

conditions, the FAA has concluded that the airplane validation program should emphasize exposure to the cruise phase of flight. During the three 1000-cycle tests conducted for the original 777 engine installation certification programs, only 91 of the total 1000 cycles were of durations of two hours or more. Since the intent of paragraph (e)(7) is to simulate an actual airline operation, this would better be accomplished through longer duration flight cycles. Long duration flight exposure provides additional confidence in the design against those cruise-related failure modes that cannot be evaluated in a cyclic test environment. Such failure modes could include freezing of entrapped water condensation or binding of propulsion system components, neither of which would likely occur in a sea level test facility.

Based on these considerations, the FAA has determined that the airplane demonstration test requirement should be refocused on those conditions that are most prevalent in an ETOPS operating environment. Those conditions include long flights to a variety of airports with broad variations of airport elevation, temperature, and humidity. It is also important that these flights expose the airplane to several enroute climbs, such as may occur with a fully loaded 777-300ER on a long-range flight, and a number of single engine diversions. As such, the FAA proposes that the airplane demonstration test requirement of paragraph (e)(7) be revised to more clearly state the objectives of the test program. Those objectives include demonstrations that the aircraft, its components, and equipment are capable of and function properly during long-range operations and airplane diversions, including engine-inoperative diversions. This change in focus constitutes a significant departure from the original purpose of the 1000-cycle airplane demonstration test requirement, as discussed in the preamble to special conditions 25-ANM-84.

Reliability of 777

In order to further justify this change in philosophy for the airplane demonstration test requirement from being a demonstration of "reliability" to a demonstration of "capability," the FAA reviewed the original intent of Special Conditions 25-ANM-84, as documented in the preamble to those special conditions. The purpose of this review was to assess whether the assumptions we made in justifying the special conditions are still valid, or

whether they should be revised based on ETOPS certification experience since their issuance in June 1994.

In the preamble to Special Conditions 25-ANM-84, the FAA stated that: "existing practices to achieve airplane certification safety objectives have involved definition of performance requirements, incorporation of safety margins, and prediction of failure probabilities through analysis and test. However, historical evidence, in general, indicates that a period of actual revenue service experience is necessary to identify and resolve problems not observed during the normal certification process. Successful achievement of this experience has been a prerequisite for granting ETOPS type design approval for a specific airplane engine combination. However, several recent airplane engine combinations incorporating new or substantially modified propulsion systems have demonstrated a high level of reliability consistent with ETOPS operation upon entry into revenue service. In addition, this high level of reliability was demonstrated by the small number of problems encountered during basic certification activity." Based on these successful airplane and engine development and certification programs, the special conditions were designed to "result in a level of airplane reliability that is equivalent to the level of reliability previously found to be acceptable based upon service experience."

The basic premise behind the engine and airplane demonstration tests required by paragraphs (e)(6) and (e)(7) of the special conditions was that those tests would provide a final validation of an "inherent" level of reliability that was the product of an enhanced design and test process. This is similar to the purpose of the function and reliability testing required by § 21.35(b)(2). The FAA's expectation for these tests was that no significant failures would occur. The probability of significant design failures occurring on a one-airplane flight test is so low that if any DO occur, that would be indicative of a design that is not suitable for ETOPS approval. This expectation is contained in the "type and frequency" requirement of special conditions paragraph (h)(1). Statistical reliability studies have shown that a much larger database would be required to validate a design's true reliability with a significant degree of confidence.

No major engine failures occurred during the 1000-cycle airplane demonstration tests for any of the three engine types certified on the Model 777 series airplane, although several engine design problems were discovered during other certification testing that affected the start and conduct of those tests. The Reliability Assessment Board (RAB) evaluated each of these design problems in compliance with paragraph (g) of the special conditions, and found the 777 to be suitable for ETOPS type design

approval with the incorporation of corrective actions identified in Appendix 1 of the RAB final recommendation reports for the three engine types. There were hardware similarities between engines with the original certified thrust ratings and follow-on higher-thrust-rated engines, and the FAA certified each of those follow-on engine derivatives for ETOPS in consideration of those hardware similarities. The FAA accepted the original baseline engine test programs as showing compliance to the 3000-cycle propulsion system ground test and 1000-cycle airplane demonstration test requirements for the follow-on derivative engines. Although the 3000-cycle and 1000-cycle tests were not repeated for those follow-on derivative engines, Boeing and the engine companies completed reduced ground and flight test demonstrations tailored to the design changes being introduced in compliance with the "Test Features" requirement of special conditions paragraph (c)(4). Therefore, the follow-on engine derivatives are not included in this analysis of the 1000-cycle airplane demonstration test requirement.

The Boeing Model 777-200 series airplane powered by Pratt & Whitney PW4077 engines was approved for ETOPS on May 30, 1995 and entered service in June 1995. By all accounts, it was a very successful new model introduction. This was followed by ETOPS approval of the 777-200 powered by General Electric GE90-77B and Rolls-Royce RB211-Trent 877-17 engines in October 1996. The inflight shutdown (IFSD) rate for all three engine types was zero for at least the first year in service. The Pratt & Whitney PW4000 reached a peak 12-month rolling average engine IFSD rate of .018/1000 hours in October 1996. The General Electric GE90 reached a peak of .021 for one month in July 1998 and the Rolls-Royce Trent reached a peak of .016 in December 1997. Although the inflight shutdown rates stayed within the allowable .02/1000 hour standard for 180-minute ETOPS, significant design problems were discovered on each engine type after ETOPS approval.

During the first two years after ETOPS approval of each engine type on the Model 777 series airplanes, the FAA was concerned that the design problems being discovered may have indicated a failure of the early ETOPS process to identify those failure modes before they occurred in service. Some failure modes had the potential to result in inflight shutdowns had they occurred under different circumstances or had they not been detected during maintenance for