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Test methods for civil multi-copter unmanned aircraft system

Méthodes d'essai pour les multicoptères civils télépilotés

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 16, *Unmanned aircraft systems*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Multi-copter unmanned aircraft system (UAS) is the most popular UAS in the market at the time of publication of this document, but the quality of products can vary significantly. However, it is difficult to evaluate the function and performance of these products as there is no unified standard test method and means to evaluate and test the multi-copter UAS. Therefore, the development of test method standards for civil multi-copter UAS is intended to provide a basis for product testing, in order to improve the product quality of the multi-copter UAS as a whole.

Test methods for civil multi-copter unmanned aircraft system

1 Scope

This document specifies test methods for civil electric multi-copter unmanned aircraft systems (UAS). This document is intended to be a general standard for testing the overall UAS functionality with the support of subsystems.

It is applicable to the category of civil electric multi-copter UAS with maximum take-off mass (MTOM) level I to level V according to ISO 21895. The configuration control and subsystem (e.g. energy system and flight control system tests) test methods are out of the scope of this document. In addition, test methods for operations in snow and icing conditions are not included either, manufacturers have procedures identified to cope with flight in those conditions.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 21384-4, *Unmanned aircraft systems — Part 4: Vocabulary*

ISO 21895, *Categorization and classification of civil unmanned aircraft systems*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 21384-4, ISO 21895 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
mission profile
specified mission to be performed, including the event and the environment sequence that the test article experiences

3.2
multi-copter UAS
rotorcraft lifted by two or more power-driven rotors on a substantially vertical axis, capable of hovering, taking off and landing vertically

4 General principles

4.1 Test purpose

The purpose of the test is to:

a) check whether the functionality, performance of the UAS meets the design requirements;

b) make recommendations on design modifications and whether to conduct supplementary tests.

4.2 Test conditions and requirements

4.2.1 Technical document

The following documents should be prepared before the test:

a) the design documents, figures and interface file which are relevant to the test;

b) operator's manual;

c) test plan

4.2.2 Test article

The test article shall fulfil the following requirements.

a) The test article shall conform to the product manuals.

b) The number of test article shall meet the test requirements.

c) The test article shall have quality inspection certificates such as the enterprise qualification certificate.

4.2.3 Equipment and instruments

Test instruments and equipment (including special equipment and auxiliary equipment) shall be verified and calibrated, and shall be qualified within the flight test limitations and within the validity period. All the test instruments used should meet the expected use requirements; and its measurement uncertainty or maximum allowable error should be less than the agreed allowable error range of the measured parameter. For test process management, refer to ISO/IEC 17025.

4.2.4 Personnel requirements

Testers shall be able to operate the test article and the test equipment proficiently. Testers shall have the corresponding competence and qualification, if required.

4.3 Test environmental requirements

Unless otherwise specified, all tests shall be performed by measuring and recording test conditions, including temperature, relative humidity, atmosphere pressure and wind speed.

4.4 Test interruption and recovery

Test interruption and recovery methods are specified as follows.

a) The test is terminated on one of the following conditions.

   1) Key indicator(s) of the test article is (are) unqualified.

   2) The test article cannot work normally due to a malfunction and cannot be repaired.

b) When the following situations occur during the test, supplementary tests should be carried out as appropriate.

   1) Individual test article failed, the cause has been identified and corrected.

   2) The original design or test article configuration was changed.

3) The test article is replaced with the components or devices that affect the technical performance.

4.5 Test outline

The test plan shall include but not limited to the following:

a) mission profile description;

b) test purpose;

c) test time and location;

d) the number and technical status of the test article and test auxiliary;

e) test article, test classification methods;

f) test requirements;

g) test interruption and recovery;

h) acceptance criteria;

i) test organization;

j) test support;

k) test safety;

m) appendix (e.g. template of data record, collection of formulae).

4.6 Test report

The test report shall include but not limited to the following:

a) serial ID of the test article and pictures of the test article overview and the key components;

b) test general introduction;

c) test item, and necessary specification;

d) test acceptance criteria;

e) test safety (procedures and limitation, etc.);

f) test results;

g) main problems that have occurred in the test and the corresponding treatments;

h) conclusion;

i) issues and suggestions;

i) appendix (e.g. test data histories).

5 Test methods

5.1 Test item

UAS test items are shown in Table 1.

Table 1 — Test item information table

No.	Test items		Subclause number
1	Basic inspection	Completeness	5.2.1
2		Appearance	5.2.2
3		Size	5.2.3
4		Weight and centre of gravity	5.2.4
5		Moving and rotating parts check	5.2.5
6		Connectors	5.2.6
7	Functional inspection and testing	Identification	5.3.1
8		Route loading	5.3.2
8		Self-test	5.3.3
10		Information display	5.3.4
11		Data record	5.3.5
12		Return to home	5.3.6
13		Automatic obstacle avoidance	5.3.7
14		Typical failure protection	5.3.8
15		Take-off/launch and landing/recovery	5.3.9
16		Warning	5.3.10
17		Locking and starting of motor	5.3.11
18		Control mode switching	5.3.12
19	Flight performance test	Maximum take-off mass	5.4.1
20		Maximum flight range	5.4.2
21		Maximum flight altitude	5.4.3
22		Maximum horizontal flight speed	5.4.4
23		Maximum steady climb rate	5.4.5
24		Altitude hold performance	5.4.6
25		Speed hold performance	5.4.7
26		Flight endurance	5.4.8
27		Fixed-point hovering	5.4.9
28		Positioning navigation	5.4.10
29		Trajectory tracking accuracy	5.4.11
30		Capability of wind resistance	5.4.12
31	Navigation system test	Static attitude accuracy	5.5.1
32		Static positioning accuracy	5.5.2
33	Data link system test	Remote control distance and telemetry distance	5.6.1
34		Information transmission distance	5.6.2
35	Environmental test	High temperature	5.7.1
36		Low temperature	5.7.2
37		Rainfall	5.7.3
38		Humidity and heat	5.7.4
39		Vibration	5.7.5
40		Shock	5.7.6

Table 1 *(continued)*

No.	Test items		Subclause number
41	Electromagnetic compatibility test	Conductive emission	5.8.2.1
42		Radiation emission	5.8.2.2
43		Radiated, radio-frequency, electromagnetic field immunity	5.8.3.1
44		Power frequency magnetic field immunity	5.8.3.2
45		Electrostatic discharge immunity	5.8.3.3
46		Electrical fast transient/burst immunity	5.8.3.4
47		Surge immunity	5.8.3.5
48		Immunity to conducted disturbances, induced by radio-frequency fields	5.8.3.6
49		Voltage sag and short supply Interruption	5.8.3.7

5.2 Basic inspection

5.2.1 Completeness

Visual inspection should be adopted for completeness checking. The test article shall be inspected and recorded item by item by following product lists.

5.2.2 Appearance

Visual inspection shall be applied for appearance checking. The inspected items generally include:

a) the uniformity of equipment coating, the correctness and clarity of product identities (brand, size, type, model, weight, etc.), and the robustness of stickers (no curl or erase);

b) the completeness of label or mark for connectors, switches, control sticks;

c) damages such as cracks, scratches, corrosions.

5.2.3 Size

The characteristic size of UA and its components (e.g. length, width, height, wheelbase, propeller/rotor radius) shall be measured and recorded referring to product specifications with size error range.

5.2.4 Weight and centre of gravity

The weight of the UA and its components shall be measured. The centre of gravity shall be within the allowable range specified by the manufacturer. Measurement methods generally include the following.

a) Mass measurement tools shall be employed for measuring the weight of the UA and its components (unit: gram). The measurement should include conditions in which the UA is equipped with different mission loads.

b) The position of centre of gravity is estimated; and it shall be checked with the designed position.

c) Tests shall be performed with the most critical centre of gravity.

5.2.5 Moving and rotating parts check

Visual inspection shall be employed for checking moving parts such as switches, buttons, foldable arms and control surfaces; and for rotating parts of the vertical lifting elements (hub, blades, blade dumpers, pitch control mechanism, and all other parts that rotate with the assembly). Mechanical movement is supposed to be smooth and reliable, without the occurrence of looseness, stagnation, shortage, deformation, etc.

5.2.6 Connectors

Connectors of the UAS shall be inspected according to indicators; results shall be recorded accordingly. Inspected items are specified by the manufacturer and may generally include:

a) fool-proofing and locking design, in-place indication;

b) operating friendliness, firm installation and connection robustness;

c) protective design for exposed connecters;

d) skewed, retracted and damaged pins;

e) non-sparking design of power connectors.

5.3 Functional inspection and testing

5.3.1 Identification

While in flight, the identification function of UAS shall be inspected through UAS surveillance system or a simulated surveillance system. The checked items include:

a) the accuracy of current flight data;

b) whether the identification of UAS and operator meet the requirements of the authority;

c) whether the reporting frequency meets the requirement of the authority.

5.3.2 Route loading

A route of typical flight mission shall be loaded to the UA prior to flight. In this loading process, the status report shall be examined. Then, how the UA follows the route shall be investigated.

5.3.3 Self-test

Once the power of UAS is engaged, visual inspection shall be used to check the voice or light indications of self-test results.

5.3.4 Information display

When UAS is powered on at the ground, the display of remote pilot station shall be examined through visual inspection. Inspected contents should be checked according to the manufacturer's specification.

5.3.5 Data record

The UAS shall be flown in a typical flight mission. After the flight, the recorded data should be read and inspected. The check items include the integrity of recorded data, the correctness of flight data and mission data. Both onboard and remote pilot station data record shall be tested.

5.3.6 Return to home

The activation and the manual intervention for abandoning mission shall be checked to confirm that it can be performed according to the manufacturer's intention.

5.3.7 Automatic obstacle avoidance

For UA with obstacle avoidance function, within the range of automatic obstacle avoidance specified by the manufacturer, the UA shall be manipulated to fly towards obstacles at the speed specified by the manufacturer until the distance is less than the safety distance specified by the manufacturer. Inspection should be made that whether the UA can avoid collision. Then, the UA shall be kept away from obstacles and the capability of regaining aircraft control should be inspected. Obstacles can be wall, glass, utility pole, power line, etc.

5.3.8 Typical failure protection

For different failure situations, visual inspection shall be made towards the protection actions such as returning to home, landing and hovering. The failure situations and corresponding testing procedures are as follows.

a) Satellite navigation signal interruption: under normal flight conditions, the UA is manipulated to fly into the space that obstructs satellite navigation signal (such as roofed buildings) until the signal is blocked completely. A corresponding failsafe operation that manufacturer states shall be examined through visual inspection.

b) Link interruption: under normal flight conditions, when the remote control and remote pilot station are turned off, a failsafe operation that manufacturer states shall be investigated through visual inspection.

c) Low battery: under normal flight conditions, the UA is kept flying until the energy is exhausted to the low power state specified by the manufacturer. A failsafe operation stated by the manufacturer which protects the UA from low battery failure shall be investigated through visual inspection.

5.3.9 Take-off/launch and landing/recovery

The following tests shall be performed on ground on a flat surface and a slope of less than 10°.

a) An automatic take-off command described in the operator’s manual shall be sent to the UA; and then inspection shall be made whether the UA is out of control, such as flipping or leaping.

b) An automatic landing command described in the operator’s manual shall be sent to the UA; then inspection shall be made whether the UA is out of control, such as flipping or falling.

5.3.10 Warning

For UAS equipped with an alarm function, once the abnormal condition specified in 5.3.8 occurs, aural or visual alarm in the UAS shall be checked through visual inspection.

5.3.11 Locking and starting of the motor

The UAS shall be powered on and then pass the self-test procedure. In the locking status, control sticks shall be pushed and pull; and then whether motor responds should be checked; once motors are started, it can be checked whether the motors drive propeller/rotor blades and rotate at idle speed. Then the power throttle shall be pushed, visual inspection should be made towards the accelerating rotation of propeller/rotor blades.

5.3.12 Control mode switching

Under normal flight conditions, the UA shall be manipulated to switch between manual control mode and automatic control mode. Whether the UA performs smooth transition flight shall be observed. There shall be no out-of-control, such as falling or flip-over.

5.4 Flight performance test

5.4.1 Maximum take-off weight

The UAS used in the test shall function correctly; and the battery shall have sufficient energy. Instead of actual mission payload, the corresponding dummy mission payload should be attached to the UA such that the total mass of the UA reaches the designed nominal value of maximum take-off mass. The UA shall be manipulated by following a prescribed typical mission profile. Then, whether the UA is capable to accomplish the mission normally shall be examined. Information of the test site shall be recorded, such as air temperature, atmospheric pressure, wind speed and altitude.

5.4.2 Maximum flight range

The UAS used in the test shall function correctly; and the battery shall have sufficient energy. It shall carry mission payload or the dummy mission payload specified by the manufacturer; and a route has been present to the UA. The UA shall take off vertically and reach a typical operational height specified by the manufacturer (if the typical operational height is not specified, a median in the range of operational height should be chosen); and the current position is recorded as position A. Then, the UA shall fly straight to position B at a typical operational speed specified by the manufacturer (if the typical operational speed is not specified, a median in the range of operational speed should be chosen). The distance between position B and position A shall be equal to the maximum flight range which is specified by the manufacturer. Subsequently, The UA shall return to a position within the range of 5 m from position A. The battery energy of UA shall be examined; and its value shall not be less than 10 % of fully charged battery energy (low energy state specified by the manufacturer). If the battery energy is not sufficient to support UA returning to home, the position C shall be recorded where battery energy reaches the low energy state specified by the manufacturer. The maximum flight range should be evaluated according to Formula (1):

$$R = \frac{1}{2}(L_1 + L_2) \tag{1}$$

where

R is the maximum flight range, in metres (m);

L_1 is the distance between position B and position A, in metres (m);

L_2 is the distance between position B and position C, in metres (m).

The described test procedure should be performed 3 times; and the minimum value of R shall be chosen. Information of the test site shall be recorded, such as air temperature, atmospheric pressure, wind speed and altitude.

5.4.3 Maximum flight altitude

The nominal value of maximum flight altitude H_{0max} under the standard atmospheric conditions of the test UA shall be converted into the value H_{max} under the current environmental conditions, according to Formula (2). The UA shall be functioning with fully charged battery, carrying the dummy mission payload specified by the manufacturer. The UA shall be manipulated to fly vertically and climb to the height H_{max}. It shall fly forward, backward, sideward, take turns, and then keep hovering for 3 min. In this procedure, the test equipment shall measure the position data (the sampling frequency of this equipment shall not be less than 10 Hz). The remote pilot station should assist the determination of whether the UA responds to commands normally. Information of the test site shall be recorded, such as air temperature, atmospheric pressure, wind speed and altitude. After the flight, the flight data recorded by the test equipment shall be read and used to determine the validity of this test. The altitude here means the altitude above sea level.

$$H_{max} = H_{0\,max} - H \tag{2}$$

where

H is the altitude of take-off point, in metres (m);

H_{0max} is the nominal value of the maximum flight altitude under standard atmospheric condition, in metres (m);

H_{max} is the equivalent height under the current atmospheric condition, in metres (m).

5.4.4 Maximum horizontal flight speed

A route shall be set to a functioning UA which is with full battery power and carries the dummy mission payload specified by the manufacturer. The UA shall take off vertically to reach a specified operation altitude. Then, it accelerates in horizontal flight until its flight speed keeps stable at the maximum horizontal flight speed V_{hm} (within an error range agreed by the requestor for testing and the test performer) with maximum continuous power at stated altitude, weight and configuration. The speed shall be hold for 5 s. In the entire test campaign, a test equipment shall measure position data (the sampling frequency of the test equipment is no less than 10 Hz); and remote pilot station can assist the determination of the flight speed the UA.

After the flight, flight data recorded by the test equipment shall be analysed. An interval of the stable flight speed should be sampled; and the average value of sample is taken as the maximum horizontal flight speed in a single flight. The procedures described in this subclause shall be repeated for 4 tests in total; and these tests are in 2 pairs which are in the opposite flight direction. An average value of the 4 tests shall be taken as the final result. The change of the altitude for maximum flight should be considered. Test condition information shall be recorded, such as weight, configuration, air temperature, atmospheric pressure, wind speed and altitude.

5.4.5 Maximum steady climb rate

A route shall be set to a functioning UA which is charged with sufficient energy and carries the dummy mission payload specified by the manufacturer. The UA shall be manipulated to fly vertically. It accelerates with maximum continuous power until its climb rate stabilizes at the maximum steady climb rate V_{vm} (within an error range agreed by the requestor for testing and the test performer). A test equipment shall measure the position data of the UA (the sampling frequency of the test equipment is no less than 10 Hz); and the remote pilot station should assist in inspecting the climb speed.

After the flight, flight data collected by the test equipment shall be analysed. An interval of the stable climb rate should be sampled; and an average value of sample is considered as the maximum climb rate in a single flight test. The procedures described in this subclause shall be repeated for 3 tests; and the minimum value of the tests is taken as the maximum climb rate. Information of the test site shall be recorded, such as air temperature, atmospheric pressure, wind speed and altitude.

5.4.6 Altitude hold performance

A route shall be sent to a functioning UA which is charged with sufficient energy and carries the dummy mission payload specified by the manufacturer. The UA shall be manipulated to fly in the following procedures.

a) Take off vertically to reach a prescribed height H_1, and then fly horizontally at speed V_1 for 30 s.

b) Climb to the height H_2 and then fly horizontally at speed V_2 for 30 s.

c) Climb to the height H_3 and then fly horizontally at speed V_3 for 30 s.

In the above procedures, H_i and V_i shall be evenly selected within the ranges of operational altitude and speed which are specified by the manufacturer. For instance, in the case that an operation altitude is 30 m, values can be selected within the ranges of 0 m to 10 m (including 10 m), 10 m to 20 m (including 20 m), 20 m to 30 m (including 30 m), respectively.

After the flight, the flight data collected by the test equipment (the sampling frequency is no less than 10 Hz) shall be analysed. In the three procedures described in this subclause, the accuracy of altitude hold performance should be evaluated: An interval of flight data can be sampled in which height is within the range (0,95 H_i, 1,05 H_i) in each procedure; and the mean H_i' and standard deviation σ_i can be evaluated. $|H_i' - H_i|$ is considered as the error of altitude hold performance at the height H_i and σ_i is the fluctuation magnitude of altitude hold performance. Information of the test site shall be recorded, such as air temperature, atmospheric pressure, wind speed and altitude.

NOTE i = 1, 2, 3.

5.4.7 Speed hold performance

A route shall be set to a functioning UA which is charged with sufficient energy and carries the dummy mission payload specified by the manufacturer. The UA shall be manipulated to fly in the following procedures.

a) Take off vertically to reach a prescribed height H_1, and then fly horizontally at speed V_1 for 30 s.

b) Climb to altitude H_2 and fly horizontally at speed V_2 for 30 s.

c) Climb to altitude H_3 and fly horizontally at speed V_3 for 30 s.

In these procedures, H_i and V_i shall be evenly selected within the ranges of operation altitude and speed which are specified by the manufacturer. For instance, in the case that an operation altitude is 30 m, values can be selected within the ranges of 0 m to 10 m (including 10 m), 10 m to 20 m (including 20 m), 20 m to 30 m (including 30 m), respectively. H_i and V_i can also be combined to generate test grids.

After the flight, the flight data collected by the test equipment (the sampling frequency is no less than 10 Hz) shall be analysed. In the three procedures described in this subclause, the accuracy of speed hold performance should be evaluated: An interval of flight data can be sampled in which height is within the range (0,95 V_i,1,05 V_i) in each procedure; and the mean V_i' and standard deviation σ_i can be evaluated. $|V_i' - V_i|$ is considered as the error of speed hold performance at the height H_i and σ_i is the fluctuation magnitude of speed hold performance. Information of the test site shall be recorded, such as air temperature, atmospheric pressure, wind speed and altitude.

NOTE i = 1, 2, 3.

5.4.8 Flight endurance

5.4.8.1 General rules

The purpose of this test is to evaluate the flight endurance under appropriate conditions. The check list for the factors influencing the enduring includes propulsion system, aerodynamics and batter performance. The UA shall be functional; and its battery shall be fully charged. The voltage threshold of low battery warning shall be set to the value corresponding to 10 % of battery energy (the low battery warning status should be also determined according to the manufacturer). The test shall be performed under two conditions, namely no-load and full-load. If the payload of UA is non-removable, it is considered that the standard configuration of UA corresponds to the full-load condition; and the method for full-load condition shall be applied in tests.

5.4.8.2 No-load hover

Under no-load condition, the UA shall be manipulated to take off vertically and hover at the height of 10 m (error range can be determined by agreement between the requestor for testing and the test performer) above the ground. It shall keep hovering until low battery warning alarms and then performs a forced landing. A timing device should be utilized for timing during the flight. Time keeping shall be stopped when performing the forced landing; and the run time of hovering shall be recorded.

NOTE Landing points can be determined by agreement between the requestor for testing and the test performer.

The procedures described in this subclause should be repeated for 3 times; and the minimum value among that of 3 tests is regarded as the result. Information of the test site shall be recorded, such as air temperature, atmospheric pressure, wind speed and altitude.

5.4.8.3 No-load horizontal flight

A route shall be set to the UA. Under no-load condition, the UA shall be manipulated to take off vertically and to reach a height of 10 m (error range can be determined by agreement between the requestor for testing and the test performer) above the ground. The UA shall fly at a typical operational speed specified by the manufacturer (if not specified, a median in the range of operational speed should be chosen) within maximum operating radius; and it shall follow an elliptical route whose short axis is greater than 200 m. It keeps flying until the low battery warning alarms and then performs forced landing.

NOTE Landing points can be determined by agreement between the requestor for testing and the test performer.

A timing device shall be utilized for timing during the flight. Time keeping shall be stopped when performing the forced landing; and run time shall be recorded. The procedures described in this subclause should be repeated for 3 times; and the minimum value among that of 3 tests is regarded as the result. Information of the test site shall be recorded, such as air temperature, atmospheric pressure, wind speed and altitude.

5.4.8.4 Full-load hover

Under full-load condition, the UA shall be manipulated to take off vertically and hover at the height of 10 m (error range can be determined by agreement between the requestor for testing and the test performer) above the ground. It shall keep hovering until low battery warning alarms and then performs a forced landing. A timing device should be utilized for timing during the flight. Time keeping shall be stopped when performing the forced landing; and the run time of hovering shall be recorded.

NOTE Landing points can be determined by agreement between the requestor for testing and the test performer.

The procedures described in this subclause should be repeated for 3 times; and the minimum value among that of 3 tests is regarded as the result. Information of the test site shall be recorded, such as air temperature, atmospheric pressure, wind speed and altitude.

5.4.8.5 Full-load horizontal flight

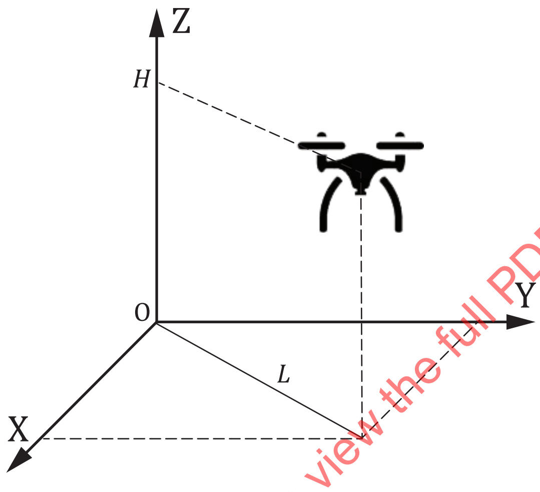
A route shall be loaded to the UA. Under full-load condition, the UA shall be manipulated to take off vertically and to reach a height of 10 m (error range can be determined by agreement between the requestor for testing and the test performer) above the ground. The UA shall fly at a typical operational speed specified by the manufacturer (if not specified, a median in the range of operational speed should be chosen) within maximum operating radius; and it shall follow an elliptical route whose short axis is greater than 200 m. It keeps flying until the low battery warning alarms and then performs forced landing.

NOTE Landing points can be determined by agreement between the requestor for testing and the test performer.

A timing device should be utilized for timing during the flight. Time keeping shall be stopped when performing the forced landing and run time shall be recorded. The procedures described in this subclause should be repeated for 3 times; and the minimum value among that of 3 tests is regarded as the result. Information of the test site shall be recorded, such as air temperature, atmospheric pressure, wind speed and altitude.

5.4.9 Fixed-point hovering

The UAS shall function correctly; and the battery shall have sufficient energy. Tests shall be performed under no-load and full-load conditions respectively. The UA shall be manipulated to take off vertically from position O and to reach a height of 10 m above the ground, as shown in Figure 1. Hover function shall be engaged and hold for 180 s. In this period, A measurement tool shall be utilized. The horizontal distance *L* and the vertical distance *H* away from the position O shall be measured at a time interval of 5 s. The test shall be repeated at 5 different locations, the mean and standard deviation of measurement results shall be recorded. Information of the test site shall be recorded, such as air temperature, atmospheric pressure, wind speed and altitude.



Key

X local frame X axis

Y local frame Y axis

Z local frame Z axis

O the take-off position

L the horizontal distance

H the vertical distance

Figure 1 — Scheme of fixed-point hover test

5.4.10 Positioning navigation

The UAS shall function correctly; and the battery shall have sufficient energy. After the UA is powered on, the number of satellites required for the test shall meet the number specified by the manufacturer. A route (straight, circular, etc.) shall be set to the UA. Under full-load condition, the UA shall be manipulated following a prescribed mission profile. A test equipment shall record the position data of UA throughout the entire flight (the sampling frequency of the test equipment is not less than 10 Hz). After the flight, the position data collected by the test equipment shall be compared with that exported from the remote pilot station or onboard data storage device, such that the accuracy of positioning and navigation can be obtained. The purpose of this test is to check the position sensing accuracy without the influence of automatic control.

5.4.11 Trajectory tracking accuracy

Use the test method in 5.4.10, the trajectory controller shall be activated to follow the pre-set trajectory. After the flight, the actual flight data collected by the test equipment should be analysed. After removing the data of transition process for turning, the position data collected by the equipment shall be compared with the pre-set trajectory to obtain the tracking accuracy of UA. The purpose of this test is to check the combined accuracy of onboard positioning and control.

5.4.12 Capability of wind resistance

The UAS shall function correctly and the battery shall have sufficient energy. After the UA is powered on, the number of satellites required for the test shall meet the number specified by the manufacturer. Artificial methods shall be employed to simulate wind speeds which are equivalent to that of the wind resistance capability, when there is no suitable natural wind. The UA shall be kept in the artificial wind field and a hover test should be performed in accordance with 5.4.9. Test results shall be observed through visual inspection. Commands of forward flight, backward flight, lateral flight and turning should be sent to the UA through the remote pilot station; whether the UA responds normally should be observed.

5.5 Navigation system test

5.5.1 Static attitude accuracy

The UAS shall function correctly; and the battery shall have sufficient energy. Use professional testing devices to fix the UA at any heading, pitch and roll attitude; and read and record the attitude data exported from the remote pilot station and the attitude data sampled by the testing devices. Control the testing devices to change the attitude of the UA; and read and record the data again. The number of testing samples should be not less than 5; and the attitude data are analysed and compared to obtain the static attitude accuracy of the UA.

5.5.2 Static positioning accuracy

The UAS shall function correctly; and the battery is sufficient charged. After the UA is powered on, the number of satellites required for the test shall meet the number specified by the manufacturer. Steps for the test are as follows.

a) Set a reference point outdoors; and record the coordinates of the point.

b) Place the UA above the reference point.

c) Read the position of the UA from the remote pilot station.

d) Compare the measured value with the reference value; and evaluate the navigation accuracy.

e) Conduct the test for five times; and calculate the average value and standard deviation.

5.6 Data link system test

5.6.1 Remote control distance and telemetry distance

Requirements for the test area are as follows.

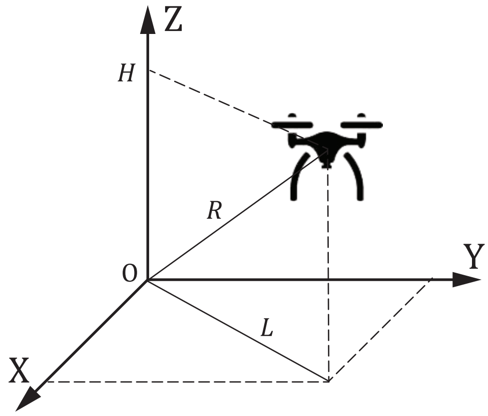
a) The test area shall be flat and open. There shall be no big reflectors, such as buildings and walls, in the area with a radius of 1,5 times of the longest remote control distance around the test centre O, which can be seen in Figure 2.

b) There shall be no signal reflection materials such as snow, tall grasses, dirt, or fence around the test area.

c) The level of electromagnetic interference shall conform to the requirement in the manufacturer's instructions.

The UA is controlled to take off from the point O. It keeps flying in low altitude (below 120 m) along a straight direction to the expected telecommunication range and confirm that the UAS does not hint a malfunction. A distance measuring tool is used to measure the horizontal distance *L* of the UA from the point O and the vertical distance *H*, respectively. Then, the distance *R* is calculated. Change the target position; repeat the test in five different positions; and take the average value. Record the temperature, atmospheric pressure, wind speed and altitude in the test area.

When the test conditions cannot be met, experiment tests should be done to determine the remote control distance and telemetry distance according to the methods in Annex A.



Key

X local frame X axis

Y local frame Y axis

Z local frame Z axis

O the take-off position

L the horizontal distance

H the vertical distance

R remote control and telemetry distance

Figure 2 — Diagram for the test of remote control and telemetry distance

5.6.2 Information transmission distance

Devices of information transmission mission are carried by a UA and the UA is controlled to fly above the designed value of the information transmission distance. Change the flight attitude of the UA for forward flying, backward flying, sideward flying, turning, and climbing to conduct the test, check the information transmission function of the UA, observe and record the data for information transmission, and check whether the quality of the data meet the operating requirements.

5.7 Environmental test

5.7.1 High temperature

5.7.1.1 High temperature storage

The test procedure for high temperature storage for UAS is as follows.

a) Put the UAS into the test chamber (room); test and record the appearance and function/performance to ensure proper assembling.

b) Set the UAS in non-operational status; regulate the test chamber (room) temperature to achieve the specified high storage temperature with the temperature rate not more than 3 °C/min; hold on till the UAS temperature is stable; then hold for 3 h.

c) Recover the test chamber (room) temperature to be the same as the laboratory environmental temperature with the temperature rate not more than 3 °C/min, until the temperature is stable.

d) Test and record the appearance and function/performance. The function/performance test should be limited to take-off and landing.

5.7.1.2 High temperature operation

The test procedure for UAS high temperature operation is as follows.

a) Put the UAS into the test chamber (room); test and record the appearance and function/performance to ensure proper assembling.

b) Set the UAS into operational status; regulate the test chamber (room) temperature to achieve the specified high operating temperature with the temperature rate not more than 3 °C/min; hold on till the UAS temperature stable; then maintain at least one flight duration.

c) Test and record the function/performance.

d) Set the UA in the non-operational status (or stop after the temperature becomes the same as the laboratory environmental temperature); recover the test chamber (room) temperature to be the same as the laboratory environmental temperature with the temperature rate not more than 3 °C/min, till the temperature is stable.

e) Test and record the appearance and function/performance. The function/performance test should be limited to take-off and landing

f) The battery security issues in a high temperature environment shall be considered during this test.

NOTE The high temperature storage and high temperature operational tests can be merged; and the temperature stability time for high temperature operation can be ignored when the high temperature storage and high temperature work are same.

5.7.2 Low temperature

5.7.2.1 low temperature storage

The test procedure for UAS low temperature storage is as follows.

a) Put the UAS into the test chamber (room); test and record the appearance and function/performance to ensure proper assembling.

b) Set the UAS in non-operational status; regulate the test chamber (room) temperature to achieve the specified low storage temperature with the temperature rate not more than 3 °C/min; hold on till the UAS temperature is stable; then hold for 3 h.

c) Recover the test chamber (room) temperature to be the same as the laboratory environmental temperature with the temperature rate not more than 3 °C/min, till the UAS temperature is stable.

d) Test and record the appearance and function/performance.

5.7.2.2 Low temperature operation

The test procedure for UAS low temperature operation is as follows.

a) Put the UAS into the test chamber (room); test and record the appearance and function/performance to ensure proper assembling.

b) Set the UAS into operational status; regulate the test chamber (room) temperature to achieve the specified low operating temperature with the temperature rate not more than 3 °C/min; hold on till the temperature is stable; then maintain at least one flight duration.

c) Test and record the function/performance.

d) Set the UAS in non-operational status (or stop after the temperature becomes the same as the laboratory environmental temperature); recover the test chamber (room) temperature to be the same as the laboratory environmental temperature with the temperature rate not more than 3 °C/min, till the temperature is stable.

e) Test and record the appearance and function/performance.

f) The test article is in low temperature after the test; then it should be dried to protect the object from potential performance degradation from condensation.

NOTE 1 The low temperature storage and low temperature operational tests can be merged; and the temperature stability time for low temperature operation can be ignored when the low temperature storage and low temperature work are same.

NOTE 2 That battery can be environmentally protected (warm) while the UA is cold-soaked according to the manufacturer's specification.

5.7.3 Rainfall

The rainfall test should be performed for the UAS as specified in IEC 60529.

5.7.4 Humidity and heat

The humidity and heat test should be performed for the UAS as specified in IEC 60068-2-78 and IEC 60068-2-30.

5.7.5 Vibration

The vibration test should be performed for the UA as specified in ISO 5309.

5.7.6 Shock

The shock test procedure should be performed for the UA as follows.

a) Fix the UA on the vibration/shock platform; attach the sensors; then test and record the appearance and function/performance to ensure proper assembling.

b) Define shock pulse specifically according to the test plan and purpose, which includes half sine, trapezoidal, terminal peak sawtooth, etc. shock impulse.

c) Start the UA; perform the shock test along three orthogonal axial directions, three times for every direction.

d) Test and record function/performance.

NOTE For some shock scenarios, it is impossible to determine which shock impulse to use for testing; it can be replaced by a test that simulates the actual scenario. For example, for a drop shock scenario, a free drop test can be carried out.

5.8 Electromagnetic compatibility

5.8.1 General principles

The emission and immunity tests in Table 2 should be performed to ensure the electromagnetic compatibility (EMC) in operation.

The UA should be fixed using a support system in the EMC test.

The support system material should be insulant and does not form a conductive loop between the UA and the ambient environment.

Table 2 — Emission and immunity test issues

Test type	Test item	Test article
Emission test	Conduction emission	Remote pilot station
	Radiation emission	UAS
Immunity test	Radio frequency electromagnetic radiation	UAS
	Power frequency magnetic field	UAS
	Electrostatic discharge	UAS
	Electrical transient pulse group	Remote pilot station
	Surge	Remote pilot station
	Conducted disturbance immunity induced by radio frequency field	Remote pilot station
	Voltage sag and short supply interruption, voltage dips, short interruptions and voltage variations	Remote pilot station

5.8.2 Emission test

5.8.2.1 Conductive emission

5.8.2.1.1 Test conditions

This test is only appropriate for remote pilot station with test conditions as follows.

a) The UAS should be in typical operation condition.

b) The quasi-peak vale measurement receiver should be according to CISPR 16-1-1; the mean vale measurement receiver should also be according to CISPR 16-1-1 and has a 6 dB bandwidth; the artificial mains V-network (50 Ω/50 µH or 50 Ω/50 µH+5 Ω) should be adapted according to CISPR 16-1-2.

c) The test site should be according to CISPR 16-1-1.

5.8.2.1.2 Test procedure

Only the AC input power port of the remote pilot station (including the device suite using the independent AC/DC power converter) and the telecommunication network should be tested. The test should be performed according to the relevant clause of CISPR 32 with the procedure as follows.

a) Arrange the remote pilot station according to relevant clause of CISPR 32.

b) Power on the UAS; complete self-test and standby.

c) Set the UA into rotor rotating state (does not necessarily take off for safety reasons); and steer the UA to perform some functions, such as camera shooting.

d) Test the corresponding ports of the remote pilot station.

e) Record the tested results.

According to the operator's manual, it is not recommended to conduct experiment on the portable remote pilot station, for example, the remote controller, when it is plugged in. However, the test should be conducted when the remote pilot station is shut down and charging. At this point, the test is only performed for the AC input power port of the remote pilot station (including the device suite using the independent AC/DC power converter).

5.8.2.1.3 Test limit

The limit value specified in IEC 61000-6-3 or IEC 61000-6-4 should be adapted according to the UAS operational environment and application.

5.8.2.2 Radiation emission

5.8.2.2.1 Test conditions

This test is appropriate for UAS with test conditions as follows.

a) The UAS should be in typical operation condition.

b) The quasi-peak vale measurement receiver should be according to CISPR 16-1-1; the mean vale measurement receiver should also be according to CISPR 16-1-1 and has a 6 dB bandwidth; the peak vale measurement receiver should also be according to CISPR 16-1-1 and has a 6 dB bandwidth.

c) The test site should be according to CISPR 16-1-1.

5.8.2.2.2 Test procedure

The test should be performed at a distance of 3 m, 10 m, or 30 m. Wherein, the 3 m distance is only for small devices (the overall size, including cable, should be within a cylindrical test area with a 1,2 m diameter and a 1,5 m height).

The test should be performed according to the relevant clause of CISPR 32 with the procedure as follows.

a) Fix the UA (including mission payload) on a table with an appropriate diameter using insulating support; and put the remote pilot station on the table and standby.

b) Power on the UAS; complete self-test; and ensure the UA is on standby in the anechoic chamber.

c) Set the receiving antenna polarization; use the remote pilot station of the same type out of the anechoic chamber to steer the UA to propeller/rotor spinning state without take-off and perform some functions, such as camera shooting.

d) Begin the test.

e) Record the tested results.

5.8.2.2.3 Test limit

The limit value specified in IEC 61000-6-3 or IEC 61000-6-4 should be adapted according to the UAS operation environment and application.

5.8.3 Immunity

5.8.3.1 Radiated, radio-frequency, electromagnetic field immunity

5.8.3.1.1 Test conditions

The test is appropriate to the UAS and should be performed in the anechoic chamber with conditions as follows:

— frequency range: select from IEC 61000-6-1 or IEC 61000-6-2 according to the UAS operation environment and application;

— modulation frequency: 1 kHz;

— modulation depth: 80 %;

— field intensity: select the test grade from IEC 61000-6-1 or IEC 61000-6-2 according to the UAS operation environment and application;

— scanning rate: current frequency 1 %;

— dwell time: not less than 1 s.

5.8.3.1.2 Test procedure

The test shall be performed as follows.

a) Fix the UA (including mission payload) on a table with an appropriate diameter using insulating support; align the nose direction of the UA with calibrated reference place; and put the remote pilot station on the table and on standby.

NOTE The remote pilot station can use external power source to ensure it is always on standby during the test. Another remote pilot station of the same type is prepared and put out of the anechoic chamber to ensure that the test operator can operate the UA out of the anechoic chamber.

b) Power on the UAS; complete self-test; and ensure the UA is on standby in the anechoic chamber.

c) Set the emission antenna polarization; use the remote pilot station of the same type out of the anechoic chamber to steer the UA into propeller/ rotor rotating state (does not necessarily take off for safety reason) and perform some function, such as camera shooting.

d) Begin the test; observe and record the function and performance change of the test article during the frequency sweep range.

e) Open the chamber; confirm that the UA flight is normal and the remote pilot station is on standby; then exchange the emission antenna polarization; repeat step d);

f) Record test results.

5.8.3.2 Power frequency magnetic field immunity

5.8.3.2.1 Test conditions

The test method can be applied to the UAS. The test should meet the following conditions.

a) Frequency: 50 Hz, 60 Hz, 16,67 Hz or others based on different operation environments. For example, if the device only works with one specified frequency, them the system only needs to be tested under this frequency.

b) Field intensity: according to the operation environment and mission objective of the UAS, the test level should be according to IEC 61000-6-1 or IEC 61000-6-2.

c) Endurance: minimum 1 min.

5.8.3.2.2 Test procedure

The test should be performed as follow.

a) Attach the induction coil to a proper position of the UAS to guarantee that the UAS locates inside the magnetic field generated by the induction coil.

b) Power up the UA and complete self-test.

c) Enforce proper level of power frequency with minimum 1 min and record the function and performance change of the UA.

d) Rotate the induction coil by 90° and repeat procedure c) until the test is finished with three orthogonal magnetic fields.

e) Take the UA out from the induction coil and put the remote pilot station inside the induction coil and repeat procedures c) and d).

5.8.3.3 Electrostatic discharge immunity

5.8.3.3.1 Test conditions

The test method should be applied to the UAS. The test should meet the following conditions.

a) Contact discharge voltage: according to the operation environment and mission objective of the UAS, the test level should be according to IEC 61000-6-1 or IEC 61000-6-2.

b) Air discharge voltage: according to the operation environment and mission objective of the UAS, the test level should be according to IEC 61000-6-1 or IEC 61000-6-2.

c) Polarity: positive and negative.

d) Number of tests: 10 for both positive and negative polarity.

e) Test interval ≥ 1 s.

5.8.3.3.2 Test procedure

The test should be performed as follows.

a) Put a wooden testbed with a 0,8 m height on the ground (the reference plane) with grounding system and attach a horizontal coupling plate on the testbed.

b) Attach a 0,5 mm insulation pad on the horizontal coupling plate and put the UAS on the insulation pad. The UAS and connecting cables are decoupled by the horizontal coupling plate with minimum 0,1 m to the plate and minimum 1 m to the wall and other metal structures.

c) Put a vertical coupling plate on the insulation pad with 0,1 m parallel to the front part of the UA.

d) Put the remote pilot station on the testbed.

e) Connect the discharge circuit cable of the electrostatic discharge gun with the grounding system. Use a specific cable with 470 kΩ resistance to connect the horizontal coupling plate with the grounding system.

f) Power up the UA and complete self-test.

g) Select a proper discharge point to conduct contact discharge for the UA and remote pilot station sequentially. Choose the testing voltage from a lower level to the required test level with minimum 1 s and record the function and performance change of the UA.

h) Select a proper discharge point to conduct air discharge for the UA and remote pilot station sequentially. Choose the testing voltage from a lower level to the required test level with minimum 1 s and record the function and performance change of the UA.

i) Record the test results.

5.8.3.4 Electrical fast transient/burst immunity

5.8.3.4.1 Test conditions

The test method should only be applied to the remote pilot station. The test should meet the following conditions.

a) Test level: according to the operation environment and mission objective of the UAS, the test level should be according to IEC 61000-6-1 or IEC 61000-6-2.

b) Repeat frequency: 5 kHz.

c) Test pulses: 5/50 ns.

d) Polarity: positive and negative.

e) Number of tests: 1 for both positive and negative polarity.

f) Test interval: ≥ 1 min.

5.8.3.4.2 Test procedure

This test is only designed for the power port and other signal ports. The test should be performed as follows.

a) Arrange the remote pilot station according to IEC 61000-4-4.

b) Power up the UA and complete self-test.

c) Steer the UA into propeller/ rotor rotating state (does not necessarily take off for safety reason) and perform some functions, such as camera shooting.

d) Conduct the experiment on the associated ports of the remote pilot station and record the function and performance change of the UA.

e) Record the test results.

According to the operator's manual, it is not recommended to conduct the experiment on the portable remote pilot station, for example, remote controller, when it is used during charging. However, the test should be conducted when the remote pilot station is shut down and charging. The test under this condition is only designed for the power port. The UA should work properly when it is switched on after the test.

5.8.3.5 Surge immunity

5.8.3.5.1 Test conditions

The test method should only be applied to the remote pilot station. The test should meet the following conditions.

a) Test level: according to the operation environment and mission objective of the UAS, the test level should be according to IEC 61000-6-1 or IEC 61000-6-2.

b) Test wave: 1,2/50 (8/20) µs.

c) Polarity: positive and negative.

d) Number of tests: 5 for both positive and negative polarity.

e) Test interval: ≥ 1 min.

