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Standard Specification for Design, Construction, and Verification of Lightweight Unmanned Aircraft Systems (UAS)[1]

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1. Scope

1.1 This specification covers the airworthiness requirements for the design of light unmanned aircraft systems. This specification defines the baseline design, construction, and verification requirements for an unmanned aircraft system (UAS).

1.2 As a minimum, a UAS is defined as a system composed of the unmanned aircraft and all required on-board subsystems, payload, control station, other required off-board subsystems, any required launch and recovery equipment, all required crew members, and command and control (C2) links between UA and the control station.

1.3 The intent is for this standard of practice for CAA, self- or third-party determinations of airworthiness for UAS. This specification provides the core requirements for airworthiness certification of lightweight (UAS) (not necessarily limited to UAs under 55 lb GTOW) or for certain CAA operational approvals using risk-based categories. Additional requirements are envisioned to address the requirements for expanded operations and characteristics not addressed by this specification.

1.4 This specification is intended to support UAS operations. It is assumed that the risk of UAS will vary based on concept of operations, environment, and other variables. The fact that there are no human beings onboard the UAS may reduce or eliminate some hazards and risks. However, at the discretion of the CAA, this specification may be applied to other UAS operations.

1.5 The values in Imperial units are to be regarded as the standard. The values in SI are for information only.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

F2245 Specification for Design and Performance of a Light Sport Airplane

F2908 Specification for Unmanned Aircraft Flight Manual (UFM) for an Unmanned Aircraft System (UAS)

F2909 Practice for Maintenance and Continued Airworthiness of Small Unmanned Aircraft Systems (sUAS)

F2911 Practice for Production Acceptance of Small Unmanned Aircraft System (sUAS)

F3002 Specification for Design of the Command and Control System for Small Unmanned Aircraft Systems (sUAS)

F3003 Specification for Quality Assurance of a Small Unmanned Aircraft System (sUAS)

F3005 Specification for Batteries for Use in Small Unmanned Aircraft Systems (sUAS)

F3120/F3120M Specification for Ice Protection for General Aviation Aircraft

F3178 Practice for Operational Risk Assessment of Small Unmanned Aircraft Systems (sUAS)

F3201 Practice for Ensuring Dependability of Software Used in Unmanned Aircraft Systems (UAS)

2.2 *ANSI Standard:*

ANSI Z535.1-1998 American National Standard for Safety Colors

2.3 *FAA Standard:*[3]

Order 8130.34D Airworthiness Certification of Unmanned Aircraft Systems and Optionally Piloted Aircraft

[1] This specification is under the jurisdiction of ASTM Committee F38 on Unmanned Aircraft Systems and is the direct responsibility of Subcommittee F38.01 on Airworthiness.

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

[3] Available from Federal Aviation Administration (FAA), 800 Independence Ave., SW, Washington, DC 20591, http://www.faa.gov.

2.4 *Federal Standard:*

14 CFR Part 107 Small Unmanned Aircraft Systems[4]

2.5 *Joint Authorities for Rulemaking of Unmanned Systems:*[5]

CS-LURS Certification Specification for Light Unmanned Rotorcraft Systems

CS-LUAS Recommendations for Certification Specification for Light Unmanned Aeroplane Systems

2.6 *Unmanned Systems Canada Best Practices:*[6]

Small Remotely Piloted Aircraft System (UAS) Best Practices for BVLOS Operations

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *abstain, v*—prior to starting a particular test method, the UA manufacturer or designated operator shall choose to enter the test or abstain. Any abstention shall be granted before the test begins. The test form shall be clearly marked as such, indicating that the manufacturer acknowledges the omission of the performance data while the test method was available at the test time.

3.1.2 *airframe, n*—airframe means the fuselage, booms, nacelles, cowlings, fairings, airfoil surfaces (including rotors but excluding propellers and rotating airfoils of engines), and landing gear of an aircraft and their accessories and controls.

3.1.3 *airworthiness, n*—condition in which the unmanned aircraft systems (UAS) (including the aircraft, airframe, engine, propeller, accessories, appliances, firmware, software, and control station elements) conforms to its design intent, including as defined by the type certificate (TC), if applicable, and is in condition for safe operation.

3.1.4 *alert, n*—a generic term used to describe a control station indication meant to attract the attention of and identify to the flightcrew a non-normal operational or airplane system condition. Alerts are classified at levels or categories corresponding to Warnings, Cautions, and Advisories. Alert indications also include non-normal range markings (for example, exceedances on instruments and gauges).

3.1.5 *analysis, n*—technique based on analytical evidence obtained without any intervention on the submitted element using mathematical or probabilistic calculation, logical reasoning (including the theory of predicates), modeling or simulation, or combinations thereof, under defined conditions to show theoretical compliance.

3.1.6 *applicant/proponent, n*—the person or organization responsible for seeking the approval to operate and operating a UA. The applicant/proponent may be one of the following entities: manufacturer, operator, or original equipment manufacturer.

3.1.6.1 *manufacturer, n*—the person or organization who causes production of a product or article. A manufacturer may also be an operator.

3.1.6.2 *operator, n*—the person or organization that applies for CAA approval to operate a UAS or who seeks operational approval for types of flight operations prohibited by a CAA for that UAS.

3.1.6.3 *original equipment manufacturer, n*—the person or organization who first produced that product or article. An OEM may also be an operator.

3.1.7 *automatic flight control system, n*—a system which includes all equipment to control automatically the flight of an aircraft to a path or altitude described by references, internal or external, to the aircraft.

3.1.8 *conflict point, n*—the time of a predicted collision or point of closest approach that is within the collision volume.

3.1.9 *continued safe flight, n*—a condition whereby a UA is capable of continued controlled flight, and landing at a suitable location, possibly using emergency or abnormal procedures, but without requiring exceptional pilot skill. Some UA damage may be associated with a failure condition during flight or upon landing.

3.1.10 *Control and Non-Payload Communications (CNPC), n*—radio frequency (RF) link(s) between the control station (CS) and the unmanned aircraft (UA), also known as the Command and Control Link(s).

3.1.11 *control station, n*—apparatus for hosting the remote pilot and her/his device to teleoperate the UAS.

3.1.12 *controlled flight, n*—a condition whereby the remote pilot or onboard systems or both, have the ability to perform functions to the extent necessary to continue safe flight and landing, but not necessarily full functional performance.

3.1.13 *demonstration, n*—technique used to demonstrate correct operation of the submitted element against operational and observable characteristics without using physical measurements (no or minimal instrumentation or test equipment). It generally consists of a set of tests selected by the supplier to show that the element response to stimuli is suitable or to show that operators can perform their assigned tasks when using the element. Observations are made and compared with predetermined/expected responses.

3.1.14 *design maximum aircraft weight,* W_{MAX}, *n*—aircraft design maximum weight for unmanned aircraft shall be the highest weight at which compliance with each applicable structural loading condition and all requirements for flight regimes is shown.

3.1.15 *Electric Propulsion Unit, EPU, n*—any electric motor and all associated devices used to provide thrust for an electric aircraft.

3.1.16 *Energy Storage Device, ESD, n*—used to store energy as part of an Electric Propulsion Unit (EPU). Typical energy storage devices include but are not limited to batteries, fuel cells, or capacitors.

3.1.17 *envelope protection, n*—the human-machine interface extension of an automatic flight control system that

[4] Available from U.S. Government Publishing Office, 732 N. Capitol St., NW, Washington, DC 20401, http://www.gpo.gov.

[5] Available from Joint Authorities for Rulemaking of Unmanned Systems (JARUS), http://www.jarus-rpas.org.

[6] Available from Unmanned Systems Canada, PO Box 81055, Ottawa, Ontario, K1P 1B1, https://www.unmannedsystems.ca.

prevents the remote pilot from making control commands that would force the aircraft to exceed its structural and aerodynamic operating limits. UAS with envelope protection are intended for non-acrobatic operation. Non-acrobatic operation includes: any maneuver incident to normal flying; stalls (except whip stalls); and lazy eights, chandelles, and steep turns, in which the angle of bank is not more than 60°.

3.1.18 *expanded operations, n*—UAS operations that typically require authorization from the CAA (for example, Operations Authorization for Specific Category UAS or Part 107 Certificate of Waiver/Authorization) with specific limitations adapted to the operation.

3.1.19 *extremely improbable, n*—a probability no greater than one occurrence every 1 000 000 (10^{-6}) flight hours.

3.1.20 *extremely remote probability, n*—a probability no greater than one occurrence every 100 000 (10^{-5}) flight hours.

3.1.21 *flight-critical system, n*—a system that, should it fail, will cause loss of control of the UA, or the UA will no longer stay capable of continued safe flight.

3.1.22 *flight manual, FM, n*—manual describing the operation of the aircraft and includes any limitations; normal, abnormal, and emergency procedures; and provides specific facts, information, or instructions, or combinations thereof, about a particular aircraft and the operation of that aircraft. **F44**

3.1.22.1 *Discussion*—For airplanes, this is identified as an airplane flight manual (AFM). For UAS, this is identified as an unmanned aircraft flight manual (UFM).

3.1.23 *flight manual supplement, FMS, n*—document that provides supplemental information, usually for equipment that is not part of the basic aircraft and included in the main flight manual.

3.1.24 *flight termination system, n*—a system that terminates the flight of a UAS in the event that all other contingencies have been exhausted and further flight of the aircraft cannot be safely achieved, or other potential hazards exists that immediate discontinuation of flight.

3.1.25 *flight training supplement, FTS, n*—document providing guidance for training for unmanned aircraft.

3.1.26 *fly-away, n*—flight outside of operational boundaries (altitude/airspeed/lateral limits) as the result of a failure, interruption, or degradation of the control station or onboard systems, or both.

3.1.27 *fly-away protection system, n*—system that will safely recover the sUA, or keep the sUA within the intended operational area, in the event of a fly-away as defined in 3.1.26.

3.1.28 *geo-fence*—a virtual geographic boundary, defined by location-based services, that enables software to trigger a response when a mobile device enters or leaves a particular area.

3.1.29 *ground roll distance, n*—the horizontal distance between start of takeoff or at a low height above ground (as used in rail-assisted launch), or both, and should be of sufficient distance to allow the UA to gain the manufacture's published climb-out speed (that is, the point when V_T is reached). This may begin at the release of brakes (that is, with traditional aircraft) or at the point of launch (for example, via hand-launch or catapult system). Alternatively referred to as "departure roll."

3.1.30 *improbable, n*—a probability no greater than one occurrence every 100 flight hours (10^{-2}).

3.1.31 *inspection, n*—technique based on visual or dimensional examination of an element; inspection is generally non-destructive, and typically includes the use of sight, hearing, smell, touch, and taste, simple physical manipulation, mechanical and electrical gauging, and measurement. No stimuli (tests) are necessary. The technique is used to check properties or characteristics best determined by observation (for example, paint color, weight, documentation, listing of code, etc.).

3.1.32 *lightweight UAS, n*—unmanned small aircraft that are approved for operation under the authority of a CAA (for example, UAS approved to operate by the FAA under 14 CFR Part 107, UAS approved to operate by EASA as Open and Specific Category UA, and UAS approved to operate by CASA as Small, Medium, or Large RPA, or combinations thereof).

3.1.33 *loads:*

3.1.33.1 *flight load, n*—those loads experienced within the operational flight envelope.

3.1.33.2 *ground handling load, n*—those loads experienced during regular operation while the aircraft is not in flight (for example, assembly, flight preparation, taxi, and maintenance).

3.1.33.3 *launch and recovery load, n*—those loads experienced during normal launch and recovery.

3.1.33.4 *landing loads, n*—the load exerted upon an aircraft at touchdown or upon a runway by an airplane during touchdown and in the landing roll.

3.1.33.5 *limit load, n*—the maximum load experienced in the normal operation and maintenance of the UA.

3.1.33.6 *load factor, n*—the ratio of a specified load to the total weight of the aircraft. The specified load is expressed in terms of any of the following: aerodynamic forces, inertia forces, or ground or water reactions.

3.1.33.7 *ultimate load*—limit load multiplied by the factor of safety (as determined by the CAA, but heuristically 1.5).

3.1.34 *loss of tailrotor effectiveness, n*—an unanticipated yaw is defined as an uncommanded, rapid yaw towards the advancing blade that does not subside of it's own accord.

3.1.35 *maneuver time, T, n*—the maneuver time, *T*, should be the time required for the specific UA to execute a maneuver that ensures the point of closest approach of a conflicting aircraft remains outside the collision volume. The manufacturer of the UAS should determine and document this value or the means of how it is determined in real time.

3.1.36 *operational envelope, n*—the subset which bounds the full set of operational cases by all associated variables (for example, speed, altitude, attitude, etc.).

3.1.37 *out of ground effect, n*—condition where the downwash of air from the main rotor (or propellers of a vertical flight aircraft) is unable to react with a hard surface (the ground), and commonly begins at altitude above ground level of approximately 0.5 to 1.0 times the diameter of the main rotor (or propellers of a vertical flight aircraft).

3.1.38 *payload, n*—any instrument, mechanism, equipment, part, apparatus, appurtenance, or accessory, including communications equipment, that is installed in or attached to the aircraft, is not used or intended to be used in operating or controlling an aircraft in flight, and is not part of an airframe, engine, or propeller.

3.1.39 *permanent deformation, n*—a condition whereby a UA structure is altered such that it does not return to the shape required for normal flight upon removal of external loads.

3.1.40 *propeller, n*—a device for propelling an aircraft that has blades on an engine-driven shaft and that, when rotated, produces by its action on the air, a thrust approximately perpendicular to its plane of rotation. It includes control components normally supplied by its manufacturer, but does not include main and auxiliary rotors or rotating airfoils of engines.

3.1.41 *propulsion system, n*—consists of one or more power plants (for example, a combustion engine or an electric motor and, if used, a propeller or rotor) together with the associated installation of fuel system, control and electrical power supply (for example, batteries, electronic speed controls, fuel cells, or other energy supply).

3.1.42 *Remote Pilot-In-Command, RPIC, n*—person who is directly responsible for and is the final authority as to the operation of the UAS; has been designated as remote pilot in command before or during the flight of a UAS; and holds the appropriate CAA certificate for the conduct of the flight.

3.1.43 *remote probability, n*—a probability no greater than one occurrence every 10 000 flight hours (10^{-4}).

3.1.44 *rotor, n*—a propeller that is positioned to provide principle lift/vertical thrust and is capable of being driven entirely by action of the air when the rotorcraft is in motion (for example, autorotative state).

3.1.45 *shall versus should versus may, v*—use of the word "shall" means that a procedure or statement is mandatory and must be followed to comply with this specification, "should" means recommended, and "may" means optional at the discretion of the applicant/proponent.

3.1.45.1 *Discussion*—"Shall" statements are requirements and they include sufficient detail needed to define compliance (for example, threshold values, test methods, oversight, and reference to other standards). "Should" statements are provided as guidance towards the overall goal of improving safety and could include only subjective statements. "Should" statements also represent parameters that could be used in safety evaluations or could lead to development of future requirements, or both. "May" statements are provided to clarify acceptability of a specific item or practice and offer options for satisfying requirements.

3.1.46 *supplier, n*—any entity engaged in the design and production of components (other than a payload which is not required for safe operation of the UAS) used on a UAS.

3.1.47 *test, n*—designed collection of methods that are used collectively to evaluate the performance of or to identify the capability of a UAS' particular subsystem or functionality.

3.1.48 *test form, n*—form corresponding to a test method that contains fields for recording the testing results and the associated information.

3.1.49 *testing task or task, n*—activities well defined and specified according to an identified metric or an identified set of metrics for the testing UAS and operators to perform in order for the UAS' capabilities to be evaluated.

3.1.50 *tethered aircraft, n*—a configuration where the unmanned aircraft remains securely attached (tethered) via a physical link to a person, the ground or an object at all times while it is flying.

3.1.51 *trial, n*—numbered used to identify a series of repetitions that a UAS is required to succeed in a standard verification method for the results to meet the required statistical significance.

3.1.52 *vertical flight aircraft, n—also referred to as "VTOL" or "vertical takeoff and landing aircraft,"* aircraft capable of vertical or near-vertical takeoffs and landings. Vertical-lift aircraft include:

3.1.52.1 *fan-in-wing aircraft*—fixed-wing aircraft with rotor fans in the wing to permit vertical or hover operations.

3.1.52.2 *powered-lift aircraft, n*—heavier-than-air aircraft capable of vertical takeoff, vertical landing, and low-speed flight that depends principally on engine-driven lift devices or engine thrust for lift during these flight regimes and on nonrotating airfoil for lift during horizontal flight.

3.1.52.3 *rotorcraft, n*—rotary-winged aircraft that lift vertically (to hover) and principally sustained in forward flight by power-driven rotor blades turning on a vertical axis.

3.1.52.4 *tiltrotor aircraft, n*—rotorcraft with the axes of the power-driven proprotor blades capable of pivoting from vertical for vertical takeoff, landing, and hover operations to horizontal to derive lift from the wing in cruise.

3.1.52.5 *tilt-wing aircraft, n*—rotorcraft with both the wing chord and the axes of the power-driven proprotor blades capable of pivoting from vertical for vertical takeoff, landing, and hover operations to horizontal to derive lift from the wing in cruise.

3.1.52.6 *vertical lift aircraft, n*—heavier-than-air aircraft capable of vertical takeoff, vertical landing, and flight that depends principally on engine-driven lift devices or engine thrust for lift during these flight regimes.

3.1.52.7 *vortex ring state, n—also referred to as "settling with power,"* an aerodynamic condition when a vortex ring system engulfs the rotor (or propellers of a vertical flight aircraft) causing severe loss of lift. Vertical lift aircraft with higher disk loading and increased blade twist are more susceptible to vortex ring state.

3.1.53 *warning, n*—a condition that requires immediate flight crew awareness and immediate flight crew response.

3.1.54 The terms "engine" referring to internal combustion engines and "motor" referring to electric motors for propulsion are used interchangeably within this specification.

3.1.55 The term "engine idle" or "throttle closed," when in reference to electric propulsion units, shall mean the minimum power or propeller rotational speed condition for the electric motor as defined without electronic braking of the propeller rotational speed.

3.2 *Abbreviations:*

3.2.1 *ADS-B*—Automatic Dependent Surveillance Broadcast

3.2.2 *AR*—aspect ratio

3.2.3 *AFCS*—Automated Flight Control System

3.2.4 *b*—wing span (m)

3.2.5 *c*—chord (m)

3.2.6 *CASA*—Civil Aviation Safety Authority (Australia)

3.2.7 *CAS*—calibrated air speed (m/s, kts)

3.2.8 C_L—lift coefficient of the fixed-wing UA

3.2.9 C_D—drag coefficient of the fixed-wing UA

3.2.10 *CG*—center of gravity

3.2.11 C_m—moment coefficient (C_m is with respect to c/4 point, positive nose up)

3.2.12 C_{MO}—zero lift moment coefficient

3.2.13 C_n—normal coefficient

3.2.14 C_{nA}—fixed-wing UA normal force coefficient

3.2.15 *EASA*—European Aviation Safety Agency

3.2.16 *FAA*—Federal Aviation Administration (FAA)

3.2.17 *g*—acceleration as a result of gravity = 9.81 m/s^2

3.2.18 *IAS*—indicated air speed (m/s, kts)

3.2.19 *ICAO*—International Civil Aviation Organization

3.2.20 *MAC*—mean aerodynamic chord (m)

3.2.21 *n*—load factor

3.2.22 n_1—fixed-wing UA positive maneuvering limit load factor

3.2.23 n_2—fixed-wing UA negative maneuvering limit load factor

3.2.24 n_3—load factor on wheels

3.2.25 *NIST*—National Institute for Standards and Technology

3.2.26 *P*—power, (kW)

3.2.27 ρ—air density (kg/m^3) = 1.225 at sea level standard conditions

3.2.28 *POH*—Pilot Operating Handbook

3.2.29 *q*—dynamic pressure

3.2.30 *RC*—climb rate (m/S)

3.2.31 *S*—wing area (m^2)

3.2.32 *TCAS*—Traffic Collision Avoidance System

3.2.33 *V*—airspeed (m/s)

3.2.34 V_A—design maneuvering speed

3.2.35 V_B—design speed for maximum gust intensity

3.2.36 V_C—design cruising speed

3.2.37 V_D—design diving speed

3.2.38 V_{DF}—demonstrated flight diving speed

3.2.39 V_F—design flap speed

3.2.40 V_{FE}—maximum flap extended speed

3.2.41 V_H—maximum speed in level flight with maximum continuous power (corrected for sea level standard conditions)

3.2.42 V_{MC}—minimum controllable airspeed

3.2.43 V_{NE}—never exceed speed

3.2.44 V_O—operating maneuvering speed

3.2.45 V_R—ground gust speed

3.2.46 V_S—stalling speed or minimum steady flight speed at which the fixed-wing UA is controllable (flaps retracted)

3.2.47 V_{S0}—stalling speed or minimum steady flight speed at which the aircraft is controllable in a landing configuration

3.2.48 V_{S1}—stalling speed or minimum steady flight speed at which the aircraft is controllable in a specific configuration

3.2.49 V_{SE}—for multiengine UA, the airspeed at which the aircraft remains capable of controlled flight the minimum number of required operational propulsion systems

3.2.50 V_X—speed for best angle of climb

3.2.51 V_Y—speed for best rate of climb

3.2.52 *w*—average design surface load (N/m^2)

3.2.53 *W*—maximum takeoff or maximum design weight (N)

3.2.54 W_E—maximum empty fixed-wing UA weight (N)

3.2.55 W_U—minimum useful load (N)

3.2.56 W_{ZWF}—maximum zero wing fuel weight (N)

3.2.57 *W/S*—wing loading (p.s.f.) due to the applicable weight of the fixed-wing aircraft in the particular load case.

4. Significance and Use/Applicability

4.1 This specification is intended for lightweight UAS permitted to operate over a defined area and in airspace authorized by a nation's civil aviation authority (CAA) with a fully interactive ground based person as "Remote Pilot in Command."

4.2 The baseline covered by this specification should not require an authorization by a Civil Aviation Authority for the flight but stay within defined boundaries for the operation (for example, distance from airports, from people, maximum weight, altitude, airspeed and operational envelope). However, unless otherwise allowed by a nation's CAA or subject to voluntarily compliance by an applicant, this specification applies to UA that:

4.2.1 Have a maximum takeoff gross weight of less than 55 lb (25 kg), including everything that is on board or otherwise attached to the aircraft, and

4.2.2 Are remotely piloted (that is, flown without the possibility of direct human intervention from within or on the aircraft), and

4.2.3 Conduct Expanded Operations that typically require authorization from the CAA (for example, Operations Authorization for Specific Category UAS or Part 107 Certificate of Waiver/Authorization) with specific limitations adapted to the operation.

4.3 These requirements apply to unmanned aircraft systems that are:

4.3.1 *Fixed-Wing*—Heavier than air and supported in flight by the dynamic reaction of the air against its wings. The UA may be powered or unpowered; the UA may have rigid, semi-rigid, or flexible wings.

4.3.2 *VTOL*—Heavier than air and capable of vertical or near-vertical takeoffs and landings. The rotor system may be powered or unpowered; Rotors may be either fixed collective pitch or collective pitch control that are not adjustable in flight. Reference 3.1.52 for characteristics by category of vertical flight aircraft.

4.3.3 Hybrid UAS (that is, incorporating gyrodyne or powered-lift flight modes) are recommended to follow the most restrictive aspects of this specification.

5. Flight

5.1 *Proof of Compliance:*

5.1.1 Each applicant who claims compliance to this specification shall be able to show compliance with the applicable requirements of this specification.

5.1.2 The applicant shall determine and document in the aircraft flight manual appropriate operating limitations and other information necessary for safe operation of the system.

5.1.3 Each of the following requirements shall be met at the most critical weight and CG configuration.

5.1.4 Unless otherwise specified, the speed range from stall to V_{DF} or the maximum allowable speed for the configuration being investigated shall be considered.

5.1.4.1 V_{DF} shall be less than or equal to V_D.

5.1.4.2 If V_{DF} chosen is less than V_D, V_{NE} shall be less than or equal to 0.9 V_{DF} and greater than or equal to 1.1 V_C.

5.1.5 The following tolerances are acceptable during flight testing:

Weight	+5 %, –10 %
Weight, when critical	+5 %, –1 %
CG	±7 % of total travel

5.2 *Load Distribution Limits:*

5.2.1 The maximum weight shall be determined so that it is not more than:

5.2.1.1 The highest weight selected by the applicant,

5.2.1.2 The design maximum weight, and

5.2.1.3 HOGE at standard atmosphere conditions (59 °F (15 °C)) and sea level pressure altitude.

5.2.2 The design empty weight shall be specified by the applicant.

5.3 *Empty Weight and Corresponding CG:*

5.3.1 The applicant shall determine the permissible range of weight and positions of the center of gravity of the UA.

5.4 *Propeller Speed and Pitch Limits*—Propeller speed (RPM) and pitch shall not be allowed to exceed safe operating limits established by the manufacturer under normal conditions (that is, maximum takeoff RPM during takeoff and 110 % of maximum continuous RPM at closed throttle and V_{NE}.

5.5 *Flight Characteristics:*

5.5.1 *Controllability and Maneuverability:*

5.5.1.1 The aircraft shall be safely controllable and maneuverable during takeoff, climb, level flight (cruise), dive to V_{DF} or the maximum allowable speed for the configuration being investigated, approach, and landing (power off and on, flaps retracted and extended, etc.) through the normal use of primary controls.

5.5.1.2 The aircraft shall be safely controllable and maneuverable during all flight phases including, where applicable:

(1) Taxi or Hover Taxi;
(2) Takeoff or Launch;
(3) Climb;
(4) Level flight;
(5) Descent;
(6) Go-around;
(7) Landing or Recovery; and
(8) At all permissible aircraft speeds and in all permissible aircraft configurations.

5.6 *VTOL:*

5.6.1 *Rotor Speed and Pitch Limits:*

5.6.1.1 *Main Rotor Speed Limits*—A range of main rotor speeds shall be established that:

(1) With power on, provides adequate margin to accommodate the variations in rotor speed occurring in any appropriate maneuver, and is consistent with the kind of governor or synchronizer used; and

(2) With power off, allows each appropriate auto-rotative maneuver to be performed throughout the ranges of airspeed and weight for which certification is requested.

5.6.1.2 *Normal Main Rotor High Pitch Limits (Power On)*—For rotorcraft, except helicopters required to have a main rotor low-speed warning, it shall be shown with power on and without exceeding approved engine maximum limitations, that main rotor speeds substantially less than the minimum approved main rotor speed shall not occur under any sustained flight condition. This shall be met by:

(1) Appropriate setting of the main rotor high pitch stop;

(2) Inherent rotorcraft characteristics that make unsafe low main rotor speeds unlikely; or

(3) Adequate means to warn the remote pilot of unsafe main rotor speeds.

5.6.1.3 *Normal Main Rotor Low Pitch Limits (Power Off)*—It shall be shown, with power off, that:

(1) The normal main rotor low pitch limit provides sufficient rotor speed, in any auto-rotative condition, under the most critical combinations of weight and airspeed; and

(2) It is possible to prevent overspeeding of the rotor without requiring exceptional piloting skill.

5.6.1.4 *Emergency High Pitch*—If the main rotor high pitch stop is set to meet subparagraph (b)(1), and if that stop cannot be exceeded inadvertently, additional pitch may be made available for emergency use.

5.6.1.5 *Main Rotor Low-Speed Warning for Helicopters*—There shall be a main rotor low-speed warning that meets the following requirements:

(1) The warning shall be furnished to the remote pilot in all flight conditions, including power-on and power-off flights, when the speed of a main rotor approaches a value that can jeopardize safe flight.

(2) The warning shall be furnished by a device.

(3) The warning shall be clear and distinct under all conditions, and should be clearly distinguishable from other warnings. A visual device that requires the attention of the remote pilot is not acceptable by itself.

(4) The warning device shall automatically deactivate and reset when the low-speed condition is corrected. If the device has an audible warning, it should also be equipped with a means for the remote pilot to manually silence the audible warning before the low-speed condition is corrected.

5.6.2 *Height/Velocity Envelope:*

5.6.2.1 The applicant shall establish the combinations of height and forward airspeed from which a safe landing cannot be made following engine failure as a limiting height-speed envelope (graph) for vertical lift aircraft.

5.6.2.2 The height-speed envelope graph must be included in the UFM.

6. Performance

6.1 *Fixed-Wing:*

6.1.1 *Stalling Speed:*

6.1.1.1 For UA that does not employ flight envelope protection, 6.1.1.2 and 6.1.1.3 shall be determined.

6.1.1.2 Wing level stalling speeds V_{S0} and V_S shall be determined by the manufacturer for a specific aerodynamic configuration or as determined by the installed flight envelope protection (for example, be determined with the engine idling, propeller in the takeoff position, and the cowl flaps closed).

6.1.1.3 Wing level stalling speeds V_{S0} and V_S should be determined by flight test at a rate of speed decrease of 1 knot/s or less, throttle closed, with maximum takeoff weight, and most unfavorable CG.

6.2 *Takeoff*—With takeoff at the maximum weight, full throttle, sea level, the following shall be measured:

6.2.1 Ground roll distance; and,

6.2.2 Distance to clear a 50 ft (15.2 m) obstacle at 1.3 V_{S1}.

6.3 *Climb:*

6.3.1 At maximum takeoff weight, flaps in the position specified for climb within the POH, and full throttle, the minimum rate of climb shall exceed 200 ft/min (1.0 m/s).

6.3.2 Rate of climb at V_Y should exceed 315 ft/min (1.6 m/s).

6.3.3 Climb gradient at V_X should exceed ½ .

6.4 *Landing*—The following shall be determined:

6.4.1 Landing distance from 50 ft (15 m) above ground when speed at 50 ft (15 m) is 1.3 V_{S0};

6.4.2 Ground rolls distance described in 6.4.1 shall be achieved with braking, if so equipped.

6.5 *Multi-Engine:*

6.5.1 For UA with multiple motors, the applicant shall determine the minimum number of operational motors required to maintain normal operation.

6.5.2 The applicant shall determine the minimum controllable airspeed (V_{MC}) for most critical configuration used in takeoff and landing operations.

6.5.3 The applicant shall comply with 6.3 for each possible permutation of operational motors.

6.6 *VTOL Performance:*

6.6.1 *Hover Taxi.*

6.6.2 *Takeoff*—With takeoff at the maximum weight, full throttle, sea level, the distance(s) required from rest to takeoff and climb to 50 ft (15 m) above the takeoff surface with zero wind shall be measured.

6.6.3 *Climb:*

6.6.3.1 At maximum takeoff weight and full throttle, the minimum rate of climb shall exceed 200 ft/min (1.0 m/s).

6.6.3.2 Rate of climb at V_Y should exceed 315 ft/min (1.6 m/s).

6.6.3.3 Climb gradient at V_X should exceed 1⁄12 .

6.6.4 *Landing*—The following shall be determined:

6.6.4.1 The distance required to land and come to rest from a point 50 ft (15 m) above the landing surface, with zero wind, and

6.6.4.2 The approach airspeed to achieve this performance.

6.6.5 *Multi-Engine:*

6.6.5.1 For UA with multiple motors, the applicant shall determine the minimum number of operational motors required to maintain normal operation.

6.6.5.2 The applicant shall determine the minimum controllable airspeed (V_{MC}) for most critical configuration used in takeoff and landing operations.

6.6.5.3 The applicant shall comply with 6.6.3 for each possible permutation of operational motors.

6.6.6 *Autorotation*—If autorotation capability is implemented to fulfill the requirements of 6.6.5, the minimum rate of descent airspeed and the best angle-of-glide airspeed shall be determined in autorotation at:

6.6.6.1 Maximum weight; and

6.6.6.2 Rotor speed(s) selected by the applicant.

7. Design

7.1 *General:*

7.1.1 All system components required for the safe operation of the UA shall be designed and constructed to:

7.1.1.1 Be appropriate to their intended function, and

7.1.1.2 Function properly when installed.

7.1.2 The UAS shall be designed and constructed to minimize the likelihood of fire, explosion, or the release of hazardous chemicals, materials, and flammable liquids or gasses, or a combination thereof, in flight or in the event of a crash, hard landing, or ground handling mishap. This includes, but is not limited to: containing the fire if the UA crashes; use of flame resistant materials; and protection against battery-induced fires.

7.2 *Equipment, Systems, and Installation:*

7.2.1 *General Function:*

7.2.1.1 Each item of equipment, each system, and each installation shall be designed and constructed so that, it does not adversely affect the response, operation, or accuracy of any equipment required for the safe operation of the UAS.

FIG. 1 ICAO Class 9 Lithium Battery Label

7.2.1.2 Each item of installed equipment in a UA shall:

(1) Be of a kind and design appropriate to its intended function;

(2) Be labelled as to its identification, function, or operating limitations, or any applicable combination of these factors, if appropriate. Small items that preclude readable labels should be easily identified via a schematic/installation drawing which depicts the item via an illustrated diagram and parts list;

(3) Be installed according to limitations specified for that equipment; and

(4) Function properly, and as designed, when installed.

7.2.1.3 There shall be a means to assure that, prior to taxi and takeoff or launch, the UAS and its subsystems are operating correctly.

7.2.2 *Installation:*

7.2.2.1 Each item of equipment, each system, and each installation:

(1) When performing its intended function, shall not adversely affect the response, operation, or accuracy of any equipment essential to safe operation;

(2) Shall be designed to minimize hazards to the safe operation of the UA in the event of a probable malfunction or failure.

NOTE 1—"Probable" above refers to malfunctions that have a reasonable likelihood of occurring, or can be envisioned to occur.

7.2.2.2 If a single failure of an UA system could result in the loss of control of the UA trajectory:

(1) The probability of such a failure under all expected operating conditions shall be extremely remote, or

(2) There shall be a means of initiating flight-termination in the event of such a failure, or

(3) There shall be an alternate means of regaining control.

7.3 *Materials and Workmanship:*

7.3.1 The suitability and durability of materials used for parts, the failure of which could adversely affect safety, shall:

7.3.1.1 Be established based on intrinsic material properties or tests;

7.3.1.2 Conform to approved specifications (such as industry or military specifications, or Technical Standard Orders) that ensure their having the strength and other properties assumed in the design data; and

7.3.1.3 Consider the effects of environmental conditions, such as temperature and humidity, expected in service.

7.3.2 Design values (strength) shall be chosen so that no structural part is under strength because of material variations or load concentration, or both.

7.4 *Airframe:*

7.4.1 The UA shall be designed and constructed so that it is possible to determine during preflight that all external doors, panels, and hatches are in the position for safe flight.

7.5 *Structure:*

7.5.1 The UA structure shall be designed and constructed so that:

7.5.1.1 The structure shall not fail at ultimate load. This shall be verified either through analysis or testing.

7.5.1.2 The UA and systems required for continued safe flight shall be designed to be capable of supporting limit loads throughout the operating envelope to include atmospheric gusts or maneuvering loads, or both.

7.5.1.3 The UA and systems required for continued safe flight shall be designed to withstand landing loads without damage that would affect safety of flight of subsequent flights unless it can be maintained, repaired, and inspected as per procedures that will ensure continued safe operation.

7.5.2 *Protection of Structure:*

7.5.2.1 Protection of the structure against weathering, corrosion, and wear, as well as suitable ventilation and drainage, shall be provided as required.

7.5.2.2 Design precautions shall be taken to minimize the hazards associated with exposed rigid sharp structural objects.

7.5.2.3 For those systems that might have components capable of causing injury, the UA shall be designed with appropriate placards alerting the crew to the risk.

7.5.2.4 Energy absorbing structure should be used where practical.

7.5.2.5 Refer to A2.2.1 for additional guidance on energy absorbing structure.

7.6 *Airspeed Limitations:*

7.6.1 All flight speeds shall be stated in terms of indicated airspeed (IAS).

7.6.2 Ground speed displays shall be clearly marked to prevent interpretation as air speeds.

7.7 *Weight and Center of Gravity:*

7.7.1 Weight and center of gravity limitations shall be provided, including reference and leveling data.

7.8 *Loads and Dynamics:*

7.8.1 *Factors of Safety*—Representative limit load cases shall be demonstrated to prove compliance with a 1.5 safety factor.

7.8.2 *Control Surface and System Loads:*

7.8.2.1 The applicant shall determine the minimum torque requirement for the mechanical output of UA control surfaces.

7.8.2.2 Binding, chafing, or jamming of controls, actuators, and control surfaces shall not occur at less than or equal to the limit load threshold.

7.8.2.3 The UAS shall be designed so that the UA can be operated within the confines of the defined operational envelope without exceptional pilot skill.

7.8.3 *Stability:*

7.8.3.1 The UA shall be designed to be longitudinally, directionally, and laterally positively statically able for all weight and CG positions in the operational flight envelope.

7.9 *Propulsion System:*

7.9.1 *Installation:*

7.9.1.1 The propulsion system shall be designed to operate throughout the flight envelope.

7.9.1.2 The propulsion system shall be designed to conform to the installation instructions.

7.9.2 *Propulsion: Powerplant, Engines, and Motors:*

7.9.2.1 Powerplant limitations shall be provided.

7.9.2.2 The UA shall be designed to initialize in a known, safe state when power is applied and consistent with whether the UA is on the ground or already airborne.

7.9.2.3 The UA's propulsion system shall be designed such that its temperature remains within its design operating limitations throughout its flight envelope.

7.9.2.4 The propulsion system should be designed to minimize failure for reasons other than insufficient fuel or electrical power and to support normal operations throughout the anticipated lifecycle of the system.

7.9.2.5 The system shall include a means for shutting down the engine on the UA during an emergency.

7.9.2.6 For aircraft using electric propulsion systems, the system shall include a means to determine the capacity remaining in the ESD.

7.9.2.7 *Performance with One Propulsion System Inoperative:*

(1) The UA should be designed so that in the event of propulsion system failure:

(a) The flight path can be controlled, or

(b) The system defaults to a safe automated recovery procedure.

(2) For UA with multiple propulsion systems, the UA should be designed and constructed so that in the event of a singular or multiple propulsion system failure:

(a) The aircraft remains capable of controlled flight, or

(b) The descent flight path can be controlled from the control station, or

(c) The system defaults to a safe automated recovery procedure.

7.9.3 *EPU Wiring:*

7.9.3.1 If the aircraft is provided with a EPU then:

(1) Wiring must be properly supported to prevent excessive vibration and withstand loads due to inertial forces during flight.

(2) Wiring carrying the power consumed by the electric motor must be supported such that any possibility for wire chafing, shorting, or adverse contact with the airframe is eliminated.

(3) Wiring connected to components of the aircraft, between which relative motion could exist, must have provisions for flexibility.

7.9.4 *Fuel and Oil System*—For UA using a combustion propulsion system:

7.9.4.1 The fuel and oil systems shall be designed and constructed to be capable of supplying adequate fuel and oil to the propulsion system throughout the entire flight envelope.

7.9.4.2 All items that are intended to be exposed to fuel, oil, and lubricating grease shall be resistant to deterioration.

7.9.4.3 Each fuel system and oil system shall be designed to be able to withstand ultimate loads; and

7.9.4.4 Each fuel system shall be designed so that it can be serviced when the aircraft is on the ground.

7.9.5 *Energy Storage Devices:*

7.9.5.1 The UA shall be designed with a redundant ESD system with sufficient stored power that the minimal configuration of the ESD packs could safely fly the UA to a safe landing area.

NOTE 2—The use of electric propulsion units has led to design trends towards the blending of the essential and non-essential bus as it relates to the electric system and propulsion system. The requirement of 7.9.5.1 is intended to reduce the probability that a non-critical electrical failure results in a critical propulsion failure. The applicant should adhere to Specification F3005 for design requirements of the energy storage devices.

7.9.5.2 The system should be arranged so that multiple batteries operate together and includes redundant wiring.

7.9.5.3 *Batteries:*

(1) Designating Level of Conformance—The system designer shall determine which battery packs in the system are to

be designated as safety-critical. If catastrophic failure of a pack in any part of the UAS can reasonably be expected to jeopardize safety, the designer shall designate that battery pack as safety-critical. A battery designated as safety-critical must fully conform to F3005 Standard Specification for Batteries for Use in Small Unmanned Aircraft Systems. If a battery is not to be designated as safety-critical, a nonconforming pack may be used in that part of the system, but a reasonable level of diligence shall be exercised to mitigate the risks associated with a catastrophic failure of that battery.

(2) Mating Connectors—The system designer shall follow the provisions of F3005 Standard Specification for Batteries for Use in Small Unmanned Aircraft Systems in selecting mating connectors for safety-critical battery packs. The system designer shall ensure that the means employed to prevent separation of the battery connector during normal operations is adequately suitable to withstand vibration and other expected conditions. Connectors shall include some means of preventing polarity reversal.

(3) Operating Environment—Any battery chosen (or designed) for the UAS shall be of sufficient design and construction such that it can be expected to remain within safe operational and performance limits during the most adverse temperature and vibration conditions in which the system is designed to operate. The UA itself shall include any system design features necessary to maintain the battery within those limits.

7.9.6 *Propulsion System Instruments:*

7.9.6.1 Propulsion system controls shall be designed to provide positive control and monitoring of the propulsion system safely under all operating conditions.

7.9.6.2 The controls for turning the propulsion system on or off shall guard against inadvertent operation.

7.9.6.3 The propulsion system onboard the UA should be designed to provide inflight fuel quantity indication for combustion propulsion or state of charge indication for electric propulsion.

7.10 *Required Equipment / On-Board Subsystems:*

7.10.1 *Command and Control Systems:*

7.10.1.1 The UAS shall be designed to allow the remote pilot in command to positively control the trajectory of the UA under normal operating conditions.

7.10.1.2 *Automatic Flight Control System:*

(1) If an automatic flight control system is installed, it shall meet the requirements of 10.3.

(2) The UAS design should include a means to determine airspeed or groundspeed, as applicable, and altitude.

(3) If a pitot static system is used it will be inspected and calibrated as required at an interval defined by the manufacturer.

(4) The UAS should be capable of down linking data concerning flight, propulsion system, and navigation parameters as identified in this specification.

(5) The system should be designed and constructed so that the aircraft remains controllable or automatically initiates a predictable and safe maneuver in the event of the failure of any flight critical component or system.

7.10.2 *Electrical System:*

7.10.2.1 The electrical system shall be designed so that:

(1) There is a means to monitor the electrical system;

(2) The electrical wiring shall be designed according to the load of each circuit;

(3) Circuit protective devices are incorporated where necessary to isolate overloaded conditions that could affect continued safe flight.

(4) Loosening of connections over the range of vibrations expected is prevented; and

(5) Design precautions shall be taken to minimize the possibility of incorrect assembly of components and equipment essential to safe operation of the UA, except where operation with the incorrect assembly can be shown to be extremely improbable.

7.10.2.2 If there is provision for applying external electrical power to the aircraft when on the ground, connection points shall be adequately labeled with respect to current and voltage and polarity limitations.

7.10.3 *Anti-Collision Lights:*

7.10.3.1 The UA should have an anti-collision light system that consists of one or more anti-collision lights located so that their light will not impair the flight crewmembers' vision or detract from the conspicuity of the position lights.

7.10.3.2 The UA should have lighted anti-collision lighting visible for at least three statute miles.

7.10.3.3 The UA should have enough lights to illuminate the vital areas around the UA, considering the physical configuration and flight characteristics of the UA.

7.10.3.4 The field of coverage should extend in each direction within at least 75° above and 75° below the horizontal plane of the UA, except that there may be solid angles of obstructed visibility totaling not more than 0.5 steradians.

7.10.3.5 Each light color should have the applicable International Commission on Illumination chromaticity coordinates as follows:

(1) Aviation Red—y is not greater than 0.335; and z is not greater than 0.002.

(2) Aviation Green—x is not greater than $0.440 - 0.320\,y$; x is not greater than $y - 0.170$; and y is not less than $0.390 - 0.170\,x$.

(3) Aviation White—x is not less than 0.300 and not greater than 0.540; y is not less than "$x - 0.040$" or "$y_0 - 0.010$," whichever is the smaller; and y is not greater than "$x + 0.020$" nor "$0.636 - 0.400x$" where y_0 is the y coordinate of the Planckian radiator for the value of x considered.

(4) The minimum light intensities in any vertical plane, measured with the red filter (if used) and expressed in terms of "effective" intensities is 80 candles.

7.10.4 *Position Lights:*

7.10.4.1 Left and right position lights should consist of a red and a green light spaced laterally as far apart as practicable and installed on the UA such that, with the UA in the normal flying position, the red light is on the left side and the green light is on the right side.

7.10.4.2 The rear position light should be a white light mounted as far aft as practicable on the tail or on each wing tip.

7.10.5 *Landing Gear:*

7.10.5.1 The landing gear, if any, shall be designed and constructed to accommodate landing loads without damage to the structure. This does not apply to frangible components.

7.10.5.2 Frangible landing gear, if any, shall be designed and constructed to accommodate landing loads without unintended damage to the structure.

7.10.5.3 If the landing gear is retractable and its status cannot be confirmed visually, there should be a means to determine the state of landing gear.

7.11 *Fixed-Wing Design:*

7.11.1 *Loads and Dynamics:*

7.11.1.1 The UA shall be designed so that the UA will remain controllable and predictable or capable of performing a safe recovery maneuver in the event of asymmetric deployment of any single, normal control surface as well as high-lift/drag devices (trailing edge flaps, leading edge flaps or slats, spoilers, falperons, and the like).

7.11.2 *Wings Level Stalls:*

7.11.2.1 The manufacturer shall design the UAS so that recovery from any departure from safe flight can be accomplished with an action that positively returns the aircraft to controlled flight or performs an automated recovery procedure.

7.11.2.2 The UA should be designed to prevent more than 20° of roll or yaw by normal use of the controls during the stall and the recovery at all weight and CG combinations.

7.11.2.3 The UA shall be designed to prevent more than 30° of roll or yaw by normal use of the controls during the stall and the recovery at all weight and CG combinations.

7.11.2.4 The loss of altitude from a stall shall be determined and listed in the POH.

7.11.2.5 Minor yaw (to to 5°) shall not have a significant influence on the stall characteristics.

7.11.3 *Propeller:*

7.11.3.1 The propeller limitations shall be established.

7.11.3.2 Propellers shall be designed to have adequate structural strength, static strength, and fatigue life.

7.11.3.3 Propulsion system shaft, propeller rotational speed, and propeller pitch shall be limited to values that will ensure safe operation under normal operating conditions.

7.11.3.4 Each part of the propeller shall be designed and constructed with considerations of likely in-service damage and wear.

7.11.3.5 The propeller shall be able to operate normally between inspection and overhaul periods.

7.11.3.6 The adjustment system of a ground-adjustable propeller shall be designed so that the UA will remain controllable and predictable or capable of performing a safe recovery maneuver in the event of asymmetric propeller blade pitch setting. Failure of structural elements need not be considered if the occurrence of such a failure is expected to be extremely remote.

7.11.4 *Required Equipment / On-Board Subsystems:*

7.11.4.1 For UA that are not equipped with automatic stall protection, a means should be provided at the control station to warn the remote pilot when the aircraft is approaching the stall.

7.11.4.2 The warning should be available to the remote pilot and be an audible or distinctive tone and a flashing visual indicator, and

7.11.4.3 Should be initiated when the aircraft is no less than 10 % above the stall speed/angle of attack.

7.12 *VTOL Design:*

7.12.1 *Rotor Components Factor:*

7.12.1.1 Each main rotor assembly (including rotor hubs and blades) must be designed as prescribed in this paragraph.

7.12.1.2 The main rotor structure must be designed to withstand the following loads:

(1) Critical flight loads, and

(2) Limit loads occurring under normal conditions of autorotation. For this condition, the rotor RPM must be selected to include the effects of altitude.

7.12.1.3 The main rotor structure must be designed to withstand loads simulating:

(1) For the rotor blades, hubs, and flapping hinges, the impact force of each blade against its stop during ground operation; and

(2) Any other critical condition expected in normal operation.

7.12.1.4 The main rotor structure must be designed to withstand the limit torque at any rotational speed including zero. In addition:

(1) The limit torque need not be greater than the torque defined by a torque-limiting device (where provided), and may not be less than the greater of:

(a) The maximum torque likely to be transmitted to the rotor structure in either direction; and

(b) The limit engine torque specified in Section 6.

(2) The limit torque must be distributed to the rotor blades in a rational manner.

7.12.2 *Flutter Prevention and Structural Stiffness:*

7.12.2.1 Each aerodynamic surface of the rotorcraft must be free from flutter under each appropriate speed and power condition.

7.12.2.2 Each major part of the vertical lift aircraft must be free from flutter and resonance, in both the free and fixed control mode at all airspeed and power conditions at speeds up to V_{NE}.

7.12.3 *Engine Torque:*

7.12.3.1 The limit torque may not be less than:

(1) For four-stroke engines, the mean torque for maximum continuous power multiplied by:

(a) 1.33, for engines with five or more cylinders, and

(b) 2, 3, 4, or 8, for engines with four, three, two, or one cylinder, respectively.

(2) For two-stroke engines, the mean torque for maximum continuous power multiplied by:

(a) 2 for engines with three or more cylinders, and

(b) 3 or 6, for engines with two or one cylinder, respectively.

(3) For rotary engines, the mean torque for maximum continuous power multiplied by:

(a) 1.33 for engines with three or more discs, and

(b) 2 or 4, for engines with two or one disc, respectively.

(4) For turbine engines, the mean torque for maximum continuous power multiplied by 1.25.

(5) For electrical engines, the maximum peak torque to be expected in the complete engine speed range.