FINAL REPORT

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FCA US LLC

STERLING HIEGHTS, MICHIGAN

STERLING HEIGHTS ASSEMBLY PLANT – NORTH PAINT SHOP TRANSFER EFFICIENCY AND CAPTURE EFFICIENCY TESTING

RWDI #1803869

November 28, 2018

SUBMITTED TO

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EXECUTIVE SUMMARY

RWDI AIR Inc. (RWDI) and JLB Industries, LLC were retained by Fiat Chrysler Automobiles (FCA) US LLC to complete compliance testing of the Topcoat operations at their Sterling Heights Assembly Plant (SHAP) North Paint Shop located at 38111 Van Dyke, Sterling Heights, Michigan. The scope of the test program was to complete paint solids transfer efficiency (TE) and Capture Efficiency (CE) testing of the Topcoat operations (FG-AUTO MACT), for one (1) representative Topcoat Booth (EU-TOPCOAT 1 or EU-TOPCOAT 2 or EU-TOPCOAT 3), on the following coatings:

- Metallic Basecoat (Granite);
- Solid Basecoat (White); and
- Clearcoat.

SHAP North Paint Shop currently operates under Title V Renewable Operating Permit (ROP) Permit # MI-ROP-B7248-2014a dated January 15, 2015. Results of the testing are considered representative of plant production. The results will be used to support on-going VOC monthly emission calculations. The testing program consisted of Transfer Efficiency (TE) testing and Capture Efficiency (CE) testing. Determination of TE and CE were conducted in accordance with all applicable procedures contained in USEPA document "Protocol for Determining the Daily Volatile Organic Compound Emission Rate of Automobile and Light-Duty Truck Topcoat Operations". The testing was completed during the week of October 22, 2018. The testing consisted of the following:

- Paint solids transfer efficiency (TE) – the percent of paint solids sprayed that deposit on the painted part was measured when applying White solid basecoat, Granite metallic basecoat and standard clearcoat in the "EU-TOPCOAT 2" line and are considered to be representative for all Topcoat Operations.

- Volatile Organic Compound (VOC) capture efficiency (CE) was completed on the flash zone, controlled booth zone and bake oven for the "EU-TOPCOAT 1" line. This includes the percent of VOC captured from the curing of the coating in the flash zone and bake oven. The flash and bake oven VOC CE is used to calculate the mass of VOC captured per gallon of applied coating solids (lb VOC/gacs) and is also referred to as oven solvent loading. Flash and Oven VOC CE was measured at "EU-TOPCOAT 1" Spraybooth when applying solid White basecoat, Granite metallic basecoat and standard clearcoat and are considered to be representative for all Topcoat Operations.

RWDI/JLB Industries used highly accurate weighing systems to determine the vehicle and panel weights before and after coating application. Calibrated volumetric flow meters, located on each applicator, were used to measure paint usage.

Material samples were collected from the paint circulation tanks directly after vehicle spray out. Determination of percent solids by weight and density was performed by Advanced Technologies of Materials laboratories, located in Waverly, Ohio.

Transfer Efficiency (TE) Results Summary

Tested Coating	Solids Transfer Efficiency (%)
Basecoat (White Solid Basecoat)	82.4%
Basecoat (Granite Metallic)	72.9%
Clearcoat	73.9%

Capture Efficiency (CE) Results Summary

		Loading (Lb/GACS)	Capture Efficiency
		EU-TOPCOAT 2	EU-TOPCOAT 2
Solid Basecoat (White)	**Flash**	3.00	**63.4%**
	Oven	1.34	
	Total	**4.35**	
Metallic Basecoat (Granite)	**Flash**	2.12	**35.0%**
	Oven	1.10	
	Total	**3.22**	
Clearcoat	**Booth**	5.00	52.1%
	Oven	3.17	33.0%
	Total	**8.16**	**85.2%**

1 INTRODUCTION

RWDI AIR Inc. (RWDI) and JLB Industries, LLC were retained by Fiat Chrysler Automobiles (FCA) US LLC to complete compliance testing of the Topcoat operations at their Sterling Heights Assembly Plant (SHAP) North Paint Shop located at 38111 Van Dyke, Sterling Heights, Michigan. The scope of the test program was to complete paint solids transfer efficiency (TE) and Oven Capture Efficiency (OCE) testing of the Topcoat operations (FG-AUTO MACT), for one (1) representative Topcoat Booth (EU-TOPCOAT 1 or EU-TOPCOAT 2 or EU-TOPCOAT 3), on the following coatings:

- Metallic Basecoat (Granite)
- Solid Basecoat (White)
- Clearcoat

SHAP North Paint Shop currently operates under Title V Renewable Operating Permit (ROP) Permit # MI-ROP-B7248-2014a dated January 15, 2015. Results of the testing are considered representative of plant production. The results will be used to support on-going VOC monthly emission calculations. The testing program consisted of Transfer Efficiency (TE) testing and Capture Efficiency (CE) testing. Determination of TE and CE were conducted in accordance with all applicable procedures contained in USEPA document "Protocol for Determining the Daily Volatile Organic Compound Emission Rate of Automobile and Light-Duty Truck Topcoat Operations". The testing was completed during the week of October 22, 2018. The testing consisted of the following:

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- Volatile Organic Compound (VOC) capture efficiency (CE) was completed on the flash zone, bake oven and controlled spraybooth zones for the "EU-TOPCOAT 1" line. This includes the percent of VOC captured from the curing of the coating in the flash zone and bake oven. The flash and bake oven VOC CE is used to calculate the mass of VOC captured per gallon of applied coating solids (lb VOC/gacs) and is also referred to as oven solvent loading. Flash and Oven VOC CE was measured at "EU-TOPCOAT 1" Spraybooth when applying solid White basecoat, Granite metallic basecoat and standard clearcoat and are considered to be representative for all Topcoat Operations.

A Source Testing Plan, for the testing, was submitted to the Michigan Department of Environmental Quality (MDEQ) on August 22, 2018. Testing was successfully completed while all process equipment was operating under normal maximum operating conditions during the week of October 22nd, 2018. A copy of the Source Testing Plan is provided in **Appendix A**.

Testing of emissions was conducted by Mr. Jim Belanger and Mr. Jeff Monache of JLB, and Mr. Brad Bergeron and Mr. Alec Smith of RWDI. Mr. Adekunle Sanni and Mr. Rohit Patel were on-site to monitor the process operation and witness the testing on behalf of FCA US LLC.

2 SOURCE AND SAMPLING LOCATIONS

2.1 Process Description

SHAP is located at 38111 Van Dyke in Sterling Heights, Michigan. The facility completes assembly and paint operations for FCA US LLC. Vehicle body panels are stamped and assembled on site from sheet metal components. The bodies are cleaned, treated, and prepared for painting in the phosphate system. Drawing compounds, mill oils, and dirt are removed from the vehicle bodies utilizing both high pressure spray and immersion cleaning/rinsing techniques. Vehicle bodies then are dip coated in electro deposition corrosion primer paint for protection. The electro primer (E-coat) is heat-cured to the vehicle body in a high-temperature bake oven. After completing the E-coat operation, vehicle bodies are conveyed to the sealer area for application of various sealants to body seams and joints. Vehicle bodies are then conveyed to an oven to cure the sealers.

After the sealer oven, the vehicles are routed to the powder prime system and then topcoat operations. In the topcoat system, the bodies receive a combination of waterborne and solvent borne coatings: basecoat and clearcoat coatings. After topcoat is applied, the vehicle is baked in the topcoat oven. After exiting the topcoat oven, the vehicles are routed to inspection.

An overview of the process to be sampled and associated sampling sites is provided below.

Figure 1: Process and Sampling Location Overview

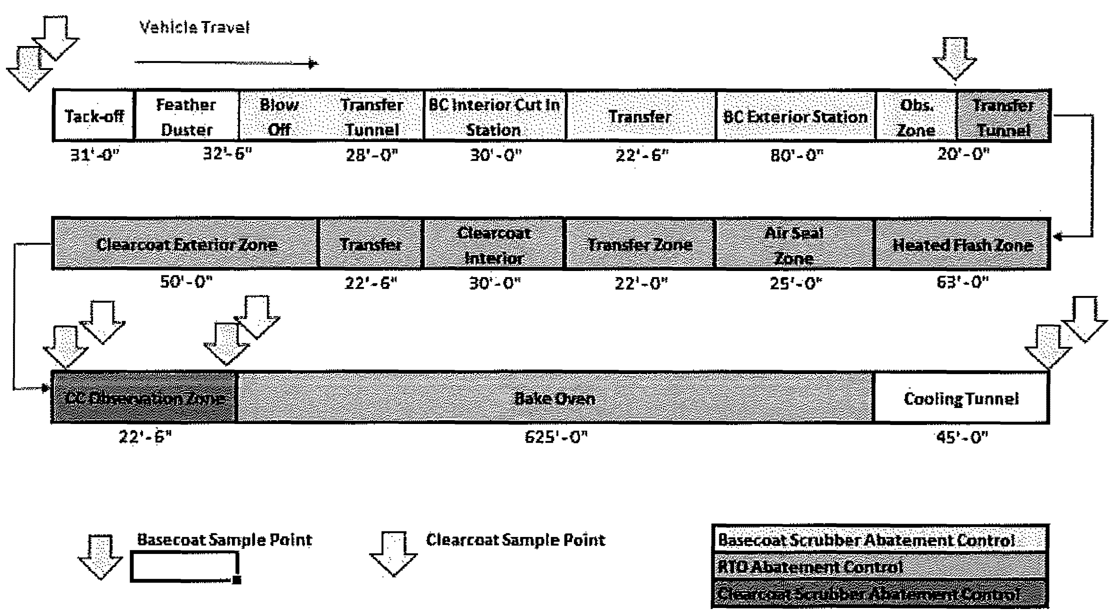

Table 2.1-1: Summary of Applicator Parameters

Operation	Manufacturer	Applicator	Fluid Tip/ Bell Size	Air Cap	Gun Voltage (kV)	RPM	Gun-to-Target Distance (inch)	Remarks
Basecoat Interior	Fanuc	P700	1.2 mm	N/A	40 kV	50,000	10 inch	Waterborne
Basecoat Exterior	Fanuc	250	0.9 mm	N/A	80 kV	75,000	8 inch	Waterborne
Clearcoat Interior	Fanuc	P700	1.2 mm	N/A	40 kV	50,000	10 inch	Solvent
Clearcoat Exterior	Fanuc	250	1.2 mm	N/A	80 kV	75,000	8 inch	Solvent

Notes: mm – millimetres
kV – kilovolts
RPM – revolutions per minute

2.2 Control Equipment

Topcoat Spray Booths are controlled using a downdraft ventilation system and water wash system below the booth grate to control paint overspray. Captured basecoat flash zone and bake oven VOC emission are directed to regenerative thermal oxidizer for VOC abatement. Clearcoat from the booth, flash zone and oven are directed to the same regenerative thermal oxidizer for VOC abatement. All controls were functioning during the testing period.

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2.3 Operating Parameters

The following process control measures were recorded during the testing:

- Coating usage;
- Application information;
- Bake Oven Temperature;
- Spray booth relative humidity; and
- Spray booth temperature.

The following summarizes the Spray booth and Bake Oven process conditions.

Table 2.3-1: Summary of Operating Conditions

Source	Spray Booth Temperature				Spray Booth Relative Humidity				Bake Oven Temperature			
	Unit	10/23/18	10/24/18	10/25/18	Unit	10/23/18	10/24/18	10/25/18	Unit	10/23/18	10/24/18	10/25/18
EU-Topcoat 2 Spray Booth	C2-1	76°F	75°F	78°F	C2-1	60%	60%	60%	Zone 1	340°F	340°F	331°F
	C2-2	76°F	76°F	74°F	C2-2	61%	61%	63%	Zone 2	370°F	370°F	380°F
	C2-3	74°F	76°F	75°F	C2-3	64%	61%	62%	Zone 3	293°F	287°F	267°F
	C2-4	75°F	75°F	75°F	C2-4	48%	46%	48%	Zone 4	291°F	281°F	273°F
	C2-5	75°F	76°F	76°F	C2-5	62%	61%	62%	Zone 5	271°F	270°F	270°F
	C2-6	73°F	72°F	73°F	C2-6	63%	65%	65%	Sill 1	270°F	270°F	86°F
	C2-7	79°F	78°F	75°F	C2-7	63%	65%	65%	Sill 2	271°F	270°F	261°F
	--								Cooling	60°F	61°F	60°F

2.4 Process Sampling Locations

A process sample of each coating applied during the testing was collected for analysis. The coatings were collected following procedures in USEPA's "Standard Procedure for Collection of Coating and Ink Samples for Analysis by Method 24 and 24A".

Coating samples were collected at the application point into four (4) ounce glass sampling jars with minimal headspace. The coating-as-applied samples were analyzed using USEPA Method 24 to measure percent VOC, percent water and density. The results are summarized below in **Table 2.4-1** and in **Appendix C.**

Table 2.4-1: Summary of Method 24 Coating Analysis

Sample	Parameter									
	Date	% Non-Volatile	% Volatile	Density		% Water	VOC		VOC-Water	
				g/ml	lb/gal		g/L	lb/gal	g/L	lb/gal
Granite Metallic Basecoat	10/25/18	32.47	67.53	1.049	8.757	44.83	241.87	2.018	454.82	3.796
White Basecoat	10/25/18	47.25	52.75	1.254	10.465	34.05	234.59	1.958	410.33	3.424
Clearcoat Part A	10/25/18	57.76	42.24	1.056	8.805	0	445.65	3.719	N/A	N/A
Clearcoat Part B	10/25/18	56.84	43.16	1.009	8.42	0	435.61	3.635	N/A	N/A

In addition, thirteen (13) samples were collected by RWDI/JLB (12 samples + 1 blank) of waterborne coatings to analyze for percent moisture. The samples were collected at the point of application on foil panels attached to the test vehicles. The coated foils were then transferred into a four (4) ounce glass sampling jar and anhydrous methanol was added to the sampling jar to allow the coating to disperse. The sample was then allowed to separate and analyzed for percent water using ASTM E203-08 "Standard Test Method for Water Using Volumetric Karl Fischer Titration". The ASTM E203 -08 coating analysis is summarized in **Table 2.4-2** and **Appendix C.**

Table 2.4-2: Summary of Volumetric Karl Fischer Titration Coating Analytical

Sample	Date	Parameter Percent Water
Blank	10/25/2018	0.13
Sample B1 White Solid	10/25/2018	0.26
Sample B2 White Solid	10/25/2018	0.25
Sample B3 White Solid	10/25/2018	0.31
Sample B4 White Solid	10/25/2018	0.15
Sample B5 White Solid	10/25/2018	0.13
Sample B6 White Solid	10/25/2018	0.14
Sample M1 Granite Metallic	10/25/2018	0.18
Sample M2 Granite Metallic	10/25/2018	0.19
Sample M3 Granite Metallic	10/25/2018	0.21
Sample M4 Granite Metallic	10/25/2018	0.17
Sample M5 Granite Metallic	10/25/2018	0.17
Sample M6 Granite Metallic	10/25/2018	0.15

3 SAMPLING AND ANALYTICAL PROCEDURES

3.1 Summary of Test Program

The topcoat process at SHAP North is comprised of three (3) topcoat paint lines consisting of the "EU-TOPCOAT 1", "EU-TOPCOAT 2" and "EU-TOPCOAT 3". The topcoat system consists of several spray sections followed by an associated curing oven. The spray booth operations are defined as follows:

- Basecoat Robots – Basecoat was applied to the exterior and interior surfaces; and
- Clearcoat Robots - Clearcoat was applied to the exterior and interior surfaces.

Skidded vehicles are conveyed through the booth and coated with topcoat materials (basecoat and clearcoat). The vehicles are processed through a bake oven where the coating is cured.

Currently, coatings are applied to the new RAM 1500 Cab production models. Production units on which an electrocoat corrosion inhibiting primer had been applied were used in the test program for the transfer efficiency testing. For the CE testing, scrap vehicles were used for the testing program. The test program is summarized below.

3.2 Transfer Efficiency Test

Transfer Efficiency testing was conducted in the Topcoat Spray Booth where White solid basecoat, Granite metallic basecoat and clearcoat were applied. Applicator and environmental conditions were monitored to ensure that the testing accurately reflected production conditions. Measured parameters included: Vehicle weight gain, material usage, material analysis (percent solids by weight and density), applicator settings, film build and oven heat settings.

A total of four (4) vehicle bodies were used in calculating test results. Three (3) vehicles were processed as normal production vehicles, and one vehicle were dedicated as no-paint, control vehicles in conjunction with the testing. All units were production vehicles with sealer.

An off-line vehicle weigh station (VWS) was constructed to measure the weight of the test units before and after each painting process. Test vehicles were routed to a dedicated conveyor spur. A fixed stop was secured to assure repeatable positioning of the vehicles. Test vehicles were lifted free from their carriers by two lift-table mounted scale bases. Ultra-high molecular weight (UHMW) plastic blocks were strategically placed on the scale bases to lift the vehicle at the center of gravity locations. The UHMW blocks minimized friction loading on vehicles and scale bases.

Vehicle weights were measured several times and recorded. All test vehicles were weighed with production fixtures (door hooks and hood props) installed. The vehicle weigh station scales were calibrated using Class-F calibration weights conforming to the National Bureau of Standards handbook 105-1. A one or two-pound avoirdupois, Class F stainless steel weight was added periodically during pre- and post-process weighing to verify scale linearity.

Coating thickness was measured on a representative test vehicle to verify paint film-build was within the production specification. The data was taken with a handheld Elcometer gauge.

Coating material usage was monitored via volumetric flow measurement devices located on each applicator. A verification of each applicator was performed by FCA personnel to ensure accurate usage measurement. Material samples of applied coatings were collected from the respective systems directly after testing. Samples were sent to Advanced Technologies of Materials for analysis to determine density by ASTM D1475 and weight solids content by ASTM D2369 (referenced in EPA Method 24). The laboratory results were used in calculating the Transfer Efficiency and Capture Efficiency values.

Production vehicles with paint shop sealer were prepared with prime and processed through the Topcoat Spray Booth. The test sequence for the Transfer Efficiency test was:

White Solid Basecoat:

1. Test Unit ID TE1 – Carrier 0179
2. Test Unit ID TE3 – Carrier 0319
3. Test Unit ID TE4 – Carrier 0233
4. Test Unit ID TE2 – Carrier 0545 (no-paint control)

Granite Metallic Basecoat:

1. Test Unit ID TE3 – Carrier 0319
2. Test Unit ID TE4 – Carrier 0233
3. Test Unit ID TE5 – Carrier 0847
4. Test Unit ID TE2 – Carrier 0545 (no-paint control)

Clearcoat:

1. Test Unit ID TE3 – Carrier 0319
2. Test Unit ID TE4 – Carrier 0233
3. Test Unit ID TE5 – Carrier 0847
4. Test Unit ID TE2 – Carrier 0545 (no-paint control)

Test Vehicles were routed through the bake oven and back to the vehicle weigh station. After cooling, the test vehicles were weighed and released to production.

3.3 Capture Efficiency Tests

A panel weigh station (PWS) was assembled at the Topcoat Spray Booth. A precision balance with measurement capability to 0.001 gram was placed on an isolation platform inside an enclosure to minimize vibration and air movement.

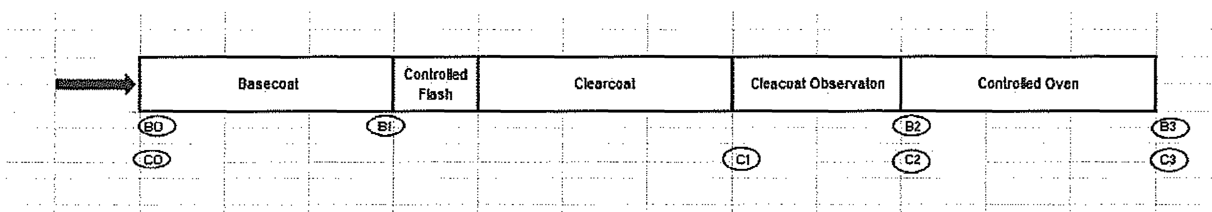
The testing conformed to the methods described in ASTM 5087-02 for solvent borne coatings and ASTM 6266-00a (Reapproved 2005) for waterborne coatings.

Test panels were placed on a test vehicle and processed with normal production spray programming.

Four (4) electrocoated panels were used for each test. Each group of test panels was weighed in four locations (see panel test diagram) to determine the relative distribution of VOC that is released in the controlled booth zone and bake oven. The panels were attached to test vehicles by magnet, which allowed for removal of the wet panels with minimal disturbance to the coating during handling. Panel mounting locations were chosen to achieve a representative coating film based on the observation of normal vehicle production.

Before the panels were coated, they were marked (1, 2, 3, 4, blank) and weighed to establish the initial unpainted panel weights (P0). The panels were then attached to a test vehicle and routed through the Spray Booth. After coating, the panels were carefully removed from the test vehicle and brought to the balance for weighing immediately upon exit from the controlled booth zone (P1). Panels were weighed again before entering the controlled bake oven (P2). The panels were then placed on the test vehicle for travel through the curing oven. Upon exiting the oven, the panels were allowed to cool and then weighed a final time (P3).

Figure 2: Panel Testing Diagram



4 TEST EQUIPMENT AND QA/QC PROCEDURES

Equipment used in this program passed the Quality Assurance /Quality Control (QA/QC) procedures. **Appendix D** contains the calibration records of the equipment and inspection sheets.

4.1 Pretest QA/QC Activities and Audits

Before testing, the equipment was inspected and calibrated according to the procedures outlined in the applicable procedures outlined in the USEPA document "Protocol for Determining the Daily Volatile Organic Compound Emission Rate of Automobiles and Light Duty Truck Topcoat Operations", as referenced in 40 CFR 63, Subpart IIII. Refer to **Appendix D** for inspection and calibration sheets.

The results of select sampling and equipment QA/QC audits are presented in the following sections. Refer to **Appendix D** for inspection and calibration sheets.

4.2 Test Equipment and QA/QC Procedures

4.2.1 Vehicle Weigh Station (VWS)

A dedicated vehicle weigh station (VWS) equipped with two 1,000 lb. capacity scale bases was used to obtain pre- and post-process vehicle weights. The VWS is accurate to better than 0.05 pounds.

The scales were calibrated as directed by the operating instruction manual. Scales were powered up and exercised by placing 250 pounds of Class F calibration weights on each scale platform. Then, the VWS was calibrated with 500 pounds of Class F calibration weights. VWS linearity was checked using a one-pound, Class F stainless steel calibration weight. The one-pound weight was also added to each test vehicle during pre- and post-process weighing to verify scale linearity.

4.2.2 Material Usage

Coating material usage was monitored via volumetric flow measurement devices located on each applicator. A verification of the applicators was performed by FCA personnel before testing to ensure accurate usage data. Paint usage was measured at each applicator in a graduated cylinder and compared to the expected volume.

A sample of each material was taken after each test and analyzed by Advanced Technologies of Materials, located in Waverly, Ohio. These values were used in calculating the paint solids sprayed and the transfer efficiency. ASTM Method D-2369 was used to determine paint solids. ASTM Method D-1475 was used to determine paint density.

4.2.3 Panel Weigh Station

A panel weigh station (PWS) with measurement capability to 0.001 gram was used to measure panel weights. The balance was warmed up and then calibrated with a 300 gram test weight. The balance was tested with 100, 50, 10 and 1 gram weights before commencing weighing operations. A blank panel weight was measured at the beginning of the testing program and again at the time of each subsequent panel weight measurement. The balance was placed on an isolation platform and inside an enclosure to minimize vibration and airflow at the measurement point.

5 RESULTS

The testing program consisted of Transfer Efficiency (TE) testing and Oven Capture Efficiency (CE) testing. Determination of TE and CE were conducted in accordance with all applicable procedures contained in USEPA document "Protocol for Determining the Daily Volatile Organic Compound Emission Rate of Automobile and Light-Duty Truck Topcoat Operations".

The test results will be used to demonstrate compliance with Auto MACT requirements and for use in monthly emissions compliance calculations for the CAAP Permit and 40CFR 63 Subpart IIII – National Emissions Standards or Hazardous Pollutants: Surface Coating of Automobiles and Light Duty Trucks, emission limits.

5.1 Results

Results are summarized in Tables 5.2-1 and 5.2-2 for TE and CE. Detailed VOC CE and paint solids TE results are presented in Table Section. All sampling field notes are provided in **Appendix F.** Sample Calculations are provided in **Appendix G.** All laboratory results are included in **Appendix C.** Process Data is provided in **Appendix B.**

Table 5.1-1: Transfer Efficiency Results Summary

Tested Coating	Transfer Efficiency (%)
White Solid (Basecoat)	82.4%
Granite Metallic (Basecoat)	72.9%
Clearcoat	73.9%

Table 5.1-2: Capture Efficiency Results Summary

		Loading (Lb/GACS)	Capture Efficiency
		EU-TOPCOAT 2	EU-TOPCOAT 2
Solid Basecoat (White)	**Flash**	3.00	**63.4%**
	Oven	1.34	
	Total	**4.35**	
Metallic Basecoat (Granite)	**Flash**	2.12	**35.0%**
	Oven	1.10	
	Total	**3.22**	
Clearcoat	**Booth**	5.00	52.1%
	Oven	3.17	33.0%
	Total	**8.16**	**85.2%**

5.2 Discussion of Results

There were no significant disruptions to the testing program.

6 PROCESS CONDITIONS

Operating conditions during the sampling were monitored by FCA personnel. All equipment was operated under normal maximum operating conditions. Process Data is provided in **Appendix B**.

Contact was maintained between the operator and the sampling team. A member of the RWDI/JLB sampling team was in contact with FCA staff during the entire sampling program.

7 CONCLUSIONS

Testing was successfully completed during the week of October 22, 2018. All parameters were tested in accordance with referenced methodologies.

Table 3 -- Granite Metallic Basecoat Transfer Efficiency Summary
SHAP North, October 2018

Vehicle ID	Vehicle Weight Gain (lb.)	Average Vehicle Weight Gain (lb.)	Average Paint Sprayed (gal)	Coating Density (lb/gal)	Weight Solids Fraction	Average Solids Sprayed	Transfer Efficiency (%)
Variable:	VWG	AVWG	APS	CD	WSF	SS	TE
Calculation:	(W2-W1)	(sumVWG-SWL)	(PS)	(Method 24)	(Method 24)	(APS*CD*WSF)	(AVWG/SS)
TE 3	0.95	1.03	0.497	8.76	0.3247	1.41	**72.9%**
TE 4	1.00						
TE 5	1.14						

FCA SHAP North
October 2018
Summary

Table 1: VOC Loading and Capture Efficiency

Process	Loading (Lb VOC/GACS)	Capture Efficiency (%)
Clearcoat Booth	5.00	52.1%
Clearcoat Oven	3.17	33.0%
Total Clearcoat	**8.16**	**85.2%**
Metallic Basecoat Flash	2.12	
Metallic Basecoat Oven	1.10	
Total Metallic Basecoat Flash and Oven	**3.22**	**35.0%**
Solid Basecoat Flash	3.00	
Solid Basecoat Oven	1.34	
Total Solid Basecoat Flash and Oven	**4.35**	**63.4%**

Table 2: Transfer Efficiency

Process	Transfer Efficiency (%)
Metallic Basecoat	72.9%
Solid Basecoat	82.4%
Clearcoat	73.9%

Table 7 -- Clearcoat Oven Capture Efficiency
SHAP North, October 2018
Solvent Loading

Sample	Blank Panel Weights (g)	Wet Panel Weights - Before Bake (g)	Panel Weights - After Bake (g)	Weight of Coating Solids Deposited (g)	Weight of VOC available for abatement (g)	Weight of VOC available per volume of coating solids (lb/GACS)
Variable	P0	P2	P3	Wcos	Wa	CL
Formula				P3-P0	P2-P3	$(W_a/W_{cos})*D_{cos}$
C1	185.042	188.008	187.250	2.208	0.758	3.26
C2	185.073	188.101	187.335	2.262	0.766	3.22
C3	184.422	187.202	186.522	2.100	0.680	3.08
C4	184.640	187.525	186.815	2.175	0.710	3.10
Average	184.794	187.709	186.981	2.186	0.729	**3.17**

Material Properties

Sample	Coating Density (lb/gal)	Mass Fraction Solids	Volume Fraction Solids	Film Build Thickness (mil)	VOC mass fraction	Solids Density (lb/gal)
Variable	W_c	W_s	V_s	mil	W_{voc}	D_{cos}
Formula						(Ws*Wc)/Vs
Clearcoat	8.61	0.5730	0.5193	2.33	0.4270	9.51

Capture Efficiency

Mass Fraction VOC in Coating	Coating Density (lb/gal)	Mass VOC per Volume Coating (lb/gal)	Transfer Efficiency (%)	Volume Fraction Solids	Volume Solids Deposited per Volume Coating Sprayed	Panel Test Result (lb VOC/ gal Solids)	Oven VOC Capture Efficiency (%)
W_{voc}	D_c	VOC	TE	V_s	V_{sdep}	P	CE
		(Dc)(Wvoc)			$(V_s)(TE)$		$(P)(V_{sdep})(100)/(VOC)$
0.4270	8.61	3.678	73.9%	0.5193	0.384	3.17	**33.0%**

Table 4 -- White Solid Basecoat Transfer Efficiency Summary
SHAP North, October 2018

Vehicle ID	Vehicle Weight Gain (lb.)	Average Vehicle Weight Gain (lb.)	Average Paint Sprayed (gal)	Coating Density (lb/gal)	Weight Solids Fraction	Average Solids Sprayed	Transfer Efficiency (%)
Variable:	VWG	AVWG	APS	CD	WSF	SS	TE
Calculation:	(W2-W1)	(sumVWG-SWL)	(PS)	(Method 24)	(Method 24)	(APS*CD*WSF)	(AVWG/SS)
TE 1	2.22	2.29	0.562	10.47	0.4725	2.78	**82.4%**
TE 3	2.14						
TE 4	2.52						

Table 5 -- Clearcoat Transfer Efficiency Summary
SHAP North, October 2018

Vehicle ID	Vehicle Weight Gain (lb.)	Average Vehicle Weight Gain (lb.)	Average Paint Sprayed (gal)	Coating Density (lb/gal)	Weight Solids Fraction	Average Solids Sprayed	Transfer Efficiency (%)
Variable:	VWG	AVWG	APS	CD	WSF	SS	TE
Calculation:	(W2-W1)	(sumVWG-SWL)	(PS)	(Method 24)	(Method 24)	(APS*CD*WSF)	(AVWG/SS)
TE 3	2.47	2.39	0.656	8.61	0.5730	3.24	**73.9%**
TE 4	2.41						
TE 5	2.30						

Note: Clearcoat is applied at a 1A:1B Ratio. Coating solids and density reflect an average of Clearcoat Part A and Part B.

Table 6 – Clearcoat Booth VOC Capture Efficiency
SHAP North, October 2018

Sample	Blank Panel Weights (g)	Wet Panel Weights - Control Zone Exit (g)	Panel Weights - after bake (g)	Weight of Coating Solids Deposited (g)	Weight of VOC remaining after zone (g)	Weight of VOC remaining per Weight Solids Deposited (g)	Mass Fraction Solids	Mass Fraction VOC in Coating	VOC fraction remaining on Panel after Zone	Section Capture Efficiency (%)
Variable	P0	P1	P3	W_{sdep}	W_{rem}	P_m	W_s	W_{VOC}	P_{VOC}	CE
Formula				P3-P0	P1-P3	W_{rem}/W_{sdep}			$(P_m)(W_s)/(W_{VOC})$	$1-P_{VOC}$
C1	185.042	188.061	187.250	2.208	0.811	0.367				
C2	185.073	188.154	187.335	2.262	0.819	0.362				
C3	184.422	187.256	186.522	2.100	0.734	0.350				
C4	184.640	187.571	186.815	2.175	0.756	0.348				
Average						0.357	0.5730	0.4270	0.479	52.1%

Booth Loading Calculation

	VOC Content (lb VOC/gal)	Volume Solids Fraction	Transfer Efficiency	Weight of VOC generated per volume of solids deposited (lb/GACS)	Capture Efficiency	Weight of VOC captured per volume of applied solids deposited (lb/GACS)
Variable	VOC	V_S	TE	VOC_G	CE	VOC_A
Formula				$VOC/(V_S*TE)$		$CE*VOC_G$
	3.677	0.519	0.739	9.58	0.521	5.00

Table 8 -- Granite Metallic Basecoat Oven Capture Efficiency
SHAP North, October 2018

	Unit	Variable	Formula	Panel 1	Panel 2	Panel 3	Panel 4	
Blank Panel Weight	g	P0		184.781	185.737	185.294	185.178	
Panel at Flash Entrance	g	P1		185.702	186.480	186.123	185.927	
Panel at Flash Exit/Oven Entrance	g	P2		185.541	186.357	185.947	185.789	
Baked Panel Weight	g	P3		185.434	186.285	185.873	185.721	
At Entrance to Flash								
% Nonvolatile	%	%NV	(P3-P0)/(P1-P0)	70.9%	73.8%	69.8%	72.5%	
% Volatile	%	%V	100-%NV	29.1%	26.2%	30.2%	27.5%	
% Water	%	$\%H_2O$	Average KF	4.29%	4.29%	4.29%	4.29%	
% VOC	%	%VOC	$\%V-\%H_2O$	24.8%	22.0%	25.9%	23.2%	Average W_{VOC1}
Weight of VOC Available for Control	g	W_{VOC}	(P1-P0)*%VOC	0.228	0.163	0.214	0.174	0.195
At Flash Exit/Oven Entrance	*Note: Flash exit and oven entrance weight are the same to allow for panel to cool before weight.*							
% Nonvolatile	%	%NV	(P3-P0)/(P2-P0)	85.9%	88.4%	88.7%	88.9%	
% Volatile	%	%V	100-%NV	14.1%	11.6%	11.3%	11.1%	
% Water	%	$\%H_2O$	Average KF	2.06%	2.06%	2.06%	2.06%	
% VOC	%	%VOC	$\%V-\%H_2O$	12.0%	9.6%	9.3%	9.1%	Average W_{VOC2}
Weight of VOC Available for Control	g	W_{VOC}	(P2-P0)*%VOC	0.091	0.059	0.061	0.055	0.067
At Oven Exit								
% Nonvolatile	%	%NV	(P3-P0)/(P3-P0)	100.0%	100.0%	100.0%	100.0%	
% Volatile	%	%V	100-%NV	0.0%	0.0%	0.0%	0.0%	
% Water	%	$\%H_2O$	Average KF	0.0%	0.0%	0.0%	0.0%	
% VOC	%	%VOC	$\%V-\%H_2O$	0.0%	0.0%	0.0%	0.0%	Average W_{VOC3}
Weight of VOC Available for Control	g	W_{VOC}	(P3-P0)*%VOC	0.000	0.000	0.000	0.000	0.000
Solids Coating Density								
Coating Density	lb/gal	W_C	Material Property					8.76
Mass Fraction Solids		W_S	Material Property					0.3247
Volume Fraction Solids		V_S	Material Property					0.2967
Solids Density	lb/gal	D_{COS}	$(W_S*W_C)/V_S$					9.58
Coating Solids Deposited								Average W_{COS}
Weight of Coating Solids Deposited	g	W_{COS}	(P3-P0)	0.653	0.548	0.579	0.543	0.581
Loading in Flash								
Weight VOC Available in Flash	g	$W_{VOC\ Flash}$	$W_{VOC1}-W_{VOC2}$					0.128
Weight of VOC available per GACS	lb/gal	C_{Lflash}	$(W_{VOC\ Flash}/W_{COS})*D_{COS}$					2.12
Loading in Oven								
Weight VOC Available in Oven	g	$W_{VOC\ Oven}$	$W_{VOC2}-W_{VOC3}$					0.067
Weight of VOC available per GACS	lb/gal	C_{Loven}	$(W_{VOC\ Oven}/W_{COS})*D_{COS}$					1.10
Weight VOC Available Total	lb/gal	C_L	$C_{Lflash}+C_{Loven}$					**3.22**
Capture Efficiency Calculation								
Mass Fraction VOC		W_{VOC}	Material Property					0.2270
Mass VOC per Volume Coating	lb/gal	VOC	W_C*W_{VOC}					1.988
Transfer Efficiency	%	TE						72.9%
Volume Solids Deposited per Volume Coating Sprayed		V_{sdep}	(V_S*TE)					0.216
VOC Capture Efficiency	%	CE	$C_L*V_{sdep}*100/VOC$					**35.0%**

Table 9 -- Granite Metallic Basecoat Karl Fisher
SHAP North, October 2018

Foil Data Flash Entrance

Sample	Foil Weights (g)	Jar & Lid Weights (g)	Jar, Lid & Coated Foil Weights (g)	Jar, Lid, Coated Foil, & Methanol Weights (g)	KF % Water in Sample (% wt)	Weight of Paint Sample on Foil (g)	Weight of Methanol Used (g)	Water in Paint Sample (wt/wt)
Variable	F	J	K	L	KF	P	M	H2O Fract
Formula						K-(F+J)	L-K	(KF*(M+P)-KFb*M)/P
M1	2.993	124.231	127.986	177.967	0.180%	0.762	49.981	3.46%
M2	3.003	124.403	128.210	173.103	0.190%	0.804	44.893	3.54%
M3	3.306	124.357	128.395	180.160	0.210%	0.732	51.765	5.87%
Average								**4.29%**

KFb | 0.130% | = | % H2O in field blank

Foil Data Oven Entrance

Sample	Foil Weights (g)	Jar & Lid Weights (g)	Jar, Lid & Coated Foil Weights (g)	Jar, Lid, Coated Foil, & Methanol Weights (g)	KF % Water in Sample (% wt)	Weight of Paint Sample on Foil (g)	Weight of Methanol Used (g)	Water in Paint Sample (wt/wt)
Variable	F	J	K	L	KF	P	M	H2O Fract
Formula						K-(F+J)	L-K	(KF*(M+P)-KFb*M)/P
M4	3.348	125.257	129.391	177.173	0.170%	0.786	47.782	2.60%
M5	2.953	123.249	126.908	165.545	0.170%	0.706	38.637	2.36%
M6	3.221	123.906	127.857	166.710	0.150%	0.730	38.853	1.21%
Average								**2.06%**

KFb | 0.130% | = | % H2O in field blank

Table 10 -- White Solid Basecoat Oven Capture Efficiency
SHAP North, October 2018

	Unit	Variable	Formula	Panel 1	Panel 2	Panel 3	Panel 4	
Blank Panel Weight	g	P0		184.912	184.916	185.239	185.570	
Panel at Flash Entrance	g	P1		186.692	186.684	186.755	187.315	
Panel at Flash Exit/Oven Entrance	g	P2		186.329	186.344	186.480	186.977	
Baked Panel Weight	g	P3		186.209	186.213	186.369	186.845	
At Entrance to Flash								
% Nonvolatile	%	%NV	(P3-P0)/(P1-P0)	72.9%	73.4%	74.5%	73.1%	
% Volatile	%	%V	100-%NV	27.1%	26.6%	25.5%	26.9%	
% Water	%	$\%H_2O$	Average KF	4.21%	4.21%	4.21%	4.21%	
% VOC	%	%VOC	$\%V-\%H_2O$	22.9%	22.4%	21.2%	22.7%	Average W_{VOC1}
Weight of VOC Available for Control	g	W_{VOC}	(P1-P0)*%VOC	0.408	0.397	0.322	0.396	0.381
At Flash Exit/Oven Entrance	*Note: Flash exit and oven entrance weight are the same to allow for panel to cool before weight.*							
% Nonvolatile	%	%NV	(P3-P0)/(P2-P0)	91.5%	90.8%	91.1%	90.6%	
% Volatile	%	%V	100-%NV	8.5%	9.2%	8.9%	9.4%	
% Water	%	$\%H_2O$	Average KF	0.42%	0.42%	0.42%	0.42%	
% VOC	%	%VOC	$\%V-\%H_2O$	8.0%	8.8%	8.5%	9.0%	Average W_{VOC2}
Weight of VOC Available for Control	g	W_{VOC}	(P2-P0)*%VOC	0.114	0.125	0.106	0.126	0.118
At Oven Exit								
% Nonvolatile	%	%NV	(P3-P0)/(P3-P0)	100.0%	100.0%	100.0%	100.0%	
% Volatile	%	%V	100-%NV	0.0%	0.0%	0.0%	0.0%	
% Water	%	$\%H_2O$	Average KF	0.0%	0.0%	0.0%	0.0%	
% VOC	%	%VOC	$\%V-\%H_2O$	0.0%	0.0%	0.0%	0.0%	Average W_{VOC3}
Weight of VOC Available for Control	g	W_{VOC}	(P3-P0)*%VOC	0.000	0.000	0.000	0.000	0.000
Solids Coating Density								
Coating Density	lb/gal	W_C	Material Property					10.47
Mass Fraction Solids		W_S	Material Property					0.4725
Volume Fraction Solids		V_S	Material Property					0.3467
Solids Density	lb/gal	D_{COS}	$(W_S*W_C)/V_S$					14.26
Coating Solids Deposited								Average W_{COS}
Weight of Coating Solids Deposited	g	W_{COS}	(P3-P0)	1.297	1.297	1.130	1.275	1.250
Loading in Flash								
Weight VOC Available in Flash	g	$W_{VOC\ Flash}$	$W_{VOC1}-W_{VOC2}$					0.263
Weight of VOC available per GACS	lb/gal	C_{Lflash}	$(W_{VOC\ Flash}/W_{COS})*D_{COS}$					3.00
Loading in Oven								
Weight VOC Available in Oven	g	$W_{VOC\ Oven}$	$W_{VOC2}-W_{VOC3}$					0.118
Weight of VOC available per GACS	lb/gal	C_{Loven}	$(W_{VOC\ Oven}/W_{COS})*D_{COS}$					1.34
Weight VOC Available Total	lb/gal	C_L	$C_{Lflash}+C_{Loven}$					**4.35**
Capture Efficiency Calculation								
Mass Fraction VOC		W_{VOC}	Material Property					0.1870
Mass VOC per Volume Coating	lb/gal	VOC	W_C*W_{VOC}					1.957
Transfer Efficiency	%	TE						82.4%
Volume Solids Deposited per Volume Coating Sprayed		V_{sdep}	(V_S*TE)					0.286
VOC Capture Efficiency	%	CE	$C_L*V_{sdep}*100/VOC$					**63.4%**

Table 11 -- White Solid Basecoat Karl Fisher
SHAP North, October 2018

Foil Data Flash Entrance

Sample	Foil Weights (g)	Jar & Lid Weights (g)	Jar, Lid & Coated Foil Weights (g)	Jar, Lid, Coated Foil, & Methanol Weights (g)	KF % Water in Sample (% wt)	Weight of Paint Sample on Foil (g)	Weight of Methanol Used (g)	Water in Paint Sample (wt/wt)
Variable	F	J	K	L	KF	P	M	H2O Fract
Formula						K-(F+J)	L-K	(KF*(M+P)-KFb*M)/P
B1	3.227	123.399	128.160	175.373	0.260%	1.534	47.213	4.26%
B2	2.859	123.441	127.920	167.102	0.250%	1.620	39.182	3.15%
B3	3.156	123.833	128.479	169.180	0.310%	1.490	40.701	5.23%
Average								**4.21%**

KFb | 0.130% | = | % H2O in field blank

Foil Data Oven Entrance

Sample	Foil Weights (g)	Jar & Lid Weights (g)	Jar, Lid & Coated Foil Weights (g)	Jar, Lid, Coated Foil, & Methanol Weights (g)	KF % Water in Sample (% wt)	Weight of Paint Sample on Foil (g)	Weight of Methanol Used (g)	Water in Paint Sample (wt/wt)
Variable	F	J	K	L	KF	P	M	H2O Fract
Formula						K-(F+J)	L-K	(KF*(M+P)-KFb*M)/P
B4	3.152	123.661	128.234	165.824	0.150%	1.421	37.590	0.68%
B5	2.728	124.101	128.236	172.819	0.130%	1.407	44.583	0.13%
B6	2.868	123.717	127.844	166.957	0.140%	1.259	39.113	0.45%
Average								**0.42%**

KFb | 0.130% | = | % H2O in field blank