Powerplants

AC 25-7A Flight Test Guide for Certification of Transport Category Airplanes, pgs 389-390

(2) Intermixing of Engines. Engines with different ratings, and/or with different cowls, may be intermixed on airplanes, provided the proper limitations and performance information associated with the engine combination are used. In general, for four-, three-, or two-engine airplanes, the performance combination is as follows:

(i) When one lower thrust engine is installed, the normal Airplane Flight Manual (AFM) performance level is reduced by an increment appropriate to the decrease in thrust resulting from the intermix.

(ii) When more than one lower thrust engine is installed, the AFM performance should be based on the thrust of the lower/lowest rated engine.

(iii) The minimum control speeds (V_{MCG}, V_{MCA} & V_{MCL}) must be based on the highest thrust engine(s).

(iv) The operating procedures must be provided for all engines installed (i.e., airstart altitude/airspeed envelopes, crew responses to engine warning systems, etc.). Differences in operating methods shall be limited to the equivalent of having a maximum of two different engines on the airplane.

(v) A maximum of two takeoff thrust settings (EPR or N_1) are permitted for airplanes with intermixed engines; this includes differences related to air conditioning pack and compressor bleed configurations.

(vi) A placard, identifying the location of the non-standard engine type, must be installed. All engine limits and instrument markings should be appropriate to the engine installed at each location. EPR, N_1, N_2, EGT, etc. limits for each engine, or the ratings at which they will be operated, must be properly presented to the pilot in accordance with §§ 25.1541 and 25.1543 and Part 121 of the FAR.

d. Engine Restart Capability - § 25.903 (e)

(1) Explanation.

(i) Approval of Engine Restart Capability. An altitude and airspeed envelope must be established by the applicant for in-flight engine restarting, and means provided to restart each engine in flight within this envelope.

(ii) Engine Restart Envelope. For turbojet and early turbofan engines with low bypass ratios (approximately one), inflight restart capability was generally provided by "windmilling" of the engine. The windmilling airflow through these engines was capable of providing enough rotational energy to permit inflight restarting throughout most of the approved airspeed-altitude operating envelope. From the experience gained with these first generation engines, acceptable restart capability has been established as 30 seconds from "FUEL ON" to ignition, and 90 seconds from "IGNITION" to stabilized idle. The 90 second ignition to idle time upper limit is based on the ability of the flightcrew to perceive the progression of the engine start by monitoring the time rate-of-change of N_2 and exhaust gas temperature. As bypass ratios increased, and rotational energy requirements increased, the "windmilling" restart envelopes became smaller. Some higher bypass ratio engines require an assist from an auxiliary pneumatic source, such as bleed air from an operating engine or an inflight operable Auxiliary Power Unit (APU), to provide restart capability over a large portion of the airplane operating envelope. Turboprop engines, particularly those with free-turbines, also require some sort of "auxiliary" start assist; this is generally provided by an electric starter or, in some cases, an inflight operable APU. Engine restart envelopes should clearly distinguish between the areas of different restart capabilities in terms of time to restart, windmilling only restart, and auxiliary air assisted restart. If an APU is required for restart over a significant portion of the operating envelope, a separate inflight start envelope should be substantiated by flight test for the APU in the "cold-soaked" condition associated with medium to high altitude cruise conditions. Engine and APU (if applicable) restart envelopes, and related procedures, should be included in the limitations section of the Airplane Flight Manual.

(iii) All-Engine Restart Capability. As technological advancements increased specific engine thrust output with a simultaneous decrease in specific fuel consumption, and wing designs produced greater lift, the number of engines required for a given airplane weight has decreased to the point where the majority of modern

transport category airplanes are equipped with just two engines. Service history has recorded a number of inflight all-engine thrust loss incidents from various causes: flameouts from inclement weather conditions, volcanic ash ingestion, fuel nozzle coking, fuel contamination and several cases of flightcrew fuel mismanagement. These incidents have occurred during takeoff climbout and in high altitude cruise. Consequently, it should be substantiated by flight test that restart capability exists following the inflight shutdown of all engines. This should be demonstrated for the momentary shutdown from a high power setting, associated with the takeoff and climb flight regimes, and the extended shutdown at medium to high altitude where the engines may be "windmilling" and/or "cold soaked."

(2) Procedures.

(i) Tests should be conducted to determine that inflight restarting can be accomplished within the envelope provided. Restarts at the conditions of the critical corners of the envelope and at or near the high altitude extremes of the envelope should be conducted to verify the boundary conditions of the envelope.

(ii) Inflight engine restart capability should also be evaluated with regard to suction feed climb conditions at the minimum suction feed relight altitude, and loss of normal AC power (Ref. § 25.1351(d)).

(iii) The engine operating characteristics should be evaluated during each restart. In particular, any tendencies for the engine to surge, dwell for abnormally long periods below idle, or produce other unusual vibration or audible noises should be noted.

(iv) To address the dual engine flameout case during takeoff and initial climb-out, with the engines initially at maximum climb thrust (or higher), it should be demonstrated that the test engine will accelerate to the initial power setting after a brief shutdown (up to 15 seconds), when the fuel source is restored.

(v) To address dual engine flameout at high altitude (greater than 20,000 feet), it should be shown, by a combination of flight test and analysis, that the engines can be restarted, and the airplane's descent arrested, with a total altitude loss of not more than 5000 feet. Additionally, engine restart should be accomplished prior to exceeding 300 knots IAS.

(vi) If an onboard auxiliary power unit (APU) is required to provide power assist for inflight engine restart, the minimum APU start reliability should be determined, and its operation evaluated by flight tests in critical portions of the flight envelope.

(vii) If start cartridges are used to provide restart capability, they should be of sufficient capacity (or number) to provide at least two start attempts for each engine.

(viii) The inflight engine restart envelope presented in the Airplane Flight Manual (AFM) should identify a "core windmill relight envelope" that will provide engine ignition within 30 seconds and stabilized idle within 90 seconds of restart initiation. A larger envelope, which includes appropriately labeled longer restart times, may be allowed if it can be shown that indication of a clear progression of engine start is provided to the flightcrew. The AFM should also contain the restart procedures appropriate to each phase of flight (i.e. low altitude "hot start," high altitude "cold soaked" start, etc.).

91. AUTOMATIC TAKEOFF THRUST CONTROL SYSTEMS (ATTCS) - § 25.904.

a. Explanation.

(1) Beginning in the 1970's, some manufacturers of turbojet powered airplanes elected to equip their airplanes with engine thrust control systems that automatically increased the thrust on the operating engine(s) when any engine failed. A similar system, referred to as an Automatic Takeoff Power Control System, was subsequently installed on turbopropeller airplanes.

(2) Takeoff performance credit was granted for ATTCS based upon prescribed system functional and reliability requirements, and performance related restrictions (e.g., initial takeoff thrust must not be less than 90 percent of that set by the ATTCS).