

(4) During the FAA/AUTHORITY flight test program, the crew should be especially alert for conditions requiring great attentiveness, high skill levels, or exceptional strength. If any of these features appear marginal, it is advisable to obtain another pilot's opinion and to carefully document the results of these evaluations. Section 27.141(b) provides the regulatory basis for these strength and skill requirements. The general requirements for a smooth transition capability between appropriate flight conditions are also included in § 27.141(b). These requirements must also be met during appropriate engine failure conditions for each category of rotorcraft.

(5) For night or IFR approval, § 27.141(c) contains the general regulatory reference, which requires additional characteristics for night and IFR flight. The appropriate flight test procedures are included in other portions of this advisory circular.

b. Procedures. none

AC 27.143. § 27.143 (Amendment 27-21) CONTROLLABILITY AND MANEUVERABILITY.

[See new AC 27.143A (dated 9/17/2009) posted as separate document in RGL with this Master AC.]

a. Explanation.

(1) This regulation contains the basic controllability requirements for normal category rotorcraft. It also specifies a minimum maneuvering capability for required conditions of flight. The general requirements for control and for maneuverability are summarized in § 27.143(a) which is largely self-explanatory. The hover condition is not specifically addressed in § 27.143(a)(2) so that the general requirement may remain applicable to all rotorcraft types, including those without hover capability. For rotorcraft, the hover condition clearly applies under "any maneuver appropriate to the type."

(2) Paragraphs (b) through (e), § 27.143, include more specific flight conditions and highlight the typical areas of concern during a flight test program.

(i) Section 27.143(b) specifies flight at V_{NE} with critical weight, center of gravity (CG), rotor RPM, and power. Adequate cyclic authority must remain at V_{NE} for nosedown pitching of the rotorcraft and for adequate roll control. Nosedown pitching capability is needed for control of gust response and to allow necessary flight path changes in a nosedown direction. Roll control is needed for gust response and for normal maneuvering of the aircraft. In the past, 10 percent control travel margin has been applied as an appropriate minimum control standard. The required amount of control power, however, has very little to do with any fixed percentage of remaining control travel. There are foreseeable designs for which 5 percent remaining is adequate and others for which 20 percent may not be enough. The key is, can the remaining longitudinal control travel at V_{NE} generate a clearly positive nosedown pitching moment, and will the remaining lateral travel allow at least 30° banked turns at reasonable roll rates? Moderate lateral control reversals should be included in this evaluation and since available roll control can diminish with sideslip, reasonable out of trim conditions

(directionally) should be investigated. This “control remaining” philosophy must also be applied for other flight conditions specified in this section.

(ii) Section 27.143(c) requires a minimum control capability for hover and takeoff in winds of 17 knots from any azimuth. Control capability in wind from zero to at least 17 knots must also be shown for any other appropriate maneuver near the ground such as rolling takeoffs for wheeled rotorcraft. These requirements must be met from standard sea level conditions to the maximum altitude capability of the rotorcraft or 7,000 feet, whichever is less. On rotorcraft incorporating a tail rotor, efficiency of the tail rotor decreases with altitude so that a given sideward flight condition requires more pedal deflection, a higher tail rotor blade angle, and more horsepower. Hence, directional capability in sideward flight (or at critical wind azimuth) is most critical during testing at a high altitude site.

(iii) Section 27.143(d) requires adequate controllability when an engine fails. This requirement specifies conditions under which engine failure testing must be conducted and includes minimum required delay times.

(A) For rotorcraft which meet the engine isolation requirements of transport Category A, demonstration of sudden complete single-engine failure is required at critical conditions throughout the flight envelope including hover, takeoff, climb at V_Y , and high speed flight up to V_{NE} . Entry conditions for the first engine failure are engine or transmission limiting maximum continuous power (or takeoff power where appropriate) including reasonable engine torque splits. For multiengine Category A installations (three or more engines) subsequent engine failures should be conducted utilizing the same criteria as that used for first-engine failure. The applicant may limit his flight envelope for subsequent failures. Initial or sequential engine failure tests are ordinarily much less severe than the “last” engine failure test required by § 27.75(b). The conditions for last-engine failure are maximum continuous power, or 30-minute power if that rating is approved, level flight, and sudden engine failure with the same pilot delay of 1 second or normal pilot reaction time, whichever is greater.

(B) For rotorcraft without transport Category A engine isolation, demonstration of sudden complete power failure is required at critical conditions throughout the flight envelope. This includes speeds from zero to V_{NE} (power-on) and conditions of hover, takeoff, and climb at V_Y . Maximum continuous power is specified prior to the failure for the cruise condition. Power levels appropriate to the maneuver should be used for other conditions. The corrective action time delay for the cruise failure should be 1-second or normal pilot reaction time (whichever is greater). Cyclic and directional control motions which are apart of the pilot task of flight path control are normally not subject to the 1-second restriction; however, the delay is always applied to the collective control for the cruise failure. If the aircraft flying qualities and cyclic trim configuration would encourage routine release of the cyclic control to complete other cockpit tasks during cruise flight, consideration should be given to also holding cyclic fixed for the 1-second delay. Although the same philosophy could be extended to the directional controls, the likelihood of the pilot having his feet away from the pedals is

much lower, unless the aircraft has a heading hold feature. Rotor speed at execution of the cruise condition power failure should be the minimum power-on value. The term "cruise" also includes cruise climb and cruise descent conditions. Normal pilot reaction times are used elsewhere. Although this requirement specifies maximum continuous (MC) power, it does not limit engine failure testing to MC power. If a takeoff power rating is authorized for hover or takeoff, engine failure testing must also be accomplished for those conditions. Following power failure, rotor speed, flapping, and aircraft dynamic characteristics must stay within structurally approved limits.

(iv) Section 27.143(e) addresses the special case in which a V_{NE} (power-off) is established at an airspeed value less than V_{NE} (power-on). For this case, engine failure tests are still required at speeds up to and including V_{NE} (power-on), and the rotorcraft must be capable of being slowed to V_{NE} (power-off) in a controlled manner with normal pilot reactions and skill. There is, however, no controllability requirement for stabilized power-off flight at speeds above $1.1 V_{NE}$ (power-off) when V_{NE} (power-off) is established per § 27.1505(c).

(v) Application of the controllability requirement for pitch, roll, and yaw at speeds of $1.1 V_{NE}$ (power-off) and below is similar to that described above for power-on testing at V_{NE} . Sufficient directional control must exist to allow straight flight in autorotation during all approved maneuvers including 30° banked turns up to V_{NE} (power-off) with some small additional allowance for gust control. Adequate controllability margins must exist in all axes throughout the approved autorotative flight envelope. Testing to V_{NE} at MC power per § 27.143(b), $1.1 V_{NE}$ at power for $0.9 V_H$ per § 27.175(b) or § 27.1505, and to $1.1 V_{NE}$ (power-off) in autorotation per § 27.143(e) should be sufficient to assure adequate control margin during a descent condition at high speed and low power. The high speed, power-on descent condition should be checked for adequate control margin as a "maneuver appropriate to the type." There has been one instance where insufficient directional pedal was available to maintain a reasonable trimmed sideslip angle with low power at very high speeds, and a case where there was insufficient forward and lateral cyclic available to reach the power on V_{NE} . The insufficient directional pedal margin was due to the offset vertical stabilizers. The lack of cyclic stick margin was because the cyclic stick migrated to the right as power was reduced, and the control limits were circular. This provided less total available forward cyclic stick travel when the cyclic was moved right and forward about 45° from the center position. Each of the above rotorcraft was certificated with a rate of descent limitation to preclude operation in the control-limited area.

(vi) An evaluation of the emergency descent capability of the rotorcraft should be made, either analytically or through flight test. Areas of consideration are the rate of descent available, the maximum approved altitude, and the time before a catastrophic failure following the loss of transmission oil pressure or other similar failure. Each rotorcraft should have the capability to descend to sea level and land from the maximum certificated altitude within the time period established as safe following a critical failure. If the time period does not permit a sea level landing, the maximum

height above the terrain must be specified in the limitation section of the Rotorcraft Flight Manual.

(3) The required controllability and maneuvering capabilities must also be considered following the failure of automatic equipment used in the control system (§ 27.672). Examples include stability augmentation systems (SAS), stability and control augmentation systems (SCAS), automatic flight control systems (AFCS), devices to provide or improve longitudinal static stability such as a pitch bias actuator (PBA), yaw dampers, and fly-by-wire elevator or stabilator surfaces. These systems all use actuators of some type, and are subject to actuator softover and hardover malfunctions. The flight control system should be evaluated to determine whether an actuator jammed in an extreme position would result in reduced control margins. Generally, if the flight control system stops are between the actuator and the cockpit control, the control margin will be affected. If the control stops are between the actuator and the rotor head, the control margins may not be affected, but the location of the cockpit control may be shifted. This could produce interference with other items in the cockpit. An example of this would be a lateral actuator jammed hardover causing a leftward shift in the cyclic stick position. Interference between the cyclic stick, the pilot's leg, and the collective pitch control could reduce the left lateral control available and reduce left sideward flight capability. In the case of fly-by-wire surfaces, both the high speed forward flight controllability and the rearward flight capabilities could be affected. Flight control systems that incorporate automatic devices should be thoroughly evaluated for critical areas. Every failure condition that is questionable should be flight tested with the appropriate actuator fixed in the critical failure position. These failures may require limitations of the flight envelope. Any procedure or limitation that must be observed to compensate for an actuator hardover and/or softover malfunction should be included in the Rotorcraft Flight Manual.

b. Procedures.

(1) Flight test instrumentation should include ambient parameters, all flight control positions, rotor RPM, main and tail rotor flapping (if appropriate), engine power instruments, and throttle position. Flight controls that are projected to be near their limits of authority should be rigged to the most adverse production tolerance. A very accurate weight and balance computation is needed along with a precise knowledge of the aircraft's weight/CG variation as fuel is burned.

(2) The critical condition for V_{NE} controllability testing is ordinarily aft CG, MC power, and minimum power-on rotor RPM, although power and RPM variations should be specifically evaluated to verify their effects. The turbine engine is sensitive to ambient temperatures which affect the engine's ability to produce rated maximum continuous torque. Flight tests conducted at ambient temperatures that cause the turbine temperature to limit maximum continuous power would not produce the same results obtained at the same density altitude at colder ambient temperatures where maximum continuous torque would be limiting. Forward CG should be spot checked for any "tuck under" tendency at high speed. The V_{NE} controllability test is normally

accomplished shortly after the $1.1 V_{NE}$ (or $1.1V_H$) point obtained during stability tests required by § 27.175(b). Controllability must be satisfactory for both conditions. If V_{NE} varies with altitude or temperature, V_{NE} for existing ambient conditions is utilized for the test. Extremes of the altitude/temperature envelope should be analyzed and investigated by flight test.

(3) The critical condition for controllability testing in a hover is ordinarily forward CG at maximum weight with minimum power-on rotor RPM. For rearward flight testing of configurations where the forward CG limit varies with weight, low or high gross weight may be critical. Lateral CG limits should also be investigated. A calibrated pace vehicle is needed to assure stabilized flight conditions. Surface winds should be less than 3 knots throughout the test sequence. Testing can be done in higher stabilized wind conditions (gusting less than 3 knots); however, these conditions are very difficult to find and the method is very time consuming due to the necessity of waiting for stabilized winds. Testing in calm winds is preferred. Hover controllability testing should be accomplished with the lowest portion of the rotorcraft at the published hover height above ground level; however, the test altitude above the ground may be increased to provide reasonable ground clearance. Although the necessary yaw response will vary somewhat from model to model, sufficient control power should be available to permit a clearly recognizable yaw response after full directional control displacement when the rotorcraft is held in the most critical position relative to wind.

(4) Prior to engine failure testing, it is mandatory that the pilot be fully aware of his engine, drive system, and rotor limits. These limits were established during previous ground and flight tests and should be specified in the TIA. Particular attention should be given to minimum stabilized and minimum transient rotor RPM limits. These values must be included in the TIA and should be approached gradually with a build-up in time delay unless the company testing has completely validated all pertinent aspects of engine failure testing. On Category A installations, the maximum power output of each engine must be limited so that when an engine fails and the remaining engine(s) assume the additional load, the remaining engine(s) are not damaged by excessive power extraction and over-tempering. This is needed for compliance with § 27.903(b). The propulsion engineer should have assured that this feature was properly addressed in the engine and drive system substantiation; however, it must be assumed that for some period of time the pilot may extract maximum available power from the remaining engine(s) when an engine fails during critical flight maneuvers. Substantiation of this feature should be accomplished primarily by engine and drive system ground tests.

(5) Longitudinal cyclic authority at V_{NE} with any power setting must permit suitable nosedown pitching of the rotorcraft. If the remaining control travel is considered marginal, tests should include applications up to full control deflection to assess the remaining authority. Some knowledge of the aircraft's response to turbulence is useful in assessing the remaining margin. As a minimum, the rotorcraft must have adequate margin available to overcome a moderate turbulent gust and must not have any divergent characteristic which requires full deflection of the primary recovery control to arrest aircraft motion. If other controls must be utilized to overcome adverse aircraft

motion, the results are unacceptable; e.g., if a pitch up tendency resulting from an actual or simulated moderate turbulent gust cannot be satisfactorily overcome by remaining forward cyclic, the use of throttle or collective controls to assist the recovery is not an acceptable procedure; however, the use of lateral cyclic to correct roll in conjunction with forward cyclic to correct pitchup is satisfactory. Obviously during the conduct of these tests, all available techniques should be utilized when the pilot finds himself "out of control." However, compliance with this section requires that recovery must be shown by use of only the primary control for each axis of aircraft motion.

(6) Cyclic control authority in autorotation must be sufficient to allow adequate flare capability and landing under the all-engine-inoperative requirements of § 27.75.

[See new AC 27.143A (dated 9/17/2009) posted as separate document in RGL with this Master AC.]

AC 27.151. § 27.151 (Amendment 27-21) FLIGHT CONTROLS.

a. Explanation. Excessive breakout or preload in the flight controls produces control system force discontinuities which result in increased workload and controllability problems for the pilot. Similarly, excessive freeplay results in lost motion which increases pilot workload and, in an extreme case, could lead to a hazardous pilot-induced oscillation. In some designs friction can provide a positive contribution to the function of the flight controls (e.g., masking aerodynamic feedback in reversible systems). At some point, friction will have a detrimental effect on the pilot's ability to properly control the machine. In the case of an irreversible design equipped with an artificial force feel system in pitch and roll, excessive friction can mask a shallow force gradient making positive stick centering and control force static stability difficult if not impossible to demonstrate. In such an instance, the initial choice of fixes might include implementation of a steeper force gradient or addition of a force preload. Unfortunately, these solutions often lead to the kinds of problems discussed earlier. Care must therefore be exercised during the initial design phase to ensure that the components and characteristics of the flight control system are well matched.

b. Procedures. Regardless of the flight control system sophistication, it is important that the test pilot understand the system configuration prior to flight evaluation. Appropriate mechanical characteristics should be documented. For VFR aircraft, the mechanical characteristics are typically assessed in flight on a qualitative basis. If a controllability or workload problem is identified, a more detailed investigation would be necessary. Since IFR certification rules include specific trim and force requirements, a more quantitative investigation of mechanical characteristics is normally conducted. The constantly varying feedback forces of reversible flight control systems generally make such designs unsuitable for IFR application. Irreversible system mechanical characteristics can often be partially documented on the ground with external hydraulic and electrical power supplies connected to the aircraft. Knowledge of the breakout, friction, and force gradient characteristics prior to flight can be useful to the pilot during flight evaluation of the system.