

proposal included an accumulation of 15,000 fleet engine hours of service experience before requesting ETOPS approval. At that time, there would be three airplanes with more than 1000 flight cycles, the total 737NG fleet would have accumulated more than 20,000 flight cycles, and the high-time airplane/engines would have more than 2000 flight cycles. During the 737NG approval process, the FAA concurred with Boeing's proposal to require 15,000 hours of service experience based on the following:

- "The FAA has agreed to the concept that ETOPS at entry into service can be achieved by appropriate design and testing as evidenced by the 777 special conditions, which have now been validated through actual service experience,

- "The 737NG/CFM56-7B airframe/engine configuration is a derivative/evolution of the existing 737-300/400/500 which through extensive service experience has demonstrated exceptional reliability, and, is approved for 120-minute ETOPS,

- "Except for the lack of a dedicated 1000-cycle ETOPS test program, design and testing of the 737NG/CFM56-7B mirrors what was done on the 777 to satisfy Early-ETOPS approval,

- "The additional 15,000 engine hour in-service evaluation plus the fact that three 180-minute single engine diversions were performed during Function and Reliability testing more than compensates for the omission of a 1000-cycle test,

- "The satisfactory performance of the 737NG/CFM56-7B airframe/engine configuration during the certification testing, and

- "The proven ability of Boeing to satisfactorily manage ETOPS airworthiness of the 777 fleet in the face of problems encountered in service. The 737NG proposal includes a problem tracking and resolution system that will remain in effect for a full 250,000 engine hours."

The Model 737-700 was the first variant of the 737NG to enter service, in December 1997. Section 4.2 of the FAA-approved 120-minute ETOPS Airplane Assessment Report for the Model 737-700, Boeing Document Number D033A003, Revision B, states that the Model 737-700 was designed, manufactured, and tested for extended range operations at entry into service. The following additional supporting statements were also made.

- a. "The 737-700 airplanes have been designed and manufactured based on regimented application of lessons learned from other ETOPS program experience as

well as the in-service experience of earlier 737 models.

- b. "The 737-700 airplane was subjected to a rigorous test program as described in following paragraphs. Production equivalent equipment where appropriate, was used to support test objectives. Equipment was production equivalent as defined at the time of the test."

No significant propulsion system design problems occurred during any of the testing described above. Two inflight shutdowns did occur during certification flight testing. One was caused by an indication fault within the electronic engine control that was corrected with a simple software change. The other was caused by an inappropriate flight test condition.

Boeing stated in the Model 737-700's 120-minute ETOPS Airplane Assessment Report that the fleet reached the 15,000-hour mark during the month of April 1998. At that time, there had been no inflight shutdowns in service. However, on May 9, 1998, before the FAA had completed its assessment of the airplane for ETOPS approval, the first inflight shutdown occurred. A second inflight shutdown occurred during the month of May, and the fleet exceeded the accepted 120-minute ETOPS standard of .05 inflight shutdowns per 1000 engine hours. Three inflight shutdowns occurred in June 1998, and one in July 1998. The peak inflight shutdown rate during this period was .085/1000 hours at the end of June 1998, which clearly did not meet the minimum standard for ETOPS type design approval.

The six engine inflight shutdowns were caused by three different failure root causes. Boeing and CFMI, the engine manufacturer, undertook aggressive actions to correct each of these design problems as they occurred. The high rate of fleet hourly accumulation during this period, however, resulted in new ETOPS reportable events occurring faster than the known problems could be corrected. This delayed FAA consideration of the Model 737-700 for ETOPS approval until the problems were brought under control. A consequence of the high rate of fleet hourly accumulation was that, with no additional inflight shutdowns, the inflight shutdown rate decreased rapidly and was within the ETOPS type design approval standard by the end of 1998. The FAA approved the Model 737-600/-700/-800 (737NG) for 120-minute ETOPS approximately one year after entry into service with over 300,000 engine-hours of service experience and an inflight shutdown rate of .020/1000 hours.

## Conclusions From Comparison of Model 777 and 737NG

In comparing the 737NG experience with that of the Model 777, the FAA observes that there is a fleet hourly accumulation rate above which aggressive problem management to qualify for early ETOPS certification may become resource prohibitive. Therefore, when certifying an airplane/engine combination that will be entering service with a high production rate resulting in a rapid accumulation of engine hours, manufacturers may find it more cost-effective to use the service experience criteria of AC 120-42A than to follow the rigorous requirements of the early ETOPS process.

As stated earlier, the Model 777 ETOPS 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." As previously noted, the current Model 777 ETOPS special conditions consist of five main elements needed to provide adequate compensation for the service experience normally required for 180-minute ETOPS eligibility described in AC 120-42A. No single element is considered sufficient by itself, but the FAA has found that the five elements combined provide an acceptable substitute for actual airline service experience. The five elements are:

1. Design for reliability.
2. Lessons learned.
3. Test requirements.
4. Demonstrated reliability.
5. Problem tracking system.

Even though the overall objective is a level of airplane and propulsion system reliability that is equivalent to that achieved through service experience, we considered the uncertainty of actually achieving that goal in the development of these special conditions. The first three elements focus on designing an airplane to eliminate sources of engine inflight shutdowns and diversions to the greatest practical extent. This is accomplished by an overall design philosophy to preclude sources of engine inflight shutdowns and diversions using the manufacturer's experience with earlier designs to identify successful and unsuccessful design features. The additional testing required by the special conditions focuses on exposing the design to conditions that in the past have contributed to engine failures, such as high engine vibration or repeated exposure to humid and inclement weather on the ground followed by long-range operation at the extreme cold