Report on TVOC Removal Testing Conducted for San Francisco International Airport at Terminal 2 and Terminal 1

By
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Submitted to
San Francisco International Airport.

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Executive Summary

The primary purpose of this testing was to confirm the efficacy of the Genesis Air photocatalytic oxidation (PCO) panels after approximately 10 years of operation serving Terminal 2. At SFO's request, testing was also performed on a PCO system in Terminal 1 provided by a different supplier, UVDI. The goal of the testing was to determine the single pass TVOC reduction efficiency of each system by simultaneously sampling the air upstream and downstream of each PCO system. The systems tested were the Genesis Air panels installed in AHU-CS2A (Gates 58 & 59) and UVDI panels with Charcoal bag filters in AHU-SF2 (Gates 20 & 22).

Test Equipment

(2) ION Tiger Total Volative Organic Compound (TVOC) meters, manufactured by Ion Science Ltd, www.ionscience.com

Minimum resolution: 1 ppb or 0.001 mg/m^3

Maximum reading: 20,000 ppm or 20,000 mg/mA^3

Accuracy: +/– 5%

Calibration: Standard calibration 100ppm isobutylene with custom calibration capability

Flow rate: 220ml/min in ambient conditions
Operating Temperature: -4-140F Humidity: 0-99% (non-condensing)

All specifications are against isobutylene calibration at 20 ^{C}, 90% RH and up to 3000 ppm unless otherwise stated.

Calibration Certificates

ION SCIENCE Inc 4153 Bluebonnet Drive, Stafford TX 77477
Telephone: 1.877.864.7710

ION

CALIBRATION CERTIFICATE

Date of Calibration: -07/17/18 T-113619
Calibrated by: - T.Forano Signed
Description: - PID Leak Detector
Manufacturer: - ION Science
Type Number: - Tiger
Serial Number: - T-113619

The relevant procedures are recorded and are available for inspection if required. The following list indicates the identification numbers of traceable items used during the calibration procedure.

BAN-21-3-1	BAN-248-100-1		

ION Science hereby certify that on the day of calibration the instrument was working according to the manufacturer's original specifications as checked by the calibration procedure, unless otherwise stated.

Applied	Instrument Indication
100 ppm Isobutylene	101.2 ppm

The estimated measurement uncertainty is ± 2.0%

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ION SCIENCE Inc 4153 Bluebonnet Drive, Stafford TX 77477
Telephone: 1.877.864.7710

CALIBRATION CERTIFICATE

Date of Calibration: -07/17/18 Certificate Number: T-113620
Calibrated by: - T.Farone Signed:
Description: - PID Leak Detector
Manufacturer: - ION Science
Type Number: - Tiger
Serial Number: - T-113620

The relevant procedures are recorded and are available for inspection if required. The following list indicates the identification numbers of traceable items used during the calibration procedure.

BAN-21-G-1	BAN-348-100-1		

ION Science hereby certify that on the day of calibration the instrument was working according to the manufacturer's original specifications as checked by the calibration procedure, unless otherwise stated:

Applied	Instrument Indication
100 ppm Isobutylene	101.2 ppm

The estimated measurement uncertainty is ± 2.0%

Test Set Up

The testing,was conducted with one TVOC meter placed upstream of a PCO system while the other meter was placed downstream of the same system. Simultaneous recordings of the entering air and leaving air TVOC levels were then taken.

Single Pass Testing & Occupied Space Testing Results

February 11, 2019.. Air testing was performed for one hour each on the Genesis Air and UVDI PCO O systems. The Genesis system consists of 6" deep panels with UV lights running through the panels at 6" vertical intervals, i.e., (4) lamps per 24" tall panel. Meters were placed upstream and downstream of each panel in order to determine each system's single pass efficiency. The data collected during the Genesis testing demonstrates an average single pass TVOC (Total Volatile Organic Compound) reduction of **92.46%**. During the testing at AHU-CS2A, a separate air sample was also taken in an occupied space that is served by that unit, Gate 58, using an Igeress TVOC Meter Model: WP6930S. The sampling showed zero TVOC's at Gate 58 (see Image 1,,p. 6).

Testing on the UVDI panels was done in Terminal 1 at AHU-SF2. The UVDI system consists of two, 0.75" deep, honeycomb-style PCO panels,arranged in series,with a single UV lamp located between the panels. Downstream of the UVDI panels is a filter section comprised of 22" Charcoal impregnated bag filters. The first round of testing consisted of removing two of the bag filters and then placing one of the Ion Tiger TVOC Meters where the two bag filters were removed. This was done in order to assess the efficacy of the UVDI panels by themselves. (Note: after the filters were removed, an inspection showed that the UV lighting was breaking them down. See Image 2, p. 10). The other Ion meter was placed upstream of the pre-filters. The first day of testing showed an unexpected result: a 31.82% increase in average TVOC's coming out of the system. As in the T2 test, a sample in the occupied space was also taken from Gates 20-21 to the food court)with the Tiger Ion meter. It showed an average TVOC level of 45.26 ppm.

Given the unexpected results observed during the UVDI testing, Genesis suggested repeating the testing and returned on Feb. 15th to perform the retest, which consisted of taking samples both without the filters (as before) and with the filters in place. Each test was conducted for one hour. The retest results showed an average **increase** of 22.95% with the bag filters removed,, with the bag filters in place showed an average increase of 31.39%.

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Conclusions

The Genesis Air system tested in Terminal 2 saw challenging conditions. Several jets were moving in and out from the gates during the sampling period. Samples taken at AHU-CS2A showed a 92.5%average reduction rate. TVOC levels taken at Gate 58 (served by AHU-CS2A) showed similar reductions.

The UVDI system in Terminal 1 was tested on two separate occasions. Test 1 was conducted on 2/11/19, and Test 2 was conducted on 2/15/19. Results for both tests showed an increase in TVOC's.

Genesis Air: 92.46% single pass Reduction	**UVDI: 31.39% single pass Increase**

Possible explanation of the Terminal 1, UVDI byproducts:

"The main concern in applications of the PCO technology in a building mechanical ventilation system is the formation of the undesired by-products. Most PCO reactions are stepwise, which means they take many intermediate steps to form the final reaction products, and a by-product may be generated by one of the PCO middle steps. The concern of the formation of more toxic byproducts during the process of UV-PCO makes it necessary to employ a chemisorbent scrubber after a PCO air cleaner in order to reduce the potential health risks and indeed improve IAQ.

The concentration of by-products reduces with the increase of the contact time of the contaminant with UV illumination. Accumulation of by-products on the catalyst surfaces results in rapid catalyst deactivation." **Photocatalytic air cleaners and materials technologies-Abilities and limitations, Department of Building, Civil and Environmental Engineering, Concordia University, Montreal, Quebec H3G 1M8, Canada**

The UVDI installation in AHU-SF2 consists of two, 0.75")deep (in direction of airflow) honeycomb-type catalyst panels and one UV lamp, which illuminates approximately 10% of the panels' surface area. By comparison, the Genesis panels are 6 inches deep with UV lights at 6" vertical intervals. The pleated design of the media allows it to be completely illuminated by the UV light while also providing greater surface area for the photocatalytic reactions to take place. A possible explanation for the increase in TVOC levels measured at the UVDI panel is that the relative lack of residence time of airflow across the PCO panel combined with insufficient energy distribution over the face of the PCO panel, which could be leading to the creation of byproducts due to partial oxidation.

The lack of proper energy distribution is demonstrated by the holes burned in the carbon bag filter. As noted above, the holes seen in the filters are at the same height as the UVGI lamp, indicating that light is penetrating completely through the honeycomb only where there is line-of-sight between the light and filter((see Image 2, page 10). If the panel was receiving ample energy distribution over the entire panel face, then we would also expect to see holes prevalent across the entire face of the bag filters.

Furthermore, the carbon bag filters appear to be off-gassing from over saturation. This is seen during Day 2 testing where the average TVOC increase w/ the bag filters in place was actually 7% higher than the TVOC levels measured without the filters. 4)

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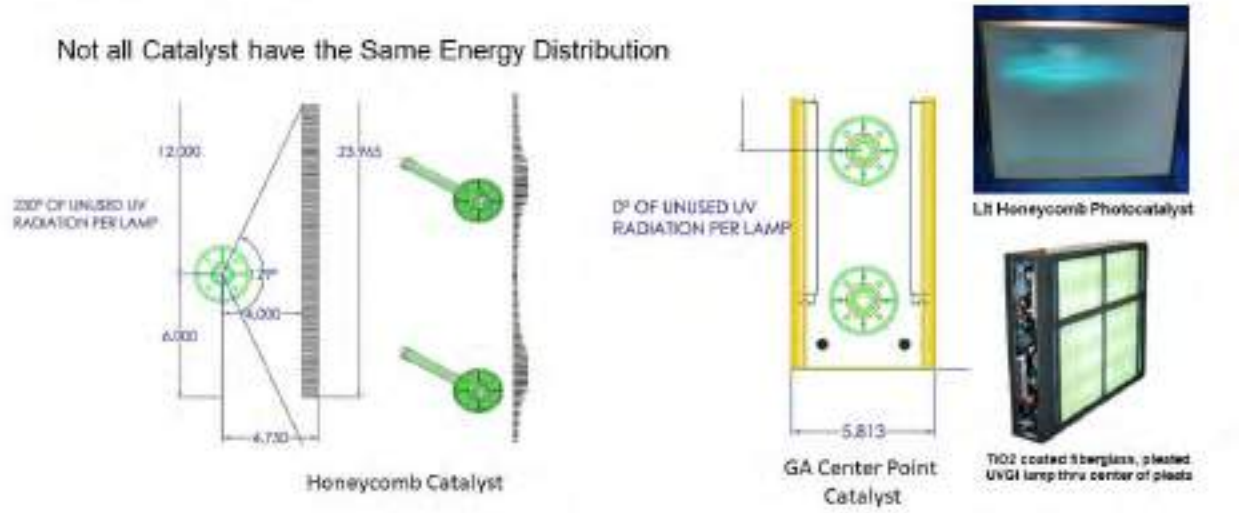

The lamps are mounted off the honeycomb catalyst 4". By doing this, the useful catalyst activation energy from the lamp is about 130 degrees about the lamp. Unless there is another honeycomb on the other side of the lamp (as in some installations), roughly 2/3 of the lamps energy is not being used to activate the catalyst. **With GAP technology, ALL 360 degrees of lamp radiation is being used for the catalyst activation.**

Data Summary

Location	Average Input TVOCs	Average Output TVOCs	Average TVOC Reduction	Data Points
Genesis Air	73.3247 ppb	5.52495 ppb	92.465%	500
T2 Gate 58 Occupied Space		0		30 minute Snap shot
UVDI Catalyst Only Day 1	81.1097 ppb	118.9502ppb	-31.82%	266
UVDI Catalyst Only Day 2	40.3842 ppb	50.05722071 ppb	-23.95%	381
UVDI Catalyst & Charcoal Bag Filter Day 2	72.42336 ppb	95.15496 ppb	-31.39%	413
Terminal 1 Gate 20 to Food Court Occupied Space Day 1		45.26ppb		69

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SFO T1 Day 1: 31.82% TVOC Increase. Graph 2

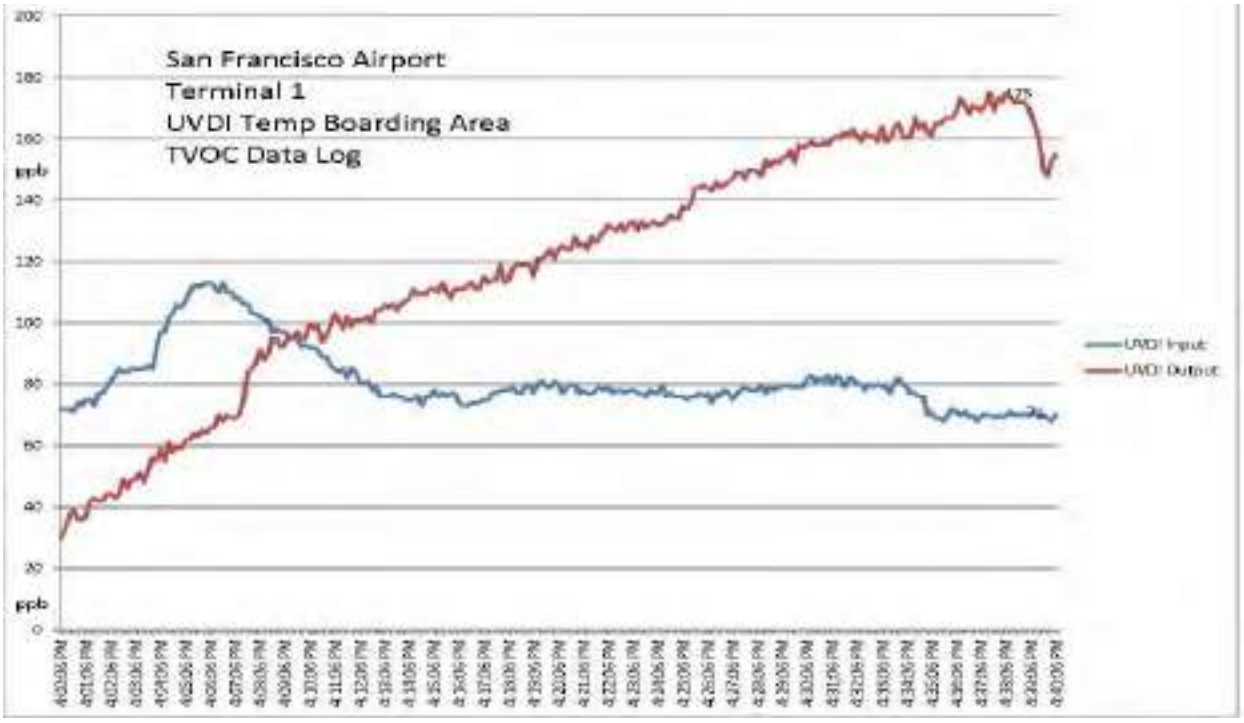

Image 1: Snap Shot SFO T2 Terminal Gate 58

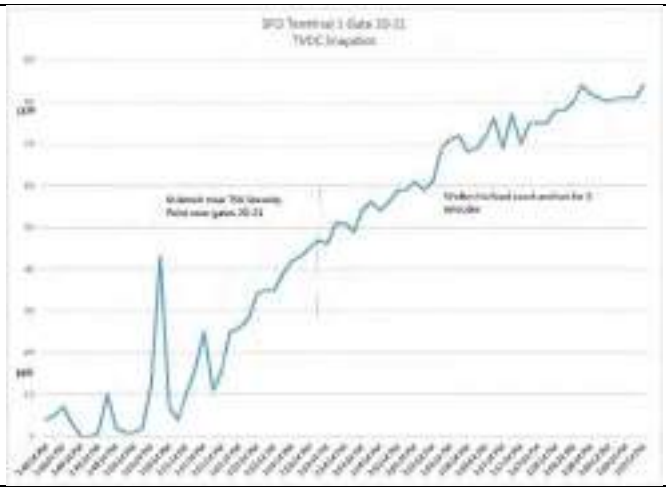

Image 3: Terminal 1 Gates 20-21 to Food Court

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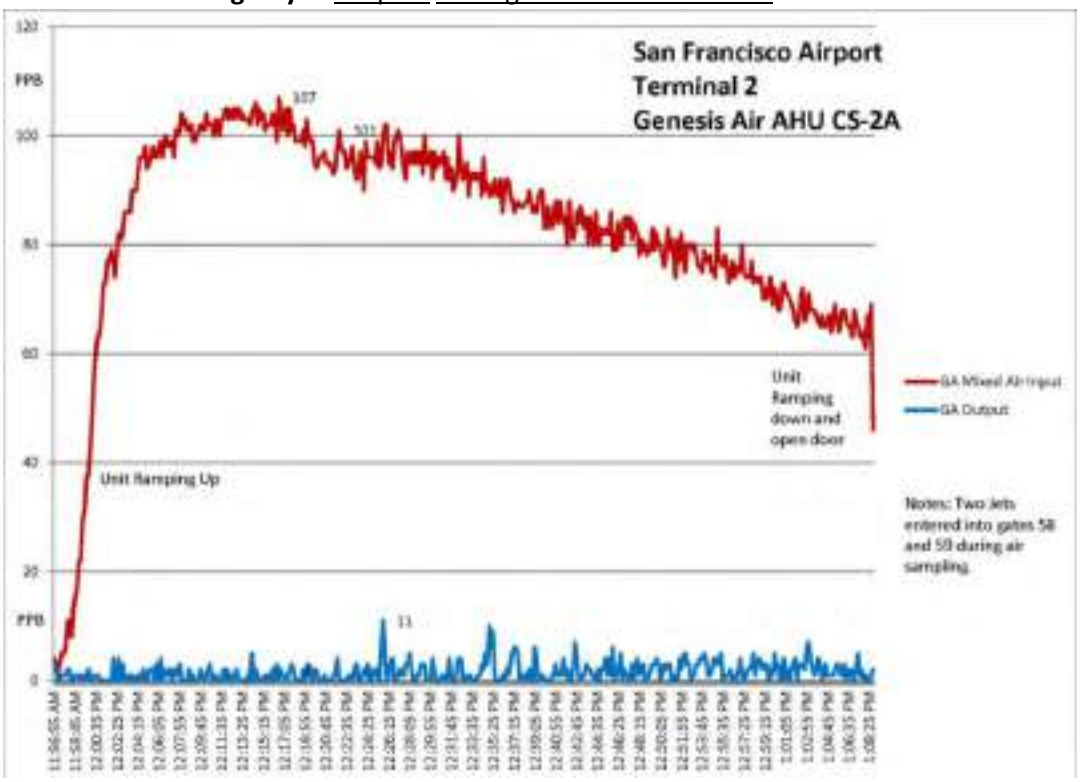
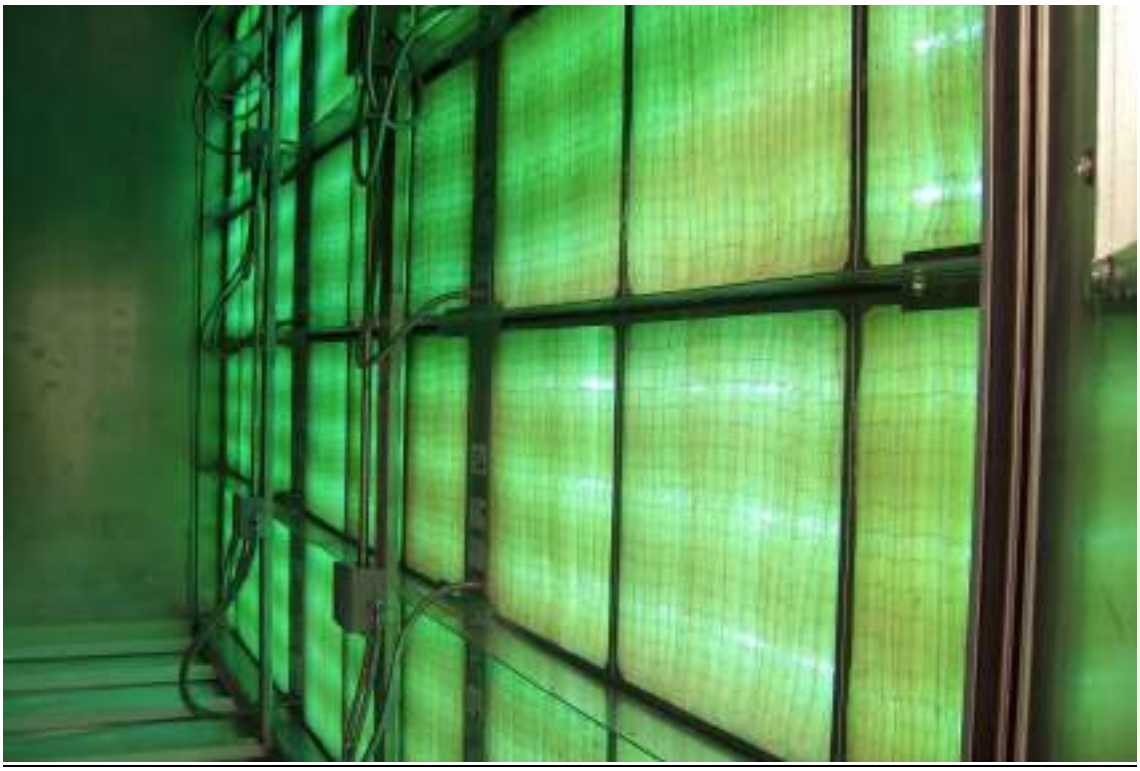
Genesis Air data log Day 1: Graph 1 Average reduction 92.465%.





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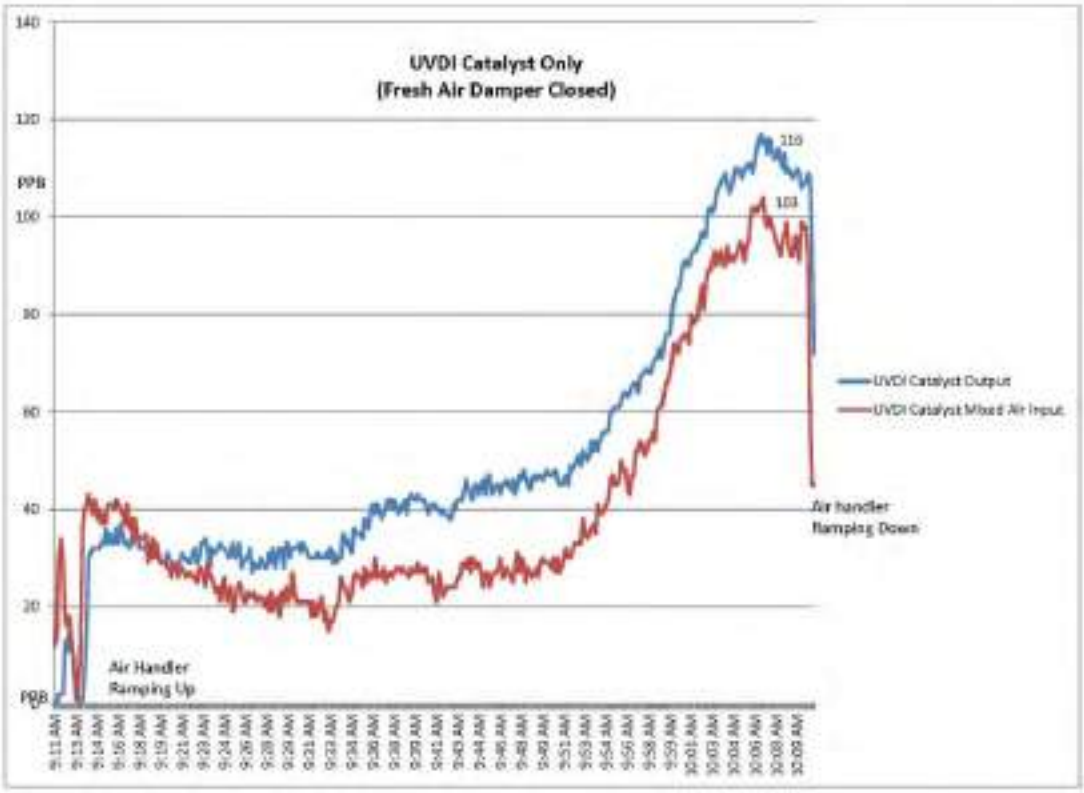
Genesis Air Terminal 2 **UVDI UVGI Lamps On Catalyst Only Charcoal Bag Filters Removed Day 2**
Average Reduction -23.95%



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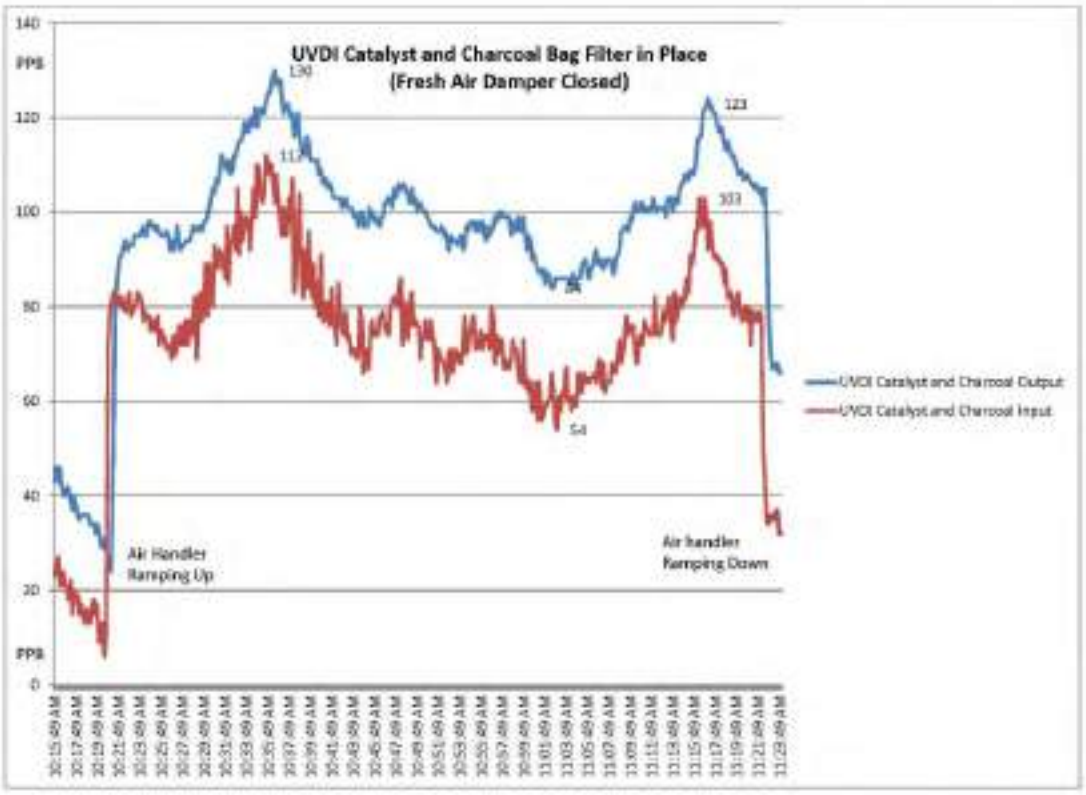
UVDI Lamp On with Catalyst and Charcoal Bag Filters installed. Average reduction -31.30%



UVDI PCO

Image 2: UVDI Charcoal Bag Filter with holes burned by UVDI Lamp.