



Document No: TR0212

Issue: 01

Date: 03/04/2020

Sheet No: 1

No of Sheets: 17

Mimaki SWJ-320EA Final Test Report

This document contains BOFA International Ltd CONFIDENTIAL PROPRIETARY INFORMATION. No intellectual property right or licence is granted by BOFA International Ltd in connection with it. It is delivered on the express condition that the document and the information contained in it shall be treated as confidential, shall not be used for any purpose other than that for which it is hereby delivered (the use and maintenance of the product supplied). It shall not be disclosed in whole or part to third parties and shall not be duplicated in any manner without BOFA International Ltd prior written consent.



Document No: TR0212

Issue: 01

Date: 03/04/2020

Sheet No: 2

No of Sheets: 17

REVISION SHEET

Issue	Reason for Revision
01	FIRST ISSUE

Compiled By:	Ross Stoneham Engineering Manager
Approved By:	Steve Lawton R&D Manager

CONTENTS LIST

1	Introduction	3
2	Test Details	3
3	Design Verification Testing	4
4	Design Validation (VOC) Test 1 Setup	6
5	Design Validation (VOC) Test 2 Setup	8
6	Test Image	10
7	Test 1 Results	10
8	Test 1 Discussion	12
9	Test 2 Results	12
10	Test 2 Discussion	17
11	Testing Summary	17

This document contains BOFA International Ltd CONFIDENTIAL PROPRIETARY INFORMATION. No intellectual property right or licence is granted by BOFA International Ltd in connection with it. It is delivered on the express condition that the document and the information contained in it shall be treated as confidential, shall not be used for any purpose other than that for which it is hereby delivered (the use and maintenance of the product supplied). It shall not be disclosed in whole or part to third parties and shall not be duplicated in any manner without BOFA International Ltd prior written consent.



Document No: TR0212

Issue: 01

Date: 03/04/2020

Sheet No: 3

No of Sheets: 17

1 INTRODUCTION

This report documents the testing performed on the BOFA designed printer manifold for the Mimaki SWJ-320EA Printer to assess the level of Volatile Organic Compounds (VOCs) emitted during print cycles. Testing consisted of running a series of test prints and measuring the VOCs emitted during the printing process. Measurements were taken in various locations over to sets of tests on two different days at Hybrid Services, Crewe. This was to gauge the atmospheric build up of VOCs in different areas around the printer as well as understand the behaviour of off-gas build up from the media roll over time. Seven print cycles were completed with extraction at different extractor and printing speeds as well as one print cycle without extraction to show the benefit of the solution. Print cycles were performed using Cyan, Yellow, Magenta, and Key (CYMK) CS100 printing ink.

The report also includes results from design verification testing in which the LEV minimum capture velocities were verified.

2 TEST DETAILS

Test Location: Hybrid Services Ltd
No 3, Gateway
Crewe
CW1 6YY

Test Date: Monday 17th February 2020 & Monday 30th March 2020

Unit Details: Type: Mimaki Printer Type: BOFA International Extractor
Model: SWJ-320EA Model: Print Pro Universal

VOC Meters: Type: Photoionisation Detector (PID)
Manufacturer Details: www.ionscience.com
Model: PhoCheck TIGER
Part Number: A-861240
Serial Number: L-107020
Calibration Cert No: 65407
Calibration Date: 19th Feb 2019
Calibration Due: 19th Feb 2020

This document contains BOFA International Ltd CONFIDENTIAL PROPRIETARY INFORMATION. No intellectual property right or licence is granted by BOFA International Ltd in connection with it. It is delivered on the express condition that the document and the information contained in it shall be treated as confidential, shall not be used for any purpose other than that for which it is hereby delivered (the use and maintenance of the product supplied). It shall not be disclosed in whole or part to third parties and shall not be duplicated in any manner without BOFA International Ltd prior written consent.



Document No: TR0212

Issue: 01

Date: 03/04/2020

Sheet No: 4

No of Sheets: 17

3 DESIGN VERIFICATION TESTING

Local Exhaust Ventilation guidelines as detailed in HSG258 (Second Edition, 2011) require a minimum of 5 m/s duct velocity within a unit to adequately transport gases and non-condensing vapours through the extraction duct work.

Table 1 - Indicative Duct Velocities, (HSG258, 2011)

Type of contaminant	Indicative duct velocity, m/s
Gases and non-condensing vapours	5
Condensing vapours, fume and smoke	10
Low or medium density, low moisture content dusts (plastic dust, sawdust), fine dusts and mists	15
Process dust (cement dust, brick dust, wood shavings, grinding dust)	Around 20
Large particles, aggregating and damp dusts (metal turnings, moist cement dust, compost)	Around 25

Using a $\varnothing 75\text{mm}$ duct (0.004417m^2), this requires a minimum air flow of ($Q = VA$) $80\text{m}^3/\text{hr}$ within the ductwork. The Print Pro Universals used with the Mimaki SWJ-320EA printer manifold have a maximum air flow (measured using Debimo blade pitot tube gauges) of $240\text{m}^3/\text{hr}$. The Print Pro Universal is recommended to be used at speed setting 3, providing $200\text{m}^3/\text{hr}$. The following capture velocity testing was completed at both recommended operating and maximum speeds.

Table 2 - Capture Velocity Range, (HSG258, 2011)

Contaminant cloud release	Example of process	Capture velocity range, m/s
Into still air with little or no energy	Evaporation, mist from electroplating tanks	0.25 to 0.5
Into fairly still air with low energy	Welding, soldering, liquid transfer	0.5 to 1.0
Into moving air with moderate energy	Crushing, spraying	1.0 to 2.5
Into turbulent air with high energy*	Cutting, abrasive blasting, grinding	2.5 to >10
*These types of cloud are difficult to control using capturing hoods.		

This document contains BOFA International Ltd CONFIDENTIAL PROPRIETARY INFORMATION. No intellectual property right or licence is granted by BOFA International Ltd in connection with it. It is delivered on the express condition that the document and the information contained in it shall be treated as confidential, shall not be used for any purpose other than that for which it is hereby delivered (the use and maintenance of the product supplied). It shall not be disclosed in whole or part to third parties and shall not be duplicated in any manner without BOFA International Ltd prior written consent.

Using a Kimo hotwire air flow gauge, the capture velocities at the point of entry to the shroud were measured on the Mimaki printer manifold. The results are shown in Figure 2.

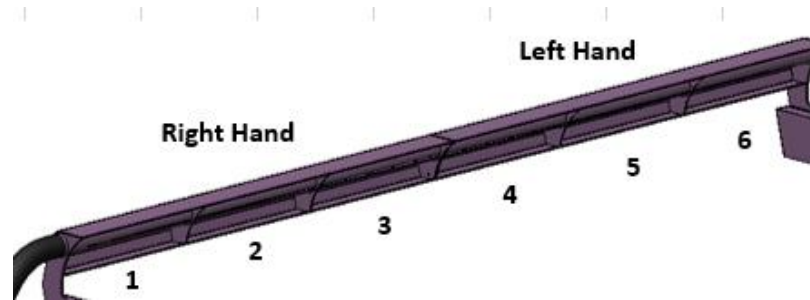


Figure 1 - Manifold Sections

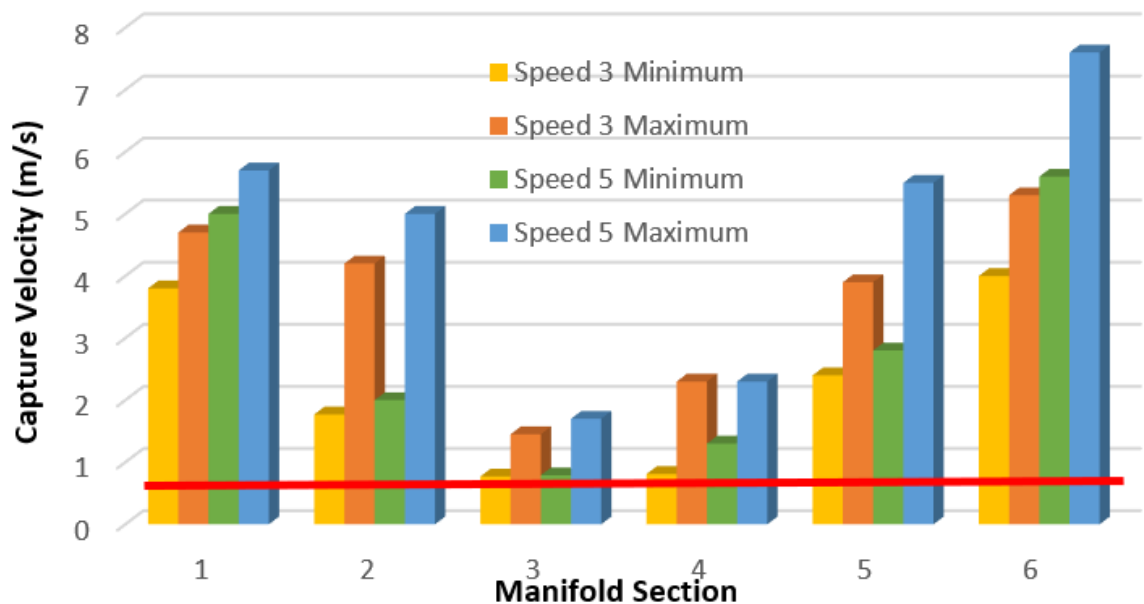


Figure 2 - Capture Velocities

According to LEV guidelines, minimum capture velocity should be at least 0.5m/s (shown in red on Figure 2). As can be seen in the results, the printer manifold velocities were at least 0.77m/s at both recommended and maximum operating speeds.

The difference between the left and right hand of the manifolds will be less when the manifold is a constant distance from the print roll media (recommended 5mm). The capture speed will also increase.

4 DESIGN VALIDATION (VOC) TEST 1 SETUP

Phase 1 of VOC testing consisted of running a series of test prints using CS100 printing ink and measuring the VOCs emitted during the printing process. Measurements were taken at three points, one in front of the left-hand manifold, one in front of the righthand manifold and another measurement location beneath the printer. All VOC readings are given in parts per million (ppm).

4 print cycles were completed in the following order and configuration:

- Print with extraction, typical printing speed, extraction speed level 3.
- Print with extraction, typical printing speed, extraction speed level 5.
- Print with extraction, maximum printing speed, extraction speed level 5.
- Print without extraction at maximum speed.

The test setup can be seen in figure 3 below.



Figure 3 - Printing test setup



Document No: TR0212	Issue: 01	Date: 03/04/2020	Sheet No: 7	No of Sheets: 17
---------------------	-----------	------------------	-------------	------------------

The inks used were CS100 Cyan, Key (Black), Magenta and Yellow. Below is a typical excerpt from the MSDS received from Mimaki.

Table 3 - Ink MSDS

SECTION 3: Composition/information on Ingredients			
3.1. Substances			
Not applicable			
3.2. Mixtures			
Name	Product identifier	Conc. (% w/w)	Classification according to Regulation (EC) No. 1272/2008 [CLP]
2-butoxyethyl acetate; butylglycol acetate	(CAS-No.) 112-07-2 (EC-No.) 203-933-3 (EC Index-No.) 607-038-00-2 (REACH-no) 01-2119475112-47	50 - 75	Acute Tox. 4 (Inhalation), H332 Acute Tox. 4 (Dermal), H312
γ-butyrolactone	(CAS-No.) 96-48-0 (EC-No.) 202-509-5 (REACH-no) 01-2119471839-21	10 - 20	Acute Tox. 4 (Oral), H302 Eye Dam. 1, H318 STOT SE 3, H336
2-methoxy-1-methylethyl acetate substance with a Community workplace exposure limit substance with national workplace exposure limit(s) (GB)	(CAS-No.) 108-65-6 (EC-No.) 203-603-9 (EC Index-No.) 607-195-00-7 (REACH-no) 01-2119475791-29	10 - 20	Flam. Liq. 3, H226 STOT SE 3, H336

Full text of H-statements: see section 16

All the inks have the same three components (see table 3), except the black ink which also contained “carbon black” (which can reasonably be assumed to not enter the vapour phase but remain on the product).

2-(2-Butoxyethoxy) ethanol	112-34-5	10	67.5	15	101.2	
2-Butoxyethyl acetate	112-07-2	20	133	50	332	Sk
n-Butyl acrylate	141-32-2	1	5	5	26	
1-Methoxypropan-2-ol	107-98-2	100	375	150	560	Sk
1-Methoxypropyl acetate	108-65-6	50	274	100	548	Sk
Methyl acetate	79-20-9	200	616	250	770	

Table 4 - UK Workplace Exposure Limits (EH40, 2005)

The UK workplace exposure limits for 2-butoxyethyl acetate and 1-methoxypropyl acetate are 20 ppm and 50 ppm respectively. There is not a workplace exposure limit for γ-butyrolactone but, unlike the 2-butoxyethyl acetate, γ-butyrolactone does not have a hazard statement about inhalation (e.g. H332) so it can be assumed to have a higher workplace exposure limit than 2-butoxyethyl acetate.

Inhaled substances not assigned WELs

147 The absence of a substance from the list of WELs does not mean that it is safe. Many substances do not have a WEL. For these substances, employers should apply the principles of good practice to control exposure to a level to which nearly all the working population could be exposed, day after day at work, without adverse effects on health.

148 If it is not possible to identify suitable exposure control measures using, for instance, *COSHH essentials*, and no WEL exists, it may be possible and useful for the employer to identify or develop an in-house exposure standard. Suppliers, trade associations or specialist advisers, eg occupational hygienists, may be able to help.

Figure 4 - COSHH Approved Code of Practice (ACOP, L5, 2013)

Based upon the above information and taking the worst case scenario of the VOC detected being 100% 2-butoxyethyl acetate, the maximum limit total ppm of VOCs allowable during the print testing is 20 ppm. The VOC sensor used was set to detect total VOCs.

5 DESIGN VALIDATION (VOC) TEST 2 SETUP

Following a number of design changes, the second round of validation testing occurred at Hybrid Services. The two Print Pro Universal extractors and manifold were setup in the arrangement shown in figure 5. The test plan follows the same philosophy and printer setup as outlined in test 1. The front of the printer is divided into four discrete zones to analyse the distribution of VOCs in the atmosphere (figure 6). This will feature later in the test results in order to show VOC accumulation due to off-gassing on printer media rolls.



Figure 5 - Test setup (excluding printer)

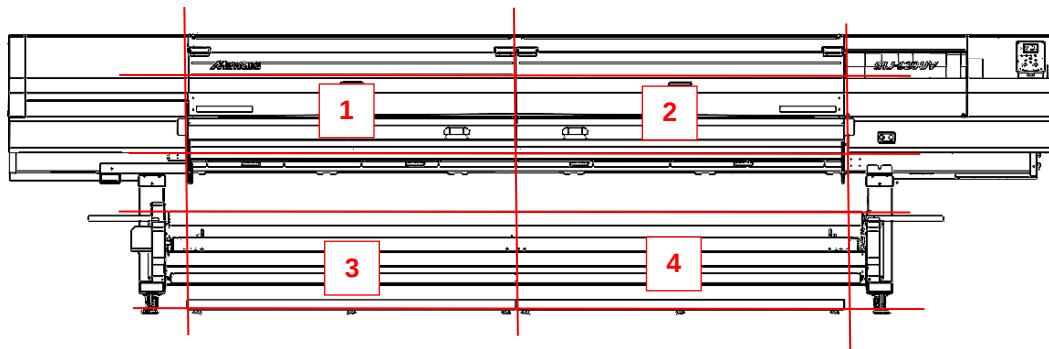


Figure 6 - VOC Test Zones

For each test, the following methodology was used:

1. Turn on extractors (both sides) to the specified speed.
2. Turn on VOC meter, set to record total PPM.
3. Record atmospheric total VOC ppm levels before starting test (0min).
4. Begin printing a suitable test image continuously at the desired speed.
5. Record the total VOC ppm levels in the various locations at the time intervals specified in the results tables.
6. Once complete, finish printing and leave extractors running until atmospheric VOC levels stabilise.
7. Repeat steps 3 to 6 for each test.
8. Turn off extractor and VOC meter once all tests complete.

There were 4 tests in total, at two different extractor speeds and two different print speeds. The plan was to gather enough data to validate the performance of the manifold over longer periods of print time with the updated design.

6 TEST IMAGE

The following print image was used for every test.



Figure 7 - Mimaki Test Print Image

This image was chosen due to its high ink coverage (70%) and is a good example of an image with maximum ink consumption. The image was also known to have produced subjectively high levels of VoC when compared to other test images.

7 TEST 1 RESULTS

Test 1.1 - Print with extraction, typical printing speed, PPU set to speed 3 (~200m³/hr)

Test 1.2 - Print with extraction, typical printing speed, PPU set to speed 5 (~240m³/hr)

Test 1.3 - Print with extraction, maximum printing speed, PPU set to speed 5 (~240m³/hr)

Test 1.4 – Print without extraction



Document No: TR0212

Issue: 01

Date: 03/04/2020

Sheet No: 11

No of Sheets: 17

Test #	Image Status	Extraction	Printing Speed	Extraction Speed	Left	Right	Below
1	Start	Yes	Typical	3	0.1	0.1	N/A
	Half printed				0.9	0.9	N/A
	Complete				1.8	2.5	0.8
2	Start			5	1.1	1.1	N/A
	Half printed				1.4	1.4	N/A
	Complete				1.4	1.7	2.2
3	Start	Maximum	5	1.1	1.1	N/A	
	Half printed			1.4	1.5	N/A	
	Complete			1.9	2.1	2.4	
4	Start		No	N/A	2	2	N/A
	Half printed				122	110	N/A
	Complete				240	251	N/A
2-butoxyethyl acetate WEL				20ppm			

Table 5 - Test Results

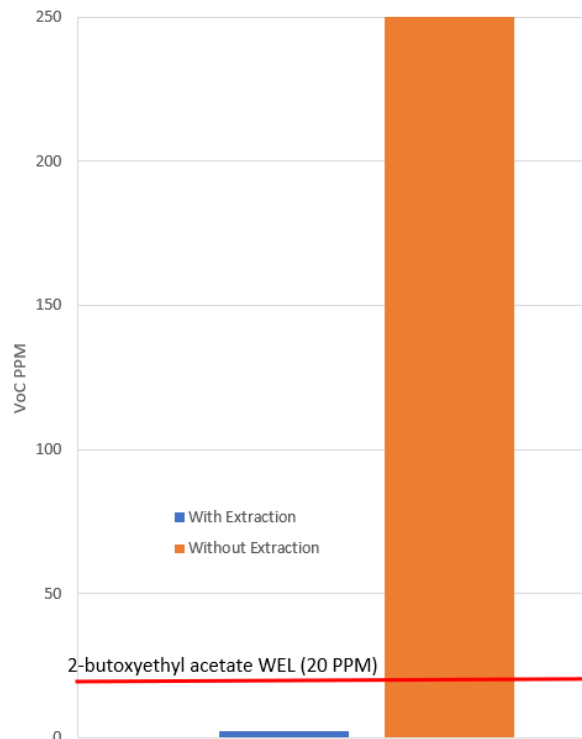


Figure 8 - Maximum recorded VoC levels

This document contains BOFA International Ltd CONFIDENTIAL PROPRIETARY INFORMATION. No intellectual property right or licence is granted by BOFA International Ltd in connection with it. It is delivered on the express condition that the document and the information contained in it shall be treated as confidential, shall not be used for any purpose other than that for which it is hereby delivered (the use and maintenance of the product supplied). It shall not be disclosed in whole or part to third parties and shall not be duplicated in any manner without BOFA International Ltd prior written consent.



Document No: TR0212	Issue: 01	Date: 03/04/2020	Sheet No: 12	No of Sheets: 17
---------------------	-----------	------------------	--------------	------------------

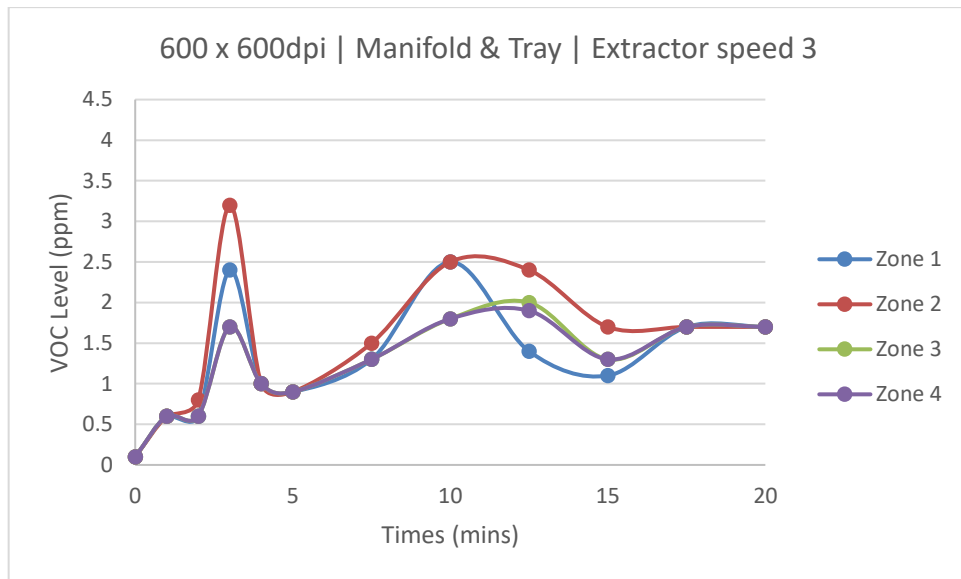
8 TEST 1 DISCUSSION

As can be seen in table 5, the short print cycles ran gave rise to measurable levels of VOC both with and without the extraction device in use. The maximum level of VOCs measured in the first 3 tests with extraction was 2.4ppm. There was not a significant amount of variation between the measurement positions, though the area below the printer did appear to have higher results which appeared to accumulate over time. When the extraction device was not active, the total levels of VOC in the atmosphere jumped quickly to over 200ppm. This is 10 times the workplace exposure limit derived from the HSE guidelines and therefore the test was aborted and no further testing took place.

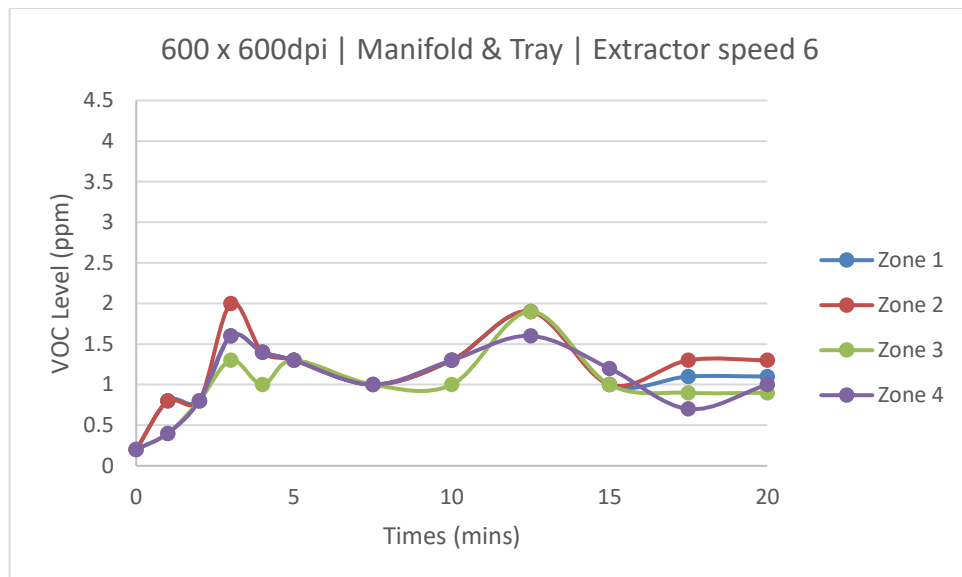
After this testing, the BOFA team made some design changes on the manifold and returned to Hybrid services some weeks later to complete some longer duration tests to further validate the performance of the device.

9 TEST 2 RESULTS

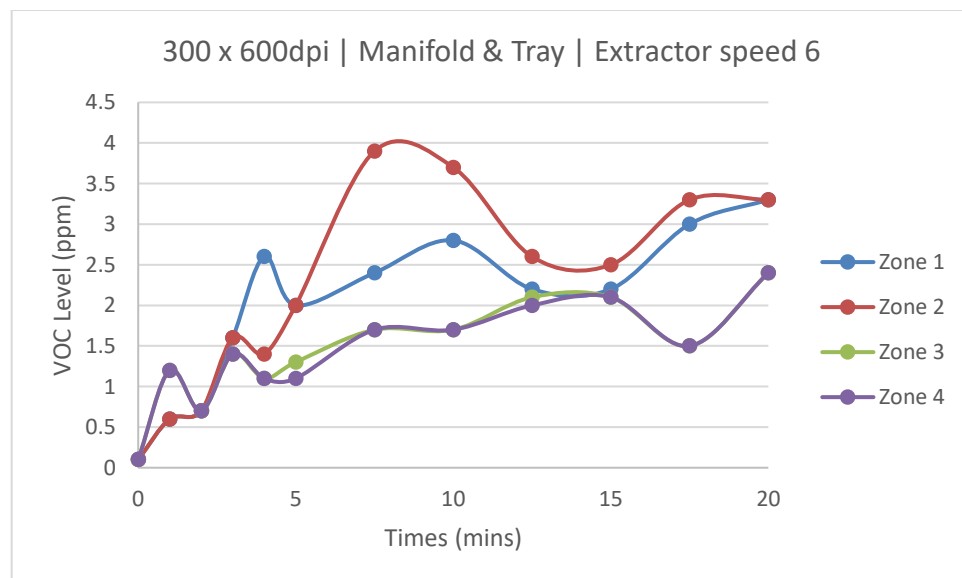
Test 2.1:



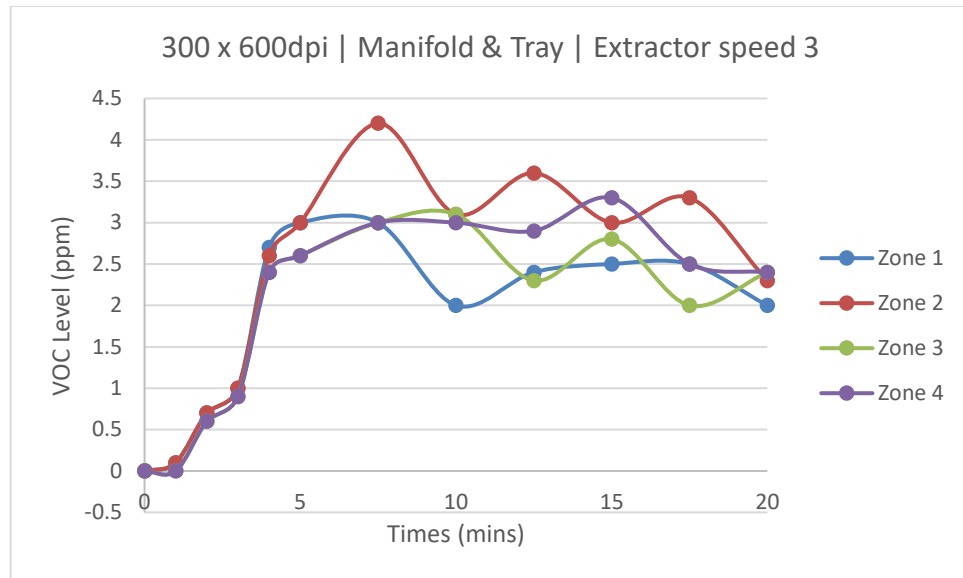
Test 2.2:



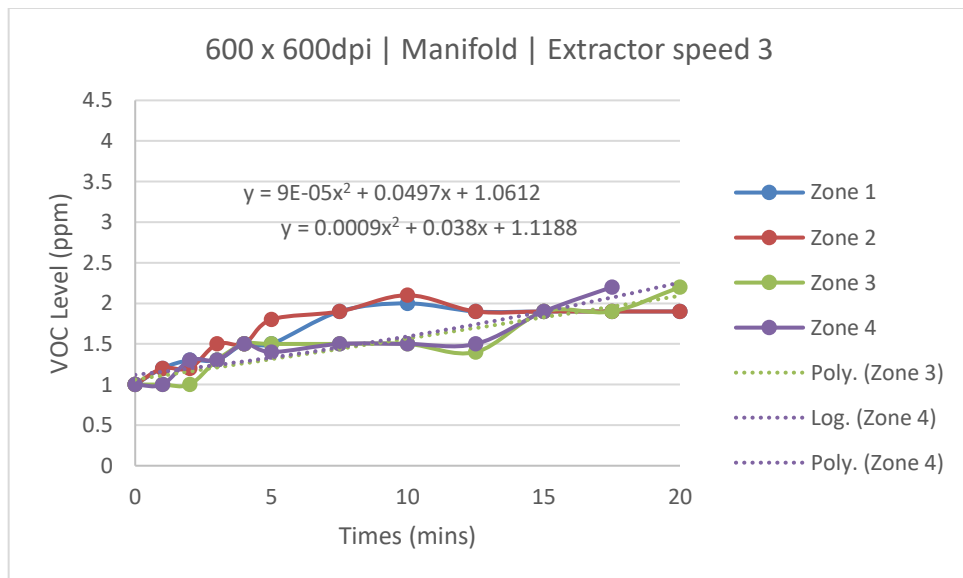
Test 2.3:



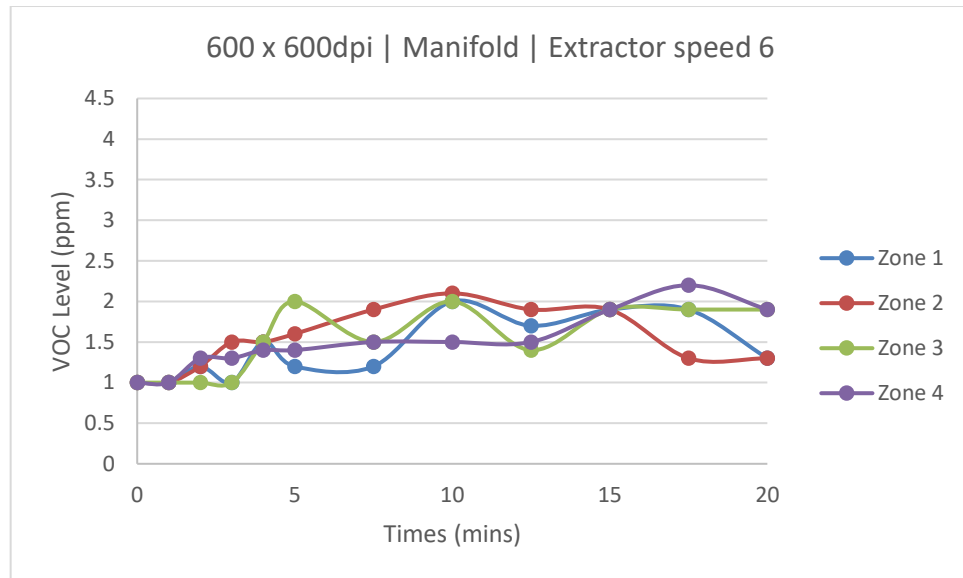
Test 2.4:



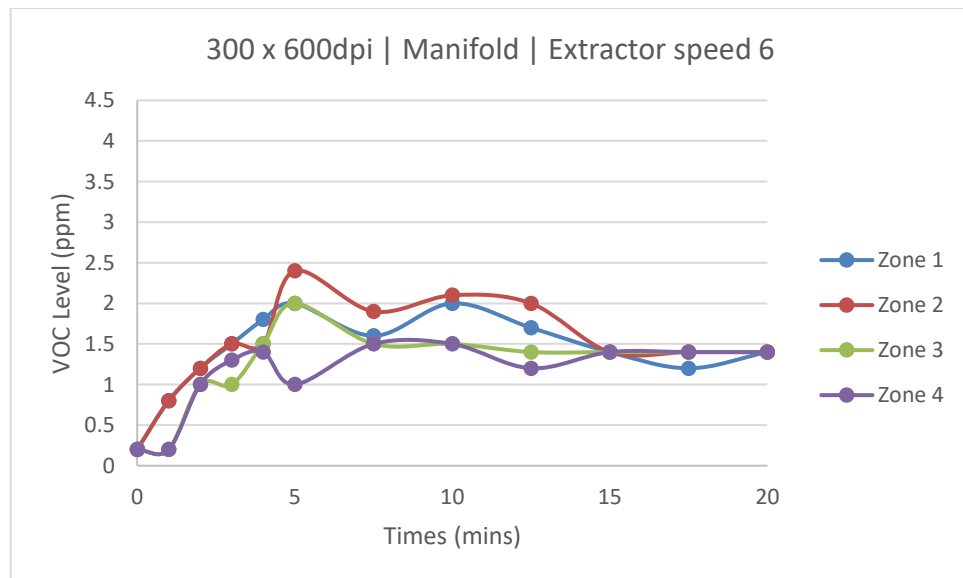
Test 2.5:



Test 2.6:



Test 2.7:



Test 2.8:



Document No: TR0212	Issue: 01	Date: 03/04/2020	Sheet No: 16	No of Sheets: 17
---------------------	-----------	------------------	--------------	------------------



This document contains BOFA International Ltd CONFIDENTIAL PROPRIETARY INFORMATION. No intellectual property right or licence is granted by BOFA International Ltd in connection with it. It is delivered on the express condition that the document and the information contained in it shall be treated as confidential, shall not be used for any purpose other than that for which it is hereby delivered (the use and maintenance of the product supplied). It shall not be disclosed in whole or part to third parties and shall not be duplicated in any manner without BOFA International Ltd prior written consent.



Document No: TR0212

Issue: 01

Date: 03/04/2020

Sheet No: 17

No of Sheets: 17

10 TEST 2 DISCUSSION

There were high levels of variability point to point during the testing, this is thought to be due to the distribution of VOC within the atmosphere as well as the measurement variation of the photometer. Ultimately, the variation will deviate around a trendline which will be the measure of our conclusions in this report. However due to the increased variation of these results, the confidence interval does give rise to questions on the conclusions being drawn. Only answerable with more testing, a higher sampling rate and lower measurement error. All of which are deemed to be over and above what is necessary in this application.

In all tests, the levels of VOC (ppm) measured remained significantly below the 20ppm HSE limit outlined previously.

One can see in the results that 600 x 600dpi printing setting released consistently higher levels of VOC. Additionally, raising the speed of the extractor marginally reduced the levels of VOC in the atmosphere. This is to be expected as the capture velocity is proportionally increased with the flow rate and therefore there is greater force pulling the VOCs into the carbon filter.

Most tests showed that the levels of VOC in the atmosphere plateaued in 20mins of printing. The only result which countered this statement is in test 5, zones 3 and 4 which appear to trend upwards. However, test 6 does present the evidence that if VOCs begin to build under the manifold, raising extractor speed would prevent further build up.

The upper zones were found mostly to have more VOC than the lower zones at the beginning of the printing. After a period of time, the lower zones in limited cases would be higher than the upper zones at the end of the test. However, in most cases this did not keep rising and is not considered a risk.

11 TESTING SUMMARY

VoC levels recorded during all the tests with extraction were found to remain below the exposure limit of 20ppm. Without extraction, the levels of VoC in the environment were, very quickly, significantly over the exposure limit.

Therefore, the extraction system provided by BOFA was found to be successful at keeping the emissions at a safe level during the testing. Additionally, it was proven that off-gassing of the ink below the printer when the media was on the reel did not present a problem over longer time periods.