Designation: D 5286 – 01

Standard Test Methods for Determination of Transfer Efficiency Under General Production Conditions for Spray Application of Paints[1]

This standard is issued under the fixed designation D 5286; 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 These test methods cover the determination of the transfer efficiency of spray-applied coatings under general plant conditions. Transfer efficiency is the ratio of paint solids deposited to the total paint solids used during the application process, expressed as a percent.

1.2 The transfer efficiency is calculated from the weight or volume of the paint solids sprayed and that of the paint solids deposited on the painted part.

1.3 Limitations include the ability to accurately determine the amount of paint solids deposited on the part and the capability of accurate measurement of the amount of paint sprayed.

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

NOTE 1—These test methods apply to general plant production equipment and procedures. A method specific to automotive plants is defined in Test Method D 5066.

NOTE 2—The relationship between volatile organic compound emission rates and transfer efficiency in automobile and light duty truck topcoat operations, EPA 450/3-88-018, referenced in Test Method D 5066 does not apply to general production facilities.

NOTE 3—A single-point transfer efficiency measurement may not represent the entire process.

NOTE 4—The operator and the spray-application equipment-operating conditions during the transfer efficiency measurement should be representative of normal operating conditions.

1.5 *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.* For specific hazard statements see Section 7, and 10.3.1.

NOTE 5—These test methods have not been adopted by federal regulatory agencies for demonstration of compliance with air pollution regulations such as VOC, HAPS, etc.

2. Referenced Documents

2.1 *ASTM Standards:*

D 1005 Test Method for Measurement of Dry-Film Thickness of Organic Coatings using Micrometers[2]

D 1186 Test Method for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to a Ferrous Base[2]

D 1200 Test Method for Viscosity by Ford Viscosity Cup[2]

D 1400 Test Method for Nondestructive Measurement of Dry Film Thickness of Nonconductive Coatings Applied to a Nonferrous Metal Base[2]

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

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

D 2697 Test Method for Volume Nonvolatile Content in Clear or Pigmented Coatings[2]

D 3925 Practice for Sampling Liquid Paints and Related Pigmented Coatings[2]

D 5066 Test Method for Determination of the Transfer Efficiency Under Production Conditions for Spray Application of Automotive Paints—Weight Basis[3]

2.2 *U.S. Government 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[4]

EPA Federal Reference Method 24—Determination of Volatile Matter Content, Water Content, Density, Volume Solids, and Weight Solids of Surface Coatings. 40 Code of Federal Regulations, Part 60, Appendix A.[4]

2.3 *National Fire Protection Documents:*

NFPA 33 Spray Application Using Flammable and Combustible Materials[5]

NFPA 86 Standard for Ovens and Furnaces[5]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

---

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

Current edition approved Jan. 10, 2001. Published March 2001. Originally published as D 5286 – 93. Last previous edition D 5286 – 95.

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

[3] *Annual Book of ASTM Standards*, Vol 06.02.

[4] Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

[5] Available from National Fire Protection Assn., Battery March, Quincy, MA 02269.

3.1.1 *paint*—the liquid material applied to coat or cover the surface of the part.

3.1.2 *transfer efficiency (volume)*—the ratio of the volume of paint solids deposited to the volume of the paint solids sprayed, expressed as a percent.

3.1.3 *transfer efficiency (weight)*—the ratio of the weight of paint solids deposited to the weight of the paint solids sprayed, expressed as a percent.

3.1.4 *volume of paint solids*—the difference in the volume of the paint solids on the part before painting and the volume of the paint solids on the part after painting.

3.1.5 *volume percent solids*—the solids content as percent of the total volume of a sample of paint used.

3.1.6 *weight of paint solids*—the difference in the weight of the part before painting and the weight of the part after painting and baking.

4. Summary of Test Methods

4.1 The weight of liquid paint used per part is determined (Procedure A). The weight solids content of the paint material is determined and used to calculate the paint solids sprayed. The transfer efficiency is calculated by dividing the weight of the paint solids deposited by the weight of the paint solids sprayed.

4.2 The volume of paint solids used per part is determined (Procedure B). The volume solids of the paint material is determined and used to calculate the paint solids sprayed. The transfer efficiency is calculated by dividing the volume of the paint solids deposited by the volume of the paint solids sprayed.

5. Significance and Use

5.1 Subject to the limitations listed in 1.3, these test methods can be used to optimize paint application processes.

6. Apparatus

6.1 *Laboratory Scale*, accurate to ± 0.001 g.

6.2 *Tension Load Cells or Comparable Platform Scales*, accurate to ± 0.02 mg (0.05 lb).

6.3 *Film Thickness Gage*, see Test Methods D 1005, D 1186, and D 1400 for type of film thickness measurement of device.

6.4 *Targets*, consisting of the parts to be coated. A minimum of two targets is required. The larger the number of targets, the greater the accuracy of the test.

6.5 *Rule and Calipers*, for measuring the diameter of the paint supply tank or pot, tank agitator shaft, etc.

6.6 *Sample Containers*, clean, dry, for sampling the paint material.

7. Hazards

7.1 For specific hazard information and guidance, consult the supplier's Material Safety Data Sheet (MSDS) for the materials used.

8. Paint Usage Measurement Procedures

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

8.1.1 The preferred method is to determine the weight of paint used during the application period studied.

8.1.2 Where direct paint usage measurement by weight is not practical, an alternative approach for determining paint usage by volume is given. The latter approach involves measuring the drop in paint level in the paint supply tank (pot) during the application period studied.

8.1.3 Where paint meter/mix equipment is used to directly feed paint application equipment, paint-component meter readings shall be deemed reliable when the meter is properly calibrated in accordance with the equipment manufacturer's calibration instructions or local calibration procedures.

9. Paint Usage Determination by Weight Procedure—Procedure A

9.1 Level and calibrate the weighing device for weighing the paint supply tank (pot).

9.2 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.

9.3 Introduce the material reduced to spray viscosity, into the supply tank (pot) 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.

9.4 Shut off the paint supply tank (pot) agitator to minimize vibration during the weighing process.

9.5 Weigh the paint supply tank (pot) before the test parts are run. Weigh the tank until two consecutive measurements are obtained within the measurement accuracy of the weighing device. Average the two readings and record, P_i.

9.6 After painting the test parts, reweigh the paint supply tank (pot) as in 9.5 and record, P_f.

Paint Deposited Determination by Weight Measurement Method, Procedure A

9.7 Set up the paint supply equipment to the spray apparatus in accordance with the manufacturer's instructions.

9.8 Ground all electrically conductive objects in the spray area, in accordance with Chapter 9.11 of NFPA 33. Except for those objects required by the process to be at high voltage.

9.9 Prior to running the test, agitate the test paint in a paint supply tank (pot) at least 30 min before paint samples are taken.

9.10 Using an airtight container, take a paint grab sample from the paint supply tank (pot) in accordance with Practice D 3925.

9.11 Determine and record the following from the paint sample:

9.11.1 Paint viscosity in accordance with Test Method D 1200,

9.11.2 Weight percent solids in accordance with Test Method D 2369. If the baking temperature in Test Method D 2369 is inadequate, use the manufacturer's recommended cure schedule, and

9.11.3 Electrical resistivity for samples applied electrostatically.

9.12 Number each part, before weighing, using a permanent marking pen.

9.13 Weigh each part and record the uncoated weight, W_i and the part number.

9.14 Attach the preweighed, labeled parts to the part holder.

9.15 If electrostatic equipment is used, the resistance shall be less than 1×10^6 Ω between the target and earth ground in accordance with Chapter 9.8 of NFPA 33.

9.16 Adjust the following equipment operating parameters, as appropriate, to the values desired for testing:

9.16.1 Paint fluid pressure, at spray gun, psi (kPa),

9.16.2 Atomizing air pressure, at spray gun, psi (kPa),

9.16.3 Rotating atomizer head speed (revolutions per minute) with and without paint fluid flow,

9.16.4 Operating voltage (kilovolts) if electrostatic equipment is used,

9.16.5 Ambient air temperature, ° Fahrenheit (Celsius).

9.16.6 Paint fluid temperature, ° Fahrenheit (Celsius) and

9.16.7 Relative humidity (percent).

9.17 For electrostatic spray equipment, measure the operating voltage and adjust it according to the manufacturer's instructions.

9.18 Run a control part weighing before, W_{ci} and after, W_{cf} the drying step. Do not apply paint to the control part. The control part is used to determine if there is any weight loss from miscellaneous materials that may occur in the drying step.

9.19 Turn on the paint spray equipment. Maintain a uniform paint flow during the test.

9.20 Turn off the paint spray equipment when the required number of parts have been painted.

9.21 Bake the painted parts per the manufacturer's recommended cure schedule.

9.22 Allow the parts to cool to room temperature prior to weighing. Weighings should be repeated until the two weights are within the accuracy of the measuring equipment.

9.23 Record the weights for the coated parts, W_f.

10. Paint Usage Determination by Volume Procedure—Procedure B

10.1 Measure the inside diameter of the paint supply tank (pot) and calculate the cross sectional area of the tank. If any objects are in the measurement zone such as agitator shafts, fill pipes, etc, the cross sectional area of these objects must be determined and the values subtracted from the cross sectional area of the tank. The difference is the net cross sectional area.

10.2 Introduce the material, reduced to spray viscosity, into the supply tank (pot) to be measured. 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.

10.3 Record the paint supply tank (pot) levels before and after the test. Take the initial reading just prior to painting the first test part. Take the final reading just after the last part has been painted. Make sure that the measurements are taken to the nearest 1⁄16 in. with a measuring stick. Measurements are made from the top of the paint supply tank (pot) to the top of the liquid level. The top of the paint supply tank (pot) is determined by laying a straightedge across the top of the paint supply tank (pot) in the same position for each measurement. The volume of any objects in the measurement zone such as agitator shafts, fill pipes, etc. must be subtracted from the total volume. Calculate the volume of paint used, V by multiplying this difference in liquid levels, before and after the test by the net cross sectional area determined in 10.1.

10.3.1 **Warning:** Measuring devices used in this procedure must be effectively grounded before contacting the paint supply tank (pot) or the liquid surface of the paint.

Paint Deposited Determination by Volume Measurement Method, Procedure B

10.4 Set up the paint supply equipment to the spray apparatus in accordance with the manufacturer's instructions.

10.5 Ground all electrically conductive objects in the spray area, except those objects required by the process to be at high voltage in accordance with Chapter 9 to 11 of NFPA 33.

10.6 Prior to running the test, agitate the test paint in a paint supply tank (pot) at least 30 min before paint samples are taken.

10.7 Using an airtight container, take a paint grab sample from the paint supply tank (pot) in accordance with Practice D 3925.

10.8 Determine and record the following from the paint sample:

10.8.1 Paint viscosity in accordance with Test Method D 1200,

10.8.2 Volume percent solids in accordance with Test Method D 2697. If the baking temperature in Test Method D 2697 is inadequate, use the manufacturer's recommended cure schedule, and

10.8.3 Electrical resistivity for samples applied electrostatically.

10.9 Number each part using a permanent marking pen.

10.10 Measure and record the surface area, A_p and the number of each part.

10.11 Attach the numbered parts to the part holder.

10.12 If electrostatic equipment is being used, the resistance shall be less than 1×10^6 Ω between the target and earth ground in accordance with Chapter 9.8 of NFPA 33.

10.13 Adjust the following equipment operating parameters, as appropriate, to the values desired for testing:

10.13.1 Paint fluid pressure, at spray gun, psi (kPa),

10.13.2 Atomizing air pressure, at spray gun, psi (kPa),

10.13.3 Rotating atomizer head speed (revolutions per minute) with and without paint fluid flow,

10.13.4 Operating voltage (kilovolts) if electrostatic equipment is used,

10.13.5 Ambient air temperature °F (C),

10.13.6 Paint fluid temperature °F (C), and

10.13.7 Relative humidity (percent).

10.14 For electrostatic spray equipment, measure the operating voltage and adjust it according to the manufacturer's instructions.

10.15 Run a control part. Do not apply paint to the control part. The control part is used to determine the base film thickness of the part.

10.16 Turn on the paint spray equipment. Maintain a uniform paint flow during the test.

10.17 Turn off the paint spray equipment when the required

number of parts have been painted.

10.18 Bake the painted parts in accordance with the manufacturer's recommended cure schedule.

10.19 Allow the parts to cool to room temperature prior to measuring the film thickness of the coating.

10.20 Measure and record the film thickness of the coating for each part, including the control part using Test Methods D 1005, D 1186, or D 1400. Record the film thickness of the coated parts as F_p and of the control part as F_c.

11. Calculation

11.1 *Transfer Efficiency by Weight Method*:

11.1.1 Calculate the average weight gain of the parts corrected for the weight gain or loss of the control part as follows:

$$W_{g,avg} = \{\Sigma(W_f - W_i)/n\} - (W_{cf} - W_{ci}) \quad (1)$$

where:

$W_{g,avg}$ = average weight gain of a part, lb (kg),
W_f = final weight of part, lb (kg),
W_i = initial weight of part, lb (kg),
n = number of parts coated,
W_{cf} = final weight of control part, lb (kg), and
W_{ci} = initial weight of control part, lb (kg).

11.1.2 Calculate the average amount of paint used during the test by either the weight method or the volume method.

11.1.2.1 *Weight Procedure (See Section* 9*)*:

$$P_{w,avg} = (P_i - P_f)/n \quad (2)$$

where:

$P_{w,avg}$ = average weight of paint used per part, lb (kg),
P_i = initial weight of paint used for test, lb (kg),
P_f = final weight of paint used for test, lb (kg).

11.1.2.2 *Volume Procedure (See Section* 10*)*:

$$P_{w,avg} = (V \times D)/n \quad (3)$$

where:

V = volume of paint used during the test, ft^3 (m^3), and
D = paint density in accordance with Test Method D 1475, lb/ft^3 (kg/m^3).

11.1.2.3 Calculate the average weight paint solids used per part during the test period as follows:

$$S_{w,avg} = P_{w,avg} \times S_{w,f} \quad (4)$$

where:

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

11.1.3 Calculate the transfer efficiency using the following equation:

$$T = 100(W_{g,avg}/S_{w,avg}) \quad (5)$$

where:

T = transfer efficiency, %.

11.2 *Transfer Efficiency by Volume Method*:

11.2.1 Calculate the average film thickness of the parts corrected for the film thickness of the control part as follows:

$$F_{p,avg} = \Sigma(F_p - F_c)/n \quad (6)$$

where:

$F_{p,avg}$ = average film thickness of the coated parts, ft (m),
F_p = film thickness of the coated part, ft (m),
F_c = film thickness of the control part, ft (m).

11.2.2 Calculate the average surface area of the parts as follows:

$$A_{p,avg} = \Sigma A_p/n \quad (7)$$

where:

$A_{p,avg}$ = average surface area of the coated parts, ft^2 (m^2),
A_p = surface area of the coated parts, ft^2 (m^2).

11.2.3 Calculate the average amount of solids deposited on each part as follows:

$$V_{g,avg} = F_{p,avg} \times A_{p,avg} \quad (8)$$

where:

$V_{g,avg}$ = average volume gain of the parts. This is the average solids, by volume, of the paint deposited on the part, ft^3 (m^3).

11.2.4 Calculate the average amount of paint used during the test by either the weight method or the volume method, as follows:

11.2.4.1 *Weight Procedure (see Section* 9 *and EPA Method 24)*:

$$P_{v,avg} = (W_i - W_f)/(n \times D) \quad (9)$$

where:

$P_{v,avg}$ = average volume of paint used per part, ft^3 (m^3).

11.2.5 *Volume Procedure (see Section* 10*)*:

$$P_{v,avg} = V/n \quad (10)$$

where:

V = volume of paint used during the test, ft^3 (m^3).

11.2.6 Calculate the average solids (volume) used per part during the test period as follows:

$$S_{v,avg} = P_{v,avg} \times S_{v,f} \quad (11)$$

where:

$S_{v,avg}$ = average volume of paint solids used per part, ft^3 (m^3),
$P_{v,avg}$ = average volume of paint used per part, ft^3 (m^3), and
$S_{v,f}$ = volume fraction solids in paint material in accordance with Test Method D 2697 .

11.3 Calculate the volume transfer efficiency using the following equation:

$$T = 100(V_{g,avg}/S_{v,avg}). \quad (12)$$

12. Report

12.1 Report the following information:

12.1.1 Transfer efficiency results,

12.1.2 Type of spray equipment,

12.1.3 Type of paint applied,

12.1.4 Paint application conditions as listed in 9.10 or 10.10, and

12.1.5 Conditions of test other than those specified in Sections 9 or 10 of these test methods.

13. Precision and Bias

13.1 *Precision*—While it may be possible to determine *Repeatibility*, it is not possible to specify the *Reproducibility* of the procedures in these test methods for measuring transfer efficiency because in general, no two production facilities have identical application systems. The precision of the referenced ASTMstandards, however apply.

13.2 *Bias*—Since there is no acepted reference material for determining bias for the procedures in these test methods, no bias statement is made for these test methods.

14. Keywords

14.1 general production conditions; solvent emission; spray applied coatings; transfer efficiency; VOC; volatile content