Ford Flat Rock Assembly Plant
Flat Rock, Michigan

Environmental Testing Program – October 2018

Transfer Efficiency
Booth Capture Efficiency
Oven Capture Efficiency

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1.0 Executive Summary

JLB Industries, LLC completed a compliance environmental testing program during the week of October 8, 2018 at the Ford Flat Rock Assembly Plant (FRAP) in Flat Rock, Michigan. The testing program included Transfer Efficiency (TE) and Capture Efficiency (CE) testing of the booth and ovens. 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* and with 40 CFR Chapter 1, Appendix A to Subpart IIII of Part 63. The test results will be used to demonstrate compliance with Auto MACT requirements and in monthly emissions compliance calculations.

Transfer Efficiency values were derived using the Ford Mustang model vehicle, which is representative of plant production. 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. Mr. Jonathan Lamb of the MDEQ witnessed a portion of the testing.

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.

Table 1 – Testing Results Summary

Tested Coating	Solids Transfer Efficiency (%)
3-Wet System (Gray Prime, Black BC and CC)	75.9%

Tested Coating	Booth Capture Efficiency			Oven Capture Efficiency
	Adjusted	Carry-Over	Total	
Prime	83.4%	0.7%	84.1%	10.6%
Basecoat	74.2%	2.4%	76.6%	11.6%
Clearcoat	40.6%	--	40.6%	32.5%

2.0 Introduction

JLB Industries, LLC (JLBI) was contracted by Ford Flat Rock Assembly Plant (FRAP) to perform Transfer Efficiency (TE) and Capture Efficiency (CE) testing program on the 3-Wet paint systems at the FRAP Assembly Plant in Flat Rock, Michigan. This testing was conducted using the Ford Mustang model during the week of October 8, 2018.

3.0 Sampling and Analytical Procedures

Transfer Efficiency Test

Transfer Efficiency testing was conducted in the 3-Wet Spraybooth #2. The test was conducted on Dark Gray Prime, Absolute Black Basecoat and Clearcoat, which are considered representative coatings for the process. 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 five vehicle bodies were used in testing. Three vehicles were processed as normal production vehicles and two vehicles were dedicated as no-paint controls in conjunction with each test. All units were production vehicles with electrocoat and 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 off-line and pushed into the VWS. 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 each 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 calibration/verification of each applicator was performed by FRAP 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 laboratories 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 3-Wet Spraybooth #2. A gap was placed before and after the test vehicles to prevent overspray. The test sequence for the Transfer Efficiency test was:

Black 3-Wet – Dark Gray Prime, Absolute Black Basecoat and Clearcoat

1. Test Unit ID 8993
2. Test Unit ID 8992
3. Test Unit ID 8972
4. Test Unit ID 8974 (No-paint)
5. Test Unit ID 8994 (No-paint)

Capture Efficiency Tests

Panel weigh stations (PWS) were assembled between the 3-Wet Spraybooths, near the exit of the basecoat controlled spray zone and the entrance to the bake oven. Weighing locations were chosen based on the controlled zone locations as outlined below in *Diagram 1 – Panel Testing Diagram.* 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. Three test runs were performed:

1. Prime Capture Efficiency
2. Basecoat Capture Efficiency
3. Clearcoat Capture Efficiency

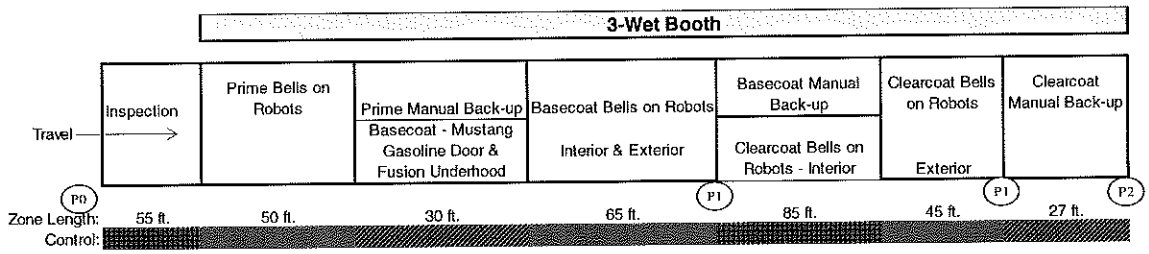
The testing conformed to the methods described in ASTM 5087-02 for solvent borne coatings. Capture Efficiency values for the controlled oven and spraybooth zones were calculated using the procedures outlined in the 40 CFR, Part 63. All test panels were placed on Ford Mustang model vehicles and processed with normal production spray programming.

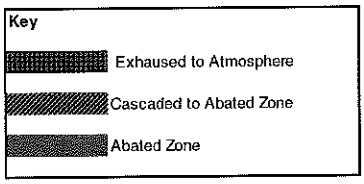
Four electrocoated panels were used for each of the tests. Each group of test panels was weighed in several locations (see panel test diagram) to determine the relative distribution of VOC that is released in the controlled spray zones and bake oven. The panels were attached to test vehicles by magnet, 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. For Booth Capture tests, panels were carefully removed from the test vehicle and brought to the balance for weighing after coating, upon exiting the controlled spraybooth zone (P1). For Oven Capture tests, panels were weighed immediately before entering the bake oven (P2). In all tests, 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). The Prime and Basecoat Panels were weighed at the entrance to the controlled clearcoat zone to identify the carryover capture in that zone.

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 200 pounds of Class F calibration weights on each scale platform. Then, the VWS was calibrated with 400 pounds of Class F calibration weights. VWS linearity was checked using a one or two-pound, Class F stainless steel calibration weight. The one or two-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 calibration/verification of each applicator was performed by FRAP paint 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. 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 Materials. These values were used in calculating the paint solids sprayed

and the transfer efficiency for each type of calculation. 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 300, 50, 20, 10 and 5 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

There were no significant disruptions to the testing program.

6.0 Summary of Results

Table 2 - 3-Wet Transfer Efficiency Calculation Summary
Ford FRAP, October 2018

Vehicle ID	Vehicle Weight Gain (lb.)	Prime Sprayed (gal)	Basecoat Sprayed (gal)	Clearcoat Sprayed (gal)
Variable:	VWG	PPS	BCPS	CCPS
Calculation:	(W2-W1)			
8993	3.62	0.199	0.447	0.529
8992	3.70	0.199	0.441	0.543
8972	3.71	0.199	0.447	0.562
Average:	3.68	0.199	0.445	0.545
AVWG:	**3.87**	AVWG=(avg VWG-SWL)		

Material	Avg. Paint Sprayed (gal)	Coating Density (lb/gal)	Weight Solids Fraction	Avg. Solids Sprayed (lb.)	Transfer Efficiency (%)
Variable:	APS	CD	WSF	SS	TE
Calculation:	(Avg PS)	(Method 24)	(Method 24)	(APS*CD*WSF)	(AVWG/SS)
Prime	0.199	9.31	0.5839	1.08	
Basecoat	0.445	7.73	0.4124	1.42	
Clearcoat	0.545	8.56	0.5581	2.60	
				5.10	**75.9%**

Control Vehicle Sealer Weight Loss

Vehicle ID	Vehicle Weight Gain (lb.)
Variable:	SWL
Calculation:	(W2-W1)
Control 1	-0.15
Control 2	-0.25
Average	-0.20

Table 3 -- Prime Booth VOC Capture Efficiency
Ford FRAP, October 2018

Sample	Blank Panel Weights (g)	Wet Panel Weights - Control Zone Exit	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	P4	W_{sdep}	W_{rem}	P_m	W_s	W_{VOC}	P_{VOC}	CE
Formula				P2-P0	P1-P4	W_{rem}/W_{sdep}			$(P_m)(W_s)/(W_{VOC})$	$1-P_{VOC}$
P1	185.352	186.652	186.514	1.162	0.138	0.119				
P2	186.006	187.215	187.092	1.086	0.123	0.113				
P3	185.331	186.530	186.401	1.070	0.129	0.121				
P4	185.168	186.366	186.237	1.069	0.129	0.121				
Average						0.118	0.5839	0.4161	0.166	**83.4%**

Table 4 -- Basecoat Booth VOC Capture Efficiency
Ford FRAP, October 2018

Sample	Blank Panel Weights (g)	Wet Panel Weights - Control Zone Exit	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	Booth Capture Efficiency (%)
Variable	P0	P1	P4	W_{sdep}	W_{rem}	P_m	W_s	W_{VOC}	P_{VOC}	CE
Formula				P4-P0	P1-P4	W_{rem}/W_{sdep}			$(P_m)(W_s)/(W_{VOC})$	$1-P_{VOC}$
B1	184.200	185.338	185.024	0.824	0.314	0.381				
B2	185.275	186.329	186.040	0.765	0.289	0.378				
B3	184.651	185.743	185.456	0.805	0.287	0.357				
B4	185.975	187.018	186.746	0.771	0.272	0.353				
Average						0.367	0.4124	0.5876	0.258	**74.2%**

Table 5 -- Clearcoat Booth VOC Capture Efficiency
Ford FRAP, 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	P2	W_{sdep}	W_{rem}	P_m	W_s	W_{VOC}	P_{VOC}	CE
Formula				P2-P0	P1-P2	W_{rem}/W_{sdep}			$(P_m)(W_s)/(W_{VOC})$	$1-P_{VOC}$
C1	185.499	188.334	187.603	2.104	0.731	0.347				
C2	186.151	188.761	188.101	1.950	0.660	0.338				
C3	185.137	187.474	186.890	1.753	0.584	0.333				
C4	185.408	187.930	187.298	1.890	0.632	0.334				
Average						0.338	0.5581	0.4419	0.427	57.3%

Paint Usage Data

Process	Applicator	Paint Sprayed (cc) Uncontrolled	Controlled
Clearcoat Interior	R1	597	
	R2		
Clearcoat Exterior	R1		197
	R2		210
	R3		238
	R4		244
	R5		189
	R6		--
	R7		191
	R8		191
Total		597	1460
Ratio		0.290	0.710

Note: Clearcoat Booth Capture Efficiency is a section capture efficiency as only the exterior application is controlled.
Booth CE is Controlled Section CE (57.3%) * The ratio of coating sprayed in the controlled section (0.710) = CC Booth CE (40.6%)

Clearcoat Booth CE: 40.6%

Table 6 -- Prime Oven VOC Capture Efficiency
Ford FRAP, October 2018

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	P3	P4	W_{cos}	W_a	CL
Formula				P4-P0	P3-P4	$(W_a/W_{cos})*D_{cos}$
P1	185.352	186.630	186.514	1.162	0.116	1.12
P2	186.006	187.193	187.092	1.086	0.101	1.04
P3	185.331	186.509	186.401	1.070	0.108	1.13
P4	185.168	186.348	186.237	1.069	0.111	1.16
Average				1.097	0.109	**1.11**

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						(Ws*Wc)/Vs
Prime	9.31	0.5839	0.4858	0.96	0.4161	11.19

Capture Efficiency

Mass Fraction VOC in Coating	Coating Density (lb/gal)	Mass VOC per Volume Coating (lb/gal)	Transfer Efficiency (%)	Volume Fraction Solids	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)			$(V_s)(TE)$		$(P)(V_{sdep})(100)/(VOC)$
0.4161	9.31	3.874	75.9%	0.4858	0.369	1.11	**10.6%**

Table 7 -- Basecoat Oven VOC Capture Efficiency
Ford FRAP, October 2018

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	P3	P4	Wcos	Wa	CL
Formula				P4-P0	P3-P4	$(W_a/W_{cos})*D_{cos}$
B1	184.200	185.204	185.024	0.824	0.180	1.71
B2	185.275	186.208	186.040	0.765	0.168	1.72
B3	184.651	185.629	185.456	0.805	0.173	1.69
B4	185.975	186.917	186.746	0.771	0.171	1.74
Average				0.791	0.173	**1.71**

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						$(W_s*W_c)/V_s$
Basecoat	7.73	0.4124	0.4064	0.79	0.5876	7.84

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
		$(D_c)(W_{voc})$			$(V_s)(TE)$		$(P)(V_{sdep})(100)/(VOC)$
0.5876	7.73	4.541	75.9%	0.4064	0.308	1.71	**11.6%**

Table 8 -- Clearcoat Oven VOC Capture Efficiency
Ford FRAP, October 2018

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	P1	P2	W_{cos}	W_a	CL
Formula				P2-P0	P1-P2	$(W_a/W_{cos})*D_{cos}$
C1	185.499	188.334	187.603	2.104	0.731	3.11
C2	186.151	188.761	188.101	1.950	0.660	3.03
C3	185.137	187.474	186.890	1.753	0.584	2.99
C4	185.408	187.930	187.298	1.890	0.632	3.00
Average				1.924	0.652	**3.04**

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	8.56	0.5581	0.5329	2.03	0.4419	8.96

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)			$(V_s)(TE)$		$(P)(V_{sdep})(100)/(VOC)$
0.4419	8.56	3.782	75.9%	0.5329	0.404	3.04	**32.5%**

Table 9 -- Prime Booth VOC Capture Efficiency (Carryover to Controlled Clearcoat)
Ford FRAP, October 2018

Oven Solvent Loading

Sample	Blank Panel Weights (g)	Wet Panel Weights - Before Control (g)	Wet Panel Weights - After Control (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	P4	W_{cos}	W_a	CL
Formula					P4-P0	P2-P3	$(W_a/W_{cos})*D_{cos}$
P1	185.352	186.638	186.630	186.514	1.162	0.008	0.08
P2	186.006	187.199	187.193	187.092	1.086	0.006	0.06
P3	185.331	186.515	186.509	186.401	1.070	0.006	0.06
P4	185.168	186.355	186.348	186.237	1.069	0.007	0.07
Average					1.097	0.007	**0.07**

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						(Ws*Wc)/Vs
Prime	9.31	0.5839	0.4858	0.96	0.4161	11.19

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 Capture Efficiency (%)
W_{voc}	D_c	VOC	TE	V_s	V_{sdep}	P	CE
		(Dc)(Wvoc)			$(V_s)(TE)$		$(P)(V_{sdep})(100)/(VOC)$
0.4161	9.31	3.874	75.9%	0.4858	0.369	0.07	**0.7%**

Table 10 -- Basecoat Booth VOC Capture Efficiency (Carryover to Controlled Clearcoat)
Ford FRAP, October 2018

Oven Solvent Loading

Sample	Blank Panel Weights (g)	Wet Panel Weights - Before Control (g)	Wet Panel Weights - After Control (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	P4	Wcos	Wa	CL
Formula					P4-P0	P2-P3	$(W_a/W_{cos})*D_{cos}$
B1	184.200	185.242	185.204	185.024	0.824	0.038	0.36
B2	185.275	186.244	186.208	186.040	0.765	0.036	0.37
B3	184.651	185.669	185.629	185.456	0.805	0.040	0.39
B4	185.975	186.945	186.917	186.746	0.771	0.028	0.28
Average					0.791	0.035	**0.35**

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						$(W_s*W_c)/V_s$
Basecoat	7.73	0.4124	0.4064	0.79	0.5876	7.84

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 Capture Efficiency (%)
W_{voc}	D_c	VOC	TE	V_s	V_{sdep}	P	CE
		$(D_c)(W_{voc})$			$(V_s)(TE)$		$(P)(V_{sdep})(100)/(VOC)$
0.5876	7.73	4.541	75.9%	0.4064	0.308	0.35	**2.4%**