90 dBA and an Action Level (AL) of 85 dBA as eight-hour TWAs.

5.0 SUMMARY OF RESULTS

5.1 AIRBORNE CONTAMINANTS

Bureau Veritas collected a total of six (6) personal air samples and six (6) area air samples as described in Table E. Photos are provided in Appendix C.

Table E: Bulb Eater® 3L Air Sampling Summary	
Sample Type	Samples Collected
Test 1 - Warehouse	
<u>Air - Personal</u> <ul style="list-style-type: none"> • 1 STEL on Operator • 1 Task-duration on Operator (including the filter and drum change-outs) • 1 Task-duration on Operator Assistant 	3
<u>Air – Area</u> <ul style="list-style-type: none"> • 1 - 20-feet southwest of Bulb Eater® 3L • 1 Filter Exhaust • 1 Lamp Staging Area 	3
Air - Field Blanks	1
DRI – Mercury Tracker	100
Totals	107
Test 2 - Office	
<u>Air - Personal</u> <ul style="list-style-type: none"> • 1 STEL on Operator • 1 Task-duration on Operator (including the filter and drum change-outs) • 1 Task-duration on Operator Assistant 	3
<u>Air – Area</u> <ul style="list-style-type: none"> • 1 - 10-feet southwest of Bulb Eater® 3L • 1 Filter Exhaust • 1 Lamp Staging Area 	3
Air - Field Blanks	1
DRI – Mercury Tracker	85
Totals	92

All air sample results collected during this assessment were below the limits of analytical detection and were less than the OSHA PEL and the ACGIH TLV.

Area sample results cannot be compared to the ACGIH TLV or the OSHA PEL; however, the results may be useful in evaluating potential exposure risks. Results of area monitoring for mercury measured during this assessment are not necessarily representative of employees' exposures and were not used in forming conclusions. Area samples were collected at a height of approximately 5-feet, representing the operator's breathing zone height, except for the filter exhaust samples which were placed on the floor at approximately 1-inch from the filter exhaust.

Detailed results of air sampling and analysis are provided in Tables 1 through 3 in Appendix A.

5.2 DIRECT READING INSTRUMENT MEASUREMENTS

Approximately 185 DRI measurements were made with the Mercury Tracker DRI during the Bulb Eater® 3L tests. These measurements were made to assess mercury vapor leakage points and to obtain real-time, mercury vapor test personnel exposure data on the Bulb Eater® 3L unit during and after tests, and on the sealed waste collection drums.

A summary of the Mercury Tracker 3000 IP DRI sample results for the Bulb Eater® 3L tests are presented in Table 7 in Appendix A. DRI measurements were made within two to three inches of the Bulb Eater® 3L unit at each of the sample locations. The DRI values shown in Table 7 are the peak instantaneous values, or highest recorded data, during a 30 second measurement period where the readings were taken each second. They are not calculated 8-hour TWA values.

The sample measurements highlighted in the color blue reveal locations on the Bulb Eater® 3L where three of the 185 DRI measurements were greater than the ACGIH TLV-TWA of 0.025 milligrams per cubic meter (mg/m^3) with one also exceeding the OSHA PEL-TWA of 0.100 mg/m^3 . Two of the DRI measurements were performed at the operator's breathing zone during the drum change-out and one during the filter replacement in both tests. The actual measurement duration was approximately 30 seconds. Detailed data of these measurements are provided in Table 7, Appendix A. The DRI values shown in Table 7 are the instantaneous values recorded each second during the 30 second measurement period. They are not calculated 8-hour TWA values. All other readings shown in Table 7 (182) were well below both the OSHA PEL-TWA and ACGIH TLV-TWA.

The three measurements collected during the filter replacement and the drum change-out tasks are summarized in Table F and detailed results of all DRI measurements are provided in Table 7 in appendix A.

Table F: Bulb Eater® 3L DRI Measurements (Three of 185 highest DRI measurements)			
Sample Point	Location	Mercury Concentration (mg/m³)	Test Area
Z1	Operator breathing zone (during filter replacement) (not shown in figure)	0.0589	Test 1 Warehouse
Z2	Operator breathing zone (during drum change-out) (not shown in figure)	0.09	
Z2	Operator breathing zone (during drum change-out) (not shown in figure)	0.137	Test 2 Office

mg/m³: Milligrams per cubic meter of air

5.3 QUANTITATIVE SAMPLING FOR PRESENCE OF MERCURY SURFACE CONTAMINATION

A surface sampling wipe was used to quantify the amount of mercury on the lid of the Bulb Eater® 3L assembly on the waste drums before and after each test cycle. Based on the analytical results of the sampling wipes, the presence or absence of mercury was confirmed on each drum before and after filling each drum with crushed lamps.

The results are summarized in Table G below and detailed results are provided in Table 3, Appendix A.

Table G: Bulb Eater® 3L Mercury Surface Contamination	
Location	Results
Test 1 – Before	Non-detected
Test 1 – After	Non-detected
Test 2 – Before	Non-detected
Test 2 – After	Non-detected

mg/in²: milligrams per square inch

Bureau Veritas used a completely unfolded surface sampling wipe to wipe the circumference of the Bulb Eater® 3L lid/drum assembly. The sampling wipe was folded in half and the circumference was wiped a second time. The sampling wipe was then folded a third time and the circumference was wiped a third time. The presence of mercury on the lid was practically non-detected as indicated in Table 3, Appendix A.

5.4 NOISE

Bureau Veritas collected a total of two (2) personal noise dosimetry measurements on the employee operating the Bulb Eater® 3L and two (2) personal noise dosimetry measurements on the employee assisting the Bulb Eater® 3L operator. Two personal noise dosimetry measurements were collected during Test 1 in the Warehouse and two measurements were collected during Test 2 in the Office. The operator's and operator's assistant calculated 8-hour TWA measured noise exposures were 64 dBA and 67 dBA for Test 1 (Warehouse), respectively. For Test 2 (Office) the calculated 8-hour TWA measured noise exposures were 69 dBA and 68 DBA, respectively for the operator and the operator's assistant. The four (4) 8-hour calculated employee exposures to noise measured during this assessment were less than the OSHA PEL and less than the OSHA AL.

A summary of the general area noise measurements is provided in Table H. Detailed results of personal noise dosimetry measurements are provided in Tables 4 and 5 in Appendix A while general area sound level measurements are provided in Table 6 in Appendix A.

Table H: Bulb Eater® 3L Sound Pressure Levels	
Location	Noise Level Range (dBA)
Warehouse Test Area	83 – 89
Warehouse Test Area – Top of Bulb Eater® 3L	90 – 105
Office Test Area	84 – 90
Office Test Area – Top of Bulb Eater® 3L	90 – 104

dBA: Decibels in the A-weighting scale

The noise dosimeters used in this assessment are accurate to ± 2 dBA. Employees' noise exposures measured at or above 83 dBA as an 8-hour TWA are potentially at or above the OSHA Action Level. Bureau Veritas recommends all employees with calculated or measured exposures of 83 dBA 8-hour TWA or above wear hearing protection during the operation of the Bulb Eater®.

6.0 DISCUSSION

Bureau Veritas collected a total of six (6) personal air samples, six (6) area air samples, 185 DRI measurements were collected with the Mercury Tracker 3000 IP DRI, and four (4) surface sampling wipes to quantify the amount of mercury on the surface of the Bulb Eater® 3L.

A total of 1,325 T-8 lamps (4-foot) were crushed during the first test (warehouse) and 1,200 lamps (267 T-12 lamps and 933 T-8 lamps) during the second test (office).

The Bulb Eater® 3L operator and assistant personal air sample results collected during this assessment were below the limits of analytical detection (or none detected) and less than the OSHA PEL of 0.1 mg/m³ and the ACGIH TLV of 0.025 mg/m³ for mercury. While three (3) of the 185 DRI peak, instantaneous measurements collected during the two test cycles were greater than the ACGIH TLV-TWA with one of these measurements also being greater than the OSHA PEL-TWA, the durations were brief (from 3 seconds to 21 seconds) as reported in Table 7, Appendix A. The readings occurred during the filter replacement and the drum change-out activities. According to the manufacturer, these activities are performed from once per month on the high end, to as infrequently as once per year depending on the number of spent lamps to be crushed. Per the Bulb Eater® 3L Operating & Maintenance Manual, when these activities are executed properly, they should take less than 10 seconds each. The three readings occurred when the personal air samples were being taken and were also factored into the 8-hour TWA's. As noted above, the operator's and operator assistant's air sample TWAs were below the OSHA and ACGIH limits. This short duration exposure during drum and filter changes has minimal effect on overall worker exposure.

Area sample results cannot be directly compared to the ACGIH TLV or the OSHA PEL; however, the results may be useful in evaluating potential exposure risks. The DRI measurements were collected at various potential emission points (connections) during both tests. The measurements collected during Test 1 (warehouse) ranged from 0.0002 mg/m³ to 0.0010 mg/m³ and from 0.0002 mg/m³ to 0.0019 mg/m³ during Test 2 (office). With the exception of the three DRI readings that were collected during the drum and filter replacements, no other DRI readings exceeded 0.0019 mg/m³. It is understood that area sample results cannot be directly compared to the ACGIH TLV or OSHA PEL, however, the continuum of these DRI readings logically indicate that those standards were not exceeded.

Based on the air contaminant sampling results, the operator and operator assistant were not exposed to excessive concentrations of mercury emissions during either of the Bulb Eater® 3L fluorescent lamp crushing operations. The DRI measurements during the drum change-out and filter replacement operations have the potential to be greater than both ACGIH TLV-TWA and OSHA PEL-TWA mercury vapor exposure limits. As noted above, these readings are for short, infrequent durations. These operations include the Bulb Eater® 3L unit removal from the full crushed lamp collection drum; full crushed lamp collection drum lid removal, replacement or tightening; and during filter unit removal and replacement. Additionally, the full waste drum exterior/Bulb Eater® 3L assembly may exhibit mercury particulate at the end of crushing operations.

Bureau Veritas collected a total of four (4) personal noise dosimetry measurements on the employee operating the Bulb Eater® 3L and an assistant. The operator's and operator's assistant calculated 8-hour TWA measured noise exposures were 64 dBA and 57 dBA, respectively, during Test 1 (warehouse) and 69 dBA and 68 dBA, respectively, during Test 2 (Office). The four (4) 8-hour calculated employee exposures to noise measured during this assessment were less than the OSHA PEL and the OSHA AL. However, Bureau Veritas recommends that all employees with calculated or measured exposures of 83 dBA 8-hour TWA or above wear hearing protection during the operation of the Bulb Eater® 3L.

7.0 CONCLUSION

Bureau Veritas offers the following conclusions based on the Bulb Eater® 3L assessment and test data:

1. The Bulb Eater® 3L system can crush an average of 1,000 lamps with an average 4-foot length well within 70 minutes into one 55-gallon drum period if the spent lamps are properly staged and an assistant is used to aid in lamp handling.
2. Operator and operator assistant are not exposed to excessive mercury concentrations in air as the personal air sampling results in this assessment did not exceed the OSHA or ACGIH exposure limits at any time during the actual crushing operations or when averaged over an 8-hour work period. All air sample results collected during this assessment were below the limits of analytical detection.
3. The chute safety covers, designed to seal open ends of lamp chutes, adequately contain soiled lamp chutes during storage and non-use.
4. Residual powder adhering to the crushing mechanism of the Bulb Eater® 3L system emits mercury vapor when the unit is separated from a full, 55-gallon crushed lamp collection drum (i.e. during drum change-out). Durations are short as exhibited in Table 7 in Appendix A.

8.0 QUALITY ASSURANCE

*As a world leader in providing services that our clients depend on, we continually strive to provide the highest quality.
This report has been reviewed as a part of our quality process.*

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ARH/th

APPENDIX A

Data Tables

**Table 1
Results of Personal Air Sampling and Analysis for Mercury**

Air Cycle Corporation
Lisle, Illinois
September 8, 2016

Bureau Veritas Project No. 07016-000101.00

Sample No.	Sample Description	Sampling Time Start/Stop	Sample Duration (minutes)	Lab Results over Sample Duration (mg/m ³)	Calculated 8-hour TWA (mg/m ³)
OSHA PEL (8-hour TWA)					0.1
ACGIH TLV (8-hour TWA)					0.025
Test 1 – Warehouse					
6350805489	Ged Zukas Bulb Eater® 3L Operator – task-duration, crushed a total of 1,325 T-8 lamps	0915/1137	142	< 0.0014	ND
6350704482	Mike Tuymer Bulb Eater® 3L Operator Assistant	0915/1137	142	< 0.0014	ND
6350805486	Ged Zukas Bulb Eater® 3L Operator – short-term, crushed 200 lamps	0915/0943	28	< 0.0073	ND
Test 2 – Office					
6350704487	Ged Zukas Bulb Eater® 3L Operator – task duration, crushed 1,200 lamps (267 T-12 lamps and 933 T-8 lamps)	1207/1400	113	< 0.0018	ND
6350704489	Mike Tuymer Bulb Eater® 3L Operator Assistant	1207/1400	113	< 0.0018	ND
6350704486	Ged Zukas Bulb Eater® 3L Operator – short term, crushed 200 lamps	1207/1225	18	< 0.011	ND
6350704483	Field Blank	--	--	< 0.00005 mg	--

OSHA: Occupational Safety and Health Administration
 PEL: Permissible Exposure Limit
 TWA: Time Weighted Average
 ACGIH: American Conference of Governmental Industrial Hygienists
 TLV: Threshold Limit Value
 mg/m³: Milligrams per cubic meter
 <: Less Than
 ND: None Detected

Note: The analytical detection limit of the analytical method used for mercury is 0.00005 mg. The field blank result was less than the analytical detection limit and it is reported as a measure of weight only as it was not exposed to a volume of air. All the sample results were also less than the analytical detection limit; therefore, the 8-hour TWA calculations were not performed, but reported as none detected.

**Table 2
Results of Area Air Sampling and Analysis for Mercury**

**Air Cycle Corporation
Lisle, Illinois
September 8, 2016**

Bureau Veritas Project No. 07016-000101.00

Sample No.	Sample Description	Sampling Time Start/Stop	Sample Duration (minutes)	Lab Results over Sample Duration (mg/m³)
OSHA PEL (8-hour TWA)				0.1
ACGIH TLV (8-hour TWA)				0.025
Test 1 – Warehouse				
6350805482	Bulb Eater® 3L Filter Air Exhaust	0915/1114	119	< 0.0017
6350805484	Approximately 20-feet northwest of Bulb Eater® 3L	0915/1146	151	< 0.0013
6350805485	Lamp Staging Area, approximately 6-feet from Bulb Eater® 3L	0915/1146	151	< 0.0013
Test 2 – Office				
6350704490	Bulb Eater® 3L Filter Air Exhaust	1207/1344	97	< 0.0021
6350704488	Approximately 20-feet northwest of Bulb Eater® 3L	1208/1406	118	< 0.0017
6350704485	Lamp Staging Area, approximately 6-feet from Bulb Eater® 3L	1208/1406	118	< 0.0017
6350704483	Field Blank	--	--	< 0.00005 mg

OSHA: Occupational Safety and Health Administration
 PEL: Permissible Exposure Limit
 TWA: Time Weighted Average
 ACGIH: American Conference of Governmental Industrial Hygienists
 TLV: Threshold Limit Value
 mg/m³: Milligrams per cubic meter
 <: Less Than

**Table 3
Results of Surface Wipe Sampling and Analysis for Mercury**

**Air Cycle Corporation
Lisle, Illinois
September 8, 2016**

Bureau Veritas Project No. 07016-000101.00

Sample No.	Sample Description	Lab Results (mg)	Calculated Concentration^(a) (mg/in²)
Test 1 – Warehouse			
SW-1	Drum #1, wiped around the circumference of the drum with the Bulb Eater® 3L lid on before crushing lamps.	< 0.0001	ND
SW-2	Drum #1, wiped around the circumference of the drum with the Bulb Eater® 3L lid on after filling the drum with crushed lamps. Filter was changed on this drum.	0.0083	0.000056
Test 2 – Office			
SW-3	Drum #2, wiped around the circumference of the drum with the Bulb Eater® 3L lid on before crushing lamps. There may have been some residual left from Test #1.	0.0045	0.000030
SW-4	Drum #2, wiped around the circumference of the drum with the Bulb Eater® 3L lid on after filling the drum with crushed lamps. Filter was changed on this drum.	0.010	0.000068

mg/in²: Milligrams per square inch

^a: The calculated concentration of mercury on the surface of the drum was calculated using the circumference (73.8 inches) of the Bulb Eater® 3L Lid and 2-inch around the circumference. The area used for the calculations was 147.6 square inches

Note:

1. The lab results are in mg/in² (surface area calculations), not mg/m³ (volumetric calculations) like the OSHA & ACGIH limits.

Table 4
Noise Dosimeter Measurements Compared to the OSHA Permissible Exposure Limit (PEL)

Air Cycle Corporation
 Lisle, Illinois
 September 8, 2016

Bureau Veritas Project No. 07016-000101.00

Noise Dosimeter Number	Employee, Location	Sampling Period		Measured Dose (percent)	Shift Length (Hours)	Projected Full Shift Dose (%)	8-hour TWA Noise Exposure (dBA)
		Start/Stop	Sample Duration (minutes)				
OSHA PEL-TWA						100	90
Test 1 – Warehouse							
3248296	Ged Zukas Bulb Eater® 3L Operator	0912/1138	146	0.8	8	2.6	64
3248297	Mike Tuymen Bulb Eater® 3L Operator Assistant	0912/1138	146	0.3	8	1.0	57
Test 2 – Office Area							
3248296	Ged Zukas Bulb Eater® 3L Operator	1207/1358	111	1.3	8	5.6	69
3248297	Mike Tuymen Bulb Eater® 3L Operator Assistant	1207/1358	111	1.1	8	4.8	68

OSHA: Occupational Safety and Health Administration
 TWA: Time-weighted average
 dBA: Decibels measured on the A-weighting scale

**Table 5
Noise Dosimeter Measurements Compared to the OSHA Action Level (AL)**

**Air Cycle Corporation
Lisle, Illinois
September 8, 2016**

Bureau Veritas Project No. 07016-000101.00

Sample Number	Employee, Location	Sampling Period		Dosimeter Reading (percent)	8-hour TWA Noise Exposure (dBA)
		Start/Stop	Sample Duration (minutes)		
OSHA Action Level				50	85
Test 1 - Warehouse					
3248296	Ged Zukas Bulb Eater® 3L Operator	0912/1138	146	6.9	79
3248297	Mike Tuymer Bulb Eater® 3L Operator Assistant	0912/1138	146	4.5	76
Test 2 – Office Area					
3248296	Ged Zukas Bulb Eater® 3L Operator	1207/1358	111	6.4	81
3248297	Mike Tuymer Bulb Eater® 3L Operator Assistant	1207/1358	111	4.8	79

OSHA: Occupational Safety and Health Administration
dBA: Decibels measured on the A-weighting scale

**Table 6
Results of Short Term Area Noise Level Measurements**

Air Cycle Corporation
Lisle, Illinois
September 8, 2016

Bureau Veritas Project No. 07016-000101.00

Location		Noise Level (dBA)	
		Range	OSHA Average
Test 1 – Warehouse, Beginning of Test (Drum Empty)			
OSHA PEL (8 – hour TWA)			90
OSHA AL (8 – hour TWA)			85
A1	5-6 ft. from drum	89	89
B	Fluorescent lamp chute entry point	93	93
C	Motor housing area	96	96
I	Filter air exit	99	99
L	Fluorescent lamp chute entry connection to drum top	98	98
M	Drum lid rim area near chute entry connection to drum top	100-105	103
N	Drum lid rim area near safety cover (opposite of M)	97	97
OBZ	Operator breathing zone	83-88	86
P	Outlet tube to lid assembly	93	93
Q	Cyclone filter connection to flexible hose	90	90
R	Flexible hose connection to filter lid	90	90
S	Filter lid connection to filter housing	93	93
T	Filter housing connection to vacuum	95	95
U	Vacuum connection to carbon canister	95-97	96
V	Safety cover	96	96
W	Belt of all-in-one chute	90-94	92
	Approximately 18-feet from drum	84	84

OSHA: Occupational Safety and Health Administration
 PEL: Permissible Exposure Limit
 TWA: Time Weighted Average
 AL: Action Level
 dBA: Decibels A-scale Slow Meter Response

**Table 6 (continued)
Results of Short Term Area Noise Level Measurements**

Air Cycle Corporation
Lisle, Illinois
September 8, 2016

Bureau Veritas Project No. 07016-000101.00

Location		Noise Level (dBA)	
		Range	OSHA Average
Test 2 – Office Area, Beginning of Test (Drum 1/3 Full)			
OSHA PEL (8 – hour TWA)			90
OSHA AL (8 – hour TWA)			85
A1	5-6 ft. from drum	90	90
B	Fluorescent lamp chute entry point	92	92
C	Motor housing area	97	97
I	Filter air exit	97	97
L	Fluorescent lamp chute entry connection to drum top	97	97
M	Drum lid rim area near chute entry connection to drum top	100-104	102
N	Drum lid rim area near safety cover (opposite of M)	100-103	102
OBZ	Operator breathing zone	81-88	85
P	Outlet tube to lid assembly	95-100	98
Q	Cyclone filter connection to flexible hose	92	92
R	Flexible hose connection to filter lid	91	91
S	Filter lid connection to filter housing	91	91
T	Filter housing connection to vacuum	94	94
U	Vacuum connection to carbon canister	95	95
V	Safety cover	96	96
W	Belt of all-in-one chute	90-94	92
	Approximately 18-feet from drum	84	84

OSHA: Occupational Safety and Health Administration
 PEL: Permissible Exposure Limit
 TWA: Time Weighted Average
 AL: Action Level
 dBA: Decibels A-scale Slow Meter Response

Table 7
Direct-Reading Measurements for Mercury
September 8, 2016
Bureau Veritas Project No. 07016-000101.00

Sample Point	Description	1 st Reading (mg/m ³)	2 nd Reading (mg/m ³)	3 rd Reading (mg/m ³)	4 th Reading (mg/m ³)	5 th Reading (mg/m ³)	6 th Reading (mg/m ³)	7 th Reading (mg/m ³)	8 th Reading (mg/m ³)
Test 1 – Warehouse (1,325 T-8 Lamps Crushed)									
Start Time		0924	0941	0953	1007	1022	1035	1100	
End Time		0934	0949	1002	1018	1032	1047	1107	1107
Ambient Temperature: 75 °F									
A1	Ambient Hg concentration before test cycle (4-6 " above floor, 5-6 ft. from drum)	0.0003	0.0003	0.0003	0.0002	0.0004	0.0002	--	--
A2	Ambient Hg concentration 30 min. into test cycle, motor on (4-6" above floor, 5-6 ft. from drum)	--	--	0.0002	--	--	--	--	--
A3	Ambient Hg concentration after test cycle, motor off (4-6" above floor, 5-6 ft. from drum)	0.0003	--	--	--	--	--	--	0.0004
B	Fluorescent lamp chute entry point	0.0003	0.0003	0.0004	0.0004	0.0003	0.0003	--	--
C	Motor housing area	0.0004	0.0003	0.0007	0.0005	0.0003	0.0004	--	--
I	Filter air exit	0.0002	0.0002	0.0004	0.0003	0.0003	0.0002	--	--
L	Fluorescent lamp chute entry connection to drum top	0.0003	0.0003	0.0004	0.0003	0.0003	0.0002	--	--
M	Drum lid rim area near chute entry connection to drum top	0.0002	0.0002	0.0003	0.0003	0.0003	0.0003	--	--
N	Drum lid rim area near safety cover (opposite of M)	0.0003	0.0002	0.0004	0.0004	0.0003	0.0003	--	--
OBZ	Operator breathing zone	0.0004	0.0003	0.0004	0.0004	0.0004	0.0005	--	--
P	Outlet tube to lid assembly	0.0004	0.0003	0.0003	0.0004	0.0003	0.0003	--	--
Q	Cyclone filter connection to flexible hose	0.0004	0.0004	0.0003	0.0004	0.0003	0.0003	--	--
R	Flexible hose connection to filter lid	0.0003	0.0004	0.0005	0.0004	0.0004	0.0004	--	--
S	Filter lid connection to filter housing	0.0003	0.0003	0.0003	0.0003	0.0003	0.0004	--	--
T	Filter housing connection to vacuum	0.0004	0.0004	0.0003	0.0003	0.0003	0.0004	--	--
U	Vacuum connection to carbon canister	0.0003	0.0004	0.0003	0.0004	0.0003	0.0003	--	--
V	Safety cover	0.0004	0.0003	0.0006	0.0004	0.0004	0.0004	--	--
W	Belt of all-in-one chute	--	--	--	--	--	--	0.0004	--
X	Compact fluorescent lamp hopper (open safety cover while crushing linear lamps)	--	--	--	--	--	--	0.0003	--
Y1	Fluorescent lamp chute entry point (full drum, machine not running) (not shown in figure)	--	--	--	--	--	--		0.0006
Y2	Filtered air exit (full drum, machine not running) (not shown in figure)	--	--	--	--	--	--		0.0004
Y3	Max reading from drum lid rim area circumference (full, sealed drum) (not shown in figure)	--	--	--	--	--	--		0.0010
Z1	Operator breathing zone (during filter replacement) (not shown in figure)	--	--	--	--	--	--		0.0589
Z2	Operator breathing zone (during drum change-out) (not shown in figure)	--	--	--	--	--	--		0.09

mg/m³: Milligrams per cubic meter of air

a: Direct-reading measurements collected after crushing 20 U-lamps

--: No measurement collected

Note: The DRI values highlighted in blue are the peak instantaneous or highest recorded values during a 30 second measurement period. Each of these blue peaks had a duration ranging from 3-21 seconds

Table 7 (continued)
Direct-Reading Measurements for Mercury
September 8, 2016
Bureau Veritas Project No. 07016-000101.00

Sample Point	Description	1 st Reading (mg/m ³)	2 nd Reading (mg/m ³)	3 rd Reading (mg/m ³)	4 th Reading (mg/m ³)	5 th Reading (mg/m ³)	6 th Reading (mg/m ³)	7 th Reading (mg/m ³)	8 th Reading (mg/m ³)
Test 2 – Office Area (1,200 T-8 Lamps Crushed)									
Start Time		1211	1228	1233	1259	1312	1322	1345	1350
End Time		1222	1230	1255	1310	1320	1336		
Ambient Temperature: 75 °F									
A1	Ambient Hg concentration before test cycle (4-6 " above floor, 5-6 ft. from drum)	0.0004	0.0010	0.0008	0.0007	0.0009	--	--	--
A2	Ambient Hg concentration 30 min. into test cycle, motor on (4-6" above floor, 5-6 ft. from drum)	--	0.0007	--	--	--	--	--	--
A3	Ambient Hg concentration after test cycle, motor off (4-6" above floor, 5-6 ft. from drum)	--	--	--	--	--	0.0007	--	0.0004
B	Fluorescent lamp chute entry point	0.0002	0.0009	0.0008	0.0009	0.0009	--	--	--
C	Motor housing area	0.0003	0.0011	0.0004	0.0009	0.0019	--	--	--
I	Filter air exit	0.0002	0.0004	0.0006	0.0005	0.0004	--	--	--
L	Fluorescent lamp chute entry connection to drum top	0.0004	0.0007	0.0008	0.0007	0.0007	--	--	--
M	Drum lid rim area near chute entry connection to drum top	0.0002	0.0007	0.0007	0.0007	0.0007	--	--	--
N	Drum lid rim area near safety cover (opposite of M)	0.0004	0.0007	0.0007	0.0007	0.0007	--	--	--
OBZ	Operator breathing zone	0.0003	0.0008	0.0008	0.0010	0.0008	--	--	--
P	Outlet tube to lid assembly	0.0005	0.0007	0.0007	0.0007	0.0008	--	--	--
Q	Cyclone filter connection to flexible hose	0.0003	0.0007	0.0007	0.0007	0.0007	--	--	--
R	Flexible hose connection to filter lid	0.0004	0.0007	0.0007	0.0007	0.0007	--	--	--
S	Filter lid connection to filter housing	0.0005	0.0007	0.0007	0.0008	0.0008	--	--	--
T	Filter housing connection to vacuum	0.0003	0.0008	0.0007	0.0007	0.0007	--	--	--
U	Vacuum connection to carbon canister	0.0003	0.0006	0.0006	0.0007	0.0008	--	--	--
V	Safety cover	0.0006	0.0009	0.0011	0.0007	0.0014	--	--	--
W	Belt of all-in-one chute	0.0005	--	--	--	--	--	--	--
X	Compact fluorescent lamp hopper (open safety cover while crushing linear lamps)	0.0006	--	--	--	--	--	--	--
Y1	Fluorescent lamp chute entry point (full drum, machine not running) (not shown in figure)	--	--	--	--	--	0.0008	--	--
Y2	Filtered air exit (full drum, machine not running) (not shown in figure)	--	--	--	--	--	0.0007	--	--
Y3	Max reading from drum lid rim area circumference (full, sealed drum) (not shown in figure)	--	--	--	--	--	--	--	0.0014
Z1	Operator breathing zone (during filter replacement) (not shown in figure)	--	--	--	--	--	--	0.0007	--
Z2	Operator breathing zone (during drum change-out) (not shown in figure)	--	--	--	--	--	--	--	0.137

mg/m³: Milligrams per cubic meter of air

a: Direct-reading measurements collected after crushing 20 U-lamps

--: No measurement collected

Note: The DRI values highlighted in blue are the peak instantaneous or highest recorded values during a 30 second measurement period. Each of these blue peaks had a duration ranging from 3-21 seconds

APPENDIX B

Bureau Veritas Laboratory Report



September 16, 2016

Alma Herrera
BUREAU VERITAS - CHICAGO
4343 Commerce Court
Suite 120
Lisle, IL 60532

Bureau Veritas Work Order No. 16090542

Reference: 07016-000101.00/ AIR CYCLE CORPORATION

Dear Alma Herrera:

Bureau Veritas North America, Inc. received 17 samples on September 09, 2016 for the analyses presented in the following report.

Enclosed is a copy of the Chain-of-Custody record, acknowledging receipt of these samples. Please note that any unused portion of the samples will be discarded 30 days after the date of this report, unless you have requested otherwise.

This material is confidential and is intended solely for the person to whom it is addressed. If this is received in error, please contact the number provided below.

We appreciate the opportunity to assist you. If you have any questions concerning this report, please contact a Client Services Representative at (800) 806-5887.

Sincerely,

Karen Coonan

Client Services Representative

Electronic signature authorized through password protection

Bureau Veritas North America, Inc.

Health, Safety, and Environmental Services

22345 Roethel Drive

Novi, MI 48375

Main: (248) 344.1770

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CASE NARRATIVE

Date: 16-Sep-16

CLIENT: BUREAU VERITAS - CHICAGO
Project: 07016-000101.00/ AIR CYCLE CORPORATION
Work Order No 16090542

The results of this report relate only to the samples listed in the body of this report.

Unless otherwise noted below, the following statements apply: 1) all samples were received in acceptable condition, 2) all quality control results associated with this sample set were within acceptable limits and/or do not adversely affect the reported results, and 3) the industrial hygiene results have not been blank corrected.



ANALYTICAL RESULTS

Date: 16-Sep-16

Client: BUREAU VERITAS - CHICAGO

Project: 07016-000101.00/ AIR CYCLE CORPORATION

Work Order No: 16090542

Sample Identification: 6350505489

Lab Number: 001A

Date Sampled: 9/8/2016

Sample Type: Anasorb C300

Date Received: 9/9/2016

Analyst: DH

Air Volume (L): 35.43

Analyte	Analytical Results			Reporting Limit (µg)	Test Method	Date Analyzed
	(µg)	(mg/m ³)	(ppm)			
Mercury	<0.05	<0.0014	<0.00017	0.05	NIOSH 6009	09/14/2016

Sample Identification: 6350704482

Lab Number: 002A

Date Sampled: 9/8/2016

Sample Type: Anasorb C300

Date Received: 9/9/2016

Analyst: DH

Air Volume (L): 35.29

Analyte	Analytical Results			Reporting Limit (µg)	Test Method	Date Analyzed
	(µg)	(mg/m ³)	(ppm)			
Mercury	<0.05	<0.0014	<0.00017	0.05	NIOSH 6009	09/14/2016

Sample Identification: 6350805482

Lab Number: 003A

Date Sampled: 9/8/2016

Sample Type: Anasorb C300

Date Received: 9/9/2016

Analyst: DH

Air Volume (L): 30.29

Analyte	Analytical Results			Reporting Limit (µg)	Test Method	Date Analyzed
	(µg)	(mg/m ³)	(ppm)			
Mercury	<0.05	<0.0017	<0.00020	0.05	NIOSH 6009	09/14/2016



ANALYTICAL RESULTS

Date: 16-Sep-16

Client: BUREAU VERITAS - CHICAGO

Project: 07016-000101.00/ AIR CYCLE CORPORATION

Work Order No: 16090542

Sample Identification: 6350805486

Lab Number: 004A

Date Sampled: 9/8/2016

Sample Type: Anasorb C300

Date Received: 9/9/2016

Analyst: DH

Air Volume (L): 6.87

Analyte	Analytical Results			Reporting Limit (µg)	Test Method	Date Analyzed
	(µg)	(mg/m ³)	(ppm)			
Mercury	<0.05	<0.0073	<0.00089	0.05	NIOSH 6009	09/14/2016

Sample Identification: 6350805484

Lab Number: 005A

Date Sampled: 9/8/2016

Sample Type: Anasorb C300

Date Received: 9/9/2016

Analyst: DH

Air Volume (L): 38.35

Analyte	Analytical Results			Reporting Limit (µg)	Test Method	Date Analyzed
	(µg)	(mg/m ³)	(ppm)			
Mercury	<0.05	<0.0013	<0.00016	0.05	NIOSH 6009	09/14/2016

Sample Identification: 6350805485

Lab Number: 006A

Date Sampled: 9/8/2016

Sample Type: Anasorb C300

Date Received: 9/9/2016

Analyst: DH

Air Volume (L): 38.13

Analyte	Analytical Results			Reporting Limit (µg)	Test Method	Date Analyzed
	(µg)	(mg/m ³)	(ppm)			
Mercury	<0.05	<0.0013	<0.00016	0.05	NIOSH 6009	09/14/2016



ANALYTICAL RESULTS

Date: 16-Sep-16

Client: BUREAU VERITAS - CHICAGO

Project: 07016-000101.00/ AIR CYCLE CORPORATION

Work Order No: 16090542

Sample Identification: 6350704487

Lab Number: 007A

Date Sampled: 9/8/2016

Sample Type: Anasorb C300

Date Received: 9/9/2016

Analyst: DH

Air Volume (L): 28.02

Analyte	Analytical Results			Reporting Limit (µg)	Test Method	Date Analyzed
	(µg)	(mg/m ³)	(ppm)			
Mercury	<0.05	<0.0018	<0.00022	0.05	NIOSH 6009	09/14/2016

Sample Identification: 6350704489

Lab Number: 008A

Date Sampled: 9/8/2016

Sample Type: Anasorb C300

Date Received: 9/9/2016

Analyst: DH

Air Volume (L): 28.08

Analyte	Analytical Results			Reporting Limit (µg)	Test Method	Date Analyzed
	(µg)	(mg/m ³)	(ppm)			
Mercury	<0.05	<0.0018	<0.00022	0.05	NIOSH 6009	09/14/2016

Sample Identification: 6350704490

Lab Number: 009A

Date Sampled: 9/8/2016

Sample Type: Anasorb C300

Date Received: 9/9/2016

Analyst: DH

Air Volume (L): 24.01

Analyte	Analytical Results			Reporting Limit (µg)	Test Method	Date Analyzed
	(µg)	(mg/m ³)	(ppm)			
Mercury	<0.05	<0.0021	<0.00025	0.05	NIOSH 6009	09/14/2016



ANALYTICAL RESULTS

Date: 16-Sep-16

Client: BUREAU VERITAS - CHICAGO

Project: 07016-000101.00/ AIR CYCLE CORPORATION

Work Order No: 16090542

Sample Identification: 6350704486

Lab Number: 010A

Date Sampled: 9/8/2016

Sample Type: Anasorb C300

Date Received: 9/9/2016

Analyst: DH

Air Volume (L): 4.39

Analyte	Analytical Results			Reporting Limit (µg)	Test Method	Date Analyzed
	(µg)	(mg/m ³)	(ppm)			
Mercury	<0.05	<0.011	<0.0014	0.05	NIOSH 6009	09/14/2016

Sample Identification: 6350704488

Lab Number: 011A

Date Sampled: 9/8/2016

Sample Type: Anasorb C300

Date Received: 9/9/2016

Analyst: DH

Air Volume (L): 29.74

Analyte	Analytical Results			Reporting Limit (µg)	Test Method	Date Analyzed
	(µg)	(mg/m ³)	(ppm)			
Mercury	<0.05	<0.0017	<0.00020	0.05	NIOSH 6009	09/14/2016

Sample Identification: 6350704485

Lab Number: 012A

Date Sampled: 9/8/2016

Sample Type: Anasorb C300

Date Received: 9/9/2016

Analyst: DH

Air Volume (L): 28.67

Analyte	Analytical Results			Reporting Limit (µg)	Test Method	Date Analyzed
	(µg)	(mg/m ³)	(ppm)			
Mercury	<0.05	<0.0017	<0.00021	0.05	NIOSH 6009	09/14/2016



ANALYTICAL RESULTS

Date: 16-Sep-16

Client: BUREAU VERITAS - CHICAGO

Project: 07016-000101.00/ AIR CYCLE CORPORATION

Work Order No: 16090542

Sample Identification: 6350704483 BLANK

Lab Number: 013A

Date Sampled: 9/8/2016

Sample Type: Anasorb C300

Date Received: 9/9/2016

Analyst: DH

Air Volume (L): NA

Analyte	Analytical Results			Reporting Limit (µg)	Test Method	Date Analyzed
	(µg)	(mg/m ³)	(ppm)			
Mercury	<0.05	--	--	0.05	NIOSH 6009	09/14/2016

General Notes:

<: Less than the indicated reporting limit (RL).

--: Information not available or not applicable.

Back sections (if applicable) were checked and showed no significant breakthrough unless otherwise noted.



ANALYTICAL RESULTS

Date: 16-Sep-16

Client: BUREAU VERITAS - CHICAGO

Project: 07016-000101.00/ AIR CYCLE CORPORATION

Sample Type: Wipe

Work Order No: 16090542

Method Reference OSHA ID-145

Date Received: 9/9/2016

RL (μg): 0.1

Analyst: DH

Lab No.	Sample Identification	Date Collected	Air Volume (liters)	Mercury			Date Analyzed
				(μg)	(mg/m^3)	(ppm)	
014A	SW-1	09/08/16	0	<0.1	--	--	09/16/2016
015A	SW-2	09/08/16	0	8.3	--	--	09/16/2016
016A	SW-3	09/08/16	0	4.5	--	--	09/16/2016
017A	SW-4	09/08/16	0	10	--	--	09/16/2016

General Notes:

<: Less than the indicated reporting limit (RL).

--: Information not available or not applicable.

Back sections (if applicable) were checked and showed no significant breakthrough unless otherwise noted.



Request for Laboratory Analytical Services

For Lab Use Only
Lab Project No.

16090542

Bureau Veritas North America, Inc.

Report results to:

Name: Alma Herrera. Alma.herrera@us.bureauveritas.com
 Company: Bureau Veritas North America
 Mailing Address: 4343 Commerce Court, Suite 120
 City, State, Zip: Lisle, Illinois 60532
 Telephone No: 708-595-1338

Bureau Veritas Project Number: 07016-000101.00

Client: Air Cycle Corporation
 Client Address: 2200 Ogden Avenue, Suite 100
 Client City, State: Lisle, IL

Collected by: Alma R. Herrera
 Relinquished by: Alma R. Herrera
 Relinquished by:
 Method of Shipment: FedEx
 Authorized by: Alma R. Herrera

Collector's Signature: Alma R. Herrera
 Received by: Alma R. Herrera
 Received by: Alma R. Herrera
 Sample Condition on Receipt: 9-4-16 11:09

Date/Time: 9-08-16 2030
 Date/Time:

Other:
(Explain)

Client Sample Identification	Date Sampled	Matrix/Media	Time Sampled (minutes)	Air Volume (Liters)	ANALYSIS REQUESTED (List each analyte on the lines below, multiple analytes per line)
6350505489 ✓	9/8/2016	Carulite (Hydrar)	142.00	35.43	Mercury
6350704482 ✓	9/8/2016	Carulite (Hydrar)	142.00	35.29	Mercury
6350805482 ✓	9/8/2016	Carulite (Hydrar)	119.00	30.29	Mercury
6350805486 ✓	9/8/2016	Carulite (Hydrar)	28.00	6.87	Mercury
6350805484 ✓	9/8/2016	Carulite (Hydrar)	151.00	38.35	Mercury
6350805485 ✓	9/8/2016	Carulite (Hydrar)	151.00	38.13	Mercury
6350704487 ✓	9/8/2016	Carulite (Hydrar)	113.00	28.02	Mercury
6350704489 ✓	9/8/2016	Carulite (Hydrar)	113.00	28.08	Mercury
6350704490 ✓	9/8/2016	Carulite (Hydrar)	97.00	24.01	Mercury
6350704486 ✓	9/8/2016	Carulite (Hydrar)	18.00	4.39	Mercury
6350704488 ✓	9/8/2016	Carulite (Hydrar)	118.00	29.74	Mercury
6350704485 ✓	9/8/2016	Carulite (Hydrar)	118.00	28.67	Mercury
6350704483 ✓	9/8/2016	Carulite (Hydrar)	0.00	0.00	Mercury
SW-1 ✓	9/8/2016	Wipe	0.00	0.00	Mercury
SW-2 ✓	9/8/2016	Wipe	0.00	0.00	Mercury
SW-3 ✓	9/8/2016	Wipe	0.00	0.00	Mercury
SW-4 ✓	9/8/2016	Wipe	0.00	0.00	Mercury

APPENDIX C

Equipment and Assessment Procedures

EQUIPMENT AND ASSESSMENT PROCEDURES

**Air Cycle Corporation
Lisle, Illinois**

Bureau Veritas Project No. 07016-000101.00

Visit Date: September 8, 2016

Test Procedure

Bureau Veritas followed Air Cycle Corporation's test procedure as described in the Protocol for Bulb Eater® 3L Testing document sent to Bureau Veritas on June 7, 2013.

Air Cycle Corporation's Protocol for Bulb Eater® 3L Testing

Crush one drum-full (approximately 1,200 lamps) each in open warehouse area and closed office space over 60-90 minute period. Use following procedure for each drum-full test:

1. Record ambient temperature.
2. Perform wipe test on drum top before lamp crushing session.
3. Use collection tube/air pump at following locations (total of 6):
 - i. 2 on machine operator.
 - a. 1 stops after approximately 200 lamps (with no drum/filter change-out), while other pump runs for duration of total test.
 - ii. 1 on separate operator assistant that helps during drum change.
 - iii. 1 at exhaust of carbon filter.
 - iv. 1 at 10-20 feet away from machine.
 - v. 1 at lamp staging area.
4. Test for noise levels:
 - i. Personal noise exposure levels on person operating the machine.
 - ii. General sound level during machine operation utilizing a Sound Level Monitor (supplied by Bureau Veritas) during machine operation.
 - iii. Measurements near machine in same locations as Direct Reading Instrument.
5. Use Direct Reading Instrument to collect data at the sampling points noted on the attached Sample Point Diagram (points A1 through V) at distance of approx. 2 inches.
 - i. Sniff sample points at 10-15 minute intervals until drum is full.
 - ii. At an intermediate time or drum level crush CFLs and/or u-bend lamps, and take sniff points on all-in-one chute as noted in attached diagram (points W and X).
6. Perform wipe test on drum top after lamp crushing session.
7. Use Direct Reading Instrument to collect data at the sampling points noted on the attached diagram (points Y1 through Y3) during non-operational period.

- i. With BE-3 not running, attached to full drum of crushed lamps.
 - a. At lamp chute entry point.
 - b. At filtered air exit.
 - ii. On sealed drum of crushed lamps
8. Use Direct Reading Instrument to collect data during filter replacement and drum change-out at distance of approximately 2 inches from operator. (points Z1 and Z2 in attached diagram).
- i. Using Direct Reading Instrument (probe at operator's breathing level)
 - ii. With collection tube/air pump on operator

Personal and Area Air Sampling

Bureau Veritas collected the personal and area air samples for mercury vapor with portable battery-powered sampling pumps by passing air at the recommended flowrate through the collection media presented in the Sampling and Analytical Methods Table. Sample collection media was placed near the employee's breathing zone and connected to the sampling pump's air inlet with Tygon[®] tubing. Each sampling pump's flowrate was measured with a primary calibration standard, Bios DryCal[®] Defender 510 calibrator (serial number 113857, calibrated on 6/28/2016), before and after the monitoring session. The Bios DryCal[®] Defender 510 calibration certificate is provided in Appendix D.

Breathing zone samples were collected by attaching the sampler in the "breathing zone" of the operator(s) being monitored. The "breathing zone" is defined as a hemisphere forward of the shoulders with a radius of approximately 6 to 9 inches.

Laboratory Analyses of Personal and Area Air Samples

All samples for laboratory analysis collected during this assessment were analyzed by the Bureau Veritas Novi, Michigan Laboratory, which is accredited by the American Industrial Hygiene Association (AIHA), Laboratory # 100967. To review the scope of accreditation, visit the accreditation organization website at www.aiha.org.

SAMPLING AND ANALYTICAL METHODS			
Substance	Flow Rate (LPM)	Sampling Media	Analytical Method
Mercury	0.250	Hopcalite tube, SKC 226-17-1A	NIOSH 6009 AA Cold Vapor

NIOSH: National Institute of Occupational Safety and Health
 LPM: Liters per minute

Direct Reading Instrument Measurements

A factory calibrated mercury vapor meter (on 5/23/2016), Mercury Tracker 3000 IP direct reading instrument (DRI). The DRI was used to measure concentrations in the ambient air before, after, and during each test cycle at all mechanical connections, junctures, and openings where mercury vapor could be emitted. The Mercury Tracker 3000 IP was also used to spot check mercury vapor concentrations in the operator's breathing zone, to check for mercury surface contamination on the unit and waste drum, and to measure breathing zone mercury vapor concentrations during waste drum change-out operations.

The Mercury Tracker 3000 IP is manufactured by Mercury Instruments GmbH Analytical Technologies in Germany and is distributed by Mercury Instruments USA, Littleton, Colorado. The instrument has a range of 0.0000 to 2,000 milligrams of mercury per cubic meter (mg/m^3) of air, an accuracy of 0.0001 mg/m^3 , and a mercury vapor sensitivity of 0.0001 mg/m^3 . The instrument's response time is continuous (which has no measuring cycles or regenerations required) and the microprocessor automatically zeroes the digital meter every minute. The Mercury Tracker 3000 IP direct reading instrument was operated continuously during every period of the test cycles.

Quantitative Sampling of Mercury Surface Contamination

A mercury surface sampling wipe was used to quantify the concentration of mercury on the surface of the Bulb Eater® 3L assembly on the waste drums before and after each test cycle. The sampling wipe was completely unfolded and used to wipe the circumference of the Bulb Eater® 3L lid/drum assembly. The sampling wipe was then folded in half and the circumference was wiped a second time. The sampling wipe was then folded a third time and the circumference was wiped a third time. The wipe samples were analyzed using the OSHA ID-145 Method.

Noise and Sound Level Measurements

Noise exposures were monitored with a Casella™ noise dosimeters set for an 80 dBA threshold, 5 dB exchange rate, and an 80-130 dBA range, according to OSHA regulations/criteria. The dosimeters (serial numbers 3248296 and 3248297) were calibrated before and after each measurement with a Casella™ calibrator. The results of these measurements are shown in Tables 4 and 5 in Appendix A.

Comparing Noise Dosimetry Results to the OSHA Action Level (AL)

The full shift exposure, including shifts exceeding 8 hours, count toward the noise exposure for comparison to the OSHA AL (Eq. 1).

$$\text{FullShift Dose} = \text{SampleDose} * \frac{\text{Shift time}}{\text{Sampletime}} \quad \text{Eq. 1}$$

The full shift dose is then used to calculate the TWA using Eq. 2:

$$\text{TWA} = 90 \text{ dBA} + 16.61 * \text{Log}_{10} \left(\frac{\text{Full Shift Dose}}{100\%} \right) \quad \text{Eq. 2}$$

Comparing Noise Dosimetry Results to the OSHA Permissible Exposure Limit (PEL)

OSHA specifies different threshold levels when comparing results to the AL and PEL. The threshold level for comparison to the AL is 80 decibels and 90 decibels for the PEL.

Therefore, noise results for comparison to the AL and PEL are presented in two separate tables in this report.

Only 8 hours of exposure counts toward the noise exposure for comparison to the PEL even if the shift is longer than 8 hours. The 8-hour noise dose is determined using this formula:

$$\text{8 - hour noise dose} = \text{Sample Dose} * \frac{480 \text{ minutes or shift time, whichever is less}}{\text{Sample time}} \quad \text{Eq. 3}$$

The TWA is calculated using this formula:

$$\text{TWA} = 90 \text{ dBA} + 16.61 * \text{Log}_{10} \left(\frac{\text{8 - hour noise dose}}{100\%} \right) \quad \text{Eq. 4}$$

Sound Level Measurements

A Casella™ CEL-63X sound level meter (serial number 0711798, calibrated on 06/23/2016) was used to measure general area noise levels. The meter was calibrated with a Casella™ calibrator Model CEL-110/2 (serial number 021137, calibrated on 06/23/2016). The results of these measurements are provided in the Table 6 in Appendix A. The calibration certificates for the sound level meter and the calibrator are provided in Appendix D.



Bulb Eater® 3L testing set-up showing portable battery-powered sampling pump and Mercury Tracker 3000 IP



Mercury Tracker 3000 IP panel face



Air samples for mercury vapor taken with calibrated, portable battery-powered sampling tube/pumps

Noise exposures were monitored with Casella® noise dosimeters and air samples for mercury vapor were taken with calibrated, portable battery-powered sampling pumps on Bulb Eater® 3L's operator, Ged Zukas and the operator assistant, Michael Tuymmer

APPENDIX D
Equipment Calibration Certificates



MIUSA
 Instrument: Tracker 3000
 Serial Number: 1000/154
 Calibration Date: 5/23/16
 Calibration Expires: 5/23/17

Calibration Report
 #540117

	1	2	3	4	5
Reference Gas Concentration $\mu\text{g}/\text{m}^3 \text{Hg}^0$ Reference to 20°C & 101.3 KPa (760 torr)	33.17 U (k = 2) .51 $\mu\text{g}/\text{m}^3$ 1.5% Relative	69.97 U (k = 2) 1.82 $\mu\text{g}/\text{m}^3$ 2.6% Relative	111.66 U (k = 2) 1.63 $\mu\text{g}/\text{m}^3$ 1.5% Relative	148.12 U (k = 2) 2.29 $\mu\text{g}/\text{m}^3$ 1.5% Relative	186.77 U (k = 2) 2.75 $\mu\text{g}/\text{m}^3$ 1.5% Relative
Instrument reading $\mu\text{g}/\text{m}^3 \text{Hg}^0$ Cal Factor as found =1.11	33.3	68	108.2	143.2	180.2
Instrument Reading $\mu\text{g}/\text{m}^3 \text{Hg}^0$ Cal Factor as left = 1.09 Pump Volume = 1.45/m	33.1	69.9	111.6	148.1	186.7

Calibration Device:

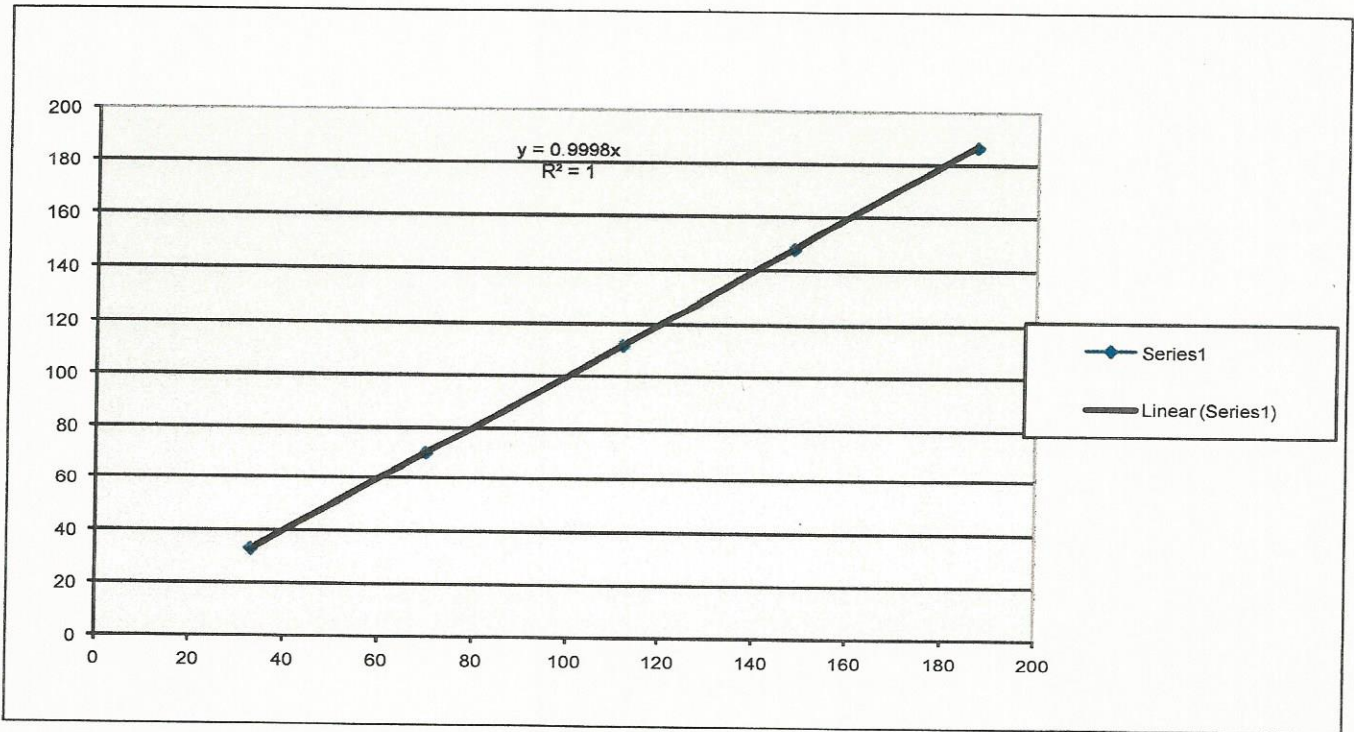
MC 3000 Calibrator Serial # 081011099 NIST Vendor Prime
 Certified by NIST Material Measurements Laboratory Analytical Chemistry Division
 Gaithersburg, MD 20899-8393
 NIST report # 639.03-12-141

Annual Service

- ✓ Replacement of carbon filter
- ✓ Replacement of all internal tubing
- ✓ Thorough cleaning of instrument
- ✓ Decontamination of glassware
- ✓ Deep cleansing of all fittings
- ✓ Complete electronic function check
- ✓ 5 Point Calibration with MC3000 Mercury Calibrator

Calibration Factor as left 1.09

Instrument Readings (ug/m3)	Reference Gas (ug/m3)	U (k = 2) ug/m3	U (k = 2) % Relative
33.1	33.1	0.51	1.5
69.9	69.9	1.82	2.6
111.6	111.6	1.63	1.5
148.1	148.1	2.29	1.5
186.8	186.7	2.75	1.5





Device Data serial #1000/154

<i>Operational Hours</i>	<i>476</i>
<i>Lamp Voltage</i>	<i>5.4V</i>
<i>Software Version</i>	<i>1.6</i>
<i>Absorbance Test</i> <i>(acceptable range .39 - .41)</i>	<i>PASS</i>
<i>No</i> <i>Pressure Cal. Gradient</i> <i>(pt correct only)</i>	
<i>No</i> <i>Pressure Cal. Constant</i> <i>(pt correct only)</i>	
<i>Data Logger Option</i>	<i>Yes</i>
<i>Combi Version</i>	<i>No</i>

Notes:

Tracker 3000 S/N 1000/154 received an annual service and calibration. On the date calibrated this instrument operated within specified tolerances.



CERTIFICATE OF CALIBRATION

Primary Flow Calibrator

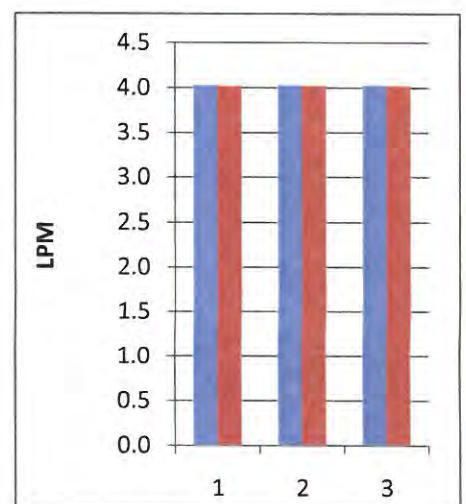
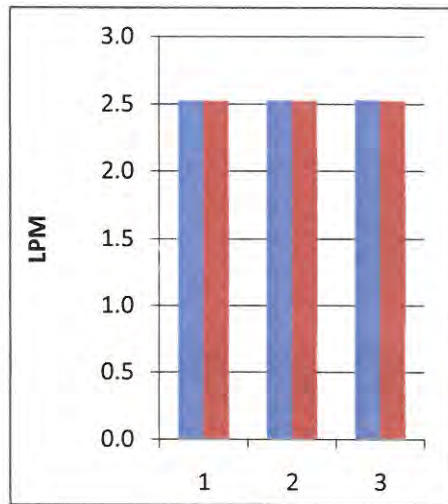
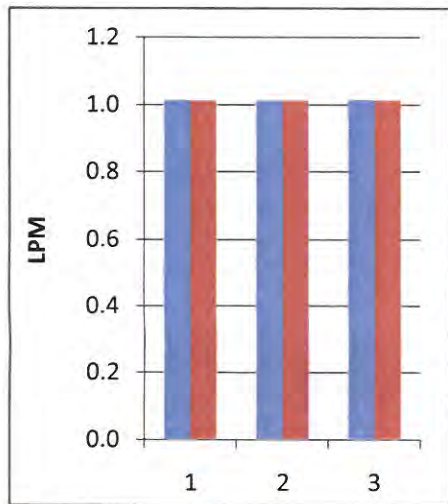
Manufacturer: BIOS
Model Number: 510-M
Serial Number: 113857
Service Order: 20575
Reference Number: 20575-510M-113857

Calibration Date: June 28, 2016
Date Due: June 28, 2017
Temperature: 75.3 °F
Relative Humidity: 52 %
Barometric Pressure: 30.20 inHg

@ 1.0 LPM	Reference L/min	Actual L/min	Relative Difference	Percent Difference
1	1.0146	1.0122	-0.0024	0.24%
2	1.0145	1.0130	-0.0015	0.15%
3	1.0149	1.0133	-0.0016	0.16%

@ 2.5 LPM	Reference L/min	Actual L/min	Relative Difference	Percent Difference
1	2.5265	2.5241	-0.0024	0.09%
2	2.5291	2.5246	-0.0045	0.18%
3	2.5302	2.5236	-0.0066	0.26%

@ 4.0 LPM	Reference L/min	Actual L/min	Relative Difference	Percent Difference
1	4.0282	4.0172	-0.0110	0.27%
2	4.0295	4.0208	-0.0087	0.22%
3	4.0301	4.0224	-0.0077	0.19%



■ Reference ■ Actual

STANDARDS

Manufacturer	Description	Model	Serial Number	Certificate Number	Due Date
Bios	Air Flow Meter	220-H	110577	86198	3/23/2017

This report may not be reproduced except in full. CIH Calibration Laboratory certifies that the instrument specified above meets the manufacturer's specifications and was calibrated using standards and instruments also listed where the accuracy is traceable to National Institute of Standards and Technology (NIST), or have been derived from accepted values of natural physical constants or have been derived by the ratio type of self calibration techniques.

Calibrated By: Adam Hunt Date: 06/28/16
 Adam Hunt - Sr. Calibration Technician

1806 South Highland Ave • Clearwater, FL 33756-1762 • USA • PH: (727) 584-5063 • FX: (727) 581-5921
 Toll Free: (888) 873-2443 • Website: <http://www.cihequipment.com>



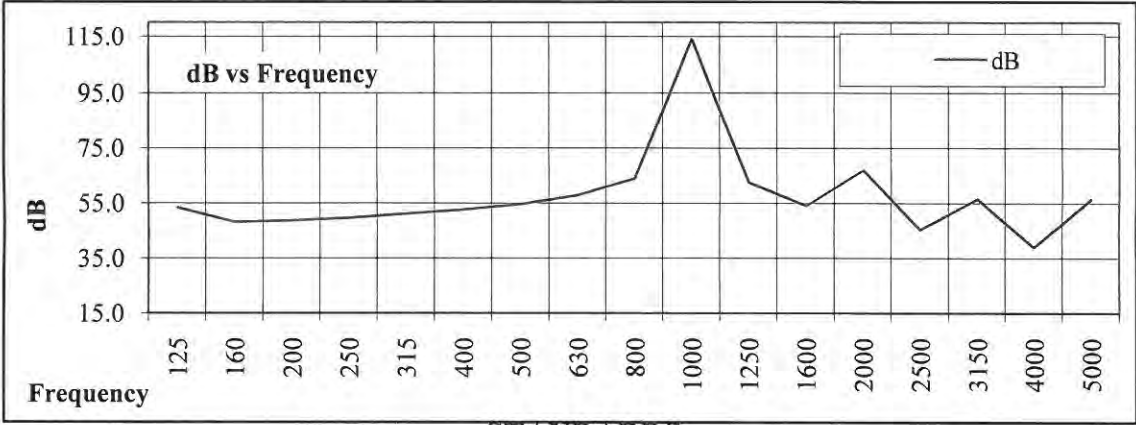
CERTIFICATE OF CALIBRATION

Acoustical Calibrator

Manufacturer: Casella
Model Number: CEL-110/2
Serial Number: 021137
Service Order: 20577
Reference Number: 20577-CEL1102-021137

Calibration Date: June 23, 2016
Date Due: June 23, 2017
Temperature: 74.1 °F
Relative Humidity: 46 %
Barometric Pressure: 30.17 inHg

Frequency (HZ)	Linear dB	Center Frequency
125	53.3	1000.1 Hz
160	48.1	
200	48.7	
250	49.7	
315	51.2	
400	52.7	
500	54.6	THD
630	57.8	0.007 %
800	64.0	
1000	114.0	
1250	62.5	
1600	54.1	
2000	66.9	
2500	45.3	
3150	56.5	
4000	39.0	
5000	56.5	



STANDARDS

Manufacturer	Description	Model	Serial Number	Certificate Number	Due Date
RION	Piston Phone	NC-72	502474	35909	4/4/2017
Stanford Research	Function Generator	DS360	33001	A1743667	10/26/2016
Fluke	Multimeter	8840A/AF	407041	A1991455	9/18/2016
PCB	Microphone	377A07	157013	CAL93-3540471655.908	3/10/2017
E-MU	DAQ	EM8740A	8740050000648H	N/A	4/7/2017
Virtins Technology	Spectrum Analyzer	Pro v3.2	B0D1DD6C	N/A	4/7/2017

This report may not be reproduced except in full. CIH Calibration Laboratory certifies that the instrument specified above meets the manufacturer's specifications and was calibrated using standards and instruments also listed where the accuracy is traceable to National Institute of Standards and Technology (NIST), or have been derived from accepted values of natural physical constants or have been derived by the ratio type of self calibration techniques. The calibration system & records are in compliance with ANSI S1.40-1983(R2006).

Calibrated By: Date: 06/23/16
 Jonathan Terry - Calibration Technician

1806 South Highland Ave • Clearwater, FL 33756-1762 • USA • PH: (727) 584-5063 • FX: (727) 581-5921
 Toll Free: (888) 873-2443 • Website: <http://www.cihequipment.com>



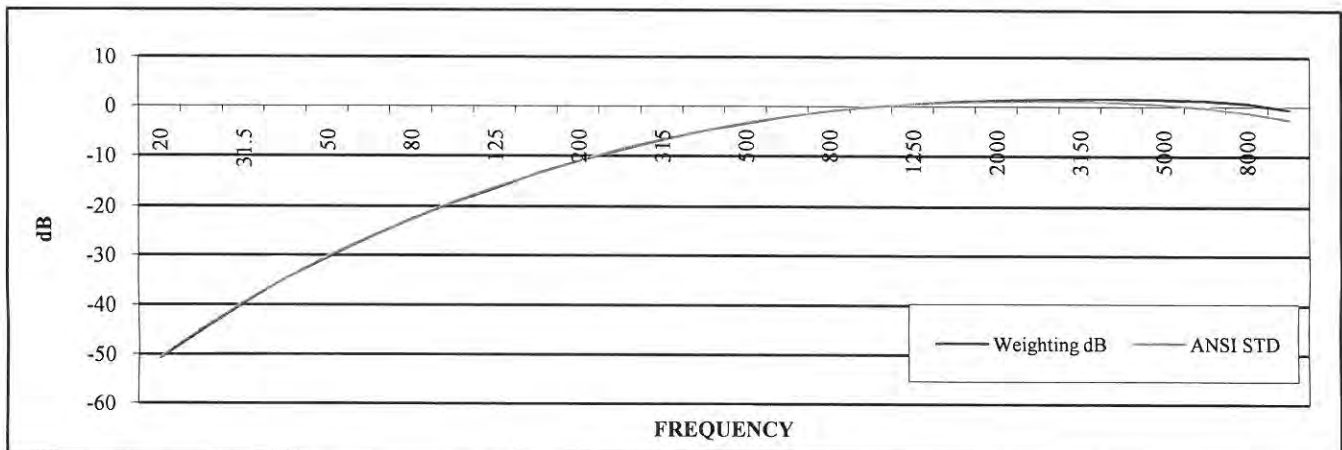
CERTIFICATE OF CALIBRATION

Sound Level Meter Type 1

Manufacturer: Casella
Model Number: CEL-63X
Serial Number: 0711798
Service Order: 20577
Reference Number: 20577-CEL63X-0711798

Calibration Date: June 23, 2016
Date Due: June 23, 2017
Temperature: 73.7 °F
Relative Humidity: 45 %
Barometric Pressure: 30.17 inHg

Frequency (HZ)	Meter Actual Display (dB)	Meter Weighting dB	ANSI STD	Tolerance	Relative Difference
20	63.4	-50.6	-50.5	± 2.5	-0.1
25	69.0	-45.0	-44.7	± 2	-0.3
31.5	74.4	-39.6	-39.4	± 1.5	-0.2
40	79.4	-34.6	-34.6	± 1.5	0.0
50	83.7	-30.3	-30.2	± 1	-0.1
63	87.8	-26.2	-26.2	± 1	0.0
80	91.6	-22.4	-22.5	± 1	0.1
100	94.9	-19.1	-19.1	± 1	0.0
125	97.7	-16.3	-16.1	± 1	-0.2
160	100.7	-13.3	-13.4	± 1	0.1
200	103.1	-10.9	-10.9	± 1	0.0
250	105.3	-8.7	-8.6	± 1	-0.1
315	107.4	-6.6	-6.6	± 1	0.0
400	109.2	-4.8	-4.8	± 1	0.0
500	110.7	-3.3	-3.2	± 1	-0.1
630	112.1	-1.9	-1.9	± 1	0.0
800	113.2	-0.8	-0.8	± 1	0.0
1000	114.0	0.0	0.0	± 1	0.0
1250	114.6	0.6	0.6	± 1	0.0
1600	115.1	1.1	1.0	± 1	0.1
2000	115.4	1.4	1.2	± 1	0.2
2500	115.6	1.6	1.3	± 1	0.3
3150	115.7	1.7	1.2	± 1	0.5
4000	115.7	1.7	1.0	± 1	0.7
5000	115.6	1.6	0.5	± 1.5	1.1
6300	115.4	1.4	-0.1	+ 1.5 to - 2	1.5
8000	114.8	0.8	-1.1	+ 1.5 to - 3	1.9
10000	113.6	-0.4	-2.5	+ 2 to -4	2.1



STANDARDS

Manufacturer	Description	Model	Serial Number	Certificate Number	Due Date
RION	Piston Phone	NC-72	502474	35909	4/4/2017
Stanford Research	Function Generator	DS360	33001	A1743667	10/26/2016

APPENDIX E
Abbreviations and Glossary

APPENDIX F

References