

loss, or inability to control engine thrust. An FAA review of the test data from the 3000-cycle tests for the three original engine types installed on the Model 777 series airplanes has shown that most of the early in-service 777 engine failure modes could have been discovered had Boeing and the engine manufacturers conducted a more thorough teardown inspection and analysis of the 3000-cycle test engine and propulsion system hardware. Part conditions noted in the teardown inspection reports for the three baseline 777 engine types did later occur in service, and they resulted in engine inflight shutdowns or airplane diversions. Because the specific condition of those 3000-cycle test parts had been characterized as minor deviations from normal however, no specific investigations into how they might progress in service had been required as a prerequisite for ETOPS approval.

Special Conditions 25-ANM-84 currently do not require a post-test teardown inspection. However, all three engine companies, in cooperation with Boeing, conducted post-test teardown inspections on the original baseline engines installed on the Model 777 series airplanes based on their own experience of what would constitute an adequate evaluation. In order to provide a consistent standard for a post-test evaluation of the 3000-cycle test hardware, the FAA is proposing a change to paragraph (e)(6) to require a complete teardown inspection of the engine and airplane nacelle test hardware after completion of the test. The inspection must include an analysis of any abnormal conditions found. The analysis must consider the possible consequences of similar occurrences in service to determine if they might become sources of engine inflight shutdowns, power loss, or inability to control engine thrust. The intent of this change to paragraph (e)(6) is to require further design analysis to catch potential sources of engine inflight shutdowns or diversions.

For similar reasons, we are proposing to add a new subparagraph (e)(7)(v) to require a post-test external and internal visual inspection of the airplane demonstration test engines and propulsion system hardware. An analysis of the inspection results must identify any potential sources of engine inflight shutdown. Appropriate corrective actions must be performed in accordance with the provisions of the special conditions.

Boeing proposed to delete the word *complete* from the description of the airplane nacelle package required for

the 3000-cycle test. The rationale for this proposed change was that without the term *complete*, it is still understood that the test is intended to be a propulsion system test inclusive of the engine buildup items, but some allowance is made for configuration differences necessary to accommodate the test setup. The FAA is concerned that, without this qualifier, it is not clear what nacelle hardware must be installed for this test. It could be misinterpreted in such a way that, for instance, a functioning thrust reverser need not be installed. Therefore, the FAA has concluded that the word *complete* must remain in the requirement. However, we agree with Boeing that those configuration differences associated with test instrumentation and test stand interfaces with the engine nacelle package may be excluded, and we propose to add that qualification to the requirement in order to clarify this intent.

Paragraph (e)(7) Airplane Demonstration Test

Number of Test Airplanes: Boeing has proposed a change to paragraph (e)(7) to allow the use of more than one airplane to comply with the airplane demonstration test requirement (three test airplanes for the current Model 777-300ER program). Boeing's justification includes the argument that using multiple airplanes is an enhancement to the ETOPS validation program that takes into account airplane-to-airplane variation. The value of obtaining ETOPS data on multiple airplanes versus one is the increased sample size. The FAA agrees that increasing the number of test airplanes in the airplane demonstration test would provide a better evaluation of airplane-to-airplane variability. The limited experience obtained during the airplane demonstration test program is not really sufficient to evaluate end-of-life wear-out failure modes, so accumulating all of the time and cycles on one airplane is not really necessary. The main program schedule benefit from using multiple flight test airplanes is that testing can be completed in a shorter period. The FAA is proposing a change to paragraph (e)(7) to require that one or more airplanes must complete the airplane demonstration test required by that paragraph.

Capability Demonstration vs. Reliability Demonstration: The 1000-cycle airplane demonstration test requirement was developed with the intent of exposing the airplane to the conditions where the greatest numbers of inflight shutdowns occur. Most inflight shutdowns occur during takeoff

and climb. The failure modes associated with these takeoff- and climb-related shutdowns tend to be cyclic in nature for a couple of reasons.¹ For failure modes where the risk of failure increases with engine thrust, the takeoff portion of the flight is most critical. Failure modes that occur due to improper maintenance or engine servicing, for instance loss of engine oil due to improper assembly of an oil tube connection, also tend to occur early in the flight. A larger number of airplane flights increases the exposure to these types of failures. Therefore, the FAA considered a cyclic test to be the most appropriate airplane validation test for the original 777 ETOPS special conditions. However, as stated above, we now consider that the 3000-cycle engine and propulsion system test required by paragraph (e)(6) provides an adequate opportunity to discover cyclic-related failure modes associated with the design when the test hardware goes through an appropriate level of post-test teardown and inspection.

For inflight shutdowns where improper maintenance is a main causal factor, the 1000-cycle airplane demonstration test provides multiple opportunities for these types of failures to occur. However, the maintenance procedure validation program required by paragraph (d)(2) is intended to minimize the probability of these occurrences. The airplane demonstration test airplane provides opportunities to demonstrate those maintenance tasks associated with the normal operation of the airplane. The FAA considers that these demonstrations can be accomplished in fewer than 1000 cycles.

Although the fewest inflight shutdowns occur during cruise, this is the phase of flight that is most important to an ETOPS operation. Traditionally, the FAA and industry have avoided trying to differentiate between those inflight shutdowns that may occur during cruise from those that would only occur in a non-ETOPS environment. The main reason for this approach in existing ETOPS policy is that by correcting all causes of inflight shutdowns, the overall integrity of the propulsion system is assured. Since adequate cyclic exposure would be evaluated by an enhanced 3000-cycle engine demonstration test, as proposed for paragraph (e)(6) of these special

¹ Data provided to the Aviation Rulemaking Advisory Committee (ARAC) ETOPS Working Group confirm that the inflight shutdown rate during the takeoff flight phase is on the order of 6 to 16 times the fleet average inflight shutdown rate and during the climb phase is 2.5 to 4.5 times the fleet average.