Ford Dearborn Truck Plant
Dearborn, Michigan

Environmental Testing Program – December 2017

Prime and Topcoat Transfer Efficiency and Capture Efficiency

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1.0 Executive Summary

JLB Industries, LLC completed a compliance environmental testing program during the week of December 4, 2017 at the Ford Dearborn Truck Plant (DTP) facility in Dearborn, Michigan. The testing program included Transfer Efficiency (TE) testing, Oven Capture Efficiency (OCE) testing and Booth Capture Efficiency (BCE) 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 in monthly emissions compliance calculations.

Transfer Efficiency values were derived for the Ford F150 truck model, which currently accounts for the majority of production volume at the facility. Personnel from the paint shop, Ford environmental staff and JLB Industries, LLC conducted the testing. These groups worked together at each stage of testing to ensure that the results were representative of production conditions.

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 Michigan laboratories, located in Livonia, Michigan.

Table 1 – Testing Results Summary

Tested Coating	Solids Transfer Efficiency (%)	Booth Capture Efficiency (%)	Oven Capture Efficiency (%)
Smoke Prime	**74.1%**	**31.5%**	**41.7%**
Black Basecoat			**13.7%**
Clearcoat		**37.0%**	**39.2%**
Black Basecoat and Clearcoat	**73.8%**		

2.0 Introduction

JLB Industries, LLC (JLBI) was contracted by Ford Dearborn Truck Plant (DTP) to perform a Transfer Efficiency (TE) and Capture Efficiency (CE) testing program on the Prime and Topcoat systems at the Dearborn Truck Plant located in Dearborn, Michigan. This testing was conducted on Ford F150 truck model during the week of December 4, 2017.

3.0 Sampling and Analytical Procedures

Transfer Efficiency Test

Transfer Efficiency testing was conducted in the Prime Spraybooth, where Smoke Exterior Prime and Black Interior Prime were applied, and the Topcoat Spraybooth, where Black 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.

All vehicles used in the testing were processed as normal production vehicles and included paint shop sealer.

An on-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-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. An applicator verification procedure was performed by Ford 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 Michigan 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 e-coat and processed through the Prime Spraybooth. The test sequence for the Transfer Efficiency test was:

Smoke Prime with Black Interior Prime

1. Test Unit ID TE 1
2. Test Unit ID TE 2
3. Test Unit ID TE 5
4. Test Unit ID TE 3 no-paint control
5. Test Unit ID TE 4 no-paint control
6. Test Unit ID TE 6 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 then routed to the Topcoat System:

Black Basecoat and Clearcoat

1. Test Unit ID TE 1
2. Test Unit ID TE 2
3. Test Unit ID TE 5

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

Capture Efficiency Tests

A panel weigh station (PWS) was assembled at the Prime and Topcoat Spraybooths. 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.

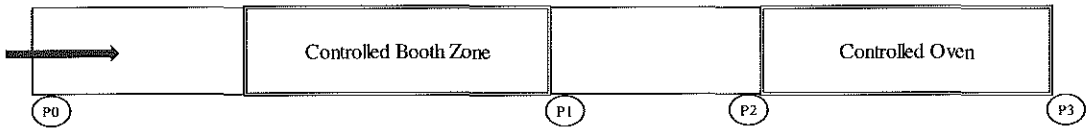
The testing conformed to the methods described in ASTM 5087-02 for solvent borne coatings and ASTM D6266-00a for water borne coatings. Capture Efficiency values for the controlled booth zones were calculated using the procedures outlined in the 40 CFR, Part 63.

Test panels were placed on Ford F150 cab and processed with normal production spray programming.

Four electrocoated panels were used for the tests. Each group of test panels was weighed in several 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 Spraybooth. 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).

Diagram 1 – Panel Testing Diagram



4.0 Test Equipment and Calibration

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 300 pounds of Class F calibration weights on each scale platform. Then, the VWS was calibrated with 600 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.

Material Usage

Coating material usage was monitored via volumetric flow measurement devices located on each applicator. A verification of the applicators was performed by Ford personnel to ensure accurate usage data. Paint usage was measured at each applicator in a graduated cylinder and compared to the expected volume. Verification data is included in section 7 of this report.

A sample of each material was taken after each test and analyzed by Advanced Technologies of Michigan, located in Livonia, Michigan. 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.

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, 20, 10 and 2 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.

5.0 Discussion of Test Results

Three test vehicles received an extra PVC coating after being pre-weighed. These vehicles were excluded from the test results. An additional no-paint control vehicle was run through the Prime Booth to quantify sealer weight loss.

VOC captured in the Prime Booth WOW Zone and from the interior robots was not tested at this time. Ford may elect to test at a future date to quantify the additional VOC captured in these zones.

6.0 Summary of Results

Table 2 - Prime Transfer Efficiency Calculation Summary
Ford DTP, December 2017

Vehicle ID	Vehicle Weight Gain (lb.)
Variable:	VWG
Calculation:	(W2-W1)
TE 2	2.31
TE 5	2.31
TE 1	N/A
Average	2.31
CTL Vehicle	-0.12
AVWG	**2.43**

(Average Vehicle Weight Gain - CTL Vehicle)

Material	Average Paint Sprayed (gal)	Coating Density (lb/gal)	Weight Solids Fraction	Average Solids Sprayed (lb.)	Transfer Efficiency (%)
Variable:	APS	CD	WSF	SS	TE
Calculation:	(Avg PS)	(Method 24)	(Method 24)	(APS*CD*WSF)	(AVWG/SS)
Interior Prime	0.011	8.72	0.5588	0.05	
Exterior Prime	0.549	9.41	0.6262	3.23	
				3.28	**74.1%**

*Vehicle TE 1 was not included in calculations due to addition of PVC after pre-weight.

Table 3 - Topcoat Transfer Efficiency Calculation Summary
Ford DTP, December 2017

Vehicle ID	Vehicle Weight Gain (lb.)
Variable:	VWG
Calculation:	(W2-W1)
TE 1	4.76
TE 2	4.82
TE 5	4.70
Average	4.76
CTL Vehicle	0.00
AVWG	**4.76**

(Average Vehicle Weight Gain - CTL Vehicle)

Material	Average Paint Sprayed (gal)	Coating Density (lb/gal)	Weight Solids Fraction	Average Solids Sprayed (lb.)	Transfer Efficiency (%)
Variable:	APS	CD	WSF	SS	TE
Calculation:	(Avg PS)	(Method 24)	(Method 24)	(APS*CD*WSF)	(AVWG/SS)
Basecoat	0.872	8.55	0.2528	1.88	
Clearcoat	0.963	8.38	0.5658	4.57	
				6.45	**73.8%**

Table 4 -- Prime Booth VOC Capture Efficiency
Ford DTP, December 2017

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	Percent of VOC remaining on Panel after Zone	Section Capture Efficiency (%)
Variable	P0	P1	P3	Wsdep	Wrem	Pm	Ws	Wvoc	Pvoc	CE
Formula				P3-P0	P1-P3	Wrem/Wsdep			(Pm)(Ws)/(Wvoc)	1-Pvoc
P1	186.696	188.706	188.134	1.438	0.572	0.398				
P2	186.588	188.767	188.179	1.591	0.588	0.370				
P3	185.740	187.660	187.123	1.383	0.537	0.388				
P4	184.804	186.729	186.193	1.389	0.536	0.386				
Average						0.385	0.6215	0.3785	0.6328	36.7%

Paint Usage Data

Process	Applicator	Paint Sprayed (Lb) not-Ctld	Ctld
Prime	Total	308	1848
	Ratio	0.143	0.857

Note: Measured Capture Efficiency is a section capture efficiency as only the exterior application is controlled.
Booth CE is Controlled Section CE (36.7%) * The ratio of coating sprayed in the controlled section (0.857)

Prime Booth Overall CE:	**31.5%**

Table 5 -- Prime Oven VOC Capture Efficiency
Ford DTP, December 2017

Oven 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/gal)
Variable	P0	P2	P3	W_{cos}	W_a	CL
Formula				P3-P0	P2-P3	$(W_a/W_{cos})*D_{cos}$
P1	186.696	188.647	188.134	1.438	0.513	3.84
P2	186.588	188.712	188.179	1.591	0.533	3.61
P3	185.740	187.592	187.123	1.383	0.469	3.65
P4	184.804	186.664	186.193	1.389	0.471	3.65
Average						**3.69**

Material Properties

Sample	Coating Density (lb/gal)	Mass Fraction Solids	Volume Fraction Solids	Average Film Build Thickness (mil)	VOC mass fraction	Solids Density (lb/gal)
Variable	W_c	W_s	V_s	mil	W_{voc}	D_{cos}
Formula						$(W_s*W_c)/V_s$
Prime	9.41	0.6215	0.5431	1.27	0.3785	10.77

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
		$(D_c)(W_{voc})$			$(V_s)(TE)$		$(P)(V_{sdep})(100)/(VOC)$
0.3785	9.41	3.562	74.1%	0.5431	0.402	3.69	**41.7%**

Table 6 - Basecoat Oven Capture Efficiency
Ford DTP, December 2017

	Unit	Variable	Formula	Panel 1	Panel 2	Panel 3	Panel 4	
Blank Panel Weight	g	P0		184.411		185.026	184.771	
Panel at Flash Entrance	g	P1		N/A		N/A	N/A	
Panel at Flash Exit/Oven Entrance	g	P2		185.010		185.720	185.350	
Baked Panel Weight	g	P3		184.943		185.620	185.271	
At Oven Entrance								
% Nonvolatile	%	%NV	(P3-P0)/(P2-P0)	88.8%		85.6%	86.4%	
% Volatile	%	%V	100-%NV	11.2%	*Panel*	14.4%	13.6%	
% Water	%	$\%H_2O$	Average KF	0.00%	*Marred,*	0.00%	0.00%	
% VOC	%	%VOC	$\%V-\%H_2O$	11.2%	*Discarded*	14.4%	13.6%	Average W_{VOC2}
Weight of VOC Available for Control	g	W_{VOC}	(P2-P0)*%VOC	0.067	*From Test*	0.100	0.079	0.082
At Oven Exit								
% Nonvolatile	%	%NV	(P3-P0)/(P3-P0)	100.0%		100.0%	100.0%	
% Volatile	%	%V	100-%NV	0.0%		0.0%	0.0%	
% Water	%	$\%H_2O$	Average KF	0.0%		0.0%	0.0%	
% VOC	%	%VOC	$\%V-\%H_2O$	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
Solids Coating Density								
Coating Density	lb/gal	W_C	Material Property					8.55
Mass Fraction Solids		W_S	Material Property					0.2336
Volume Fraction Solids		V_S	Material Property					0.2643
Solids Density	lb/gal	D_{COS}	$(W_S*W_C)/V_S$					7.56
Coating Solids Deposited								Average W_{COS}
Weight of Coating Solids Deposited	g	W_{COS}	(P3-P0)	0.532		0.594	0.500	0.542
Loading in Oven								
Weight VOC Available in Oven	g	$W_{VOC\ Oven}$	$W_{VOC2}-W_{VOC3}$					0.082
Weight of VOC available per GACS	lb/gal	C_{Loven}	$(W_{VOC\ Oven}/W_{COS})*D_{COS}$					**1.14**
Capture Efficiency Calculation								
Mass Fraction VOC		W_{VOC}	Material Property					0.1902
Mass VOC per Volume Coating	lb/gal	VOC	W_C*W_{VOC}					1.626
Transfer Efficiency	%	TE						73.8%
Volume Solids Deposited per Volume Coating Sprayed		V_{sdep}	(V_S*TE)					0.195
VOC Capture Efficiency	%	CE	$C_L*V_{sdep}*100/VOC$					**13.7%**

Table 6 - Basecoat Oven Capture Efficiency (Continued)
Ford DTP, December 2017

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
1	2.795	125.616	129.044	194.453	0.095%	0.633	65.409	-0.63%
2	3.005	125.188	128.877	199.004	0.086%	0.684	70.127	-1.55%
3	2.807	125.705	129.212	201.185	0.088%	0.700	71.973	-1.35%
Average								0.00%

KFb 0.102% = % H2O in field blank

* Average water in paint sample is presented as 0% due to more water in field blank than on foil samples.

Table 7 -- Clearcoat Booth VOC Capture Efficiency
Ford DTP, December 2017

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	Percent of VOC remaining on Panel after Zone	Section Capture Efficiency (%)
Variable	C0	C1	C2	Wsdep	Wrem	Pm	Ws	Wvoc	Pvoc	CE
Formula				C2-C0	C1-C2	Wrem/Wsdep			(Pm)(Ws)/(Wvoc)	1-Pvoc
1	185.299	187.867	187.086	1.787	0.781	0.437				
2	185.166	187.791	187.003	1.837	0.788	0.429				
3	185.639	188.403	187.596	1.957	0.807	0.412				
4	185.154	188.008	187.190	2.036	0.818	0.402				
Average						0.420	0.5745	0.4255	0.5671	43.3%

Paint Usage Data

Process	Applicator	Paint Sprayed (Lb) not-Ctld	Ctld
Clearcoat	Total	526	3119
	Ratio	0.144	0.856

Note: Booth Capture Efficiency is a section capture efficiency as only the exterior application is controlled.
Booth CE is Controlled Section CE (43.3%) * The ratio of coating sprayed in the controlled section (0.856)

Clearcoat Booth Overall CE:	**37.0%**

Table 8 -- Clearcoat Oven VOC Capture Efficiency
Ford DTP, December 2017

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/gal)
Variable	P0	P1	P2	W_{cos}	W_a	CL
Formula				P2-P0	P1-P2	$(W_a/W_{cos})*D_{cos}$
1	185.299	187.821	187.086	1.787	0.735	3.56
2	185.166	187.748	187.003	1.837	0.745	3.51
3	185.639	188.345	187.596	1.957	0.749	3.31
4	185.154	187.953	187.190	2.036	0.763	3.24
Average						3.41

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						$(W_s*W_c)/V_s$
Clear	8.35	0.5745	0.5541	2.06	0.4255	8.66

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)	VOC Oven Capture Credit (%)
W_{voc}	D_c	VOC	TE	V_s	V_{sdep}	P	CE
		$(D_c)(W_{voc})$			$(V_s)(TE)$		$(P)(V_{sdep})(100)/(VOC)$
0.4255	8.35	3.553	73.8%	0.5541	0.409	3.41	**39.2%**