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Standard Practice for Determining Application Rates and Distribution Patterns from Aerial Application Equipment[1]

This standard is issued under the fixed designation E642; 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 practice covers uniform procedures for determining and reporting application rates and distribution patterns from agricultural aircraft. This practice should not be used for making biological performance tests.

1.2 The procedures covered deal with both fixed and rotary-wing aircraft equipped with either liquid or dry material distribution systems.

1.3 The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to inch-pound units that are provided for information only and are not considered standard.

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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E726 Test Method for Particle Size Distribution of Granular Carriers and Granular Pesticides

2.2 *ASAE Standard:*

ASAE S327.1 Terminology and Definitions for Agricultural Chemical Application[3]

3. Test Conditions

3.1 The physical characteristics of the liquid or dry material have an effect on the application rate and the distribution patterns. If inert test solutions for materials are substituted for the materials to be applied, they shall have physical characteristics similar to those of the material to be applied. If toxic materials are used in the tests, all safety precautions prescribed by the manufacturer and governmental authority for handling, loading, application, and disposal of toxic materials shall be observed.

3.2 Pattern tests shall be conducted, with wind speeds not exceeding 16 km/h (10 mph), measured 2.5 m (8.2 ft) above the land surface or crop canopy. If wind occurs, flights shall be made both into and with the wind to minimize the effects of wind velocity on ground speed. Flights shall be made parallel to or within 20° of the direction of the wind to minimize errors due to crosswinds. These restrictions do not apply to the output rate tests.

4. Procedure

4.1 A complete procedure shall consist of five parts:

4.1.1 Determination of the output rate from the aircraft system.

4.1.2 Determination of the swath distribution pattern by recovery of the applied materials from suitable collectors.

4.1.3 Determination of usable swath width for field applications.

4.1.4 Determination of the rate of application of the spray mixture or dry material, and

4.1.5 Determination of the uniformity of distribution of several swaths.

4.2 *Output Rate Determination:*

4.2.1 *Liquid Materials*—Determine the output rate by the amount of liquid discharged from the tank for a measured time interval while the aircraft is in flight under normal conditions. The time interval shall be sufficient to permit accurate measurement of liquid discharged and to minimize errors due to turning the system on and off. Run the system for at least 30 s and measure to the nearest 0.5 s. Measure the amount of liquid used by either refilling the tank to the initial level or by measuring the amount remaining in the tank and subtracting from the initial amount. Measurement precision shall be ±2 % of the amount discharged in the test. If the liquid dispersal system can be operated with the aircraft stationary, the test can be accomplished without actually flying the aircraft. Report

[1] This practice is under the jurisdiction of ASTM Committee E35 on Pesticides, Antimicrobials, and Alternative Control Agents and is the direct responsibility of Subcommittee E35.22 on Pesticide Formulations and Delivery Systems.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Society of Agricultural and Biological Engineers (ASABE), 2950 Niles Rd., St. Joseph, MI 49085, http://www.asabe.org.

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output rate in litres per minute (gallons per minute), and note the nozzle (boom) pressure.

4.2.2 *Dry Materials*—If venturi distributors are used, determine the output rate by measuring the amount of material discharged from the hopper over a given time interval while the aircraft is in flight under normal conditions. Precision of measurement of time and materials as specified in 4.2.1 shall apply here. Run tests with the aircraft hopper filled to at least 25 % of capacity. Report the output rate, in kilograms per minute (pounds per minute), and the control settings used to achieve this rate.

4.3 *Swath Distribution Pattern Test:*

4.3.1 Conduct this test by flying the aircraft over the center of a collection line placed at a right angle to the line of flight. The collection line may be placed on the land surface or crop height (or any other height consistent with the purpose of the test), and shall permit collection of a representative sample of the distribution pattern for the dispersed material. Fly the aircraft at a height suited to the type of material applied and the purpose of the application. The airspeed shall be that for the intended application and the flight shall be level and straight. Extend the collection line at least 3 m (10 ft) beyond the ends of the pattern being tested. Measure ambient temperature, humidity, and wind speed and direction (with respect to the line of flight) at 1 to 3 m (3 to 10 ft) above the land surface or crop canopy. Note the height of flight and the airspeed.

4.3.2 Turn on the distribution equipment in the aircraft at least 100 m (300 ft) prior to crossing the collection line, and continue operating it the same distance beyond. Run three replications of each test. Make each replication with a separate single pass of the aircraft. Note the direction of flight with respect to wind direction.

4.3.3 *Spray Test Procedure and Target Collectors:*

4.3.3.1 An inert chemical or dye tracer material may be added to the contents of the spray tank, or the active chemical may be used as a tracer for the spray pattern tests. If inert materials are used, include suitable amounts of emulsifier, spreader-stickers, and other solvents and carriers to closely simulate the material to be applied.

4.3.3.2 The spray collection line may be composed of discrete targets or a narrow continuous surface. Quantitative analysis of the spray deposited on the target collector(s) may be accomplished by electronic scanning or by washing tracer material from the collector surface(s).

4.3.3.3 If the pattern is determined from the amount of tracer material recovered from the line, the surface of the collector(s) shall permit all or a constant percentage of the tracer to be removed by washing. If the tracer used degrades due to exposure to sunlight, age, or other factors, the results should be corrected to compensate for the degradation. If discrete targets are used, they may be flat sheets, or have raised edges to facilitate washing. The exposed flat surface (exclusive of raised edges) shall have an area of at least 50 cm^2 (7.8 $in.^2$). Spacing of descrete targets across the swath shall not exceed 1 m (3.3 ft).

4.3.3.4 For samples that are electronically scanned to measure deposition on the sample surface based on droplet size and numbers, an appropriate area must be scanned to obtain a true representation of the droplet-size distribution in the sample.

4.3.3.5 *Qualitative Spray Distribution Pattern Measurement*—A qualitative measure of the distribution pattern may be used to diagnose and correct distribution system deficiencies (plugged or worn nozzles, improper size nozzles, system leaks, improperly placed nozzles, and so forth). Qualitative distribution pattern measurement techniques may employ discrete sample targets or a continuous collector placed across the flight line of the aircraft. The measurement technique used should provide a relative or absolute measure of the deposition on the sample surfaces across the flight line.

4.3.4 *Dry Material Test Procedure and Collectors:*

4.3.4.1 Granular materials are normally tested by capturing samples of the swath in buckets or collectors that are high enough to prevent the particles bouncing into or out of the containers. Collect dust or other small particles on greased boards or other sticky surfaces, or in shallow pans. Weigh or count the material collected in these devices, or dissolve in a solution for analysis as appropriate.

4.3.4.2 The area of the top opening of the collectors shall be 0.1 m^2 (1 ft^2) or larger, to provide a representative sample of the deposit. Spacing of the collectors along the swath shall not exceed 1 m (3 ft).

4.4 *Sample Analysis and Conversion of Swath Distribution Pattern Data:*

4.4.1 *Spray Pattern Test:*

4.4.1.1 For quantifying spray deposits using tracer materials, any type of sample analysis may be used that is compatible with the spray tracer. Examples are photoelectric colorimetry, absorption or emission spectroscopy, and liquid or gas chromatography, where the sensitivity of the analysis shall be at least 2 ppm. After a collector is washed in accordance with 4.3.3, the concentration of tracer may be determined by use of a standard calibration curve developed for the tracer and the analytical method employed. The rate of spray deposit in litres per hectare (gallons per acre) may then be determined for each location across the collection line as follows:

$$D = (K \times V_t \times C_t)/(C_s \times A) \qquad (1)$$

where:

D = deposit rate, L/ha (gal/acre),
K = constant, 10^5 (or 1657),
A = collector area, cm^2 ($in.^2$),
$_t$ = volume of solvent used to wash tracer from target, mL,
C_t = concentration of tracer washed from collector, mg/L, and
C_s = concentration of collector in original spray solution, mg/L.

4.4.1.2 Quantifying spray deposits using image scanning of discrete or continuous sample surfaces shall utilize sufficient size classes, preferably at least 20, to accurately define the droplet size distribution. A droplet size versus spread factor function covering the droplet size range encountered under test conditions (temperature and relative humidity) shall be developed for the sample surface material and test liquid and used in calculating the deposit volume per unit of area.

4.4.2 *Dry Material Test*—If the dry material deposited in the collection device at each location across the line of collectors is weighed, the deposit rate may be determined in kg/ha (lb/acre) as follows:

$$D = (K \times W)/A \tag{2}$$

where:

D = deposit rate, kg/ha (lb/acre),
K = constant, 10^5 (13 829),
W = weight collected, g, and
A = area of collector opening, cm^2 (or $in.^2$).

If the collected material is of a nature to make counting of individual particles desirable, express the results as the number of particles per unit area, such as cm^2, 0.1 m^2, m^2 ($in.^2$, ft^2). If the material collected is a dust, it may be desirable to use greased boards or other sticky surfaces, or shallow pans holding a solute as collectors. Procedures similar to those outlined in 4.4.1 may be used for analysis of dust deposits if the dust itself can serve as the tracer material, or a suitable tracer material is mixed with the dust. Express the deposit rate in kilograms per hectare (pounds per acre) at each location across the line of collectors.

4.5 *Plotting the Distribution Curve and Evaluating Swath Widths*—Data for each test replication from 4.4.1 or 4.4.2 will be plotted with the rate of deposit on the ordinate and the location of deposit with respect to the aircraft center line on the abscissa. This data, or the resulting plot, or both, will be used to determine the maximum effective swath width for each replication either by inspection as described in 4.5.1 or by simulated overlapping of swaths and statistical analysis as described in 4.5.2. The usable swath width will be obtained by averaging the maximum effective widths determined for the individual replicates and will be used in calculating the rate of application as described in 4.6.

4.5.1 *Effective Swath Width by Inspection*—The distribution pattern for most aerially applied materials should approximate either a triangular or a trapezoidal pattern with the maximum rate of deposit under the flight path of the aircraft. The rate of deposit should taper off evenly at the edges of the pattern. The effective swath width may be determined as the distance between points on either side of the pattern where the rate of deposit equals one half of the maximum rate for the pattern. If a pattern contains spurious peak deposit rates or other irregularities, it should either not be used to determine effective swath width or such irregularities should be discounted.

4.5.2 *Effective Swath Width by Simulated Overlapping and Statistical Analysis*—The single swath patterns shall be plotted around the aircraft center line as multiple adjacent swaths, with additive deposits in the overlapped regions to obtain a composite plot showing simulated field distribution. Since the distribution patterns often are not perfectly symmetrical, plots may be prepared to simulate both the one-direction and back-and-forth methods of application. Enough patterns must be overlapped to ensure a representative simulated field distribution that would be unaffected by additional swaths (a minimum of four swaths for one-direction or five for back-and-forth application, if the tails of the distribution pattern extend beyond the center line of adjacent swaths). If the single swath patterns are skewed due to crosswind, simulated field distributions for back-and-forth applications may indicate artificial irregularities. Determination of the effective swath width from the simulated field distribution data is accomplished by calculating the coefficient of variation (CV) in accordance with 4.7.3, for overlapped rates of deposit obtained from sampling intervals from one swath center line to the next for one-direction application, or from two swath spacings for back-and-forth application. Field distribution simulations will be made and CV's calculated for swath center line spacings ranging from one sampling interval width to the total width of the single swath pattern. Swath increments for the CV calculations shall not be greater than the sampling interval (or one meter for continuous sampling) across the swath. The largest swath width associated with the minimum acceptable CV for the intended application shall be considered the effective swath width.

4.6 *Rate of Application*—Calculate the overall rate of application as follows:

$$R = (Q \times K)/(V \times S) \tag{3}$$

where:

R = rate of application, L/ha or kg/ha (gal/acre or lb/acre),
Q = output rate, L/min or kg/min (gpm or lb/min),
K = constant, 600 (495),
V = velocity over ground, km/h (mph), and
S = usable swath width, m (ft).

4.7 *Uniformity of Distribution*—Use the coefficient of variation to express the uniformity of distribution of application resulting from multiple adjacent swaths. The multiple swaths can be simulated for each distribution pattern replication plotted in 4.5 or from actual flight tests using a sufficiently long collection line. Also plot the resulting distribution to permit visual examination for deposit peaks and low points that may occur.

4.7.1 *Simulated Field Distribution:*

4.7.1.1 Determine the simulated field distribution for each swath distribution pattern obtained in 4.3 using the effective swath width determined in accordance with 4.5.1 or 4.5.2. Develop the simulated field distribution by accumulating the collector readings that result when swaths are combined, using the effective swath width. Use individual replicates of the swath pattern, not averages. If swath widths other than the effective swath width (4.5.1 or 4.5.2) are used, note it.

4.7.1.2 If the tails of the pattern do not extend beyond the center line of the adjacent swaths, two swaths shall be required to simulate one-direction applications and three shall be required to simulate back-and-forth applications. If the tails of the pattern do extend beyond the center line of adjacent swaths, four swaths will be required to simulate one-direction and five to simulate back-and-forth applications. If the swaths are arithmetically overlapped in reverse order to simulate back-and-forth application it should be recognized, as in 4.5.2, that pattern skew due to crosswind will result in unreliable simulations.

4.7.2 *Measured Field Distribution:*

4.7.2.1 If actual flight tests are used to determine field distribution, determine the number of adjacent swaths required for one-direction and back-and-forth applications as indicated in 4.7.1.2 for simulated field distribution, and extend the sample collection line to simultaneously sample the number of adjacent swaths required. Swaths may be flown in alternate back-and-forth application directions or all in the same direction as desired. (It should be recognized that in most cases the two sides of the aircraft will give different distribution patterns and that field distribution data for alternate flight direction will differ from that of one-way flight direction.)

4.7.2.2 Use only the central portion of the field distribution data (simulated or measured) that provides complete swath overlap to compute the coefficient variation. For a three-swath distribution pattern, use the portion from the center line of the first swath to the center line of the third swath. If five swaths are required to provide complete overlap, use the portion from the center line of the second swath to the center line of the fourth swath. If only two swaths are required (one-direction application where pattern tails do not extend beyond the center of adjacent swaths), use the portion between the two swath center lines. If four swaths are required (one-direction application where pattern tails do extend beyond the center of adjacent swaths), use the portion between the center lines of the second and third swaths.

4.7.3 Determine the mean value, standard deviation, and coefficient of variation as follows:

4.7.3.1 *Arithmetic Mean:*

$$\bar{X} = \sum x_i / n \tag{4}$$

where:

X = arithmetic mean deposit,
x_i = reading for one sampling interval for the combined swaths, and
n = number of collector locations used.

4.7.3.2 *Standard Deviation:*

$$SD = \left[\frac{\sum \left((x_i) - \bar{X} \right)^2}{n - 1} \right]^{1/2} \tag{5}$$

$$= \left[\frac{\sum (x_i^2) - \left(\sum x_i \right)^2 / n}{n - 1} \right]^{1/2}$$

4.7.3.3 *Coefficient of Variation:*

$$C = (SD \times 100)/X \tag{6}$$

5. Report

5.1 The report shall include the following information on the aircraft, distribution equipment, output rates, and distribution pattern tests.

5.1.1 *Aircraft Data:*

5.1.1.1 Aircraft model, type, manufacturer's name, and year manufactured.

5.1.1.2 Wing span, presence and type of wing tip spoilers, or modification of wings from that of original equipment.

5.1.1.3 Engine manufacturer, horsepower rating (normal sea level flight for a stated rpm), propellor manufacturer, model, and length.

5.1.1.4 Hopper capacity, both volume and mass.

5.1.1.5 Gross aircraft weight at one-half upper volume load.

5.1.2 *Dispersal System Used for Liquid or Dry Materials:*

5.1.2.1 *Liquid Dispersal*—The following information shall be reported:

(1) Manufacturer, type, size of pump, and method of driving pump.

(2) Size, type, and length of boom.

(3) Number, size, type, spacing (if symmetrical), orientation of atomizing devices, and their position relative to the chord of the wing. If the atomizer spacing is not symmetrical, a diagram showing the position of each atomizer relative to the center line of the aircraft shall be included.

(4) Spray mixture ingredients and proportions of each.

(5) Spray pressure, measured at the boom. (This shall be the same for the output test and the distribution pattern test.)

5.1.2.2 *Dry Material Dispersal*—The following information shall be reported:

(1) Manufacturer, type, and model of distribution equipment.

(2) For venturi spreaders, dimensions of frontal opening, throat, width and depth of discharge end, overall length, and location under the fuselage shall be reported. Any vane adjustments should be noted, as well as any modifications from the original design.

(3) For rotary spreaders, the rotor size and vane configuration, speed, and location shall be reported.

(4) For gravity feed to the spreader, the type and size of metering gate should be indicated. For positive feed, the details of the metering device should be recorded. If agitation of the hopper is included, it should be indicated as to type and speed.

(5) The name, particle size, particle shape, and bulk density of the material being applied should be reported. If the manufacturer's report of the sieve analysis is unavailable or voided, then a sieve analysis of the product shall be made using procedures set forth in Test Method E726 (or equivalent).

5.1.2.3 *Output Rate*—The results of the test, outlined in 4.2.1 or 4.2.2, shall be reported as the mean value of several test runs. The time interval and quantity of material discharged for each test run shall also be reported.

5.1.2.4 *Distribution Pattern Test*—The results of this test shall include the following information:

(1) Height of flight above land surface.

(2) Air speed or ground speed of aircraft.

(3) Weather data as outlined in 4.3.

(4) Size, orientation, type and height of the collection line above the lane surface or crop canopy and, if descrete targets are used, their spacing and number. If containers are used for capturing dry materials, the height of the container wall, the presence of liquid, or the type of sticky material used for trapping granules or dust shall be reported.

(5) The type of land surface (bare asphalt, cement) or crop type and height in the area where the test is conducted.

(6) Graphical presentation of individual swath patterns as outlined in 4.5.

(7) Usable swath width as determined in 4.5.

(8) Average rate of application as outlined in 4.6.

(9) Field application uniformity data, including the arithmetic mean, standard deviation, and coefficient of variation as outlined in 4.7, shall be reported as mean values from the replicated tests. The method of combining the swaths (alternate

or one-way flight direction) shall be indicated, as well as whether this is a simulated or an actual test. Plots of individual multiple adjacent swath patterns used to determine field application uniformity shall be included.

6. Keywords

6.1 aerial; agricultural; aircraft; application; calibration; chemical; collectors; dispersal; distribution; dry material; fertilizer; granules; liquid; output; pattern; pesticides; rate; sampling; seed; spray; swath; swath width

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