Designation: D 5066 – 91 (Reapproved 2001)

Standard Test Method for Determination of the Transfer Efficiency Under Production Conditions for Spray Application of Automotive Paints—Weight Basis[1]

This standard is issued under the fixed designation D 5066; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method provides procedures for determination of the transfer efficiency (using a weight method) under production conditions for in-plant spray application of automotive paints as outlined in Section 18 of EPA 450/3-88-018.

1.2 The transfer efficiency is calculated from the weight of the paint solids sprayed and that deposited on the painted part. The recommended approach involves painting the part directly. Also described is an alternative approach for painting parts covered with aluminum foil.

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* Specific hazard statements are given in 10.1.8.1.

2. Referenced Documents

2.1 *ASTM Standards:*

D 1475 Test Method for Density of Paint, Varnish, Lacquer, and Related Products[2]

D 2369 Test Methods for Volatile Content of Coatings[2]

2.2 *USEPA/MVMA (Motor Vehicle Manufacturers Association) Standards:*

EPA 450/3-88-018, U.S. Environmental Protection Agency Protocol for Determining the Daily Volatile Organic Compound Emission Rate of Automobile and Light Duty Truck Topcoat Operations,[3]

EPA Federal Reference Method 24—Determination of Volatile Matter Content, Water Content, Density, Volume Solids, and Weight Solids, of Surface Coatings[4]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *paint*—the liquid material that is applied onto the part to cover or coat the surfaces.

3.1.2 *transfer efficiency*—the ratio of the weight of paint solids deposited to the total weight of paint solids used during the application process, expressed as a percent.

3.1.3 *paint weight solids content*—the weight of the nonvolatile materials in the liquid paint material divided by the total weight of the paint, times 100, determined by Test Method D 2369.

3.1.4 *paint density*—the mass of a unit volume of the liquid paint material at any given temperature, determined by Test Method D 1475.

3.1.5 *satellite paint supply system*—a smaller, paint-circulating system separate from the main production paint-circulating supply system capable of supplying paint under the same conditions.

4. Summary of Test Method

4.1 The weight of the part to be painted is determined before and after the paint application process. The weight of liquid paint used per part is determined from material usage and part processing records. The determined weight solids content of the paint material is determined and used to calculate the paint solids sprayed per part. The transfer efficiency of the process is calculated by dividing the weight of paint solids deposited by the weight of the paint solids sprayed.

5. Significance and Use

5.1 This test method is specifically directed at the spray painting of automobile car and light duty truck bodies. The general principles are applicable to the painting of other automotive parts.

5.2 This test method may also be used to measure transfer efficiency in full-sized painting facilities simulating production conditions and operations.

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[1] This test method is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings, Materials, and Applications and is the direct responsibility of Subcommittee D01.55 on Factory Applied Coatings on Preformed Products.

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[2] *Annual Book of ASTM Standards*, Vol 06.01.

[3] Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. Refer to EPA 450/3-88-018 dated December 1988. This protocol makes reference to the determination of production spray transfer efficiency.

[4] Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. Refer to CFR 40, Part 60, Appendix A.

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6. Interferences

6.1 Limitations include the ability of the weighing device to determine accurately the weight of the paint solids deposited on the part and the capability of accurate measurement of the amount of paint sprayed (see Section 7).

6.2 It may be difficult to cover the surface of complex shaped parts with aluminum foil (see 11.6.11).

7. Apparatus

7.1 *Tension Load Cells*, with upper/lower transition pieces.

7.1.1 682-kg (1500-lb) capacity with 0.02-kg (0.05-lb) precision for weighing automobile body and support frame.

7.1.2 227 to 364-kg (500 to 800-lb) capacity with 0.02-kg (0.05-lb) precision for weighing mix tanks or automobile components.

7.1.3 A safety cable is required for upper to lower transition.

7.2 *Electronic Digitizer/Readout*, readability of 0.02 kg (0.05 lb) and special filtering.

7.2.1 The electronic digitizer/readout shall meet OIML (International Organization of Legalized Metrology) specifications.[5]

7.3 *Voltage Regulator*.

7.4 *Swivel Devices*, as required.

7.5 *Rule and Calipers* for measuring diameter of paint supply tank shaft, etc.

7.6 *Sample Containers*, clean and airtight for paint material.

7.7 *Lifting Device and Support Frame Apparatus* to lift body.

7.7.1 Total weight must not exceed capacity of load cell or scale.

7.8 *Standard Calibration Weight*, approximately 0.9 kg (2 lb).

7.9 *Measure Stick*, Starret precision spring tempered, satin chrome finish, 36 in. (91.4 cm), with 4R graduations, or equivalent.

8. Paint Usage Measurement Procedures

8.1 Transfer efficiency measurement requires that accurate measurements be made of the quantity of paint material used in the application process during the time period associated with the coating of specific vehicles or parts. Two general procedures are applicable for accurately measuring paint usage.

8.1.1 The preferred procedure is to determine the weight of paint used during the application study period. Under typical production conditions, such weighing may be difficult, due to the large number of applicators requiring paint supply from a common tank. If a separate, isolated paint supply tank is used in the test; it is important to control paint viscosity, temperature, and flow rate consistent with the regular production system (see 9.1).

8.1.2 Where direct paint usage measurement by weight is not practical, an alternative procedure for determining paint usage by volume is suggested. This procedure involves measuring the drop in paint level in the paint supply tank during the test. To provide sufficient accuracy, it may be necessary to paint a “block” (isolated group) of similar vehicles or parts from the paint supply system while usage measurements are taken. Typically, this may require painting approximately 30 vehicles (see 9.2).

9. Paint Usage Determination by Weight Procedure

9.1 This procedure for determining paint usage during the test is preferred when a satellite paint supply system is available for the process to be tested. With this procedure, it is usually easier to isolate paint usage for measurement purposes, and accurate results can be obtained with a smaller number of vehicles or parts (see 9.1.1).

9.1.1 At least 2.27 kg (5.0 lb) of paint material must be used during the test with the specified weighing equipment.

9.2 Before a satellite paint supply system can be used, it must be demonstrated that the system is capable of supplying the paint at sufficient volume and pressure to maintain normal process conditions (fluid deliveries of the spray devices) and that the paint can be maintained at a representative temperature and viscosity for the duration of the test period. These requirements can best be assured by mounting the satellite tank on a load cell or scale and directly piping it into the production supply system of the spraybooth. For this procedure the requirements are as follows:

9.2.1 Level and calibrate a weighing device (see Section 7) for weighing the satellite supply tank.

9.2.2 If an electronic weighing device is used, it must be turned on long enough to achieve stability, following the manufacturer’s directions. All weighing devices must be situated to minimize disturbance from vibration or air movement.

9.2.3 Introduce the paint material, reduced to spraying viscosity, into the tank to be weighed. Before the test is conducted, be certain that fluid flows are properly set, that all supply and return lines are filled with the paint, and that no leaks are present in the piping system.

9.2.4 Shut off the agitator to minimize vibration during the weighing of the system.

9.2.5 Calibrate the weighing device in accordance with manufacturer’s instructions. Weigh and tare a lifting frame, if used to support the satellite paint supply tank.

9.2.6 Weigh the satellite paint supply tank before the test vehicles or parts are run. Flexible connections are required to minimize strain. Carefully note the configuration of the tank so that the same configuration is used for both initial and the final weighing (that is, hose connections, height, etc.). Weigh the tank until 2 consecutive measurements are obtained within the measurement error of the weighing system ± 0.02 kg (0.05 lb). Average the two readings. The satellite tank may be left on the weighing device during the painting operation to monitor painting usage on a continuous basis.

9.2.7 After painting the test vehicles or parts, reweigh the satellite paint supply tank in accordance with 9.2.5 and 9.2.6.

9.2.8 Obtain representative paint samples immediately after completion of the test for solids and density analysis.

[5] The sole source of supply of the electronic digitizer, Model 5322, known to the committee at this time is Sterling Scale Co., 20950 Boening, Southfield, MI 48075. If you are aware of alternative suppliers, please provide this information to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

10. Paint Usage Determination by Tank Level Measurement (Volume Procedure)

10.1 This procedure for determining the paint usage requires that the drop in the liquid level in the system supply tank be measured accurately. This procedure is applicable with either a satellite system or a main-mix room supply system. A sufficient number of parts must be processed in the test block to provide at least a 7.6-cm (3-in.) drop in the liquid level in the paint supply tank. Careful measurement is critical to the overall accuracy of the transfer efficiency test. This procedure consists of the following:

10.1.1 Accurately measure the inside diameter of the paint supply tank(s) to be used for the various test materials. If the agitator shafts, fill pipes, or any other objects are located in the measurement zone, the occupied volume of these items must be determined and subtracted from the total volume. Careful selection of the section of the tank for the test measurement will minimize the difficulty of this task. The measurements are used to develop a conversion factor between level drop and volume of paint.

10.1.2 Most main paint supply systems consist of two tanks connected together to maintain the material supply. During the test, the paint supply tank must be isolated. Check to ensure that there is no leakage or overflow between the two tanks and that the directional valves for paint return function properly. Make sure that these checks are made just prior to and after the test, and are done by measuring the volume in both tanks.

10.1.3 Place the test paint, which has been reduced to spraying viscosity, into the paint supply tank to be measured. No material additions or reductions may be made to the tank during the test. Before the test is conducted, make certain that valving is set so that paint is being drawn from the test tank and returned to the test tank, and that all air has been removed from the delivery system.

10.1.4 With satellite paint supply tank systems, special care must be taken to ensure that all fluid lines are completely filled.

10.1.5 Prior to taking the volume measurement, turn off any agitation within the tank that will interfere with the measuring process and then turn it back on after the measurement.

10.1.6 Record the tank levels before and after the test. Take the initial reading just prior to the first test vehicle or part of the block that enters the first application station in the tested process. Take the final reading just after the last vehicle or part has left the last application area in the tested process.

10.1.7 With clearcoat (or other paint materials that cannot be isolated to a specific block of cars due to other connected operations such as repair), take the initial reading as the first vehicle or part in the test block enters the first station applying clearcoat. Take the final reading when the vehicle after the last job in the test block enters the first station, applying clearcoat (the same point at which the initial reading was taken). If this is not done, the block size for clearcoat will be different from the block size for basecoat (this is acceptable but must be accurately reflected in the calculations).

10.1.8 The measurements are to be taken to the nearest 1.6 mm (1⁄16 in.) with a measuring stick with 1.6 mm (1⁄16-in.) or less graduations. Measurements are made from the top of the tank to the top of the liquid level at least 7.6 to 10.2 cm (3 to 4 in.) from the sides of the tank. The top of the tank is to be determined by laying a straight edge across the top of the tank in the same position for each measurement.

10.1.8.1 **Warning:** Any measuring instruments used in this procedure must be effectively grounded before contacting the coating tank or coating liquid surface. Review all measuring instruments for suitability and resistance to the paint solvents prior to the test.

10.1.9 It may be necessary to provide two-way radio communication between the mix-room monitor and the tested process operation to coordinate the measurement process and timing.

10.1.10 Obtain representative paint samples immediately after completion of the test for density and solids determinations.

11. Paint Solids Deposited Measurement Procedure

11.1 To determine the transfer efficiency, it is necessary to determine both the weight of paint solids sprayed per vehicle or part and the weight of paint solids actually deposited onto the object in the tested process. These are obtained by weighing vehicles or parts incorporated in the same sample (block) used to obtain the paint usage measurement.

11.2 *Vehicle or Part Weighing Procedure*— The weight of paint solids deposited during the application process is determined by weighing the vehicle(s) or part(s) prior to and after the paint is applied and baked. At least two vehicles or parts are required to be tested. A control part is also run and weighed before and after the application process. No paint is applied to the control part in the process. The control is required to determine weight loss from miscellaneous materials (primarily sealants and plastics applied prior to the tested process) that may occur in the drying oven. The difference in the weight of the measurement vehicles adjusted for the weight loss in the control vehicle or part, is the weight of paint solids applied in the tested process.

11.3 Weighing of the parts requires the use of a precision weighing device and digitizer as described in 7.1 and 7.2. A lifting frame and hoist are required to support the test vehicle. The measurement site(s) must be selected to avoid disturbance caused by air movement or production activities and to allow convenient removal of the test vehicles or parts from the production line and their subsequent replacement to the production line. Fork trucks or other mechanical handling aids along with sufficient manpower to move the vehicle bodies into and out of the weighing frame will be required.

11.3.1 Passenger car bodies generally will weigh 364 to 409 kg (800 to 900 lb). Since the maximum capacity of the specified load cell is 682 kg (1500 lb), the weight of the lifting frame and rigging must be kept to less than 273 kg (600 lb) or a higher capacity load cell with the specified accuracy must be utilized.

11.4 It is critical that the vehicles or parts be allowed to cool completely to room temperature prior to weighing. Closely monitor heavy metal sections (usually around the door frames) as these areas will cool more slowly than exterior body surfaces. If during the weighing process there is any doubt that the vehicle or part is fully cooled, weigh the test part and allow it to stand 15 to 20 min and weigh again. If a weight increase

of more than 0.02 kg (0.05 lb) is noted, allow the body to cool an additional 15 to 20 min and repeat the weighing procedure. Repeat this process until consistent weights are obtained.

11.5 Check that all accessories and miscellaneous materials (hangers, spacers, etc.) remain in the same position (either on or off) for both the initial and final weighings.

11.6 *Weighing Procedure*:

11.6.1 Turn on the weighing device and digitizer and allow them to warm up in accordance with the manufacturer's instructions.

11.6.2 Zero the instrument in accordance with manufacturer's instructions.

11.6.3 Attach the lifting frame to the load cell. Lift and weigh the frame until two consecutive readings within 0.02 kg (0.05 lb) are obtained. Record this tare weight, W_t.

11.6.4 Mount a completely cooled vehicle or part into the lifting frame. Lift the test unit until it is completely clear of the carrier and fully suspended by the load cell. If the test unit does not hang level, adjust the suspension point on the lifting frame and recheck for proper tare weight. If necessary, the calibration weights may be used to help level the test unit, but be certain to include this weight in the initial weight.

11.6.5 Allow the suspended vehicle or part to completely stabilize (usually 2 to 3 min). Be certain that nothing is touching the test unit or suspension frame and record the weight.

11.6.6 Add a standard calibration weight to the suspended vehicle or part and check for instrument accuracy. Recalibrate the system if a discrepancy is noted.

11.6.6.1 Select the calibration weight to represent the estimated increase in weight of the vehicle or part in the painting process.

11.6.7 Lower the vehicle or part back onto the carrier to remove the weight from the load cell. Relift the vehicle or part and weigh as just indicated until two consecutive weights within 0.05 lb (0.02 kg) are obtained. Record the average of two consecutive initial weights, that is W_i for part (1) and $W_{c,i}$ for the control.

11.6.8 Remove the first body and repeat 11.6.5 through 11.6.7 for the other vehicles and the weight loss control vehicle (if included in this test run). Between test measurements and after the last unit is weighed, resuspend the empty lifting frame and verify the tare weight, W_t.

11.6.9 Apply the paint to the specified vehicles or parts, allowing the control unit to proceed through the spraybooth and oven uncoated.

11.6.9.1 Considerable care must be taken in handling the weighed units to eliminate any weight gain or loss due to handling, parts addition, parts removal, or miscellaneous debris.

11.6.10 After the vehicles or parts have been painted and cured in the oven, allow them to cool to room temperature prior to reweighing. Repeat the weighing procedure in 11.6.1. through 11.6.8 and record the weights, $W_{l,f}$ for the coated part (1) and $W_{c,f}$ for the control.

11.6.11 *Foiled Part Procedure*—The procedure is identical to that described in 11.2 except that aluminum foil is preapplied to the vehicle or part. All the surfaces to be painted are covered with foil as smoothly and tightly as possible to ensure that the covered surface is representative of the area painted in the normal production environment.

12. Measurement of Other Paint Usage

12.1 When the measurement of paint used cannot be completely isolated to the application process under test because of the process and facilities arrangement, it may be necessary to obtain an estimate of paint solids deposited from the same paint supply system in the nonisolated operations (such as repair, etc.). With this estimated value, the total paint solids deposited in the main process can be directly correlated to the amount of paint used in calculating the resultant transfer efficiency. Such a correlation can be established by either making a separate estimate or measurement of the paint used or the paint solids deposited outside the tested process. The amount of material involved should be small (less than 5 %) relative to the total paint used or deposited.

12.2 While an estimate of paint used is generally preferred, in practice it is usually easier to obtain an estimate of the amount of paint solids deposited onto the test unit. For repair type operations, an estimate of paint solids applied may be obtained by counting the number of panels repaired while the test block is being processed and multiplying by the square feet per panel and the average film build applied (determined from measurements or historical data). This technique works well since almost all repairs involve complete body panels for which data can readily be obtained.

13. Analysis of Paint Samples

13.1 Make the following analytical determinations for each paint sample obtained:

13.1.1 *Weight Fraction Solids*, in accordance with Test Method D 2369 per EPA Federal Reference Method 24.

13.1.2 *Paint Density*, in accordance with Test Method D 1475.

13.2 These determinations are required to calculate transfer efficiency. Obtain separate determinations for each paint material used in each test.

14. Calculations and Report Submission

14.1 Upon completion of the test and receipt of the paint analytical results, the transfer efficiency calculations can be made in accordance with the following procedure:

14.2 Calculate the average weight gain of the vehicle or part, corrected for the weight gain or loss of the control unit.

$$G_{avg} = \frac{\text{Sum}[W_f - W_i]}{n} - [W_{c,f} - W_{c,i}] \quad (1)$$

where:

G_{avg} = average weight gain, kg (lb),
W = weight, kg (lb),
W_f = final weight, kg (lb),
W_i = initial weight, kg (lb),
n = number of test units coated,
c = control,
$W_{c,p}$ = final weight of control vehicle or part, kg (lb), and
$W_{c,i}$ = initial weight of control vehicle or parts, kg (lb).

14.3 Calculate the average amount of paint used during the

test period by either the weight procedure or the volume procedure.

14.3.1 *Weight Procedure* (see Section 9):

$$P_{avg} = [P_i - P_f] / m \quad (2)$$

where:

P_{avg} = average weight of paint used during the test, kg (lb),
P_i = initial weight, kg (lb),
P_f = final weight, kg (lb), and
m = number of units measured.

14.3.2 *Volume Procedure* (see Section 10):

$$P_{avg} = (V \times P) / m \quad (3)$$

where:

V = volume of paint used during the test,
D = paint density in accordance with Test Method D 1475, and
m = number of units measured.

14.4 Calculate the average paint solids used during the test period.

$$S_{avg} = P_{avg} \times F \quad (4)$$

where:

S_{avg} = average weight of paint solids used during the test, lb (kg), and
F = weight fraction solids in the paint material from Test Method D 2369.

14.5 Calculate the transfer efficiency T result.

$$T = G_{avg} / S_{avg} \times 100 \quad (5)$$

15. Precision and Bias

15.1 *Precision*—Engineering estimates based on error assumptions indicate an accuracy of ±5 % can be expected for typical automotive painting operations.

15.2 *Bias*—Since there is no accepted reference procedure suitable for determining the bias for this test method, no statement on bias is being made.

16. Keywords

16.1 automotive painting; production method; spray-applied; transfer efficiency

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