U.S. Department
of Transportation
Federal Aviation
Administration

Advisory Circular

Subject: WATER INGESTION TESTING FOR TURBINE POWERED AIRPLANES
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Initiated by: ANM-110
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Change:

1. PURPOSE. This advisory circular (AC) describes a method of demonstrating compliance with the requirements of the Federal Aviation Regulations (FAR) concerning the ingestion of water from the runway/taxiway surface into the airspeed system, the engine, and essential auxiliary power unit (APU)[1] air inlet ducts of turbine engine powered airplanes. Like all advisory circular material,it is not mandatory and does not constitute a regulation. It is for guidance purposes and to provide an example of a method which has been found acceptable.

2. APPLICABLE FAR SECTIONS.

a. Sections 23.1091(c)(2) and 25.1091(d)(2) of the FAR.

b. Sections 23.1325(a), 25.1323(d), and 25.1325(b) of the FAR.

3. RELATED ADVISORY CIRCULAR. AC 91-6A, Water, Slush, and Snow on the Runway, dated May 24, 1978.

4. BACKGROUND.

a. The Problem. Airplane turbine engines are susceptible to surge, stall, and flameout when they ingest excessive quantities of water. All certificated turbine engines have demonstrated a capability of ingesting simulated rainfall without suffering operating problems. The quantities of water spray ingested by an engine as the airplane passes through water standing on runways and taxiways may exceed the water quantities used in the engine certification testing. The regulations require that the airplane design prevent hazardous quantities of water or slush from being ingested into engines and APUs during takeoff, landing, and taxiing. Also, water ingestion into the airspeed system may cause system malfunctions during takeoffs and landings. It is often practical to investigate these effects concurrently with the engine water ingestion evaluation.

b. Critical Case. If a critical water ingestion problem exists, it typically exists during takeoff when engine power demands are high. The airplane tires cause bow waves, side spray, and "rooster tails" (spray which is

[1] An essential auxiliary power unit produces bleed air and/or power to drive accessories necessary for the dispatch of the airplane to maintain safe operation.

thrown off the tire as it rotates) which can collect into concentrated water streams that may be ingested by the engine. If the quantity of water is excessive, the operation of the engine may be affected sufficiently to cause an unsafe condition. Additionally, certain airplane designs may allow for ingestion of hazardous quantities of water during landing rollout while using reverse thrust.

c. Limiting Water Depth. Airplanes should be capable of operating on wet runways with areas of standing water without creating adverse engine, APU, and airspeed system operating characteristics due to water ingestion. Takeoffs should not be attempted when standing water, slush, or wet snow greater than one-half inch in depth covers an appreciable part of the runway (reference AC 91-6A, "Water, Slush, and Snow on the Runway," dated 5/24/78). Therefore, one-half inch water depth is the accepted test criteria for demonstrating compliance with the referenced regulatory requirements concerning water ingestion effects on engines, APUs, and airspeed systems. An applicant seeking airworthiness approval may demonstrate the water ingestion characteristics of the engine and airspeed system by conducting tests in a one-half inch deep water test bed. Upon a successful demonstration, the airplane is approved without an operating limitation on runway water depths. If the airplane can demonstrate successfully only at some shallower water depth, then the lesser depth becomes a limitation on that airplane's operation.

5. WATER INGESTION TEST PROGRAM.

a. Determination of Need To Test. The airplane configuration generally determines the spray pattern of the water. The applicant may show compliance with §§ 23.1091 and 23.1325 or §§ 25.1091, 25.1323, and 25.1325 of the FAR by analysis acceptable to the FAA or by test.

b. Test Plan. If it is determined that a test is needed to evaluate the airplane spray characteristics, the applicant should submit a test plan. The test plan should include, at least, data describing the test airplane's configuration, the test facility, the selected water test depth, the test instrumentation, and the detailed test procedure.

c. Test Considerations. The demonstration tests should be extensive enough to clearly show the critical water ingestion characteristics of the airplane, if any. The number of test runs should be sufficient to demonstrate all critical phases of the takeoff, landing, and taxi operations. The test procedures outlined in paragraph 5d describe a preliminary test encompassing test runs at different speeds, but at reduced thrust settings, in order to demonstrate that no engine inlet or airspeed port is wetted and that water ingestion is not likely at higher thrust settings. If, after a sufficient number of test runs at different speeds, it is obvious by inspection of the wetted surfaces that water ingestion would not occur even at higher thrust settings, further testing is not warranted.

d. Suggested Test Procedure.

(1) Airplane Configuration. All portions of the airplane that may influence the water spray patterns should be the production configuration. If spray deflectors (chine tires, fenders, etc.) are used, the predicted in-service wear patterns should be included in the demonstration testing. If the engine pneumatic systems (air conditioning, anti-ice, etc.), the APU electrical and pneumatic loads, and the state of the engine and APU ignition systems could have an influence on engine and essential APU operating characteristics while the powerplants ingest water, the most critical powerplant operating configuration that is consistent with the applicant's recommended procedures for operation on wet runways should be used. In addition to testing the takeoff configuration, if the landing configuration redirects the water spray into a critical pattern, simulated landing tests should be conducted.

(2) Test Facility. The test facility must have adequate space for simulated takeoff runs (also taxi and landing runs, if required). The water test bed should be constructed so that the selected water depth can be maintained over not less than 90 percent of the test bed area. Intermediate dams are allowed within the water trough in order to maintain a more consistent water depth on sloped or uneven surfaces. The test bed length should not be less than that required to produce a spray pattern of one second duration at critical test speeds. The test bed width need only accommodate one landing gear if acceptable data are presented to the FAA which show the nose gear spray combined with the main gear spray is not more hazardous than the spray produced by each separately. If a water depth less than one-half inch is used, then that depth becomes an operational limitation for the airplane.

(3) Data Collection. The applicant is expected to provide adequate personnel and equipment to collect the test data. The following list is the suggested data which are to be collected:

(i) Airplane Performance Data. The operating characteristics of the engine (and APU, if applicable) should be recorded. The airplane velocity should be recorded when it enters and exits the test bed. Any engine sounds which are indicative of engine distress should be noted. The airspeed system should be monitored to observe any fluctuations from water ingestion.

(ii) Water Spray Pattern. The pattern of water spray on the airplane should be recorded. This can be accomplished by coating the appropriate areas of the airplane with agents which identify the wetted areas and by using suitable high speed video recording equipment. The origin, trajectory, and configuration of the water spray should be recorded.

(iii) Meteorological Data. The appropriate meteorological data including wind velocity should be recorded for each test run. If no local airport facilities provide this data, appropriate equipment should be provided by the applicant.

(iv) Pilot Comments. Pilot comments should be noted to determine if the takeoff would have been affected by abnormal audible engine sounds, airplane instrument anomalies, etc.

(4) Test Runs. The purpose of the test runs is to demonstrate compliance with the relevant regulations by determining that the water spray characteristics of the airplane are not hazardous to its operation. If the individual spray patterns indicate that the combined spray patterns of the nose and main landing gear do not combine to produce a more hazardous spray pattern, then each gear may be tested individually. If the nose gear or the main gear is determined to be the most critical, only that gear need be tested. However, if data from the individual tests show the possibility of a combined spray pattern presenting a hazardous condition, nose and main gear combination testing should be performed.

(i) Engine Thrust or Power Settings. The tests should be conducted with the appropriate thrust or power setting. However, during preliminary tests to determine airplane speeds for critical water spray patterns, reduced power settings may be used to facilitate establishing target test bed entry speeds. If any engine inlet or airspeed system port or probe is wetted during reduced power test runs, additional testing at the appropriate power setting should be conducted for that speed range. If the reduced power test runs demonstrate that no critical speed exists, and would not likely exist at higher power settings, further testing of that configuration is not necessary.

(ii) Test Speeds. To establish the critical speed range, test runs through the water trough should be conducted in speed increments of not more than 20 knots. If a critical speed region is determined, smaller test speed increments may be required throughout that speed range. If preliminary tests or analysis, acceptable to the FAA, satisfactorily show that a test speed range is not critical with respect to engine or airspeed system water ingestion, test runs need not be conducted at speeds within that range.

(iii) Test Configurations. The following ground operational phases should be tested for their water ingestion characteristics, unless it has previously been determined that a hazard does not exist.

(A) Simulated Takeoff (if required). If tests of the takeoff configuration are deemed necessary, the runs through the test trough should be conducted at the critical speeds. If the rotated airplane attitude is suspected to be critical, at least one run at V_R should be conducted with the airplane rotated to the normal rotation angle to show what influence this combination of power, flaps, and angle has on the spray pattern.

(B) Simulated Landing (if required). If tests of the landing configuration are deemed necessary, then the runs through the test trough should be conducted at any critical speeds from the touchdown speed to the lowest appropriate speed using the normal approved landing configuration. Engine power settings appropriate for landing and roll-out should be used. If thrust reversers or reversing propellers are provided, additional water ingestion tests should be considered to evaluate the use of these systems while operating on wet runways.

(C) Taxiing (if required). Airplane speeds, power settings, and configurations appropriate for normal taxi operations should also be tested. This requirement is usually covered during takeoff tests.

(iv) Pretest Activity. The water depth, wind velocity, and ambient temperature should be recorded before each test run. The water depth should meet the 90 percent criteria before beginning any test run. Winds parallel to the water trough may interfere with maintaining consistent water depth, unless dams are used throughout the trough.

(v) Test Activity. Outside observers should be provided to determine if the airplane remains in the test bed. The observers should also note the water spray pattern, listen for abnormal engine sounds, and observe the affect of the wind on the spray pattern. The motion/video cameras, if used, should record the test run. The preliminary test data collected on each test run should be provided so that a determination can be made that the test run parameters were met. Usually, it is apparent to the observers at the completion of each test run whether the run was valid and if a critical speed was identified. Failure to attain the desired speed or stay within the test bed may disqualify the run.

6. FINDING.

a. No hazardous quantities of water are considered to have been ingested when review of the collected test data shows that:

(1) No engine flameout, performance degradation, distress, or airspeed fluctuations occurred which would create a safety hazard during any of the test runs through the selected water depth; and

(2) If engine sounds denoting engine distress, such as pops or bangs, or cockpit instrument indications of engine surge or stall occurred, they were not of sufficient magnitude to cause a pilot in service to abort the planned operation.

b. If the above criteria are not met using the prescribed water depth, test runs at another water depth must be performed to establish an operational limit.

7. AIRPLANE FLIGHT MANUAL. If compliance with the water ingestion test criteria is demonstrated at a water depth less than that specified, the lesser depth becomes a limitation in the Airplane Flight Manual. The limitation should specify the water depth for which the airplane was found acceptable. For all airplanes, any special instructions for operation in runway/taxiway standing water should be included (e.g., special tires, flap settings, engine ignition setting, or reverse thrust or propeller setting, etc.). Any special airplane handling techniques necessary to ensure compliance with the water ingestion test requirements should be compatible with the handling techniques assumed in establishing the Airplane Flight Manual performance characteristics.

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