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General requirements for unmanned aerial vehicle (UAV) cleaning operations

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Foreword

This document is drafted in accordance with the rules given in GB/T 1.1-2020 "Directives for standardization—Part 1: Structure and drafting rules for standardization documents".

This document was proposed by and is under the jurisdiction of the Shenzhen Unmanned Aerial Vehicle Industry Association.

Introduction

With the increasing height of urban buildings and the large-scale development of new energy facilities, traditional manual cleaning methods for high-rise building facades, photovoltaic power stations, wind turbine blades, etc., face challenges such as low efficiency, high costs, and prominent safety risks. Meanwhile, breakthroughs in drone technology, driven by the low-altitude economy, provide innovative solutions for these cleaning fields. By utilizing UAVs for precise positioning, intelligent obstacle avoidance, and efficient cleaning operations, cleaning efficiency is significantly improved, and personnel safety risks are avoided. This technological innovation not only addresses the pain points of traditional industries but also aligns with the "service-oriented, intelligent, and green" development direction of the low-altitude economy.

However, the current field of drone cleaning operations lacks unified technical specifications, which restricts technology promotion and large-scale application. To standardize the technical requirements, operational procedures, and safety standards for UAV cleaning operations, and to ensure operational safety and service quality, this group standard is formulated.

This document, based on industry practical experience, proposes systematic requirements for key aspects of UAV cleaning operations, including operational preparation, equipment configuration, operational specifications, safety protection, and quality assessment. It aims to provide technical guidance for industry practitioners and a reference basis for regulatory authorities, promoting the standardized and professional development of UAV cleaning operations.

1 Scope

This document specifies the technical requirements, operational procedures, safety measures, and inspection methods for using unmanned aerial vehicles (UAVs) for cleaning operations. It is applicable to the cleaning operations of facilities such as building facades, photovoltaic panel equipment, and wind power equipment. Other UAV cleaning operations may refer to this document.

2 Normative References

The following documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition (including any amendments) applies.

- GB 38508 Limits of volatile organic compounds (VOCs) content in cleaning agents
- GB/T 2680 Determination of luminous transmittance, solar direct transmittance, total solar energy transmittance, ultraviolet transmittance and related glazing factors of building glass
- GB/T 5226.1 Safety of machinery - Electrical equipment of machines - Part 1: General requirements
- GB/T 18451.2 Wind turbines - Power performance testing
- GB/T 18570.3 Preparation of steel substrates before application of paints and related products - Tests for the assessment of surface cleanliness - Part 3: Assessment of dust on steel surfaces prepared for painting (pressure-sensitive tape method)
- GB/T 25030 Quality requirements for building cleaning and maintenance
- GB/T 38924 Environmental test methods for civil light and small unmanned aircraft systems
- GB/T 39293 Industrial cleaning - Terminology and classification
- JB 8526 Safety specification for high-pressure water jet cleaning operations
- SB/T 10737 Service specification for high-altitude exterior wall cleaning
- DB34/T 3083 Service specification for building exterior wall cleaning

3 Terms and Definitions

For the purposes of this document, the following terms and definitions apply.

3.1 UAV cleaning system

A system consisting of a UAV with communication and control functions and supporting cleaning equipment, used for cleaning operations.

3.2 UAV tethered system

An unmanned aerial vehicle system that connects the UAV to a ground power supply device via a physical cable (tether cable). This system achieves continuous power transmission through the cable, supporting the UAV to complete ultra-long endurance operations (usually several hours to tens of hours) within a limited airspace.

3.3 UAV cleaning operations

Cleaning operations performed on facilities such as building facades, photovoltaic panels, or wind power equipment using a UAV cleaning system.

3.4 Cleaning mediator

A general term for substances that directly contact the object to be cleaned and the dirt, and can transmit or enhance the force for removing dirt.

3.5 Cleaning efficiency

The area or volume of the object cleaned per unit of time, usually expressed in m^2/h or m^3/h.

3.6 Visible light transmittance

The ratio of the transmitted luminous flux to the incident luminous flux under the conditions of CIE D65 standard illuminant and CIE standard photopic observer, within the visible light spectrum (380nm~780nm), calculated according to the method specified in GB/T 2680-2021.

3.7 Photovoltaic generation efficiency

The solar power generation efficiency per unit area of a photovoltaic panel, η is calculated by the following formula:

$$\eta = \frac{P}{A * I}$$

Where:

η — Photovoltaic panel generation efficiency

P (W) — Photovoltaic panel generation power

A (m^2) — Surface area of the photovoltaic panel

I (W/m^2) — Solar irradiance on the photovoltaic panel

3.8 Pressure-sensitive tape

Pressure-sensitive tape with a width of 25mm, colorless and transparent. When tested according to the 180° peel test method specified in IEC 454-2, the measured peel strength shall be ≥190 N/m.

4 Technical Requirements

4.1 UAV System Requirements

a) The UAV shall have a product certificate of conformity.

b) The UAV shall have stable flight performance, with a flight altitude capability of 100-500 m.

c) The UAV shall have an endurance of ≥30 min and a payload capacity of ≥10kg; or an endurance of ≥15min and a payload capacity of ≥35kg, to meet the needs of different cleaning scenarios; if equipped with a tethered system, the tethered system shall have an automatic cable retraction and deployment function.

d) The UAV shall be equipped with a visible light camera and an obstacle avoidance system; the camera resolution shall be ≥1080P, and the illuminance shall be ≥0.1 lux.

e) The UAV protection level shall be ≥IP55.

f) The UAV shall be equipped with BDS and GPS dual positioning systems and have an automatic return-to-home function.

g) After modification, the UAV shall comply with the management regulations of the category to which it belongs after modification, and shall not violate the requirements of the "Interim Regulations on the Flight Management of Unmanned Aerial Vehicles".

4.2 Cleaning Equipment Requirements

4.2.1 Cleaning Equipment Requirements

a) The water pressure range at the outlet of the water pump shall be adjustable, the minimum shall meet the needs of cleaning operations, and the maximum shall not exceed the maximum pressure tolerance of the operating surface.

b) The water outlet should preferably be equipped with a rotating device to adapt to different cleaning conditions.

c) The cleaning equipment shall have an anti-leakage function.

4.2.2 Cleaning Media Requirements

a) The pH value of the cleaning media shall be in the range of 4~10, and shall not contain toxic or harmful chemical substances. The content of volatile organic compounds shall comply with the provisions of GB 38508-2020; the main performance indicators for clean water, neutral, weakly alkaline, and weakly acidic cleaning media are detailed in Appendix B.

b) Softened water with a TDS value ≤30 mg/L should be used for cleaning building facades. If other water sources are used, the TDS value should be ≤300 mg/L.

4.3 Communication and Control System Requirements

a) The UAV shall have remote control and real-time monitoring functions, with a communication distance ≥1km.

b) The communication system shall have anti-interference capability and comply with the requirements of the Ministry of Industry and Information Technology document No. (2023) 252.

c) The control system shall have emergency hover and landing functions.

5 Operational Preparation

5.1 Operational Environment Assessment

5.1.1 Meteorological conditions shall be assessed before operation. Operations shall be suspended when wind speed is ≥ level 6, or during rain, snow, or when the temperature is ≤10℃.

5.1.2 Obstacles in the operational area shall be checked before operation to ensure a clear flight path for the UAV.

5.2 Equipment Inspection

5.2.1 Check the UAV battery level, motor status, and sensor functions. The battery level shall be ≥80% before starting operations.

5.2.2 Check the water pressure, flow rate, and cleaning media reserve of the cleaning equipment. Water pressure, flow rate, and cleaning media reserve shall meet operational requirements.

5.3 Emergency Plan

5.3.1 A specific emergency plan shall be formulated before operation based on the operational environment, equipment status, and potential risks, clarifying emergency response procedures, personnel responsibilities, and disposal measures.

5.4 Personnel Training

5.4.1 UAV pilots shall hold a civil UAV pilot license certified by the Civil Aviation Administration or relevant government departments that corresponds to the operated model, and shall have passed specialized training for high-altitude cleaning operations.

5.4.2 Operators of the UAV cleaning system shall be familiar with the emergency plan, master emergency handling methods, and conduct regular emergency drills.

5.5 Airspace Application

5.5.1 Airspace control conditions during the operation period shall be checked before operation, and a flight operation plan shall be submitted to the local relevant management department. Operations can only be carried out after obtaining permission.
5.5.2 The scope and altitude limits of the operational airspace shall comply with relevant regulatory requirements.

5.6 Operational Insurance

5.6.1 Before carrying out UAV cleaning operations, liability insurance shall be purchased in accordance with the law.

6 Operational Requirements

6.1 Building Facade Cleaning

6.1.1 The cleaning route and the operating altitude of the UAV-borne equipment shall be reasonably planned. The distance between the nozzle of the UAV cleaning system and the building surface shall be maintained at 0.5~2.0m.
6.1.2 An appropriate water pressure range shall be selected based on the actual condition of the object to be cleaned. The outlet pressure of the water pump shall be ≤25 MPa.
6.1.3 The cleaning effect shall be checked after cleaning to ensure no residual stains; if there are areas that are not cleaned properly, secondary cleaning shall be performed.

6.2 Photovoltaic Panel Equipment Cleaning

6.2.1 If the UAV is equipped with a high-pressure water gun for cleaning operations, the cleaning pressure shall be controlled within the tolerance range of the photovoltaic panel equipment to prevent damage to the photovoltaic equipment components. The outlet pressure of the water pump shall be ≤9Mpa.
6.2.2 [This sub-clause appears to be missing in the original document's table of contents and text. If it exists, it's not provided in the text.]

6.2.3 The equipment condition shall be checked after cleaning to ensure that the equipment surface is intact and the components are not damaged; if there are areas with poor cleaning effect, secondary cleaning shall be performed.

6.3 Wind Power Equipment Cleaning

6.3.1 For cleaning or maintenance operations on the surface of wind turbine blades, the nozzle pressure shall be controlled within the pressure tolerance range of the blades. The outlet pressure of the water pump shall be ≤25 Mpa.

6.3.2 After the operation, check whether the blade surface is clean and intact.

6.3.3 During the operation, prevent cleaning media from entering the interior of the equipment, which could affect the wind turbine bearings and electrical components.

7 Safety Requirements

7.1 Operational Safety

7.1.1 The operational environment shall meet the flight environment requirements specified in the operation manual provided by the UAV equipment manufacturer.

7.1.2 Safety warning lines or isolation facilities shall be set up around the operational area to prohibit unrelated personnel from entering. When the operational altitude is ≤10m, the radius of the warning area shall not be less than 15m; when 10m < operational altitude ≤30m, the radius of the warning area shall not be less than 30m; when the operational altitude is >30m, the radius of the warning area shall not be less than 50m.

7.1.3 The area for UAV take-off, landing, and equipment placement shall not be less than 5m×5m, and clear warning signs shall be set up at the boundaries of the site.

7.1.3 Operators shall wear safety helmets, protective goggles, and anti-slip shoes, and shall also be equipped with a first-aid kit. (Note: 7.1.3 is repeated, this is the second instance)

7.1.4 Operators shall not work continuously for more than 2 hours at a time.

7.1.5 Single-person, single-control operation is prohibited; a UAV pilot and a safety observer must be present.

7.2 Equipment Safety

7.2.1 The UAV shall have an emergency stop function, and the emergency stop button shall be located in a position easily accessible to the operator.

7.2.2 The cleaning equipment shall have anti-leakage protection and undergo regular safety inspections.

7.3 Environmental Safety

7.3.1 If the wastewater after cleaning is directly discharged, it shall meet the indicator requirements of GB8978-1996 "Integrated wastewater discharge standard".

7.3.2 If the cleaning media used has a pH value outside the specified range due to severe contamination of the equipment being cleaned, it shall be ensured that the cleaning media does not damage the facilities in the operational area, and the cleaning wastewater shall be intercepted and treated.

7.3.3 The site shall be cleaned up after the operation to avoid leaving debris. Clean-up includes residual cleaning media, equipment packaging materials, etc.

8 Inspection and Acceptance

8.1 Cleaning Effect Inspection

8.1.1 After cleaning, the glass surface of the building facade shall be clean and bright, with no obvious dirt, water marks, or water stains; the decorative surface of the exterior wall shall be free of obvious dirt and have a bright color.

8.1.2 After cleaning, the surface of the photovoltaic panel shall have uniform reflection, no scratches, coating peeling, or frame corrosion; junction boxes, cables, etc., shall be well-sealed, and surface dirt shall be basically removed.

8.1.3 After cleaning, the wind power equipment shall maintain its aerodynamic shape intact, with no erosion or coating peeling on the surface, no looseness at bolted connections, and ice and dirt on the surface of wind turbine blades shall be basically removed.

8.1.4 Inspection Methods

a) Building curtain wall: Visually inspect the exterior wall surface for no obvious dirt; the visible light transmittance of the glass and the results of the glass surface dust cleanliness test (tested according to Appendix C) can be used to identify the cleaning effect.
b) Photovoltaic panel: Use white gloves or white gauze to wipe the glass surface at the four corners and the middle position of the module. There should be no obvious dust on the gloves or gauze; the photovoltaic panel power generation capacity and the results of the surface dust cleanliness test (tested according to Appendix C) can be used to identify the cleaning effect.
c) Wind power equipment: The output power (unit: W or kW) test results of the wind turbine can be used to identify the cleaning effect. The test method can refer to the relevant provisions of the national standard GB/T 18451.2-2021 "Wind turbines - Power performance testing".
8.1.5 The cleaning effect inspection shall be recorded and serve as the basis for acceptance. Inspection records include comparative photos before and after cleaning, test data, etc.

8.2 Equipment Status Inspection

8.2.1 Check the operating status of the UAV and cleaning equipment. Equipment status inspection shall be conducted regularly.
8.2.2 Record equipment usage and perform regular maintenance. Maintenance includes equipment cleaning, parts replacement, etc.

Appendix A: UAV Cleaning Operation Record Form

(Informative)

The UAV Cleaning Operation Record Form is shown in Table A.1.

Table A.1 UAV Cleaning Operation Record Form

Operation Date	Operation Location	Operation Content	Operator	Equipment Status	Remarks

Appendix B: Performance Indicators of Cleaning Media

(Normative)

The main performance indicators for cleaning media selected for drone cleaning operations are detailed in Table B.1.

Table B.1 Performance Indicators of Cleaning Media

Cleaning Medium	Appearance	pH Value
Clean Water	Colorless transparent liquid	7.0
Neutral Cleaning Medium	Clear liquid	6.0-8.0
Alkaline Cleaning Medium	Clear liquid	8.0-10.0
Acidic Cleaning Medium	Clear liquid	4.0-6.0

Appendix C: Test for Dust Cleanliness on Glass Surfaces

(Normative)

C.1 Method Summary

Press the pressure-sensitive tape onto the glass surface, remove the tape with adhered dust, place it on a monochromatic display panel that contrasts with the color of the dust, examine it with a magnifying glass, and assess the amount of dust adhered to the pressure-sensitive tape.

C.2 Apparatus and Materials

The apparatus and materials used for the test are as follows:

- Pressure-sensitive tape (The minimum peel strength required for the pressure-sensitive tape needs to be tested; data is currently unavailable).
- Display panel (Refers to a display panel with a color contrasting with the dust to serve as a background).
- Magnifying glass (The magnification of the magnifying glass is 10x).

C.3 Procedure

C.3.1 Before starting each series of tests, discard the first three turns of the pressure-sensitive tape pulled out, then pull out about 200mm for use.

C.3.2 Touching only the ends of the adhesive side, press about 150mm of the newly pulled pressure-sensitive tape firmly onto the test surface. Place the thumb across one end of the pressure-sensitive tape, move the thumb while maintaining pressure, and press along the tape at a constant rate back and forth. Press in each direction 3 times, with each pass lasting 5s~6s. Then remove the pressure-sensitive tape from the test surface, place it on an appropriate display panel, and then press it down with the thumb to adhere it to the panel.

C.3.3 Visually compare an area of the pressure-sensitive tape with the equivalent sized areas specified in Figure C.1 to assess the amount of dust on the tape, and record the rating from the reference diagram that it most closely resembles.

C.3.4 For each glass surface tested, conduct no fewer than 3 independent tests. If the test results are not distributed over one or fewer quantity ratings, conduct at least 2 more tests and take the average value.

C.3.5 After the test is completed, remove all pressure-sensitive tape or any adhesive residue remaining on the test surface.

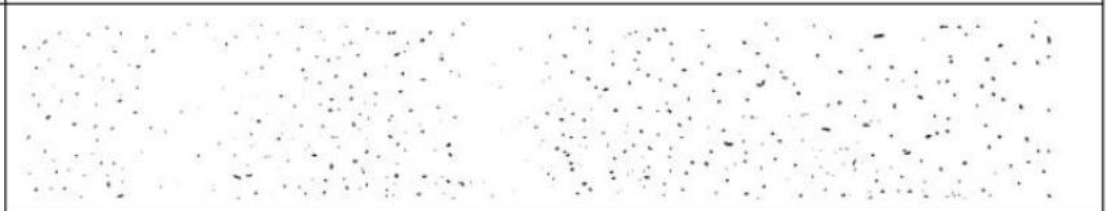
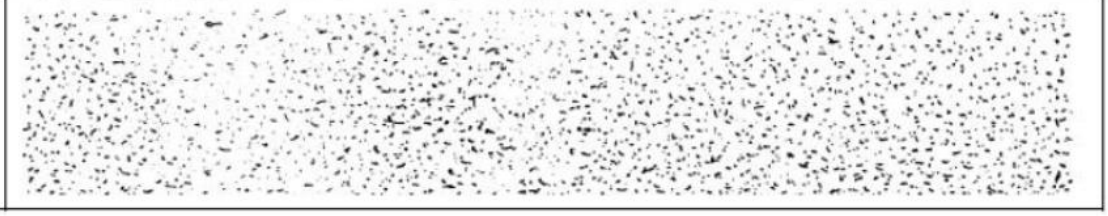
等级	图　示
1	
2	
3	
4	
5	

Figure C.1 Reference diagrams corresponding to dust quantity ratings 1, 2, 3, 4, and 5