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भारतीय मानक मसौदा

मानव रहित हवाई छिड़काव प्रणाली — परीक्षण प्रक्रिया

Draft **Indian Standard**

UNMANNED AERIAL SPRAYING SYSTEMS — REQUIREMENTS AND TEST PROCEDURE

ICS **65.060.40**

Agricultural Machinery and Equipment Sectional Committee, FAD 11	Last date for Comments: **10 March 2025**

FOREWORD

(*Formal clause will be added later*)

Unmanned Aircraft System (UAS) is an aerial vehicle without human pilot on board. Also known as Unmanned Aerial Vehicle (UAV) or Remotely Piloted Aircraft (RPA) or Drone. Nowadays Unmanned Aircraft System (UAS) are coming equipped with tanks to carry desired chemicals, along with a spraying mechanism such as nozzles or sprayers to spray those chemicals on the targeted area. This system attached to the UAS is called as Unmanned Aerial Spraying System (UASS) which is a modern technology used in agriculture to apply plant protection products (PPP).

Continuous advances in flight control, flight duration, and payload potential have led to increase in usage of UAS for agricultural purpose. The use of Unmanned Aerial Systems (UAS) in agriculture is rapidly evolving, with Unmanned Aerial Spraying Systems (UASS), commonly known as drone sprayers, already being utilized for applying pesticides in various crops across the country. UASS has the potential to provide an aerial spray, where, handheld / portable, terrestrial vehicles, or manned aircraft might pose significant safety hazards. However, spraying from UASS can impact the surrounding environment in various ways such as misapplication, accidents during the application, improper design, inadequate weather condition, etc. It is important to consider biological and ecological factors in plant protection practices. Therefore, this standard is being brought which will cover the terminologies, requirements, and tests to be conducted on Unmanned Aerial Spraying Systems (UASS) for establishing its performance.

In preparation of this standard, considerable assistance has been drawn from ISO 23117-1 : 2023 ‘Agricultural and forestry machinery — Unmanned aerial spraying systems — Part 1: Environmental requirements’ and ISO/DIS 23117-2 ‘Agricultural and forestry machinery — Unmanned aerial spraying systems — Part 2: Test methods to assess the horizontal transverse spray distribution. In the Indian Standard, following modifications have been made with respect to the ISO standard:

1) Technical content of both ISO 23117-1 : 2023 and ISO/DIS 23117-2 has been merged into a single standard.
2) Some terminologies such as pay load, autonomous flight, drift, buffer zone, spray coverage, spray density, etc., have been added.
3) Additional requirements for UAS and UASS have been provided.
4) An exhaustive list of equipments required for testing of UASS has been provided.
5) Specification sheet of UASS and performance data sheet have been provided, to record data pertaining to testing of UASS.
6) Clause for residue management and safety precaution to be taken while testing UASS have been provided.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'.The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

CONTENTS

Draft **Indian Standard**

UNMANNED AERIAL SPRAYING SYSTEMS — REQUIREMENTS AND TEST PROCEDURE

1 SCOPE

This standard covers the terminologies, requirements, and tests to be conducted on Unmanned Aerial Spraying Systems (UASS), commonly called as drone sprayer used in agriculture, forestry, turf and amenity areas.

The standard specifies field measurements of spray deposition to determine the quantity and distribution of spray in a plane surface area in the transverse direction to the flight direction, treated by specific Unmanned Aerial Spraying Systems (UASS) with downward directed application.

2 REFERENCES

The Indian Standards listed below contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated therein.

IS/ISO No.	*Title*
IS 12239 (Part 6) : 2019 / ISO 4254-6 : 2009	Agricultural machinery — Safety : Part 6 Sprayers and liquid fertilizer distributors
IS 17799 : 2022	Unmanned aerial vehicles UAV — Drones for agricultural purposes
IS 18381 (Part 1) : 2023	Unmanned aerial vehicles (UAV) — General requirements — Part 1 Applications other than military purposes
ISO 9357 : 1990	Equipment for crop protection — Agricultural sprayers — Tank nominal volume and filling hole diameter
ISO 8169 : 1984	Equipment for crop protection — Sprayers — Connecting dimensions for nozzles and manometers
ISO 10626 : 1991	Equipment for crop protection — Sprayers — Connecting dimensions for nozzles with bayonet fixing
ISO 5682-2 : 2017	Equipment for crop protection — Spraying equipment Part 2: Test methods to assess the horizontal transverse distribution for hydraulic sprayers
IS 18602 : 2024 / ISO 25358:2018	Crop protection equipment — Droplet-size spectra from atomizers — Measurement and classification
ISO 5682-1 : 2017	Equipment for crop protection — Spraying equipment Part 1: Test methods for sprayer nozzles

3 TERMINOLOGY AND DEFINITIONS

For the purpose of this standard the following terms and definitions shall apply.

3.1 Unmanned Aircraft System (UAS) — Aircraft and its associated elements which are operated remotely or automatically.

3.2 Unmanned Aerial Spraying System (UASS) or Drone Sprayer — Spraying system, including hardware such as spray tank, pump, hoses, nozzles/atomizers etc., necessary for the application of a spray liquid from a UAS, as well as hardware and software necessary for the remote and/or automatic control of the application.

3.3 Spray Pattern — The shape and distribution of liquid droplets deposited on target surface which are ejected from a sprayer nozzle.

NOTE — The spray pattern is influenced by a number of factors, including the nozzle design, the pressure of the spray, the wind speed, and the target surface.

3.4 Payload Capacity — The maximum weight of liquid or solid materials that UAS can carry and apply while maintaining safe flight and effective operation.

3.5 Autonomous Flight — A flight in which the UAV is controlled by a computer program without human intervention during execution.

3.6 Buffer Zone — Untreated areas around sprayed fields to protect non-target organisms.

NOTE — Buffer zone is created to minimize the risk of pesticide liquid chemical exposure.

3.7 Drift — The off-target movement of spray particles due to wind, turbulence, or electrostatic forces.

3.8 Nozzle — A device that is used to break up a liquid into droplets.

3.9 Test Liquid — A mixture of water, tracer and/or plant production products (PPP) and/or additives which is sprayed during the test.

3.10 Spray Droplet Size — The size of spray droplets is measured in microns, where a micron is 1/1000 of a millimeter or about 1/25,000 of an inch.

3.11 Droplet Deposition — The amount of spray liquid ~~pesticide~~ deposited on the target surface is a measure of spray efficacy. Uniform droplet deposition ensures that all areas of the target are adequately treated.

3.12 Volume Median Diameter (VMD) — (DV0.5) refers to the midpoint droplet size (median), where half of the volume of spray is in droplets smaller, and half of the volume is in droplets larger than the median.

3.13 Coefficient of Variation (CV) — Measures the variability of droplet deposition across the target area. A lower CV indicates more uniform coverage.

3.14 Overlap — The degree to which adjacent swaths overlap, ensuring that no areas are missed during spraying. Proper overlap prevents gaps in coverage.

3.15 Application Rate — The amount of pesticide applied per unit of area. Accurate application rates minimize wastage and maximize pest control efficacy.

3.16 Number Median Diameter (NMD) — The diameter representing the point at which 50 percent of the number of droplets in the spray are smaller and 50 percent are larger. NMD is usually smaller than VMD because most pesticide sprays usually contain a large number of very small droplets.

3.17 Spray Coverage — The amount of spray that is deposited on the target surface. It is usually expressed as a percentage of the total area sprayed.

3.18 Spray Density — The number of droplets per unit area of the target surface.

3.19 Swath Width (*W*) — The width of the area that the UASS can spray in a single pass (*see* Fig. 1).

3.20 Average Crop Canopy Height (*H*) — The average height of the crop from the ground level (*see* Fig. 1).

3.21 Effective coverage of Nozzle (*b*) — The swath width of single nozzle measured at the crop canopy/target surface (*see* Fig. 1).

3.22 Nozzle height (*h*) — Vertical height of the nozzle tip from the spray target surface (*see* Fig. 1).

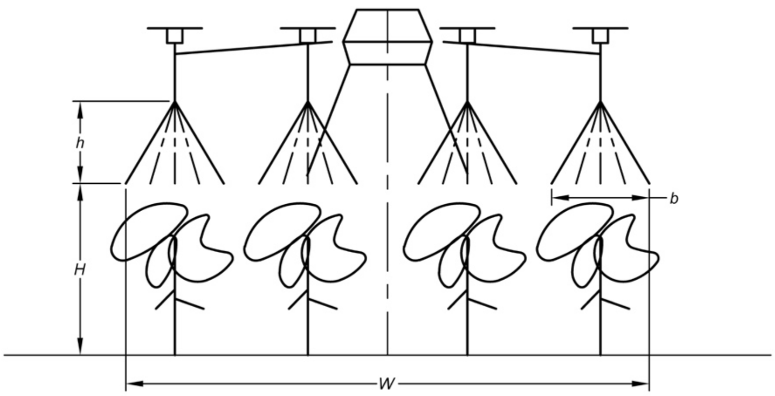


FIG. 1 TYPICAL ILLUSTRATION OF UASS

key

W – Swath width of sprayer
H – Target Surface height
h – Operational Nozzle height
b – Effective coverage of nozzle

3.23 Flight Route — Pre-determined path taken by the UAS.

3.24 Functional Test — Test to assess the performance of the UASS to ensure its proper operation under normal conditions.

3.25 Uni-directional Application — Spraying successive adjacent swaths with the same heading using the same nozzles/atomizers as shown in Fig. 2.

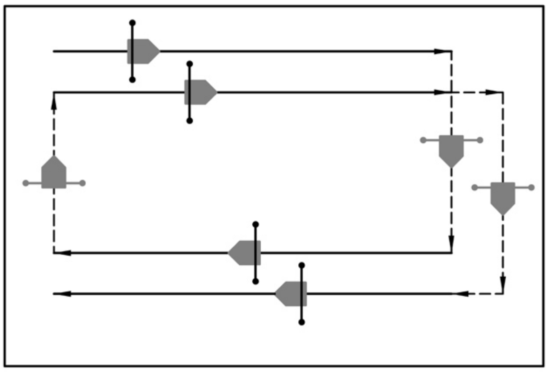


FIG. 2 UNI-DIRECTIONAL APPLICATION

3.26 Progressive Application with Alternating Heading and Same Nozzles/Atomizers — Spraying successive adjacent swaths with alternating heading using the same nozzles/atomizers as shown in Fig. 3.

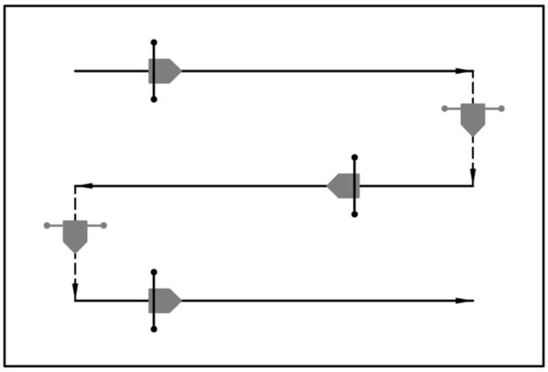


FIG. 3 PROGRESSIVE APPLICATION WITH ALTERNATING HEADING AND SAME NOZZLES/ATOMIZERS

3.27 Progressive Application with fixed heading and same nozzles/atomizer — Spraying successive adjacent swaths with fixed heading using the same nozzles/atomizers as shown in Fig. 4.

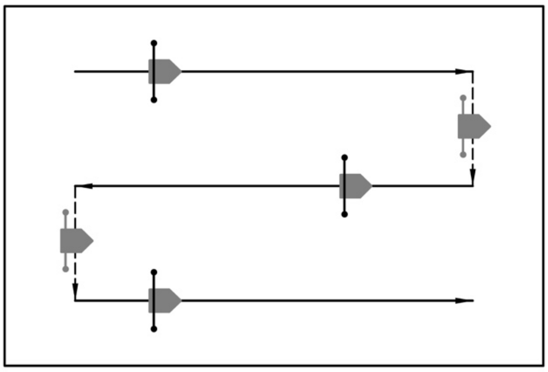


FIG. 4 PROGRESSIVE APPLICATION WITH FIXED HEADING AND SAME NOZZLES/ATOMIZERS

3.28 Progressive application with fixed heading and alternating nozzles/atomizers — Spraying successive adjacent swaths with fixed heading and spray system adjusting so that only rear nozzles/atomizers (relative to flight direction) are used for application in each pass as shown in Fig 5.

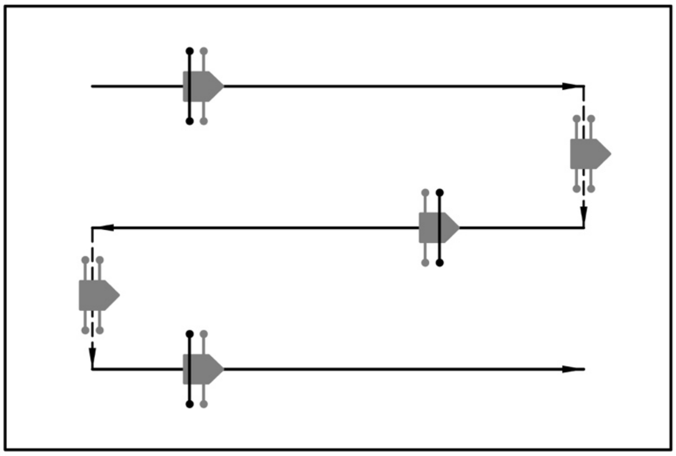


FIG. 5 PROGRESSIVE APPLICATION WITH FIXED HEADING AND ALTERNATING NOZZLES/ATOMIZERS

3.29 Characteristic Dimension — Diameter of the smallest circle, the circumference of which envelops the paths of all the rotor tips placed on the horizontal plane.

4 REQUIREMENTS

4.1 General Requirements of UAS and UASS

a) The UASS shall be attached to a UAS capable of flying in automatic spray control mode following pre-defined flight lines with pre-defined height and speed, although manual spray control mode can be used. Compliance shall be checked by inspection.

b) Applicant should submit the specifications of UASS as per Annex A.

c) The UAS shall be fitted with an altitude sensor to ensure that the desired height above the crop is maintained throughout the spraying mission.

d) The Global Navigation Satellite System (GNSS) accuracy of the UAS and accuracy of the map shall be characterized and the same shall be utilized to define the safety/buffer margin while creating the geo-fencing around the field or obstacles. The GNSS may preferably have support for NavIC (Navigation with Indian Constellation).

e) Additional electronic devices, such as multispectral imaging, photography, data logging from sensors located in agricultural fields etc. may be considered for usage in UAS for agricultural purpose. The additional equipment/components, if any, fitted to the UAS shall not create navigational or aerodynamic interference to the safe operation of the UASS.

f) The UAS should have fail-safe features like return to home (RTH) or hover in conditions of empty tank/loss of signal/low battery/geo-fence breach.

g) The UAS may also have feature of automation restart from the point of RTH engagement.

h) The UAS shall have capability to handle variable payload (depleting tank).

j) The nozzle system should be attached in such a manner that the spray swath is continuous.

k) The UASS shall be leak proof and dripping of spray liquid shall not be there during application.

4.2 Spray Tank

4.2.1 *General*

a) The spray tank is for refilling of spray liquid; the spray tank, filled with water to the nominal volume shall not leak after being dropped vertically from a height of 0.7 m to the horizontal concrete surface. Compliance shall be checked by the functional test and visual inspection.

b) The spray tank should be so designed to reduce surging of the contained liquid by the use of baffles or appropriate design.

c) The spray tank shall allow pressure compensation as it empties, without any leakage of spray liquid. Compliance shall be checked by functional test.

d) The spray tank emptying device shall allow complete emptying of the residual material in the tank in a controlled manner without spillage or accidental discharge. Complete emptying of the residual is considered to have been achieved when there are no visible puddles at the bottom of the tank after 5 minutes of drainage. It shall be possible to collect the spray liquid at the outlet without contaminating the environment or equipment parts of the UASS or UAS. Compliance shall be checked by functional test, with a suitable collector used to check that there is no spillage during emptying.

e) The position of the spray tank should allow its easy replacement (with a pre-filled spray tank) or access for filling while still attached to UASS which shall ensure no spillage. Compliance shall be checked by functional test.

f) The spray tank should be made such that it allows the pilot to estimate visually the amount of spray liquid contained in the tank from outside. Compliance shall be checked by functional test.

4.2.2 *Dimension*

The total spray tank volume shall be at least 5 percent greater than the nominal volume that is declared by the UASS manufacturer to minimize the risk of spillage from overfilling. Compliance shall be checked by measurement.

4.2.3 *Tank Contents Indicator(s)*

The nominal volume level on the spray tank shall be clearly marked. It shall be durable and easily readable. Compliance shall be checked by inspection.

4.2.4 *Spray Tank Filling Hole, Strainer and Lid*

a) The diameter of the tank filling hole shall be in accordance with Table 1 of ISO 9357. Compliance shall be checked by inspection and measurement.

b) A strainer shall be installed in an easily accessible location of the spray hose upstream of the pump. The depth of the strainer shall be large enough to prevent overflow of the filling hole when tested by the procedure. The strainer should be supplied by the UASS manufacturer. Compliance shall be checked by functional test.

c) Spray tank opening lid shall be able to be fitted and removed without the use of a tool and shall ensure a closed position without leaks during normal operation. Compliance shall be checked by functional test.

4.3 Hoses, Connectors and Spray Booms

4.3.1 *Hoses and Connectors*

Hoses and connectors shall be secured and have sufficient fastening strength to prevent unintentional disconnection of hoses. There shall be no visible leakage from hoses and connectors. Compliance shall be checked by inspection and functional test.

4.3.2 *Design and Location*

a) The bending radius of hoses shall be within limits recommended by the hose manufacturer. Hoses shall not have any deformations, such as twisting and folding that will restrict liquid flow. Compliance shall be checked by inspection.

b) A spray boom, if present, shall be designed to prevent unintentional folding or detaching during the spraying operation. Compliance shall be checked by functional test.

4.4 Nozzles/ Atomizer

4.4.1 Nozzles/Atomizers shall be appropriately mounted to prevent unintentional detachment during the spraying operation. Compliance shall be checked by functional test.

4.4.2 Each nozzle/atomizer shall be fitted at a predetermined position and equipped with a fast acting anti-drip device. The amount of dripping shall not exceed 1 ml per nozzle during a period of 2 min, starting 1s after the spray stop control has been activated while UASS is spraying at its achievable maximum flow rate. Compliance shall be checked by measurement as per Annex B.

4.4.3 Nozzles/Atomizers flow rate data as well as droplet size category as given in IS 18602 shall be achievable in the nozzle manufacturers' specification sheet. Compliance shall be checked as by inspection.

4.4.4 Where the spraying system uses rotary atomizers shall be possible to adjust the spray characteristics to the different application conditions to minimize the use and/ or environmental impact of PPPs. Compliance shall be checked by functional test.

4.4.5 The flow rate of individual nozzles/atomizers measured when mounted on the UASS, shall not deviate by more than 10% from the intended flow rate of each nozzle/atomizer mounted. Compliance shall be tested by measurement according to ISO 5682-2.

4.5 Filters

a) Spray liquid going to the nozzles/atomizers shall be filtered on the pressure side. The mesh width of these filters shall correspond with the size of the nozzles/atomizers to be used according to the recommendation of the nozzle/atomizer manufacturer. Compliance shall be checked by inspection.

b) Filters shall be installed at a freely accessible place. Compliance shall be checked by inspection and functional test.

NOTE — The operator should be capable of removing and cleaning filters, while wearing appropriate protective gloves, and without being contaminated by spray liquid or causing environmental contamination.

4.6 Remote Control Device

a) The spray application shall be controllable by the remote operator. The remote control device shall have a trigger or buttons for selecting the spray mode and provide means for starting/stopping of the spray. In the automatic mode, manual spray control device should not be operated.

b) The remote control device shall provide information necessary for spray control such as pump on/off and spraying discharge or flow rate or UAS height. Compliance shall be checked by functional test.

4.7 Cleaning

The UASS should have proper cleaning system so that complete emptying and easy and thorough cleaning is ensured without contaminating the environment.

NOTE — When selecting a UASS, the ability for external cleaning should be taken into consideration.

4.8 Control of Spray Drift

The UASS should have proper control system to reduce spray drift as much as possible by considering:

a) Type, configuration and location of nozzles/atomizers;

b) Sensors (radar, barometric) to determine distance from the target surface being sprayed;

c) Rotor numbers and rotor positions;

d) Flying speed limitations;

e) Anemometer

NOTE — Refer to IS 18602 for nozzle spray droplet spectra

4.9 Spray Liquid Pump(s)

Flow rate and pressure provided by the pump(s) shall be sufficient for the range of spray parameters (number and size of nozzles/atomizers, flight speed, volume application rate) specified by the UASS manufacturer. Compliance shall be checked by measurement.

5 TEST MATERIALS AND REQUIREMENTS FOR SPRAY DEPOSITION

5.1 Principle of the Test

Spray distribution depends on the operational parameters of the UASS as well as the environmental and weather conditions, therefore the requirements provided in **5.2**, **5.3**, **5.4**, **5.7**, **5.8** and **5.9** shall be followed.

Spray distribution can be expressed as an absolute amount of spray liquid per unit area and/or in relative terms as a percentage of the intended spray volume or tracer dose rate.

5.2 Test Site

5.2.1 The test site, which surrounds and includes the test area, shall have free areas to reduce the effect of surrounding obstacles affecting wind conditions in the test area. The test area shall be level ground (maximum 2 % percent gradient is allowed), with a bare soil surface or short mowed grass of maximum 8 cm height. The distance (D) in Fig. 6 between the border of test area and surrounding vegetation or building may vary but shall be a minimum of 10 m or 10 times the height of surrounding vegetation or building height (H) whichever is greater.

5.2.2 The length of test area in Fig. 6 which is parallel to the flight route shall be greater or equal to 60 m. The width of test area shall be at least 30 m.

5.2.3 The flight route, the collector line and the take-off/landing position of the UASS shall be marked visibly in the test area. The minimum distance between the end of the collector line and the edge of the test area shall be 1.5 m. The test area shall have sufficient, equal, track length before and after the sampling area to ensure the intended liquid output from the UASS attached to UAS is achieved over the sampling area. This length will depend on the size, and flight speed of the UAS. To ensure consistency of liquid output, concentration within the sampling area and flight speed whilst spraying, the minimum flight distance whilst spraying shall include 20 m before and after the line of collectors (*see* Fig. 7). Layout and size of the test site and the test area (as shown in Fig. 6 and Fig. 7) shall be fully reported with the test results. The size of test site is dependent on the size of the UASS and application parameters and shall therefore be adjusted accordingly.

When spraying over a bare ground surface the ground surface conditions, such as ploughed surface or prepared seedbed, shall be recorded and reported.

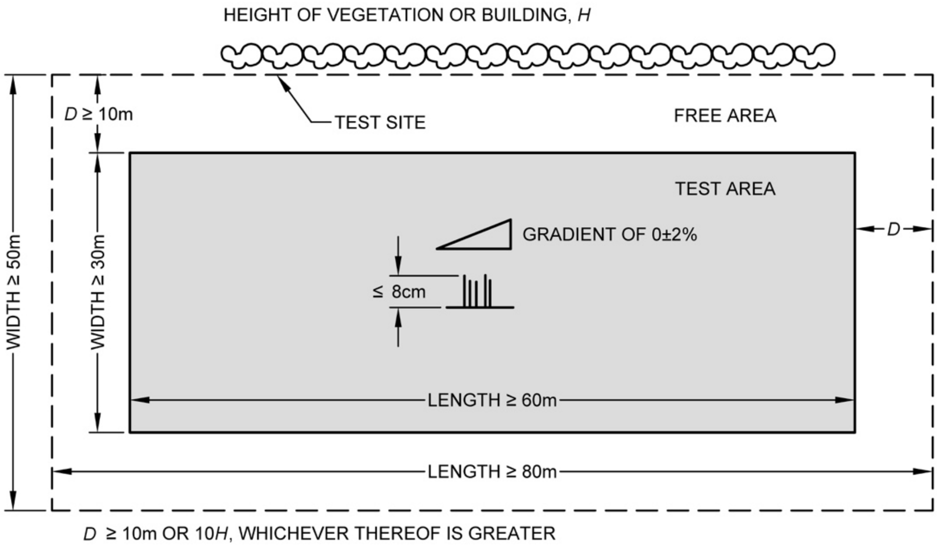


FIG. 6 LAYOUT AND SIZE OF TEST SITE

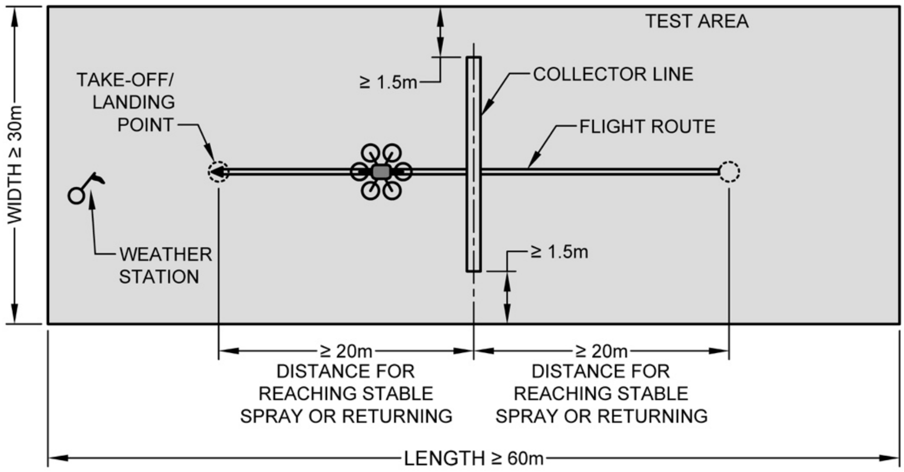


FIG. 7 CONFIGURTAION OF TEST AREA

5.3 Operation

It is recommended to fly the UASS at a height of 1 to 3 m above the targeted surface and at a speed not exceeding 6 m/s (21.6 kmph) during spraying. DGCA certified Pilot, Test Engineer and a representative of the test applicant should be present during testing.

NOTES

1) Flying the UASS at a lower altitude can help reduce the impact of wind on the UASS.
2) Before testing the UASS, all the sensing systems such as speed sensor, height sensor, pump discharge sensor, etc., shall be calibrated to achieve optimal performance.

5.4 Weather

5.4.1 Weather conditions shall comply with the following parameters when measured at the minimum sample rate of 1 per second in all cases.

a) ambient dry temperature of 5 °C ~ 35 °C
b) relative humidity of 15 % ~ 90 %
c) mean wind speed of ≤ 3.0 m/s.

5.4.2 The use of UAS for spraying shall be avoided in high temperature conditions (> 35 °C), high humidity conditions (> 90 percent). It shall be avoided immediately before and after the rain and also opposite to wind direction.

5.4.3 The wind speed shall be stable during the test and the wind direction shall remain within ± 45° of the measured mean direction during the test.

5.4.4 Weather conditions (temperature, relative humidity, wind direction, and wind speed) shall be measured during the period 5 minutes before spraying, during spraying and 5 minutes after spraying. These measurements shall be taken at a location 15 m from the flight path upwind, once the flight route has been determined (*see* **6.2.1**). Wind speed shall be measured at 1.5 m ± 0.1 m above the ground. Deposition data shall be excluded if the average wind speed is > 3.0 m/s when measured for a 3 second period while the UAS attached with UASS is flying over the sampling collectors.

5.4.5 Temperature inversions (when an upper layer of air is warmer than the air below it) affect spray deposition measurements and increases the risk of spray drift. This shall be avoided by not conducting tests shortly (1 hour) before sunset or after sunrise if there are clear skies at sunset.

NOTE — Temperature inversions can be detected by smoke or dust hanging in the air and/or only rising slowly.

5.5 Residue Management

When working with toxic materials, it is important to follow all safety precautions prescribed by the manufacturer and regulating authorities for handling, loading, application, and disposal. It is important to clean and flush distribution equipment used in field applications before starting the test procedure to ensure that there is no residue left. Special cleaning agents may be necessary to neutralize previously used pesticides or additives.

5.6 Safety Precautions

Prior to initiating any tests, the pilot and all test site personnel should be thoroughly briefed on test procedures. At the flight test area, all personnel should stand clear of the UASS flight path. Special safety precautions should be observed when stationary tests are conducted to prevent serious injury by a moving propeller or rotor. If toxic materials are used, personnel should remain clear of application and drift areas, and appropriate precautions should be taken to prevent contamination of test personnel and test site.

5.7 Test Equipment

The list of test equipment given in Table 1 shall be calibrated regularly and physically checked before and after each test.

Table 1 Test Equipment
(*Clause* 5.7)

S.No.	**Item**	**Accuracy**	**Application**
(1)	(2)	(3)	(4)
i)	Thermometer	± 0.5 ℃	Weather ambient temperature
ii)	Hygrometer	± 5 percent	Weather relative humidity
iii)	Anemometer	± 0.1 m/s	Wind speed

iv)	Wind direction meter	± 5°	Wind direction
v)	Timers	± 0.5 s	Recording the time during 13 alibration and testing
vi)	Clamp-on AC/DC power meter	2.0 percent ± 5 digits	Measure current, without interrupting the current flow or using test leads
vii)	Measuring tape (at least 50 m)	± 1.10 mm	Measure distance or size
viii)	Steel tape (at least 5 m)	± 1.10 mm	Measure distance or size
ix)	Graduated measuring cylinder (Capacity: 1000 mL)	Within 0.5 to 1 percent error	Measure volumes (amounts) of liquids.
x)	Weighing scale (Capacity: 50 kg)	Within 0.1 percent error	Measure the weight of goods, such as bulk items and raw materials.
xi)	Vernier caliper	up to 0.02 mm	Measure the internal diameter, fine thickness etc.
xii)	Water sensitive paper (WSP) (52 mm x 76 mm) or (26 mm x 76 mm)	-	Nozzle Spray Droplets characteristics
xiii)	WSP Image processing system	600 dpi, *Min*	Processing the droplets deposited on WSP
xiv)	Marking pegs	-	Mark the position of a point, line or feature on the ground.
xv)	Sound level meter, dB(A)	0.1 dB(A)	measure and manage noise from a variety of sources
xvi)	Liquid test material	-	-

NOTE — Image processing system shall have resolution of 600 dpi or greater. Fluorometers and spectrophotometers shall have a maximum error of 1 % full scale

5.8 Collectors

The sampling collectors shall have a flat surface and should be horizontally positioned on the ground. The recovery of the sprayed tracer from the collectors shall be determined prior to the experiment. The collectors shall provide a minimum of 90 percent recovery.

Sampling collectors shall be of the same type/material. Examples of some collector materials that can be used are:

a) Acetate sheets;

b) Aluminium foil;

c) Filter paper;

d) Chromatography paper;

e) Filter material–Technofil TF-250, Camfil CF;

f) Water sensitive papers;

g) Krome Kote cards;

h) Petri dishes.

NOTE — Mixing collectors can lead to misleading results.

Care shall be taken to ensure that the sampling collectors used to verify the applied dose and spray volume rate do not saturate. This shall be checked before the test(s).

Any collectors and/or different collector positions can be used as long as they shall provide equivalent results to the collectors and collector positions specified.

The results of the drop distribution measurements can be statistically evaluated in accordance with the analysis of variance (ANOVA),10 percent.

See Annex C for calculations and expression of spray distribution results.

5.9 Spray Liquid/Test Liquid

5.9.1 The spray liquid to be used for the purpose of the test shall have physical properties representative of liquids typically used in the application of PPP. A representative test liquid can be achieved by addition of water-soluble non-ionic surfactant at rate typically from 0.005 percent to 0.5 percent (v/v), following the surfactant manufacturer's recommendation using one of the following.

a) Clean tap water plus non-ionic surfactant if water-sensitive papers are used as the collectors;
b) Clean tap water with food or fluorescent dye plus non-ionic surfactant if glossy coated papers are used as the collectors;
c) Clean water plus non-ionic surfactant with tracers.
d) Spray deposition can be measured with a tank mix of water and PPP to take into account the effect of formulations, either one of the components of the PPP or an added tracer can be measured.

5.9.2 If a Ready to Use product is the PPP of interest then either the actual PPP to be used or an appropriate blank representative of these formulations shall be used for the purposes of the test.

NOTE — Appropriate health and safety precautions shall be followed if PPPs are used.

5.9.3 The tracer shall be stable in field conditions with less than 5 percent degradation for at least the total collection time of all collectors in the field with tracers if other collectors are used. The recovery of the tracer from the collector shall be at least 90 %, preferably 95 % (*see* **3.5** of ISO 24353-1)

5.9.4 The composition of the spray liquid and spray liquid properties shall be documented in the test report.

6 TEST PROCEDURE

6.1 Overall Test Process

Test for assessing horizontal transverse spray distribution of an UASS is conducted in five stages as in Table 2.

Table 2 Five Stages and Actions Needed in the Test
(*Clause* 6.1)

Stage	Action Needed
A	Check weather conditions for 10 minutes to ensure they satisfy the requirements given in **5.4**.
B-1	Determine the flight route based on the data from stage A and make a visible mark as specified in **5.2.1**.
B-2	Test the flow rate of nozzles/atomizers as specified in **6.2.3**.
B-3	Position and secure the collectors as specified in **6.2.2**.
B-4	Load the test liquid onto the UASS as specified in **6.2.4**.
C-1	Start measuring weather conditions as specified in **5.4**.
C-2	Spray the test liquid while flying over the flight route during stage C-1.
C-3	Check if the weather conditions during stage C-2 satisfy the requirements given in **5.4**.
D	If weather conditions are satisfied, collect and store the sprayed collectors as specified in **6.4.1** and **6.4.2**. Repeat actions from stage B-3 to stage D until at least 3 sets of sprayed collectors under the same test condition (e.g., flying speed, nozzle height, etc.) are obtained.
E-1	Select the admissible collectors.
E-2	Evaluate spray deposition on collectors and calculate the Coefficient of Variation (C.V.) of a single pattern as specified in **6.5.1**.
E-3	Determine the effective swath width as specified in **6.5.2**.

6.2 Preparation of the test

6.2.1 *Determination of the Flight Route*

Measure the weather data particularly wind speed and direction for at least 10 minutes prior to setting up the test to check if weather conditions in test site satisfy the requirements of **5.4**.

The flight route of the UASS should be as close as parallel to the wind direction as possible (preferably within 15°), thereby minimizing the effects of crosswind on the spray pattern, with stable wind conditions required (*see* **5.4**). Set the flight centerline and mark it visibly on the ground using rope or a series of short flag poles. Place the line(s) of collectors in the sampling test area at 90° to the direction of flight route while spraying.

6.2.2 *Disposition of collectors*

The sum of the total collector area can be adapted to attain the resolution of interest. The minimum requirements on the collector are:

a) Minimum size of a collector is 20 cm^2;

b) Maximum distance between adjacent collector's centre to centre is 0.5 m.

The collector type, location and size shall be documented in the test report.

Position and secure the collectors along a line with maximum collector spacing of 0.5 m, at a height of 10 cm or less above the ground. The length of the collector line shall be longer than manufacturer's declared spacing between flight routes; (*see* Fig. 8). The collectors shall be secured on bars or plates to ensure they do not change position or orientation due to the rotor downwash from the UASS. Identification number of the collector starts from the left to the right of the spray-flying direction for the data analysis.

NOTE — The real ground is not a perfect plane, so the collectors are fixed on bars or plates.

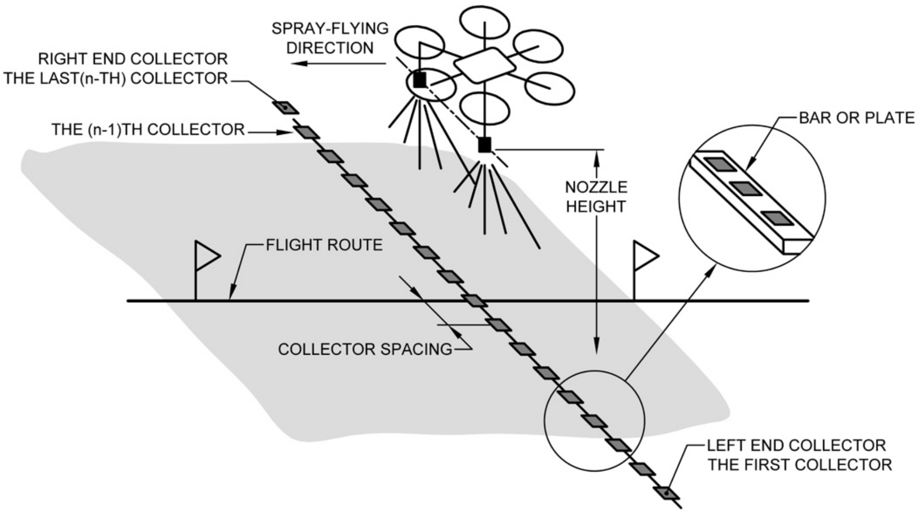


FIG. 8 EXAMPLE OF THE COLLECTOR'S DISPOSITION

6.2.3 *Flow Rate Test of Nozzles/Atomizers*

6.2.3.1 Flow rates of nozzles/atomizers shall be tested in the stationary condition i.e. with the spray system operating whilst the UAS is not flying. Nozzle/atomizer flow rate shall be tested according to **6.5** of ISO 5682-1. The test flow rate of each nozzle/atomizer must be set based on the value recommended by the UASS manufacturer.

6.2.3.2 Individual nozzle/atomizer flow rates shall be measured with test liquid in the stationary condition while all nozzles/atomizers are spraying with a maximum error of ± 0.1 l/min.

6.2.3.3 If a ready-to-use product is the PPP of interest then either the PPP or an appropriate blank representative of these formulations shall be used for the purposes of these flow rate tests.

NOTE — Appropriate health and safety precautions shall be followed if PPPs are used.

6.2.3.4 Calculate total flow rate of UASS and check if it satisfies the required spray volume per unit area assuming the flying speed and spray flight route spacing (or 'interval') as recommended by the manufacturer.

6.2.3.5 Individual nozzle/atomizer flow rates shall comply with the requirement of individual nozzle/atomizer flow rates and the total flow rate shall be reported in the test report.

6.2.4 *Loading the Spray Liquid*

The spray tank shall be filled to 75 percent of its nominal volume declared by the UASS manufacturer.

6.3 Flying and Spraying in the Test

a) A UASS spray deposition test shall be repeated at least three times due to the large influence of meteorological conditions, particularly wind velocity, and the complexity of rotor downwash/ground effects with associated variability in results i.e. spray patterns, achieved. The more flight replicates that can be undertaken the more confidence there will be in determining spray patterns and swath width achieved (since individual test flights can produce significantly different data).

   Collectors need to be removed and stored (for separate analysis) following each test spraying flight/pass.

b) Nozzle/atomizer type, size, arrangement/configuration and height and the flight speed when spraying in the test shall be that recommended by the UASS manufacturer unless there is a specific alternative purpose (but the manufacturer's recommendation shall also then be documented in the test report.)

c) The flight route of the UAS attached with UASS should be as close as parallel to the wind direction as possible (preferably within 15°), thereby minimizing the effects of crosswind on the spray pattern, with stable wind conditions required (*see* **5.4**). It is imperative to ensure the UAS is flown straight and level throughout the test and any deviation from the flight centerline shall be recorded in the test report.

6.4 Data Collection

6.4.1 *Handling of collectors*

Procedures for handling spray collectors both prior to and post exposure to the test spray to minimize the risk of cross contamination shall be established.

NOTE — When water sensitive paper (WSP) is used to get visual information on spray distribution, handling WSPs in a gloved hand to prevent colour change is necessary.

The potential for cross contamination and tracer degradation shall be monitored during the test using clean collectors and those loaded with a measured volume of the spray liquid. (*see* Annex D, **D-4**).

6.4.2 *Collection and Storage of the Collectors*

After spraying, gather the collectors as soon as possible following the tracer requirements (within 30 minutes at most), code them with a reference and store them in a dark, dry and, depending on the properties of tracers. Collectors for image analysis should be dried and stored to prevent any corruption of the collector image

NOTE — Extract the tracer or active ingredient from the collectors and determine the test spray deposition (for example using a fluorimeter/spectrophotometer as described in Annex D) under laboratory conditions.

6.4.3 *Determination of Background Emissions*

Background emission from the collectors shall be determined using the provisions provided in Annex D. The average reading of the blank collectors should not be higher than 0.1% of the average reading of the sprayed collectors. Accuracy of the measuring device, artificial collector types, and background emission from artificial collectors shall be recorded and chosen to obtain a coefficient of variation of the background emission lower than 10% (of at least 10 collectors; *see* Annex D).

6.4.4 *Selection of Admissible Collectors*

Measure the spray deposition on the collectors in each spray line and calculate the mean of spray deposition for each line. Compare the deposition on each collector with the mean value of the collector line from which it came. If the spray deposition of a collector is less than 1% of the mean value, then the deposition data from that collector shall be discarded. The remaining collectors shall be re-coded from 1 to n. If deposition on the collector positioned at each end of the line is found to be more than 1% of the mean value of deposition of that collector line, all test data from the test flight shall be discarded.

6.5 Data Analysis

6.5.1 *Uniformity of Distribution*

6.5.1.1 The coefficient of variation (C.V.) can be used to determine and express the uniformity of distribution of the spray pattern from a single test spray pass over a horizontal plane surface such as a flat field. The data for each individual replicate spray pattern shall first be graphed as a single pattern (to show the pattern and enable establishment of the centre of distribution (CoD) in relation to the flight centreline as shown in Fig. 9 before any totaling or averaging of the results as a check for anomalies/outliers contained in the data sets (which could be due to malfunctioning spray equipment or incorrect installation and/or calibration), which shall be discarded if this is the case (simple averaging without this pre-analysis can mask significant variations in the spray pattern between replicates). Data from at least 3 usable replicates is required to calculate effective swath width.

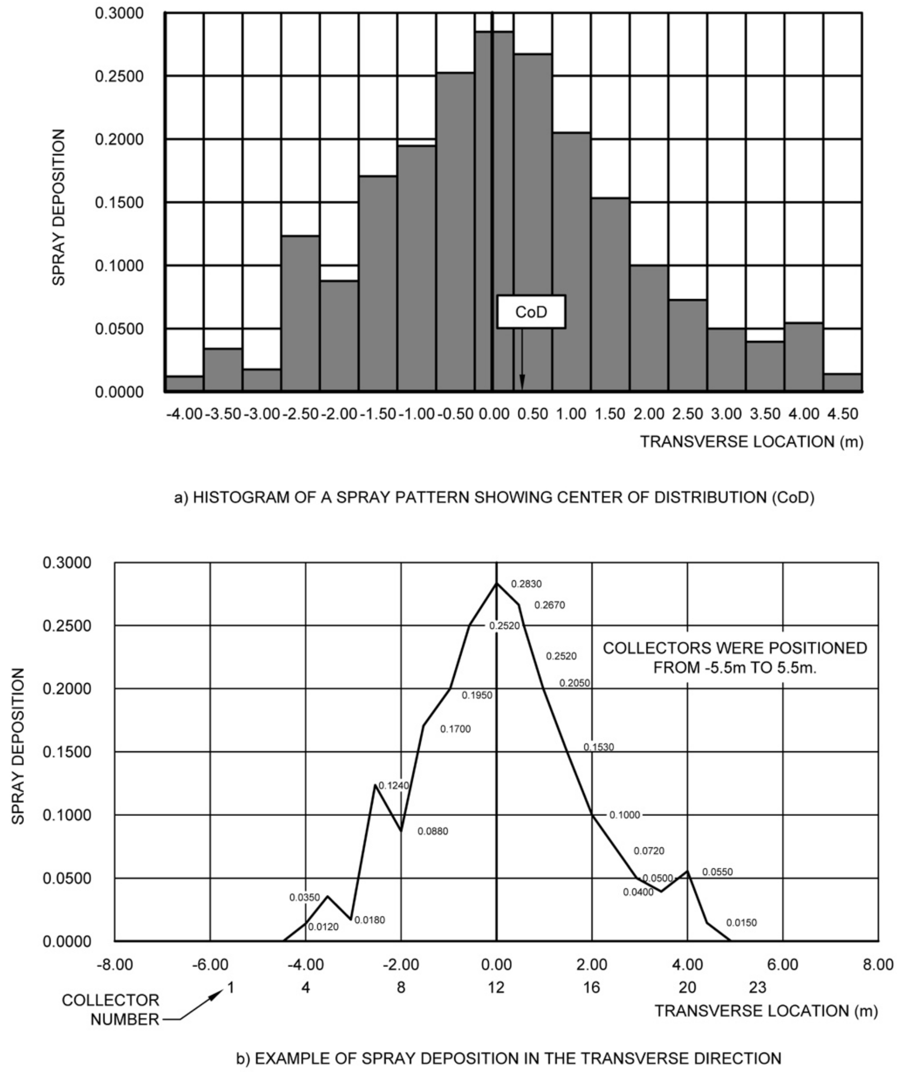


FIG. 9 SPRAY PATTERN FROM A SINGLE TEST SPRAY PASS

6.5.1.2 The center of distribution is a parameter defining the center position of the spray swath from the deposition distribution. Fig. 9 a) shows an example of a single spray pattern which was obtained from 23 collectors positioned from -5.5 m to 5.5 m in the transverse direction (x direction), normal to the flight route. If admissible collectors (*see* **6.4.4**) are selected, the spray pattern would be a histogram shown in Fig. 9 b). The x-position of CoD is calculated analogue to the centre of gravity of a diagram bounded by the spray deposition graph and the x-axis as follows:

$$x_{CoD} = \frac{\sum_1^n x_i d_i}{\sum_1^n d_i} \qquad (1)$$

Where;

n the total number of admissible collectors

x_i the x-directional position of the i-th collector, of which origin is located at the intersection of the flight route and the transvers base line

d_i deposition on the i-th admissible collector

6.5.1.3 These graphs are then overlapped as multiple adjacent swaths to obtain a composite graph showing simulated overlapping deposition patterns, with the flight centreline separation adjusted if necessary. Spray patterns are generally not symmetrical so graphs should be prepared for both uni-directional and progressive applications with alternating heading.

6.5.1.4 In the case of uni-directional and progressive application with fixed heading, no reversing of adjacent swaths is required as the right of the spray pattern will overlap onto the left of the spray pattern of the previous swath. In the case of progressive application with alternating heading, it will be necessary to reverse the simulated adjacent swaths as the right of the spray pattern will overlap onto the right of the spray pattern of the previous swath.'

It may be preferable to only test the type of application used by the UASS under test (if only one type is available in automatic modes). If this is agreed, then the following text could also be added:

'If the UAS operates in automatic mode in only one of these application types (one-direction, alternating heading progressive application or fixed heading progressive application) then it may be preferable to only carry out measurements for this application type.'

6.5.1.5 Only the central portion of the overlapped deposition data shall be used to calculate the C.V. and this portion shall be recorded in the test report diagram relating to the layout of collectors. If the effective swath width is equal to or greater than 50 % of the total spray pattern width, this shall include data from one swath centerline to the next for one-direction spraying or the data from the centerline of the first swath to the centerline of the third adjacent swath for progressive spraying. If the effective swath width is less than 50 % of the total spray pattern width, additional overlaps shall be added until the region for calculation is unaffected by the addition of deposition data from additional overlapping swaths.

6.5.1.6 The C.V. needs to be calculated for both one direction and progressive spray passes for effective swath centerline spacing ranging from one sampling interval width to the total width of the single swath pattern (swath increments from this calculation shall not be greater than the sampling interval across the effective swath).

6.5.1.7 Average test spray deposition ($\bar{d}$) is given by;

$$\bar{d} = \frac{\sum_{i=1}^{n} d_i}{n} \qquad (2)$$

6.5.1.8 Definition of C.V. is given by:

$$C.V. = \frac{d_{STD}}{\bar{d}} \times 100 \text{ percent} \qquad (3)$$

$$d_{STD} = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(xd_i - \bar{d}\right)^2},$$

Where

d_{STD} – the standard deviation of the deposition

NOTE — The maximum allowed C.V. value is 30 percent at present.

6.5.1.9 The results of all deposition measurements shall be statistically evaluated in accordance with the analysis of variance (ANOVA), 10 percent.

6.5.2 *Determination of the Effective Swath Width*

6.5.2.1 For the evaluation of the effective swath width, C.V. values for numerical superposition of the measured spray deposition distributions at various distance (multiple of the collector spacing or 0.5 m) between fictive flight lines shall be calculated. The first fictive distance between flight lines is recommended between three times of the characteristic dimension of UAS and one half of the range of single spray pattern as a multiple of 0.5 m.

6.5.2.2 Using the measured single spray pattern, determine patterns of adjacent flight in both left and right side of the single flight (*see* Fig. 10 in Annex E). The spray pattern in uni-directional application would be the same as the single spray pattern. The distribution of adjacent reverse flying in the progressive application with fixed heading and same nozzles/atomizers is not the reverse of the first distribution because an UAS is changing its direction without rotation. However, the distribution of adjacent flying in the progressive application with alternating heading and the same nozzles/atomizers would be the reverse of the single spray pattern.

6.5.2.3 Evaluate overlapped deposition value by adding deposition value of offset spray pattern at each collector position within the range of the single spray pattern and calculate the C.V. The effective swath width is determined by deciding allowable or admissible uniformity of horizontal transverse spray distribution. The effective swath width is the distance between adjacent flight lines resulting in the required uniformity of spray deposition (i.e. coefficient of variation). Fig. 10 c) in Annex E shows overlapped spray patterns with three different distances between flight routes. In this example, the effective swath width is determined as 5 m when based on a target C.V. value of 30 %.

6.5.2.4 The effective swath width shall be determined three times using 3 different sets of data for single spray pattern. The three effective swath widths and average of them shall be reported in the test report with the target C.V. value.

NOTE — Effective swath width is valid only for the UASS at the test condition.

6.5.2.5 If a spray pattern satisfying the desired C.V. criterion has been achieved flying parallel to the mean wind direction it is possible to study cross wind effects on this spray pattern, if desired, by changing the test flight route relative to the mean wind direction.

7 TEST REPORT

7.1 Data Relating to the Unmanned Aircraft Spraying System

7.1.1 *General Structure*

The UASS manufacturer details should be documented as well as the UASS type, model number, year of manufacture and mass of the UAS and UASS with maximum payload:

a) Manufacturer of UASS;
b) UASS type and model;
c) Mass of UAS;
d) Mass of UASS;
e) Maximum spray payload.
f) Unique Identification System (UIN)

7.1.2 *Rotor* System (*Motor and Propeller System*)

a) Diagram of rotor placement and dimensions;
b) Number of rotor axis;
c) Specification of Motor
d) Length of Propeller
e) Pitch (inch) of Propeller

7.1.3 *Flight Controller*

a) Automatic control or manual control
b) Serial Number of Flight Controller

7.1.4 *Sensors*

a) Ground position sensor
b) Height sensor
c) Other sensors if used

7.1.5 *UASS Working Condition*

a) Flying speed (m/s)
b) Flying height (m)

7.1.6 *Nozzles/Atomizers*

a) Configuration of the spray boom if exist
b) Type, size and number of nozzles/atomizers (and nozzle/atomizer manufacturer)
c) Nozzle/atomizer height(m)
d) Spray quality (Spray Deposition Pattern
e) Pump type, specification, manufacturer
f) Pump working pressure of hydraulic energy nozzles/working rpm of rotary atomizers

g) Discharge Rate (l/min) with specification value and measurement value

7.1.7 *Data Relating to the Test Site*

a) Bare ground or vegetation (type and height)
b) Surface roughness
c) Slope of field
d) Ground conditions e.g. wet/dry, dusty (from UASS rotor downwash)

7.1.8 *Data Relating to the Spray Liquid*

a) All spray liquid ingredients shall be reported;
b) Tracers (ID e.g. colour index number, batch), additives, PPP used;
c) Spray dose (active ingredient, tracer, additive) including specific rheological parameters e.g. viscosity and surface tension, at 20 ± 2 °C and preferably also at the temperature during the test;
d) Tracer or PPP concentration based on representative samples of the spray liquid taken (preferably at the nozzle outlet) for analysis immediately before and after spraying and before and after each replication.

7.1.9 *Data Relating to the Collectors*

Placement of collectors relative to flight centre line and test area, indicating/marking which collectors were used in the calculation of the coefficient of variation (C.V.);

a) Type of collectors;
b) Size and shape of collectors;
c) Collector height;
d) Collector area; and
e) Collector fixing device.

7.1.10 *Test Report*

The test report shall include the following information in the order given*:*

a) Name of testing agency;
b) Test report number;
c) Title;
d) Purpose and scope of test;
e) Methods of test;
f) Description of the UASS
g) Specifications;
h) Results;
j) Observations (include pictures);
k) Summary of results; and
m) Names, signatures, and designation of test engineers.

7.2 Formulas to be used during calculations of various parameters are given Annex F.

7.3 Performance test data shall be recorded as per Annex G.

8 EXPRESSION OF RESULTS

8.1 The spray distribution shall be evaluated for single spray pattern and (simulated) overlapped spray pattern.

8.2 For single spray pattern, the test spray deposition shall be expressed in amount of spray liquid or tracer per unit area (e.g. μl/cm^2, ng/cm^2), % of spray volume applied, % of coverage of a collector or number of droplets per unit area on different collector locations.

8.3 For overlapped spray pattern, the effective swath width shall be determined by assuming various C.V. levels (for example 20 percent, 30 percent, 40 percent), using the deposition data for single spray patterns and simulating overlaps as described in **6.5.2**. The mean or median deposition and minimum and maximum deposition values and deviations are also relevant.

8.4 The test report shall provide the following information:

a) Variation in deposition, expressed as Coefficient of Variation (CV);

b) Mean or median deposition values (spray liquid or tracer per unit area (e.g. μL/ cm^2, ng/ cm^2), % of spray volume applied and/ or % of maximum spray volume recovered, % of coverage of a collector or number of droplets per unit area);

c) Deposition value at each collector location (spray liquid or tracer per unit area (e.g. μL/ cm^2, ng/ cm^2), % of spray volume applied and/ or % of maximum spray volume recovered, % of coverage of a collector or number of droplets per unit area);

d) Maximum deposition values (spray liquid or tracer per unit area (e.g. μL/ cm^2, ng/ cm^2), % of spray volume applied and/ or % of maximum spray volume recovered, % of coverage of a collector or number of droplets per unit area);

e) Minimum deposition values (spray liquid or tracer per unit area (e.g. μL/ cm^2, ng/ cm^2), % of spray volume applied and/ or % of maximum spray volume recovered, % of coverage of a collector or number of droplets per unit area);

f) Effective swath width for desired CV value (m, %).

NOTE — once an effective swath width/ distance between adjacent flight lines has been calculated as above then the application rate can be calculated as per below formula:

$$Application\ rate\ (l/ha) = 600\,\frac{flow\ rate\ (l/min)}{flight\ speed\ (km/\ h)\ \times effective\ swathwidth\ (m)}$$

ANNEX A
(*Clause* 4.1)
SPECIFICATIONS OF UASS

A-1 APPLICANT INFORMATION

Name of Applicant :
Address :
Tel. No. :
Name of Manufacturer :
Address :
Tel. No. :

A-2 GENERAL INFORMATION

Make	:	Type	: ______________________
Category	:	Type Certificate	: ______________________
Serial No.	:	Brand/Model	: ______________________
UIN No.			
Date of Unit Manufacture	:		
Testing Agency	:	Test Engineer	: _______________
Location of Test	:	Date of Test	: _______________

	Folded	Unfolded	Folded	Unfolded
A-3 OVERALL DIMENSIONS, mm :				
a) xLength :				
b) Width :				
c) Height :				

A-4 WEIGHT, kg

a) Net weight (excluding battery)
b) Gross weight (including battery and full tank)

A-5 SPRAYER SYSTEM

a) Tank

i) Material
ii) Number
iii) Shape

iv) Dimensions
v) Size of filter/strainer mesh, hole/cm^2

b) Pump
i) Type
ii) Operating Pressure
iii) Discharge Rate
iv) Power Rating

A-6 NOZZLE

a) Type
b) Make and Model
c) Number of Nozzles
d) Material
e) Swath, m
f) Maximum spray rate per nozzle, L/min

A-7 UAS

a) Electronic Speed Controller

i) Brand
ii) Make and Model

b) Rotor
i) Motor
1) Make and Model
2) Number
3) Power Rating,
ii) Propeller
1) Material
2) Number
3) Length, mm
4) Pitch, mm
5) Weight

c) Flight Parameters

i) Rated takeoff weight, kg
ii) Maximum takeoff weight, kg

d) Battery

i) Make and Model
ii) Type
iii) Number
iv) Number of Cells
v) Weight, kg
vi) C-Rating
vii) Voltage
viii) Capacity/battery life, mAh
ix) Recommended charging time, h

e) Battery Charger Capacity, W

f) Remote controller

i) Model
ii) Make

g) Display Details

i)
ii)

h) Fail Safe features

i)
ii)

NOTE — If it is a hybrid drone, specification of engine shall also be provided.

ANNEX B

(*Clause* 4.4.2)

SPRAY PATTERN AND DROPLET ANALYSIS SAMPLING PROCEDURES

B-1 MEASURING DISCHARGE PER NOZZLE

B-1.1 On a stable and level surface, the spray tank shall be filled at a full capacity. The discharge shall be allowed to continuously flow for one minute.

B-1.2 On each nozzle, the discharge collected for one minute shall be measured using a graduated cylinder or weighing scale. The actual discharge rate for each nozzle shall be computed and recorded. For sprayers with varying nozzle settings, the discharge rate shall be measured at maximum, intermediate, and minimum discharge settings.

B-1.3 A minimum of three test trials shall be conducted for nozzle discharge test.

B-2 MEASURING NOZZLE DRIPPING

During operation at its rated maximum flow rate, the amount of dripping of the sprayer shall not be more than 1 mL per nozzle for 2 min, starting 1 s after the spray stop control has been engaged.

B-3 MEASURING SPRAY DROPLET SIZE

B-3.1 The test shall be conducted in the field with a recommended wind speed conforming to **5.3**. Record the ambient relative humidity and temperature during the test.

B-3.2 The multi-rotor RPA-powered sprayer shall be tested at a recommended altitude conforming to **5.3**.

B-3.3 A minimum of five wooden blocks, each with a water sensitive paper attached on the top, shall be placed in the centre of the plot and perpendicular to the direction of travel of the UASS.

B-3.4 Water Sensitive Papers (WSPs, area of 76 mm x 52 mm) shall be inserted into each of the paper clips spray application.

B-3.5 Start the spraying operation. Shortly after spraying, wait for the WSP to dry (1 min to 5 min), then collect the dried spray (WSP) targets and place inside a sealable plastic bag.

B-3.6 Scan each of WSP card and analyze it using an image analysis system or any methods of determining spray droplet size.

B-3.7 Determine the Volume Median Diameter (VMD) and number and volume of spray droplet per area.

B-4 HANDLING OF SAMPLES

B-4.1 All representative samples shall be collected properly without damaging or imprinting the sensitive paper for better analysis. They shall be placed in a dry and sealed container.

B-4.2 The samples shall be scanned and analyzed using an image processing software, to determine the volume median diameter, droplet distribution, and volume sprayed per unit area.

ANNEX C
(*Clause* 5.8)
CALCULATIONS AND EXPRESSION OF THE SPRAY DISTRIBUTION RESULTS

C-1 EXAMPLES OF COLLECTORS USED FOR SPRAY DISTRIBUTION MESUREMENTS

a) Water sensitive paper (WSP), commercially available in different sizes

b) Kromekote cards (KC), commercially available one sided and two sided and in different sheets sizes

C-2 MEASURED SPRAY DISTRIBUTION ON COLLECTORS ON THE GROUND

C-2.1 Spray distribution can be measured by placing water sensitive papers (WSP) or kromekote cards (KC) on the collector places. After spraying of test liquid, spray deposition on the WSP or KC will be visible as a pattern of spots. Drop patterns on a WSP turn the yellow card into a yellow card with blue spots where the droplets hit the paper. This pattern of spots can be analyzed with image analysis systems and produce spray distribution parameters as percentage of area covered with spots and the number of spots per unit area.

C-2.2 Values of measured spray distribution shall be indicated as the percentage of area covered by spots (% coverage), and the spot number as number of spots per unit area (spots/cm^2).

C-2.3 Average spray coverage ($\overline{x}$) shall be given in percentage of the ground area.

C-2.4 Average spot number ($\overline{x}$) shall be given in spots/cm^2.

C-2.5 The number of the spray distribution on the sampling places shall be reported as the coefficient of variation (CV) of the measured spray distribution (% coverage or spot number) values or the maximum deviation (d_{max}).

C-3 CALCULATION

Average spray distribution (coverage of spot number) ($\overline{x}$):

$$\overline{x} = \frac{\sum_{i=1}^{n}(x_i)}{n} \qquad \text{(F.1)}$$

Where

n is the number of collectors;

$\overline{x}$ is the spray spots (coverage or spot number) collected on collector i.

Maximum deviation (d_{max}):

$$d_{max} = max\left(\frac{|x_i - \overline{x}\,|}{\overline{x}} \times 100\right)$$

Coefficient of variation (CV):

$$CV = \frac{d_s}{\overline{x}} \times 100$$

Where

d_s is the standard deviation.

$$d_s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \overline{x})^2}$$

ANNEX D

(*Clause* 6.4.1)

FLUORIMETRY/SPECTROPHOTOMETRY AND DEPOSITION CALCULATION

D-1 GENERAL

D-1.1 Fluorimetry is a well-known quantitative measurement technique for spray deposition and spray drift with accuracy up to 10 ppb. When fluorescent dye is used as a tracer, it is important to optimize the excitation and emission wavelength of the fluorimeter to the tracer to maximize discrimination of tracer and background fluorescence. Noise or background fluorescence can come from the collector, the dilution liquid (e.g. fluorescence of tap or demineralized water can change in time) and the pollution of the capillary (measuring) cell in the fluorimeter. When collectors are placed on ground surface care has to be taken about the background fluorescence from the contamination by dust from ground surface.

D-1.2 Spectrophotometry is a relatively cheap and easy quantitative measurement technique with reasonable accuracy of 1 ppm or lower. A spectrophotometer is commonly used for the measurement of transmittance or reflectance of solutions, transparent or opaque solids or gases. Each molecule will absorb light of specific wavelengths. The amount of light which passes through the material is indicative of the concentration of certain chemicals. A spectrophotometer is composed of light source, monochromator, detector, and sample chamber that is a cuvette made of glass or quartz. Tracers such as metal ions and food dyes which show strong solubility can be measured by the spectrometry using a calibration curve. Food dyes are stable and nontoxic. Synthetic food dyes are not present in the nature, so background reading for these should be zero unless there is contamination.

D-2 READING FLUORIMETRY/SPECTROPHOTOMETRY AND CALCULATION

D-2.1 Soak collectors with dilution liquid to get the tracer into solution. Minimize the volume of the dilution liquid to maximize fluorescent/water soluble tracer recovery, but it is dependent on the collection area and the spray content caught. The dilution volume and the amount of tracer on the collector also determine the recovery from the collector surface. Investigate in advance the optimal dilution volume and time necessary for the tracer to get in solution.

D-2.2 The reading of the fluorimeter/spectrophotometer is related to the amount of tracer in solution through a calibration curve. This curve, within limits of the scale is a straight line (e.g. $10 < x < 950$ of 0 – 1000), and determined through sampling known concentrations of the tracer.

D-2.3 Calculate from the reading of the fluorimeter/spectrophotometer, the calibration line, the collector surface area, the tracer concentration in the spray liquid, the background fluorescence (collector and dilution liquid), and the volume of dilution liquid, the amount of spray deposition per unit area can be calculated, e.g. in μl/cm^2, in accordance with formula D.1. From this spray deposition, the percentage of spray deposition on a collector can be calculated by relating the spray deposition to the amount applied in the field on the same unit of area, in accordance with formula D.2.

$$\beta_{dep} = \frac{(\rho_{smpl} - \rho_{blk}) \times F_{cal} \times V_{dil}}{\rho_{spray} \times A_{col}} \qquad \text{(E.1)}$$

$$\beta_{dep\%} = \frac{\beta_{dep}}{(\beta_v/100)} \times 100 \qquad \text{(E.2)}$$

Where,

β_{dep} is the spray deposition, expressed in microliters per square centimeter (µl/cm^2);

$\beta_{dep\%}$ is the spray deposition percentage (%);

β_v is the spray volume, expressed in liters per hectare (l/ha);

ρ_{smpl} is the fluorimeter/spectrophotometer reading of the sample;

ρ_{blk} is the fluorimeter/spectrophotometer reading of the blank (collector + dilution water);

F_{cal} is the relationship between fluorimeter/spectrophotometer reading and tracer concentration [(µg/l)/fluorimeter scale unit];

V_{dil} is the volume or dilution liquid (e.g. tap or demineralized water) used to solute tracer from collector, expressed in litres (l);

ρ_{spray} is the amount of tracer solute in the spray liquid, samples at the nozzle/atomizer, expressed in grams per litres (g/l);

A_{col} is the (projected) area of the collector to catch spray, expressed in square centimeters (cm^2).

D-3 BACKGROUND COLLECTORS

D-3.1 The determination of the background reading from collectors can be obtained by taking at least 10 collectors; soaking the collectors with the agreed dilution volume for the collector type; and determining the fluorescence/spectrophotometer value according to the protocol. The mean background value is determined from the individual fluorimeter/spectrophotometer readings.

D-3.2 It is advised to take up in the standard analysis procedure of the collectors from the test area to put a blank water sample and a blank collector for background determination at the beginning and at the end of the series of samples.

NOTE — In case of spectrophotometry, background reading of collectors is not necessary.

D-4 RECOVERY OF TRACER FROM COLLECTORS

D-4.1 The determination of the recovery of the selected tracer from the chosen collectors can be obtained by comparison of fluorescence values obtained from the collectors for a specified quantity of tracer to the absolute measurement of fluorescence value for that same quantity of tracer.

D-4.2 Take at least 10 collectors and apply a specified amount of spray liquid with tracer evenly on the collector using a suitably sized pipette. Soak the collectors with the selected dilution volume and soaking time for the collector type and then determine the fluorescence/spectrophotometer value according to the protocol.

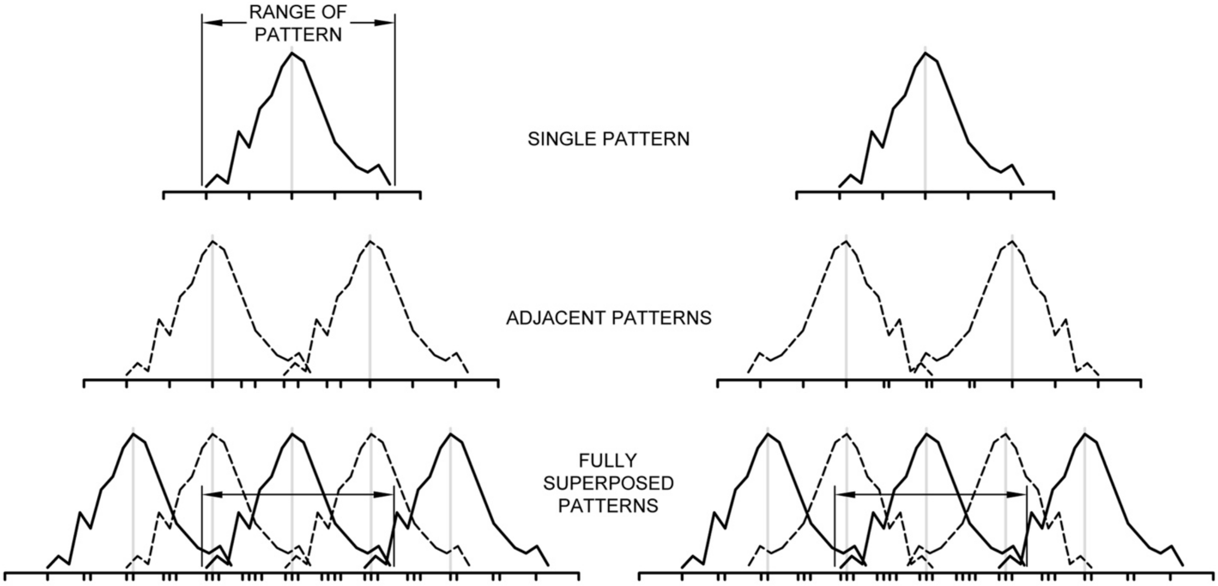
D-4.3 An absolute fluorescence/spectrophotometer value for this quantity of tracer should also be measured. This can be done by placing the same specified amount of tracer into the dilution volume with no collector, leaving an adequate amount of time for it to enter the solution. The fluorescence/spectrophotometer value of this can then be measured according to the protocol.

D-4.4 The ratio of the recovered tracer from the collectors to the absolute measurement will determine the recovery level of tracer from the collector.

D-4.5 The concentration of the applied tracer solution is preferably similar to the spray liquid concentration to be used in the field for the spray deposition experiment.

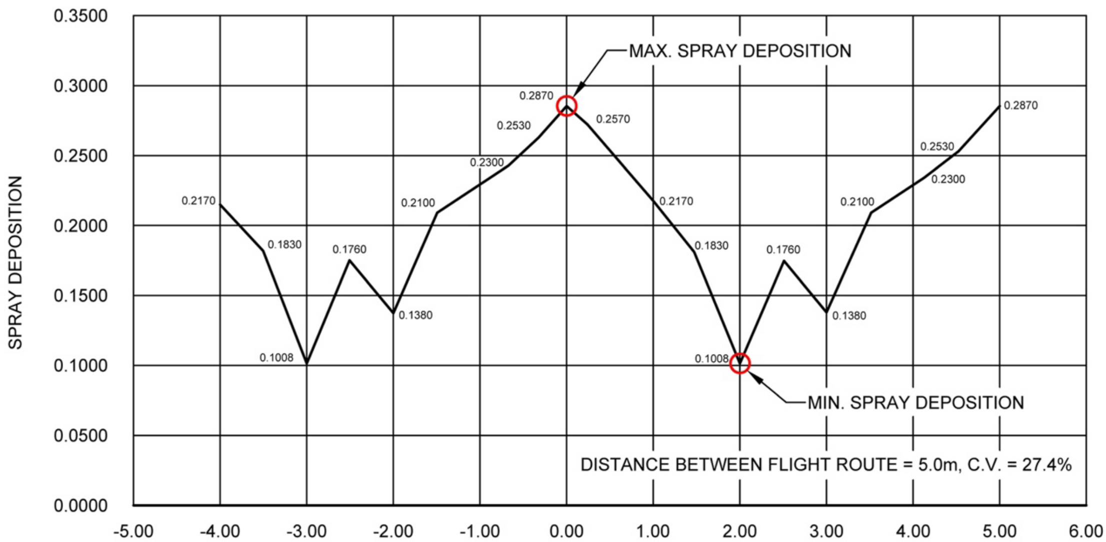
ANNEX E
(*Clause* 6.5.2.2 *and* 6.5.2.3)
PROCESS OF EFFECTIVE SWATH WIDTH DETERMINATION

E-1 *see* Fig. 10 a) and Fig. 10 b) showing how to get an overlapped deposition distribution for unidirectional application and progressive application with fixed heading. Fig. 10 c) shows an example of spray distribution with 27 % of C.V.



a) UNI-DIRECTIONAL APPLICATION

b) PROGRESSIVE APPLICATION WITH FIXED HEADING



c) OVERLAPPED SPRAY DEPOSITION WITHIN THE SPRAY RANGE WITH VARIOUS DISTANCES BETWEEN ADJACENT FLIGHT ROUTES IN CASE OF UNI-DIRECTIONAL APPLICATION MODE

FIG. 10 ILLUSTRATION OF EFFECTIVE SWATH WIDTH FROM A SINGLE SPRAY PATTERN

ANNEX F
(*Clause* 7.2)
FORMULAS TO BE USED DURING CALCULATIONS AFTER TESTING

F-1 ACTUAL FIELD CAPACITY

$$AFC = \frac{0.006\,A_t}{T}$$

where:

AFC — actual field capacity, ha/h
A_t — area covered during test, m^2
T — total testing time
T= Tp (Productive time) + Tn (Non-Productive time)

F-2 THEORETICAL FIELD CAPACITY, TFC

$$TFC = \frac{W * S}{10}$$

where:

TFC — theoretical field capacity, ha/h
W — effective swath, m
S — operating or traveling speed, km/h

F-3 FIELD EFFICIENCY

$$FE = \frac{AFC \times 100}{TFC}$$

where:

FE — is the field efficiency, %
FC_{α} — is the actual field capacity, ha/h
FC_t — is the theoretical field capacity,

F-3.1 Application Rate Based on Spray Time

$$A_{ct} = \frac{V}{T}$$

where:
A_{ct} — is the application rate per unit time, L/h
V — is the volume of spray liquid consumed, L
T — is the spray time of sprayer, h

F-3.2 Application Rate Based on Area Covered

$$A_{ca} = \frac{V}{A_t}$$

where:

A_{ca} — is the application rate per area covered, L/ha
V — is the volume of spray liquid consumed, L
A_t — is the area covered during test, ha

F-4 OPERATING/TRAVELING SPEED

$$S_o = \frac{3.6D_t}{T_t}$$

where:
S_o — is the operating or traveling speed, km/h
D_t — is the traveling distance, m
T_t — is the traveling time to cover D_t distance, s

F-5 FUEL CONSUMPTION RATE (ENGINE OPERATED UASS)

F-5.1 Based on Operating Time

$$F_{ct} = \frac{F_v}{T_e}$$

where:

F_{ct} — is the fuel consumption per unit time, L/h
F_v — is the volume of fuel consumed, L
T_e — is the total fuel consuming time of engine, h

F-5.2 Based on Area Covered

$$F_{ca} = \frac{F_v}{A_t}$$

Where,
F_{ca} — is the fuel consumption per area covered, L/ha
F_v — is the volume of fuel consumed, L
A_t — is the area covered during test, ha

G-6 BATTERY CONSUMPTION RATE, PERCENT PER HOUR

ANNEX G

(*Clause* 7.3)

PERFORMANCE TEST DATA SHEET

Test Trial No. : ________________________ Date: __________ Test Engineers : _______
Location : ____________________________ Assistants : _____________________________
Machine : ____________________________ Test Applicant : ________________________
Manufacturer : ___________________________

G-1 TEST CONDITIONS

a) Field Conditions
  i) Location
  ii) Field Type
  iii) Field Dimensions
    1) Length, m
    2) Width, m
    3) Area, m^2

b) Ambient Conditions
  i) Temperature
    1) Wet bulb, °C
    2) Dry bulb, °C
  ii) Relative humidity, %

c) Wind
  i) Air velocity, m/s
  ii) Direction of wind

d) Weather Condition

G-2 FIELD PERFORMANCE

a) Programmed Settings
  i) Field dimensions, m
    1) Length
    2) Width
  ii) Altitude, m
  iii) Application rate, L/ha
  iv) Discharge rate, L/min
  v) Travelling speed, km/h

b) Area Sprayed, m^2
c) Battery Voltage, DCV

i) Initial
ii) Final

d) Flight Time, s
e) Spray Time, s
f) Operating Time, s
g) Distance Travelled, m
h) Hovering Time, s
i) Max Operating Speed, m/s
j) Volume Sprayed, litres
k) Actual Field Capacity

i) _______ha/h
ii) ________h/ha

l) Theoretical Field Capacity

i) ________ha/h
ii) ________h/ha

m) Application Rate

i) ________L/ha
ii) ________L/h

G-3 NOZZLE PERFORMANCE TEST

a) Nozzle Discharge Test
b) Discharge, L/min

S.No. (1)	Item (2)	Trial 1 (3)	Trial 2 (4)	Average (5)
i)	Nozzle 1			
ii)	Nozzle 2			
iii)	Nozzle 3			
iv)	Nozzle 4			
v)	Others			

c) Total Discharge Rate, L/min
d) Average Nozzle Discharge Rate, L/min

G-4 SPRAY DISTRIBUTION

a) Altitude, m
b) Effective Swath, m

G-5 REMOTE CONTROLLER

a) Operating Power, W
b) Recommended Storage Temperature, °C

G-6 DROPLET SIZE ANALYSIS

S.No	Item	Trial 1	Trial 2	Average
(1)	(2)	(3)	(4)	(5)
i)	DV, 5, µm			
ii)	Droplet Distribution, Spray Droplets/cm2			
iii)	Spray Volume Per Unit Area, µL/cm²			
iv)	Average DV 5, µm			

G-7 CAPACITY/BATTERY LIFE, mAh

G-8 OBSERVATIONS

a) Number of Operator
b) Dismantling and Maintenance (rotors, batteries, spray tank and etc.)
c) Warning and Safety Stickers
d) Failures or Abnormalities of the Sprayer or its Component Parts During and Ater the Operation
e) Maximum Wind Resistance Recommended by the Manufacturer (based on Operator's Manual)
f) Other Remarks

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