

Proposed (Temporary) Deviation on Fuel Quantity Indication System

Applicable to Boeing 787

Introductory note:

The following Deviation shall be subject to public consultation, in accordance with EASA Management Board decision 12/2007 dated 11 September 2007, Article 3 (2.) of which states:

"2. Deviations from the applicable airworthiness codes, environmental protection certification specifications and/or acceptable means of compliance with Part 21, as well as important special conditions and equivalent safety findings, shall be submitted to the panel of experts and be subject to a public consultation of at least 3 weeks, except if they have been previously agreed and published in the Official Publication of the Agency. The final decision shall be published in the Official Publication of the Agency."

Statement of Issue

EASA has informed Boeing that compliance with Special Condition E-14, addressing CS 25. 1305(a)(2) requirement, required that the 787 incorporates additional low fuel alerting message, as follows :

- (a)(2) A fuel quantity indicating system, which:
 - *(iv) provides adequate fuel system information to the crew, including alerts, that consider abnormal fuel management or transfer between tanks, and possible fuel leaks in the tanks, the fuel lines and other fuel system components and the engines.*

The alert, FUEL FLOW ENG L/R EICAS, is already planned to be incorporated in the design for compliance with 14 CFR K25.1.4(a)(3) which applies to ETOPS FAA certification beyond 180 minutes. Compliance with EASA Special Condition E-14 requires however incorporation in the TC configuration, regardless of the approved maximum diversion time.

The late identification of the need for this additional alerting message in support of compliance with the EASA Special Condition E-14 makes impossible for Boeing to incorporate the change without significant further delays to type certification and entry into service due to the need for software revisions for multiple systems.

The 787 airplane, initially to be certified for 180 ETOPS capability, incorporates a low fuel alerting architecture similar to previous Boeing airplane models, providing the crew multiple messages capable of indicating a potential fuel leak and is compliant with 14 CFR 25.1305 and 1309(c). The implementation of the FUEL FLOW ENG L/R advisory message should be incorporated prior to delivery of the first beyond-180-ETOPS customer, anticipated to occur prior to the first delivery to an EASA-regulated operator.

Then, the Boeing Company has requested a time limited deviation from the Special Condition, CRI E-14, with respect to the implementation of the FUEL FLOW ENG L/R EICAS advisory message.

The incorporation of the requested message is planned for implementation in the first quarter of 2012, and which is anticipated to occur prior to delivery of an EASA-regulated operator. The temporary deviation is to be granted through March 31, 2013. While Boeing anticipates that the revised alerting function will be implemented in time for the first delivery of an EASA-regulated operator, the addition of approximately one year would mitigate any unforeseen implementation difficulties.

B787 – Deviation E-23 - Fuel Quantity Indication System –

The following rationale are supporting the request from the Boeing Company to deviate from the Special Condition, CRI E-14, Fuel Quantity Indication System, for a limited period of time, with respect to the addition of the FUEL FLOW ENG L/R EICAS advisory message :

- The 787-8 low fuel alerting system, based on prior Boeing designs, incorporates lessons learned from industry experience. The designs are well proven with no in-service fuel exhaustion events attributed to the alerting system architecture.
- The additional FUEL FLOW ENG L/R advisory message is intended to enhance identification of specific fuel leak scenarios. This indication will occur prior to other low fuel alerting indications in the event of a leak downstream of an engine fuel flow sensor when operating on centre wing tank fuel.
- The initial 787 type certification will be limited to a 180 Minute ETOPS approval. Operations with diversion times of 180 minutes or less are not exposed to any fuel leak scenario where absence of the FUEL FLOW ENG L/R advisory message would prevent successful diversion capability.

1. Low Fuel Alerting Design:

The Boeing 787 low fuel alerting messages are the same as prior Boeing designs. Improvements have been made to incorporate lessons learned from industry fuel events and increase the flight crew awareness. The messages that are part of the 787-8 Type Certificate configuration, and a description of each, are the following:

INSUFFICIENT FUEL – EICAS Advisory

The logic behind the 787 INSUFFICIENT FUEL EICAS advisory is consistent with that used on previous airplanes. However, the 787 INSUFFICIENT FUEL message is an EICAS advisory rather than an FMC Scratchpad message as on previous designs. The fuel volume recorded by the FMF is decremented by the actual fuel consumed. As the fuel is consumed, the calculated fuel quantity will use the planned fuel flow profile to project the reserves remaining at the destination. When the system projects a landing with less than the entered reserves, the INSUFFICIENT FUEL message will set.

FUEL DISAGREE – EICAS Advisory

The alert appears if there is a discrepancy between the FMF Calculated quantities and the FQIS totalizer quantities.

FUEL IMBALANCE – EICAS Advisory

The FUEL IMBALANCE EICAS advisory annunciates when the fuel quantity difference between the two main tanks exceeds a threshold, determined by the fullness of the tanks.

FUEL QTY LOW – EICAS Caution

The FUEL QTY LOW caution message uses FQIS totalizer information. The message is provided as a final alert to the flight crew, and coincides with approximately 30 minutes of useable fuel in the lowest main tank.

Flight Crew Procedures and Checklists

Each alert described above has an associated procedure and checklist. The basic 787 procedures and checklists remain aligned with current in-service airplanes. Enhancements have been made to the checklists following evaluation of in-service events where clarity could have aided the crew in completing the action in a timelier manner. All procedures lead to the Fuel Leak Checklist.

Flight Crew Training

The alerts and associated procedures are provided to aid the flight crew in understanding specific scenarios and providing guidance to the appropriate action. These alerts work in concert with the manner in which flight crews are trained.

Consumption of the centre tank prior to using main tank fuel is common across Boeing airplanes due to the commonality in fuel feed designs. Thus, the management of fuel for each airplane is nearly identical. Training includes emphasis for the following scenarios:

Fuel Balancing – Flight crews are trained that arbitrary use of the fuel balance feature could result in pumping usable fuel overboard. As a result, flight crews are trained to follow the FUEL IMBALANCE procedure, and if necessary, the Fuel Leak Checklist, prior to initiating fuel balancing following activation of the FUEL IMBALANCE EICAS advisory message. Additionally, the 787 incorporates a balance monitoring system. If the fuel balance is taking longer than projected, the system will terminate the balance and notify the crew.

Fuel Leaks – Flight crew training and operational requirements drive the flight crews to maintain a fuel log, allowing comparison of actual fuel burn with the flight plan fuel burn, aiding in early detection of potential fuel leaks. Training programs guide the flight crews to the Non-normal checklists and procedures associated with any of the EICAS fuel quantity alerts. Pilots are also trained that deviations from the planned fuel plan should be considered a result of a fuel leak, unless the crew can account for the deviation due to increased winds, change in altitude from the flight plan, or airplane speed or performance variances.

Specific to the operational requirements (EU-OPS 1.375 In-flight fuel management), flight crews are required to carry out fuel checks at regular intervals in-flight. In the event the in-flight fuel monitoring shows arrival with lower than planned fuel, the crew is required to seek an alternate airport. The initial delivery configuration of the 787 low fuel alerting system provides timely notification to the flight crew to carry out these actions should the flight crew inadequately perform these duties.

2. Fuel Leak Scenarios:

Boeing has evaluated the 787 fuel alerting design against all possible fuel leak scenarios. These included fuel tank structural leaks, and plumbing leaks upstream or downstream of the engine fuel flow meter. The evaluation of leak scenarios was also specific to the engine fuel feed configuration (centre or main tank feed).

This evaluation identified one scenario, a leak downstream of the fuel flow meter while feeding the engines from the centre tank fuel, where the first alert which would occur is the INSUFFICIENT FUEL advisory. Certain remote leaks could delay annunciation of the INSUFFICIENT FUEL message just prior to transition from centre to main tank feed, or potentially near an Equal Time Point requiring complete main tank fuel volume. As will be discussed further, ETOPS missions having up to and including 180 minute diversion approval only require a portion of the main fuel tank volume to complete the diversion.

3. Airplane Capability:

The requirements of CS 25.903(b)(1) and 25.903(d)(1), in accordance with AMC 20-128A, are satisfied within the basic certification, minimizing the hazard associated with fuel leaks due to an uncontained engine failure, including fuel exhaustion. As a result, the main wing tank sizing and design protects fuel for completing the most critical diversion scenario, designed to be 330 minutes for the 787. By comparison, completion of a 180 minute diversion would require slightly more than ½ of the main tank volume (at the most critical engine out condition). The multiple messages provided to the crew with the current design provide adequate and timely alerting to allow the crew to terminate the leak before fuel is limited.

Finally, Boeing has completed a System Safety Analysis per CS25.1309 of scenarios that could result in lost fuel or fuel availability. No combinations of failures having a probability greater than 1E-09 per flight hour were identified that would result in the loss of accessibility to critical mission fuel. Further, Airplane Flight Manual limitations are in place to protect the fuel feed sequence, using centre tank prior to using main tank fuel.

4. Summary:

The combination of the alerting system design (including flight crew procedures), flight crew training, and airplane design, provides a robust low fuel alerting system, providing sufficient awareness to the flight crew to preclude a fuel exhaustion event. In support of the FAA ETOPS Beyond 180 minutes project, Boeing has proposed implementation of an additional FUEL FLOW ENG L/R message to address the scenario of a leak downstream of the fuel flow meter while feeding from the centre wing tank, further described below.

5. Implementation:

Boeing has elected to choose an option that compares actual engine fuel flow with the predicted fuel flows for the commanded thrust to alleviate the potential of shutting down the incorrect engine. Due to the need to reduce the potential for nuisance messages, a number of parameters are used to verify the airplane state before the logic is activated. Additionally, the cumulative effects of system tolerance, environmental variability, and

performance degradation have been built into the system to reduce the potential for nuisance messages.