Investigation report

D1/2011L

In-flight fuel leak in a passenger aircraft on 15 January 2011

Translation of the original Finnish report

OH-AFJ

Boeing 757-28A

INVESTIGATION REPORT: D1/2011L **INVESTIGATORS:** Hans Tefke, Tero Järvinen (until 26.6.2011), Erja Savela and Kai Leisma

COMPLETED: 4.2.2013

Time:	15 January 2011, about 13:06–14:31 UTC	
Place:	En-route from Helsinki to Las Palmas in the airspace of the Netherlands, Belgium and France	
Type of aircraft:	Boeing 757-28A	
Registration:	OH-AFJ	
Engines:	Rolls Royce RB-211-535E4	
Year of manufacture:	1994	
Type of flight:	Scheduled charter flight	
Damage to aircraft:	No damage	
Number of persons onboard:	8 crew members and 210 passengers	
Pilots:	**Pilot-in-command:** Age 35	**Co-pilot:** Age 41
Licences:	JAR airline transport pilot, valid until 31.10.2011. All required ratings were valid.	JAR commercial pilot, valid until 30.9.2011. All required ratings were valid.
Flying experience:	**Total flight hours:** 5719 **Flight hours with this type:** 2805	**Total flight hours:** 3324 **Flight hours with this type:** 1420
Meteorological information:	Paris Charles de Gaulle airport: wind from 210 degrees, wind speed 14 kt, gusts 21 kt, visibility over 10 km, broken clouds, cloud base 1700 ft, temperature 11°C, dew point 5 °C and atmospheric pressure from the average sea level (QNH) 1024 hPa.	

SYNOPSIS

An incident occurred on 15 January 2011 to a Boeing 757-28A twin-engine passenger aircraft, registration OH-AFJ, which was on a scheduled charter flight FIF-661 from Helsinki to Las Palmas. The aircraft was operated by Air Finland Ltd and owned by International Lease Finance Corporation. After about two hours in-flight, the pilots' fuel monitoring showed that fuel consumption was higher than calculated. On closer examination, the pilots concluded that there was a fuel leak and traced it to the right fuel system or engine. The fuel leak was so large that the captain decided to land at the nearby Paris Charles de Gaulle airport. The incident did not result in injuries to persons or any other damage.

The Safety Investigation Authority, Finland (SIA) was informed of the incident soon after the aircraft had landed at Charles de Gaulle airport and started a preliminary investigation. On 3 February 2011 by decision No. D1/2011L, the SIA named Matti Sorsa, Tero Järvinen and Kai Leisma as investigators for this incident. Investigator Matti Sorsa was discharged from his duties as an investigator at his own request from 9 February 2011, and investigator Hans Tefke was named to replace him. Later, investigator Tero Järvinen was discharged from his duties as of 27 June 2011 after he was employed by the Finnish Transport Safety Agency. Investigator Hans Tefke was then named investigator-in-charge, accompanied by investigators Erja Savela and Kai Leisma as members of the commission. On 14 September 2011, the investigation group invited Markku Roschier as an adviser in issues related to organisations.

Pursuant to Annex 13 to the Convention on International Civil Aviation, the flight safety investigation authority of the United Kingdom (Air Accidents Investigation Branch, AAIB) appointed Steve Moss to participate in the investigation as an accredited representative of the state of engine manufacture, and Kelvin Smith from Rolls-Royce to assist him. Later during the investigation, Kevin M. Munro from Rolls-Royce replaced Kelvin Smith as an assistant.

The sequence of events was established through interviews of the parties involved, flight and aircraft documents, and flight data recorder print-outs. The investigation focused on pre-flight maintenance actions, which were examined based on the aircraft maintenance records as well as other documents and evidence provided by the organisations. On 25 October 2011, the investigation group familiarised themselves with the maintenance action in question, the maintenance procedures, working environment and the incident aircraft.

Air Finland Ltd was declared bankrupt by a decision of Vantaa district court on 28 June 2012.

The SIA requested comments on the draft Final Report in accordance with EU Regulation 996/2010 from the parties involved, Finnish Transport Safety Agency, Air Finland Ltd and Finnair Technical Services (FTS), as well as from AAIB, the French flight safety investigation authority (BEA), the National Transportation Safety Board (NTSB), European Aviation Safety Agency (EASA), Rolls-Royce, Icelandair Technical Services (ITS) and Aviacare. Their comments were received by 26.11.2012. The comments have been taken into account in the investigation report.

All times in this investigation report are in Co-ordinated Universal Time (Finnish time -2 hours).

The material used in the investigation is stored at Safety Investigation Authority, Finland (SIAF).

1 FACTUAL INFORMATION

1.1 Events before the flight

On 11–14 January 2011, the aircraft was maintained by FTS at Helsinki-Vantaa airport. The maintenance included defect repairs and component changes in both engines. An engine run-up was performed on the day before the incident flight before a certificate release to service was issued.

The crew reported for the flight approximately one hour and 15 minutes before the scheduled departure time. They started preparations for departure after arriving at the aircraft. The captain made a walk-around inspection and checked e.g. the aircraft documents and logbooks. The fuel load sheet was missing from the flight plan documents, but was later found with the assistance of ground handling personnel. The total amount of fuel taken was also unclear. According to the pilots, about 300 kg of fuel seemed to be missing due to the instability of centre tank fuel quantity indication. The amount displayed varied after refuelling, but stabilised before departure. At departure, the indicators showed over 1200 kg of extra fuel.

1.2 Events during the flight

The beginning of the flight was normal, and the co-pilot was the pilot flying. Cruise altitude was reached about 20 minutes after take-off (at 10:41). The fuel quantity was checked in-flight for the first time at 11:51. When comparing the calculated fuel amount (in accordance with the flight plan) with the actual fuel amount (as displayed by fuel quantity indicators), no significant difference was found.

According to the flight data recorder, the right engine oil pressure and temperature values started changing at 12:38. The oil temperature dropped and the oil pressure rose. However, the readings for oil temperature and pressure remained within the acceptable tolerances. The flight crew did not notice or consider the issue significant.

According to the flight plan remarks made by the co-pilot the next fuel check was made at about 13:11. At that time, the actual fuel quantity was some 1700 kg less than calculated. After the pilots noticed that the fuel consumption was higher than normal, they started to suspect an engine fuel leak and started to monitor the fuel amount more closely. The shortened monitoring interval was 17 minutes. During the monitoring period, the difference between the calculated and actual fuel quantity increased by another 600 kg. At the captain’s request, the purser went to the cabin window to check if some fuel leaking out from the engines could be seen. The purser saw no signs of a fuel leak.

At that stage, the centre fuel tank was about to run empty in a few minutes. The pilots waited for the low fuel pressure indicator lights to illuminate as a sign that the centre fuel tank was getting empty. By this procedure, the pilots wanted to find out whether the fluctuation of the centre tank fuel quantity indication before the flight had something to do with the higher fuel consumption in-flight and rule out the possibility of an indicator malfunction. The low fuel pressure lights illuminated normally, which confirmed to the pilots that there was an actual fuel leak. The leak was located to the right fuel system or right engine. The captain went to the cabin himself to see from cabin windows if there was fuel leaking from the engine. He saw no signs of a leak either.

After about half an hour, the fuel leak was found to be so large that the captain decided to discontinue the flight and land at the nearby Paris Charles de Gaulle airport. The flight was already slightly past Paris, but the pilots regarded Charles de Gaulle airport as the most suitable landing site as it was close and familiar to both pilots. Moreover, company aircraft had been maintained at that airport, and customer services were considered better at a large airport. The pilots prepared for a change of flight plan by entering the approach route into the aircraft navigation system.

At about 13:30 the captain requested an ATC clearance for approach and landing to Paris Charles de Gaulle airport. When the controller asked for the reasons, the pilots told that they had a fuel leak. The controller understood the reply as a declaration of emergency, and instructed the crew to select the emergency code 7700 in the transponder. At 13:39 the aircraft diverted to Charles de Gaulle airport. The controller granted the flight priority over other traffic. The co-pilot went to get the necessary material for approach and landing from the cockpit book shelf. The pilots switched duties so that the captain became the pilot flying and the co-pilot handled radio communications.

The cabin crew was instructed to prepare the cabin for landing. During approach, the captain informed the passengers of the situation in English and the co-pilot in Finnish. Before final approach, everything was ready for landing in the cabin. All flight deck conversations were in English during the whole flight, although it is not the native language of either pilot.

According to calculations made during the investigation based on flight plan notes, fuel consumption from the right wing tank was about 63 kg/min higher than from the left wing tank after the centre fuel tanks were empty. The pilots did not consider the increasing fuel imbalance a problem. At 13:52 the pilots received a Fuel Config warning, as the difference in fuel quantity between the right and left fuel tank exceeded 885 kg. No action was taken to correct the fuel imbalance before landing.

According to the co-pilot’s interview about 10 minutes before landing, the pilots reached the checklist item which required the leaking engine to be shut down (Quick Reference Handbook, Non-Normal Checklists Fuel; see Appendix 2). However, the captain decided not to shut down the right engine until during the ground run, since the right engine was running well and he considered it safer to fly with two live engines under these circumstances rather than with one engine, the left engine. According to the captain there had been vibration in the left engine during the flight. Vibration had also occurred on previous flights. In the maintenance prior to the event flight attempts were made to solve the vibration problem. In addition, the captain wanted to consume fuel in order to reduce aircraft landing weight. According to the co-pilot they might have not been able to land in 10 minutes, if they had shut down the right engine, because other procedures would have followed the shutting down. Another reason for the decision not to shut down the engine was according the co-pilot that there was no fire although fuel had been leaking for some time already. The pilots had concluded that the fuel does not leak in a critical place when considering risk of fire. The captain turned on the Auxiliary Power Unit (APU) on final before landing.

The plane landed at Charles de Gaulle airport at 14:21. At the time of landing, the fuel imbalance due to the fuel leak was about 1700 kg. Reverse thrust was not used during ground run, as the pilots estimated that it might suck any leaking fuel into the hot sec-

tions of the engine. The captain shut down the right engine on the runway after touch down.

Emergency vehicles had been alerted to secure the landing, and they escorted the aircraft to the apron. The pilots taxied with one engine and shut the left engine down later at the apron. The rescue personnel checked the aircraft for fuel leaks. Because no fuel leak was detected and there was no risk of fire, the passengers were not evacuated, but remained on board at their seats waiting for bus transport to the airport terminal.

After the passengers had been transferred to the terminal, the maintenance staff started searching for the fuel leak. They asked the flight crew to "wet motor"[1] the right engine to locate any fuel leak. The leak was soon located, and the captain ordered a repair and made an entry of the fuel leak in the aircraft technical log. After defect repair, the work was signed as completed in the technical log and the aircraft was ferried to Helsinki-Vantaa airport to resume normal operations.

The captain filed a Mandatory Occurrence Report (MOR) to the airline company and the Finnish aviation authority during the ferry flight. The report contained fuel leak events during the flight, but it did not contain information about exceeding the maximum allowed fuel imbalance and flying outside the approved performance envelope.

The investigation group did not obtain any cockpit voice recording for the incident flight. The cockpit voice recorder starts to record automatically when the first aircraft engine is turned on, and stops recording automatically five minutes after both engines have been shut down after the flight. By opening the VOICE RECORDER circuit breaker, it can be ascertained that the recorder will not start recording again. The circuit breaker is located in the cockpit overhead panel. The circuit breaker was not opened after the engines were switched off at Charles de Gaulle airport, nor was the cockpit voice recorder removed or replaced before the ferry flight. In B757 aircraft, the cockpit voice recorder is capable of recording for the last 30 or 120 minutes.

1.3 Continuing airworthiness management and maintenance arrangements

Air Finland operated three Boeing 757 aircraft fitted with Rolls Royce engines. The company's continuing airworthiness management organisation was located in the immediate vicinity of Helsinki-Vantaa airport and had three permanent employees. The organisation was responsible for all of its own and subcontracted airworthiness management operations. The airline had a subcontracting agreement with Icelandic ITS on several sectors of continuing airworthiness management. The general sectors covered by the agreement were:

- developing and updating the maintenance programme
- maintaining and monitoring the aircraft maintenance status (scheduled maintenance, out-of-phase maintenance tasks) and the maintenance status of all time-limited components
- monitoring the airworthiness directives (AD) and service bulletins (SB) concerning the airframe and engines
- recommendations for service bulletins to be implemented

[1] In wet motoring, the engine is rotated normally with the starter while the ignition system is turned off. Fuel is flowing into the engine.

- maintenance planning (long-term, short-term), maintaining the list of timely maintenance tasks and compiling the work packages to be ordered and work cards
- storage of maintenance documents
- maintaining and storing the technical logs for the airframe, engines and APU
- maintaining and using the reliability programme
- engine condition monitoring
- drawing up repair and modification plans, updating them where necessary
- supplying components and materials
- carrying out airworthiness reviews.

Air Finland made the decisions concerning subcontracted services provided by ITS, such as work orders, component replacements and changes in the maintenance programme. The airline was responsible for verifying the work carried out by the maintenance organisations when accepting it. In this context, the airline also ensured that the aircraft was airworthy. The airline scheduled the maintenance actions to fit in their flight programme.

Air Finland had maintenance contracts with ITS and FTS. Both maintenance organisations provide services to B757 aircraft of their own airline companies and to other customers. Air Finland's main partner was ITS.

The maintenance contract with ITS covered both line and base maintenance. In accordance with the contract, C-check was to be carried out at ITS in Reykjavik and A-maintenance could be made in a maintenance organisation and location selected by the airline. ITS does not have any line maintenance base at Helsinki-Vantaa airport.

The maintenance contract with FTS only covered line maintenance. The contract entitled FTS to use an EASA Part-145 approved subcontractor without specific approval from Air Finland. In accordance with the contract, Air Finland had a component and spare part store in FTS's premises. The airline mainly used FTS services at Helsinki-Vantaa airport.

1.4 Maintenance actions before the flight

For the maintenance before the incident flight, Air Finland ordered FTS to carry out a daily check, update the avionics database and make one defect repair in the cabin. Air Finland also wanted to order a replacement of the right engine accessory gearbox, replacement of the left reverse section of the left engine and rearrangement of fan blades. However, FTS told that they did not have sufficient maintenance staff available for the additional tasks at the moment. Air Finland then contacted ITS and agreed that ITS maintenance staff would carry out the additional tasks in FTS's premises at Helsinki-Vantaa airport. FTS's quality assurance accepted the procedure. In the same context, it was agreed that the additional tasks would be carried out under FTS's approval certificate and FTS would issue the certificate release to service, since Helsinki-Vantaa is not a line maintenance base for ITS. FTS appointed one of its own staff members to issue the certificate release to service.

Air Finland made a work order for the additional tasks directly to ITS with identification WO #85. FTS must open a Maintenance Visit Plan (MVP) document for every mainte-

nance visit. All maintenance actions ordered and any other work performed shall be recorded in the document. However, this work order was not reflected in the MVP content as instructed by FTS, but the MVP only contained entries about the daily check and associated maintenance actions ordered earlier.

FTS viewed the ITS maintenance team as belonging to the category ”other working team”, which would be subject to FTS’s quality monitoring. Despite that, the competence of ITS team members was not actually assessed. FTS quality assurance manager orally instructed the inspectors to supervise the work of the ITS team, to monitor progress and to make sure that they had sufficient approved instructions at their disposal. The supervising actions were not documented.

The work order contained the following tasks, in numerical order: replacement of integrated drive generator (No. 1), generator disconnect function check (No. 2), inspection of removed accessory gearbox (No. 3), gearbox lubrication before removal (No. 4), packing and storage of the removed gearbox (No. 5) and replacement of left-hand thrust reverse (No. 6).

The work performed was confirmed by ITS’s stamp on the work order tasking and work instructions. Although the work instructions describe several tasks on the same page, the whole page had been confirmed by one date and stamp at the bottom.

The work package only contained instructions for replacement of the generator. For the other tasks (No. 2–6) there were only work cards. The work order did not contain the gearbox replacement task. According to FTS supervisors, the ITS maintenance team had the instructions for gearbox replacement with them, but since the task was not included in the work order, compliance with the instructions had not been monitored and any maintenance documents were not saved.

The work instructions for gearbox replacement consist of 23 pages. The instructions contain nine items, each of which describes the removal and installation of several components. For two engine components, there are separate work instructions. Moreover, the gearbox replacement requires the removal and installation of 12 appliances with separate work instructions. The work instructions specify the spare parts and equipment needed, any alternative procedures e.g. according to modification level, and any necessary measurements which must be recorded. The last item in the work instructions is the requirement for engine run-up.

The only acknowledgement of engine run-up was found in task No. 1 concerning generator replacement. The replacement task includes engine run-up at idle for leak check (item 10). The item was confirmed by ITS stamp. From this and the logbook entry ”run-up ITS” made by FTS Maintenance Operation Center (MOC) for OH-AFJ, ITS performed the run-up. Due to inadequate documentation, the extent of engine run-up could not be determined.

The list of spare parts and materials used was missing from the work package based on the work order. There was no airworthiness document for the installed gearbox either, and the list of tools used was missing.

FTS did not issue a certificate of release to service for the work performed in accordance with the work order tasking, or for the daily check and associated tasks which had

been ordered earlier. The tasks were recorded as completed in the aircraft technical log. According to the log, ITS had removed and rearranged the fan blades and replaced the right engine gearbox and left thrust reverse for the left engine.[2] The declaration text in accordance with EASA Part-145 was missing from the log book sheet.

As regards the daily check, a certificate release to service was issued for the defect repair in the cabin, while the other tasks were only recorded in the technical log. Airworthiness documents for the spare parts used were not included in the work package. There were no markings by the continuing airworthiness management organisation of acceptance of the maintenance work.

1.5 Defect repair after the incident

At Paris Charles de Gaulle airport, the captain opened the defect in the aircraft technical log. According to the logbook text, a fuel leak was observed in the right engine during flight and the flight was diverted to Charles de Gaulle airport.[3] Defect repair was ordered from the Dutch company Aviacare. The open defect in the technical log also served as a work order.

At the airport, the defect was located to a coupling in the fuel tube that leads to the right engine high-pressure fuel pump. An o-ring (Figure 1) used for sealing the coupling had partly bulged out from its groove. A total of about 4100 kg of fuel leaked out through this coupling during the flight.

Figure 1. Damaged o-ring photographed at Charles de Gaulle airport.

As a corrective action, it had been recorded in the technical log that the seal ring in the fuel tube to the high-pressure fuel pump was found damaged and the seal ring was replaced. The item of instructions used for the replacement was also recorded.[4] In connection with the defect repair, the maintenance staff had opened another defect, which required right engine run-up for leak check.[5] As a corrective action, it was recorded that right engine run-up had been performed and no fuel leak was found.[6] The part number

[2] Technical log sheet 007137 contains the following entries: "DE #7084 performed by ITS. Fan blades removed and rearranged" and "WO #85 performed by ITS. Eng #2 high speed ext. gear box replaced". Technical log sheet 007138 contains the following entries: PART 145 release: Daily Check performed 15.01.2011 at 10.00 FI.145.0001, and signature of the acknowledging person. "WO #85 DE 7073 performed by ITS. Eng #1 thrust rev. LH replaced."

[3] Right engine fuel leak observed during flight. Diverted into CDG.

[4] Found H.P. fuel tube to H.P. fuel pump seal ring damaged. Seal ring replaced I.A.W. AMM 73-11-03 Fig. 401. – SA-TIS.

[5] REF to item1: R/H engine run up required for leak check.

[6] R/H engine run up C/OUT. NIL fuel LAR observed.

of the replaced seal was recorded as KB27121. Both defects were signed as repaired on 16 January 2011. The exact time was not given.

The maintenance organisation having repaired the defect did not file any technical malfunction report. However, in accordance with Annex 2 to Commission Regulation No 2042/2003, paragraph 145.A.60(a), the organisation shall report to the competent authority, the state of registry and the organisation responsible for the design of the aircraft or component any condition of the aircraft or component identified by the organisation that has resulted or may result in an unsafe condition that hazards seriously the flight safety.

The maintenance staff did not return the damaged seal to the maintenance organisation for storage, but discarded it. The investigation group has no information of any report to the company quality assurance department. According to Civil Aviation Publication (CAP) 382, “The Mandatory Occurrence Reporting Scheme”, 3.8 Retention of Parts Involved in Occurrences, any part that is the subject of an occurrence report or involved in or the cause of an incident is to be removed from the aircraft and prominently identified as the subject of an investigation. The part must then be returned to Stores and brought to the attention of Quality Assurance for decisions on further action on the part as the nature of the occurrence dictates.

The removal and installation of the fuel tube that leaked during the flight was part of the gearbox replacement task. The tube removal and installation is included in the work instructions for high-pressure fuel pump removal and installation, which describes four different alternatives depending on the modification level of the coupling. However, no signed task card or certificate release to service showing the required revision level of the maintenance instructions was available for either of the tasks (gearbox replacement or defect repair after the incident). Therefore it cannot be ascertained which work instructions were used to perform the task.

1.6 Pilot refresher training

The captain attended Air Finland’s Operator Proficiency Check (OPC) on 28 October 2010 in accordance with the training programme and the co-pilot on 15 September 2010. The proficiency check was conducted in a flight simulator in Finland, supervised by an Air Finland instructor. The flight covered e.g. the operation of the fuel system, a single-engine approach and a missed approach with single engine. The proficiency check was preceded by theoretical knowledge instruction, in which the fuel system and other aircraft systems were discussed. Both pilots successfully completed the refresher training.

1.7 Instructions for engine fuel leak situations

The B757 Flight Crew Operations Manual includes a Quick Reference Handbook (QRH), which provides instructions for abnormal situations. QRH item Engine Fuel Leak (see Appendix 2) contains a checklist with instructions for situations where an engine fuel leak is suspected or confirmed. According to the checklist, the centre fuel tank pump switches must first be turned off. After that, the fuel consumption in right and left fuel tank must be observed to identify in which tank the fuel quantity decreases faster. The checklist determines the problem as engine fuel leak, if the fuel imbalance between

tanks increases by 500 kg or more in 30 minutes. A visual check for fuel leak should also be made if possible.

When the engine fuel leak has been confirmed, the checklist instructs the pilots to shut down the leaking engine. After engine shut-down the normal Fuel Management Procedure should be resumed, making sure that all the remaining fuel can be used in the operating engine.

According to the aircraft manufacturer, the maximum allowed fuel imbalance between the right and left tank is 885 kg. If this is exceeded during flight, a Fuel Config warning is shown on the flight deck. The Fuel Config warning is also issued if the centre tank fuel pumps are switched off while there is more than 500 kg of fuel in the centre tank, or if the fuel quantity in either main tank is less than 1000 kg.

1.8 Properties of B757 aircraft in single-engine conditions

In single-engine conditions, the B757 aircraft is not capable of maintaining the cruise altitude, and the cruising speed decreases about 60 knots. The cruise altitude can, however, be maintained at FL 250 or lower. There are no limitations as regards the direction of turn, since the aircraft has sufficient directional stability and the rudder is effective. At high engine power settings, such as in go-around, almost full rudder deflection is needed to prevent sideslip. In a single-engine situation with the APU operative, all systems can be used except for minor devices related to passenger convenience.

1.9 Organisations

Air Finland Ltd

The number of Air Finland's Air Operator Certificate (AOC) was FIN-023 and it was valid for an unlimited time. The certificate was based on the requirements of European Parliament and Council Regulation 216/2008 and Commission Regulation 859/2008. Revision no. 21 of the Operations Manual A concerning flight operations, dated 31 December 2010, was in use at the time of the incident. The revision of the Operations Manual B concerning the aircraft was 12 and it was dated 1 June 2010. The company had a valid Operating Licence. The AOC and Operating Licence had been issued by the civil aviation authority of Finland.

Air Finland's Continuing Airworthiness Management Organisation approval reference was FI.MG.0001 and it was valid for an unlimited time. The approval was based on the requirements of European Parliament and Council Regulation 216/2008 and Commission Regulation 859/2008. The latter Regulation also contains Annex 1, Part-M, dealing with continuing airworthiness management. Revision no. 10 of the company's Continuous Airworthiness Management Exposition, dated 1 September 2010, was in use at the time of the incident. This approval is required for the Air Operator Certificate to remain valid. The approval had been granted by the civil aviation authority of Finland.

Finnair Technical Services (FTS)

FTS's aeroplane maintenance organisation approval reference is FI.145.0001. The approval is based on the requirements of European Parliament and Council Regulation 216/2008 and Commission Regulation 859/2008. The latter Regulation also contains Annex 2, Part-145, dealing with maintenance operations. Revision no. 2 of the company Maintenance Organisation Exposition, dated 30 September 2010, was in use at the time of the incident. The approval has been granted by the civil aviation authority of Finland. It is valid for an unlimited time and covers commercial air transport operations. The scope of work specified in the approval includes the aeroplane/powerplant combination in question, both for line and base maintenance.

Icelandair Technical Services (ITS)

ITS's aeroplane maintenance organisation approval reference is IS.145.0002. The approval is based on the requirements of European Parliament and Council Regulation 216/2008 and Commission Regulation 2042/2003. The latter Regulation also contains Annex 2, Part-145, dealing with maintenance operations. The approval has been granted by the civil aviation authority of Iceland. It is valid for an unlimited time and covers commercial air transport operations. The scope of work specified in the approval includes the aeroplane/powerplant combination in question, both for line and base maintenance.

Competent civil aviation authority of Finland

The competent civil aviation authority in Finland is the Finnish Transport Safety Authority. It oversees Air Finland's EU OPS 1 and Part-M operations as well as FTS's Part-145 operations. The investigation group studied the results of audits made by the aviation authority before the incident flight, in which the operations referred to above were reviewed.

The last audit of Air Finland's OPS 1 operations before the incident flight was performed on 21 September 2010. No serious findings were made during the audit, but there were ten minor findings and one comment was issued. The findings and the comment had no effect on the incident under investigation.

The Part-M audit preceding the incident flight was carried out in two parts. The first part was conducted on 22 October 2009 in ITS's premises in Iceland. The audit concerned the subcontract between Air Finland and ITS as well as the operations performed under it, and two level 2 findings were recorded. The second part of the audit was carried out on 9–10 March 2010 in Air Finland's premises at Vantaa and resulted in one level 2 finding. The findings recorded had no effect on the incident under investigation.

The Part-145 operations of FTS were audited in three parts before the incident flight at Helsinki-Vantaa airport technical area. Two of the audit visits concerned aeroplane maintenance. The aeroplane maintenance audit performed on 4–8 October 2010 resulted in 14 level 2 findings. Five of the findings were related to maintenance instructions, traceability of parts and airworthiness. One finding concerned the issue of certificate release to service. The second aeroplane maintenance audit, which was carried out on 9–10 November 2010, focused on subject 145.55, Maintenance records. It resulted in eight level 2 findings, one of which concerned the procedures for spare part acceptance.

Based on the information obtained, the audits were performed in due time and appropriate corrective actions had been presented. The incident now under investigation revealed similar non-compliances in FTS maintenance operations as the audits.

The operations of ITS are overseen by the civil aviation authority of Iceland. As the sequence of events indicates that ITS only provided the staff resources, the activities of the Icelandic aviation authority were not investigated.

1.10 Earlier similar incidents

1.10.1 In-flight fuel leak in a B757 aircraft on 9 June 2007

The incident occurred on Air Finland's flight KKK7214 from Alesund, Norway to Antalya, Turkey on 9 June 2007. A fuel imbalance developed between the right and left tank during the flight, and the Fuel Config warning light was illuminated when the aircraft was taxiing after landing. The SIA investigated the incident, which was assigned the identification number D9/2007L. The investigation revealed that the incident was mainly caused by the right engine high-pressure fuel pump, which had been mechanically damaged. About 800 kg of fuel had leaked out through the drain pipe.

The investigation showed that the pilots did not first perceive the situation as a fuel leak. After the fuel leak was confirmed on the ground, they did not immediately shut down the engine.

The airline dealt with the incident shortly after the flight. The incident and corrective actions were discussed in a meeting of the company Flight Safety and Quality Team on 28 November 2007. A fuel leak situation was included in the pilots' simulator training. The incident and corrective actions were reviewed with all company instructors in an instructors' meeting held on 12 November 2007. The airline also made an amendment to its Operations Manual, Part A after the incident.

1.10.2 Leaks in fuel tube couplings

According to a study published by AAIB on 6 July 2010, there had been 24 reported fuel leaks through couplings of the high-pressure fuel pump tube in Rolls-Royce RB211-535E4 engines between January 2008 and July 2010. The statistics were collected from users of RB211-535E4 engines worldwide. One of the incidents occurred in-flight and led to a diversion, whereas the other fuel leaks were detected during maintenance.

The study reports that the engine manufacturer found a connection between the manufacturing tolerance of the fuel tube seal groove and the fitting of the seal. To rectify the situation, the manufacturer issued in November 2009 Service Bulletin RB.211-73-G230 about enlarging the seal groove with a new part. This Service Bulletin is non-mandatory and can be implemented either during engine overhaul or without removing the engine from the aircraft.

2 ANALYSIS

2.1 Events during the flight

The first indication of the beginning engine fuel leak was the decreasing of the oil temperature and raising of the oil pressure in the right engine. The pilots did not notice or consider the abnormalities significant, as the instrument readings were still within the acceptable tolerances. The change in the values was caused by increased fuel flow through the fuel-oil heat exchanger as a result of the fuel leak. The heat exchanger is designed to heat the fuel to melt any ice crystals before the fuel flows through the filter, and at the same time, to cool the engine oil. An increased fuel flow causes the oil to cool down more than intended. Cooler oil, in turn, is higher in viscosity, which causes the oil pressure reading to rise. This phenomenon is widely known in aviation.

In the second fuel check made in accordance with the normal procedure, the pilots noticed a significant difference between the calculated and actual fuel quantity. The pilots began to suspect an engine fuel leak. They shortened the monitoring interval due to increased fuel consumption, which is not a procedure listed in the QRH. Monitoring the situation took time, which could have been used to carry out the procedures required by QRH. After the pilots noticed the significant difference between calculated and actual fuel quantity and suspected an engine fuel leak, they should have initiated the procedures specified in the QRH Engine Fuel Leak check list (see Appendix 2).

After the difference between calculated and actual fuel quantity had grown larger, the pilots' suspicion about an engine fuel leak grew stronger. Since the centre fuel tank was getting empty and they would turn off the fuel pumps after a few minutes in any case, the pilots thought about finding out the possible connection between the unstable fuel quantity indication for the centre fuel tank at the beginning of the flight and the abnormal fuel consumption. The low fuel pressure warning lights were illuminated after the centre tank was empty. This confirmed it to the pilots that there was an actual fuel leak. After the fuel leak was confirmed in the right-hand fuel system or engine, the pilots should have shut down the right hand engine according to the QRH.

It is difficult to see any leaking fuel from the cabin windows, because the direction of vision is very slant and only a narrow area can be seen at a time. To form an overall picture, it is necessary to inspect the area from several cabin windows. The leaking fuel was probably covered by turbulent air in the jet blast and partly blended with bypass air.

The captain's decision to discontinue the flight and land at Charles de Gaulle airport was correct. After the pilot reported a fuel leak, the air traffic controller took the actions necessitated by the incident. These actions can be considered sufficient.

Since the limit value of 500 kg in 30 minutes as specified by the QRH was exceeded and the situation was therefore determined as a fuel leak, QRH instructs to shut down the leaking engine. After shutting down the engine, QRH instructs to resume the normal fuel management procedure, making sure that all the remaining fuel can be used in the operating engine and no fuel imbalance between tanks develops. Because the pilots deviated from the QRH instructions, a Fuel Config warning was illuminated in the cockpit. QRH also gives separate instructions for those situations. The maximum fuel imbalance allowed by the Aircraft Flight Manual is limited to 885 kg. Although the fuel imbalance in-

creased all the time, the pilots took no action. As the flight was continued while the fuel imbalance increased after the Fuel Config warning the flight was then outside the approved performance envelope and the situation developed into a serious incident according to the ICAO classification. The pilots did not file appropriate reports about exceeding the approved performance envelope.

The threshold to shut down an operating engine is high. In this case the vibration in the left engine and the need to consume extra fuel for landing raised pilots' already high threshold to shut down the leaking right engine. If the pilots had shut it down and flown with a single engine, it would have been more difficult to control the aircraft. However, the pilots' decision not to shut down an engine that was leaking fuel and deviate from instructions was not justified. In the investigators' opinion, B757 aircraft is not considered particularly challenging to fly in a single-engine situation. In pilots' opinion the actions chosen by them were safer than the procedure described in the QRH.

At the time of the incident, the pilots did not know exactly where the leaking fuel came from and where it might end up. It is impossible for pilots to assess the risk of fire associated with a fuel leak from the cockpit. An in-flight fuel leak should always be considered to involve a risk of fire, although the fuel used in turbine engines is not very easily ignited.

According to the engine manufacturer, the reasons for shutting down a leaking engine are to make sure that the fuel quantity is sufficient for the remaining flight and to reduce the risk of fire. The risk of fuel flowing in a place in the engine compartment where it might be ignited depends on flight altitude, engine power setting, configuration, airspeed and the progress of damage during the flight. It must also be noted that reverse thrust during landing roll may change the flow in the engine so that the risk of fire increases. When the engine was shut down after the touch down, the fuel leak stopped and there was no longer any risk of fire as the aircraft taxied to the apron.

If the situation of the incident flight was simulated on a proficiency check, deviating from the check list procedures would cause the check flight to be failed. Consequently, the actions of the pilots cannot be considered fully acceptable. Deviating from QRH procedures is only allowed if it is absolutely necessary for flight safety reasons.

After the aircraft was parked at the apron at Charles de Gaulle airport, the other engine was shut down. The cockpit voice recorder (CVR) had automatically stopped recording five minutes after that. Because the CVR circuit breaker had not been opened, the CVR may have started recording again for a short time when the engine was wet motored. At the latest, the CVR recording was fully erased during the ferry flight, since the circuit breaker had not been opened or the recorder changed before the flight. To save the recording, the CVR should either have been changed at Charles de Gaulle airport or the aircraft should have been flown to Helsinki with the circuit breaker opened and the CVR changed there.

The cockpit voice recording for the incident flight would help to confirm the course of events as told by the pilots and to rule out any lapses of memory as regards the sequence and timing of the events.

All in-flight discussions between the pilots were in English, which is not the native language for either pilot. In an abnormal situation, using a foreign language may sometimes

hamper or slow down the handling of the issue. Investigators' opinion is that the use of a foreign language did not influence on the course of events.

2.2 Maintenance actions before the flight

The deficiencies in maintenance documentation related to work order WO #85 and the work package associated with the daily check were not detected before or after maintenance. The certificate release to service issued did not meet the EASA requirements. As a result, the aircraft was not airworthy as regards the maintenance actions carried out. In the investigators' opinion, FTS should have issued its own certificate release to service for the maintenance. The fact that the declaration in accordance with Part-145 was missing from Air Finland's technical log sheet was a non-compliance that had not been detected by Air Finland's internal quality assurance or in any audits made by the aviation authority. The procedures described in FTS's and Air Finland's agreement on operating instructions were not followed during the maintenance work.

An acceptance marking by the continuing airworthiness management organisation was missing from the maintenance documents. Consequently, the acceptance of the maintenance work was not in compliance with EASA Part-M requirements. When the work is accepted, the organisation should e.g. compare the work order to the certificate release to service issued for the work completed. The person accepting the maintenance should determine whether the work performed meets the requirements for continuing airworthiness management. Any deficiencies as regards the work and the maintenance documentation should be detected in that inspection. In this case, the non-compliances went undetected or did not lead to actions.

After the maintenance, the right engine was test run at idle for about 10 minutes and then shortly at take-off power. Based on the interviews, no abnormalities were detected during the test run or at the engine compartment inspection after it.

The investigators found three possible causes for the fuel leak.

The engine manufacturer has established a connection between the manufacturing tolerance of the seal groove and the seal used. It is possible that the fitting of the seal becomes too tight, in which case the seal may be pressed incorrectly against the edge of the groove. The metal surfaces of the flanges will then not settle tightly against each other, even if the bolts of the couplings are tightened to the correct value. Engine vibration and changes in fuel pressure may weaken the incorrectly pressed seal. The failed seal will cause a fuel leak after some time.

After a modification in accordance with the manufacturer's Service Bulletin SB RB.211-73-G230, the fitting of the seal in the coupling improves. The modification is recommended to be carried out at next scheduled engine maintenance or overhaul. Responsibility for implementing the modification rests with the operator's continuing airworthiness management organisation. The modification had not been made to the leaking engine by the time of the incident flight.

Another alternative is that the bolts between the flanges had not been tightened to the final value of 100 lb.in. The fuel tube is made of steel alloy, and because of its rigidity, both ends of the tube and the seals must fit into place almost simultaneously. After initial

installation, the flange mounting bolts must be tightened to the value of 100 lb.in. The coupling from which the fuel leaked with its attachment bolts was relatively well visible. However, it is difficult to find enough space for the torque wrench when tightening the bolts, because several tubes for different engine systems are routed past or under the mounting flange. The investigators consider this maintenance error as a possible cause of the fuel leak.

The third alternative is that a wrong seal had been installed. The investigators do not regard the installation of a wrong part as a likely cause of the fuel leak, but it cannot be fully excluded. The mechanism in which a wrong seal could have caused a fuel leak could not be traced. The maintenance staff that made the defect repair in Paris had discarded the replaced parts, and the installed seal could not be inspected to check the part number or to detect any damage. The documentation of FTS maintenance work was inadequate and could not be used to ascertain the correctness and airworthiness of the part used.

2.3 Complexity of the maintenance task

The tightening torque to be used is not given directly in the maintenance task instructions, but all values have been collected into separate tables. The correct value must be specifically searched from the table. Using the wrong table or any misinterpretation will probably lead to an incorrect torque value.

Replacing the accessory gearbox is a complex task with several work stages. It consists of about 200 items to be separately mounted. Without appropriate and sufficiently detailed work tasking and task cards, some stage of the work may be inadvertently skipped or carried out incompletely. The risk is further increased by shift changes, pauses and other external distractions, such as using the mobile phone.

In aircraft maintenance, as well as in other sectors of aviation, many different checks and safeguards are used to ensure flight safety and reliability of operations. In this case, the mechanics who carried out the maintenance work had checked the result twice, and the person who issued the certificate release to service checked it for the third time. The quality of the checks depends on personal skill and attitude, and on the prevailing organisational culture. The tightness of the bolts can eventually be only ensured by testing with the torque wrench. However, checking all the couplings in this way would be frustrating and uneconomic, as the same work would be carried out twice. If the couplings had been secured by lockwire or marked with inspection lacquer after tightening, the final inspection could have been made visually for this part.

2.4 Organisations

Air Finland had subcontracted a significant part of its continuing airworthiness management functions. The airline company had a small organisation and limited resources for supervising the subcontracted work. In the case under investigation, personnel from several different organisations participated in the Part-M functions and their supervision. The lack of assertive and consistent management led to deficiencies and deviations in the supervision of the maintenance work and in continuing airworthiness monitoring. The company instructions were not sufficient to ensure adequate supervision of several operators.

FTS's organisation was not able to supervise the maintenance work performed. The confusion was increased by Air Finland's direct work order to ITS, which ITS did not refuse. FTS had appointed a member of its own certifying staff to supervise the maintenance. FTS's quality assurance department agreed to the ITS maintenance team working in FTS's premises. However, the actual division of responsibilities and supervisory functions of the maintenance supervisor was unclear. ITS carried out the ordered work package as their own project and incorrectly entered a maintenance release in the aircraft technical log without having a line maintenance approval for Helsinki-Vantaa airport. FTS should have assessed the competence of the ITS team and placed them directly under the responsibility of the person supervising the maintenance. Moreover, the spare parts supplied by ITS for the maintenance work should have been delivered through FTS's own stores. Air Finland's work order to ITS should have been included in FTS's work package, and FTS should have issued a certificate release to service for the whole maintenance. Once the maintenance was completed Air Finland's continuing airworthiness management organisation should have accepted the aircraft from maintenance and checked the documents before it was released to service.

Management of the fuel leak repair in Paris was left to the captain's responsibility, although Air Finland's continuing airworthiness management organisation should have been actively involved. For this reason, the maintenance documents issued for the defect repair in Paris were inadequate.

The audits carried out by the civil aviation authority were sufficient in number. In the investigation group's opinion, however, the audits could have more precisely focused on the subcontracting alternatives made possible by maintenance agreements between the organisations and their management. The functional deficiencies and procedural errors could also have been detected by both organisations' quality departments.

During the investigation, it could not be ascertained who was responsible for the management of Air Finland's storage shelves in FTS's premises. Audits performed by the aviation authority revealed deficiencies in the same areas.

In 2007, the airline company's B757 aircraft had a similar engine fuel leak as that now under investigation. The pilots deviated from QRH instructions as regards shutting down the engine in that case as well. As a result, the company included the fuel leak situation in its pilot training programme and made a corresponding amendment to its Operations Manual. In the case now under investigation, the pilots had received refresher training a few months before the incident, and the functioning of the fuel system had also been addressed. As the pilots deviated from the QRH instructions in a similar situation anyway, the company should check whether its training for fuel leak situations is sufficient.

3 CONCLUSIONS

3.1 Findings

1. The pilots' licences and required ratings were valid.

2. A maintenance inspection was made to the aircraft in FTS's premises immediately before the incident flight, including a daily check, component replacements and defect repairs. The largest single work in the maintenance was the change of the right engine accessory gearbox.

3. The first indication of the beginning engine fuel leak was the decreasing of the oil temperature and raising of the oil pressure in the right engine. The pilots did not notice the abnormalities when they began or the observation did not lead to any actions.

4. In another fuel check made in accordance with the normal procedure, it was noticed that fuel consumption had been 1700 kg higher than calculated. The pilots started to suspect an engine fuel leak.

5. Pilots started to monitor the fuel consumption more closely during a monitoring period of 17 minutes. During the period about 600 kg of more fuel leaked out.

6. The captain and the purser did not see any fuel leaking from the engine when looking out from the cabin windows.

7. The pilots located the fuel leak to the aircraft's right fuel system or right engine.

8. The captain decided to discontinue flight and land at Paris Charles de Gaulle airport.

9. The pilots selected the emergency code in the transponder as instructed by ATC.

10. The pilots deviated from the QRH instructions, which required that the leaking engine should be shut down. This caused the maximum allowed fuel imbalance to be exceeded, and a Fuel Config warning was illuminated in the cockpit. The warning did not lead to any actions.

11. As the flight was continued while the maximum allowed fuel imbalance was exceeded the flight was then outside the approved performance envelope and the situation developed into a serious incident according to the ICAO classification.

12. The leaking engine was shut down on the ground after touch down, and the fuel leak stopped.

13. The pilots did not file appropriate reports to the competent aviation authority and company's continuing airworthiness management organisation about exceeding the approved performance envelope.

14. The defect having caused the fuel leak was repaired at Charles de Gaulle airport. The o-ring that caused the leak was discarded, although it should have been preserved.

15. The aircraft cockpit voice recording was completely erased during the ferry flight at the latest and therefore the investigators did not have the recording from the event time.

16. The modification to improve the fitting of the seal in the coupling had not been carried out in the leaking engine before the incident flight.

17. The removal and installation of the fuel tube that leaked during the flight is part of the gearbox replacement task.

18. The maintenance work order was inadequate. There were no maintenance documents for the replacement of the right engine accessory gearbox. Maintenance documents were not available for the engine run-up either, such as a test run protocol showing the content and results of the test. The airworthiness of the seal installed in the leaking coupling could not be ascertained. The torque used for tightening the coupling attachment bolts could not be verified either.

19. The certificate release to service entered in the aircraft technical log did not contain the declaration required by EASA Part-145. Consequently, the aircraft was not airworthy or fit for flight as regards the maintenance work performed.

20. The acceptance of the maintenance work was not in compliance with EASA Part-M requirements.

21. ITS carried out the maintenance without a line maintenance approval at Helsinki-Vantaa airport.

22. FTS was unable to supervise the maintenance work and issued an incorrect certificate release to service.

23. Air Finland's quality department did not address the incident during the investigation.

24. FTS's quality department addressed the incident during the investigation.

3.2 Probable causes and contributing factors

The immediate cause of the incident was a fuel leak from a fuel tube coupling in the right engine high pressure fuel pump. The investigation group found three possible causes for the fuel leak.

The most probable cause leading to the fuel leak, as concluded by the investigation group, is that the fitting of the seal was originally too tight, for which reason the seal may have been pressed incorrectly against the edge of the groove when it was installed during maintenance before the incident flight. A contributing factor to this fuel leak mechanism would be that the airline had not carried out the non-mandatory modification sug-

gested by the engine manufacturer's service bulleting SB RB.211-73-G230, which would have improved the fitting of the seal in the coupling.

Another possible cause for the fuel leak is that the bolts between the coupling flanges had not been tightened up to the instructed final value during maintenance before the incident flight. In this case, there would be several contributing factors. Firstly, it is challenging to find the correct value for the tightening torque in the tables of the manual. Secondly, there is little space in the engine compartment for turning the torque wrench, which may have made it more difficult to tighten the bolts. Thirdly, the coupling had not been secured by lockwire or marked with inspection lacquer after tightening, which hampered the inspection of the final tightness. Inadequate supervision of the maintenance would probably also have contributed to this mechanism.

The third possible cause for the fuel leak is that a wrong seal was inadvertently installed in the coupling during maintenance before the incident flight. The investigation group does not consider this likely, but it cannot be fully excluded. Inadequate supervision of the maintenance would probably have contributed to the installation of the wrong seal.

The in-flight fuel leak resulted in an incident. The pilots did not shut down the leaking engine during the flight, although the Quick Reference Handbook (QRH) instructs to do so in engine fuel leak situations. The pilots' deviation from QRH instructions caused the maximum allowable fuel imbalance to be exceeded as the fuel leak continued, which led to operations outside the approved performance envelope and the incident developed into a serious incident according to ICAO classification.

4 SAFETY RECOMMENDATIONS

4.1 Safety actions already implemented

Finnair Technical Services quality management organisation has reviewed its customer procedures and emphasized the correct way of using and filling out maintenance documents in its trainings.

The Safety Investigation Authority, Finland has not been informed of any other actions taken during the investigation to prevent similar incidents in the future.

4.2 Safety recommendations

The Safety Investigation Authority, Finland will not issue any safety recommendations. Originally, it intended to issue four safety recommendations to Air Finland Ltd, but since the company was placed into liquidation during the investigation, any recommendations can no longer be directed to the airline. Nevertheless, the content and justifications of the original safety recommendations are described in the following paragraphs, so that the suggestions for safety improvement resulting from the investigation can be made generally known.

The pilots deviated from the QRH instructions for fuel leak situations when they did not shut down the leaking engine. As a result, the maximum allowable fuel imbalance was exceeded as the fuel leak continued, which led to operations outside the approved performance envelope and the incident developed into a serious incident according to ICAO classification. For this reason, the Safety Investigation Authority, Finland intended to recommend the airline to check whether its pilot training was sufficient as regards fuel leak situations.

The investigation revealed deficiencies in the operations of the airline company's continuing airworthiness management organisation (EASA Part-M) with regard to the acceptance and management of maintenance work. For this reason, the Safety Investigation Authority, Finland intended to recommend the airline to make sure that the operating procedures of its continuing airworthiness management organisation are in compliance with the company instructions as approved by the competent civil aviation authority of Finland.

If the original fitting of the coupling seal that leaked fuel during the incident flight was too tight, it may have been pressed incorrectly against the edge of the groove when it was installed during maintenance before the flight. The engine manufacturer has, in 2009, issued a non-mandatory service bulletin SB RB.211-73-G230, which would improve the fitting of the sealing groove. The Safety Investigation Authority, Finland intended to recommend the airline to implement the engine manufacturer's service bulletin in all B757 aircraft used for its operations.

The declaration text in accordance with EASA Part-145 requirements was missing from the certificate release to service contained in the aircraft technical log. Consequently, the aircraft was not airworthy or fit for flight on the incident flight as regards the certificate release to service for the maintenance work performed. The Safety Investigation

Authority, Finland intended to recommend the airline to change the certificates release to service of all aircraft operated by it so that they would include the declaration in accordance with EASA Part-145 requirements.

4.3 Other remarks and suggestions

For the maintenance work in question, there is a task list available in which each work stage is identified. The task list has separate columns for signatures by the maintenance staff and the inspector. If this task list was properly completed, the maintenance staff could be assured that the work is carried out in correct order and any items are not left out. Moreover, marking the torque values and wrenches used for tightening the components, such as bolts, on the task list would make sure that the coupling is tightened to the final value.

The Safety Investigation Authority, Finland suggests that the task list should be completed item by item as the work progresses, so that the maintenance staff would sign each item after the task is performed and also write the torque values and identifications of the wrenches used in the appropriate field.

In the investigation group's opinion, audits carried out by the civil aviation authority in the organisations involved were sufficient in number, but more attention could have been paid to subcontracting arrangements.

Appendix 1

SUMMARY OF THE RECEIVED COMMENTS ON THE DRAFT FINAL REPORT

FINNISH TRANSPORT SAFETY AGENCY

The Finnish Transport Safety Agency did not have any comments.

AIR FINLAND LTD

Air Finland Ltd bankrupt's estate did not have any comments.

FINNAIR TECHNICAL SERVICES (FTS)

FTS did not have any comments.

In connection with the investigation report's section 1.4 Safety actions already implemented FTS mentioned that its quality management organisation has reviewed its customer procedures and emphasized the correct way of using and filling out maintenance documents in its trainings.

UK AIR ACCIDENTS INVESTIGATION BRANCH (AAIB)

AAIB did not have any comments.

ROLLS-ROYCE

Rolls-Royce did not have any comments.

AVIACARE

Aviacare did not have any comments.

Aviacare mentioned that it takes notice of the conclusions of the investigation report. Aviacare will inform its engineers of the legal requirement to safeguard all material related to incidents/accidents until it can be released as instructed by the operator or the overseeing authority.

EUROPEAN AVIATION SAFETY AGENCY (EASA)

EASA did not have any comments.

NATIONAL TRANSPORTATION SAFETY BOARD (NTSB)

NTSB did not have any comments.

Boeing 757 Flight Crew Operations Manual – Engine Fuel Leak

Engine Fuel Leak

Condition: An in flight engine fuel leak is suspected or confirmed.(Items which may indicate an engine fuel leak are listed in the Additional Information section at the end of this procedure.)

1 C L and C R PUMP switches . . . . . Off

2 Do **not** accomplish the following checklist:

FUEL CONFIGURATION

3 FWD and AFT FUEL XFEED switches . . . . . Off

4 Identify an engine fuel leak by observing a left or right main tank fuel quantity decreasing faster than the other.

5 An increase in fuel imbalance of approximately 500 kilograms or more in 30 minutes should be considered an engine fuel leak.

6 **If** conditions allow:

Visually check for engine fuel leak.

7 Choose one:

◆Engine fuel leak **confirmed**:

►►**Go to step 17**

◆Left and right main tank quantities **decrease at the same rate**:

►►**Go to step 8**

8 Resume normal fuel management procedures.

▼ Continued on next page ▼

Appendix 2

▼ Engine Fuel Leak continued ▼

9 Choose one:

◆FUEL DISAGREE-PROG 2 **and** FUEL QTY ERROR-PROG 2 messages are **not** shown on the CDU scratchpad:

►►**Go to step 12**

◆FUEL DISAGREE-PROG 2 **or** FUEL QTY ERROR-PROG 2 message is **shown** on the CDU scratchpad:

►►**Go to step 10**

10 PROGRESS PAGE 2 . . . . . SELECT

11 TOTALIZER or
CALCULATED . . . . . Select USE for the most accurate indication

■ ■ ■ ■

12 Choose one:

◆LOW FUEL message **not** shown:

■ ■ ■ ■

◆LOW FUEL message is **shown**:

FWD and AFT FUEL XFEED switches . . . On

This ensures all fuel is available if the low tank empties.

►►**Go to step 13**

▼ Continued on next page ▼

▼ Engine Fuel Leak continued ▼

13 PUMP switches (all) . . . . . ON

This ensures all fuel is available.

14 Plan to land at nearest suitable airport.

15 Avoid high nose up attitude and excessive acceleration and deceleration.

16 Do **not** accomplish the following checklist:

LOW FUEL

■ ■ ■ ■

17 A/T ARM switch . . . . . OFF

18 Thrust lever
(affected side) . . . . . Confirm . . . . . Idle

19 FUEL CONTROL switch
(affected side) . . . . . Confirm . . . CUTOFF

20 Choose one:

◆APU is **available**:

►►**Go to step 21**

◆APU is **not available**:

►►**Go to step 22**

21 APU selector . . . . . START, then ON

22 GND PROX FLAP OVRD switch . . . . . OVRD

OH-AFJ, OH-AFK

23 Transponder mode selector . . . . . TA

▼ Continued on next page ▼