

INCIDENT

Aircraft Type and Registration:	Boeing 757-2K2, G-LSAN	
No & Type of Engines:	2 Rolls-Royce RB211-535E4 turbofan engines	
Year of Manufacture:	1994 (Serial no: 26635)	
Date & Time (UTC):	7 August 2012 at 1535 hrs	
Location:	Over the North Sea, approximately 85 nm north-east of Newcastle Airport	
Type of Flight:	Commercial Air Transport (Non-Revenue)	
Persons on Board:	Crew - 2	Passengers - 1
Injuries:	Crew - None	Passengers - None
Nature of Damage:	None	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	51 years	
Commander's Flying Experience:	8,058 hours (of which 6,017 were on type) Last 90 days - 136 hours Last 28 days - 41 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB	

Synopsis

Approximately three hours of a post-maintenance airtest had elapsed when the flight crew identified a lateral fuel imbalance, which they determined as being caused by a fuel leak from the right engine. The flight crew carried out the 'Engine Fuel Leak' QRH checklist which resulted in the right engine being shut down, following which the crew made a single-engine diversion and landing at Newcastle Airport, without further incident. The cause of the fuel leak was identified as a damaged O-ring seal in a part of the right engine's fuel system that had been recently replaced due to embodiment of a recommended Service Bulletin. The engine manufacturer and maintenance organisation involved are both implementing safety actions intended to prevent a recurrence.

History of the flight

The aircraft had undergone a 'C-check' maintenance inspection and, following two uneventful post-maintenance flights totalling 1 hour and 20 minutes, was being flown on an airtest prior to release to service. Approximately three hours of the airtest had elapsed when, during a routine fuel check, the crew noticed a lateral fuel discrepancy of approximately 600 kg, with the right wing fuel tank quantity indicating less than the left wing fuel tank. Shortly afterwards the EICAS FUEL CONFIG warning illuminated as the fuel imbalance increased to 800 kg.

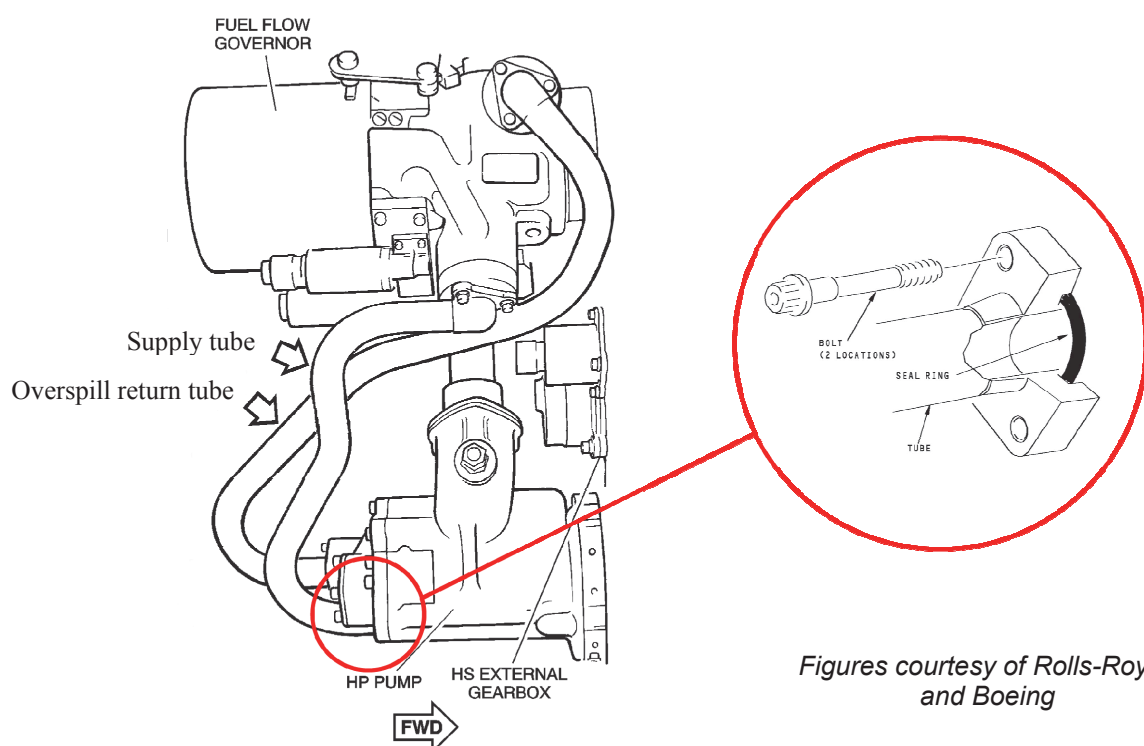
The flight crew carried out the 'Fuel Configuration' section of the quick-reference handbook (QRH), which

further directed them to complete the QRH's 'Engine Fuel Leak' checklist; this required a visual check for an engine fuel leak. An engineering observer who was aboard the aircraft for the airtest reported that he could see fuel leaking from the right engine and this was visually confirmed by the first officer. The commander made a PAN radio call to Scottish ATC and requested a direct routing to Newcastle Airport, some 85 nm to the south west, which he determined to be the closest suitable airport. The flight crew then completed the 'Engine Fuel Leak' checklist by shutting down the right engine, following which they carried out an uneventful single-engine diversion and landing at Newcastle Airport.

Engineering inspection

Inspection of the right engine's fuel system revealed that the source of the fuel leak was the pump-end flanged joint of the fuel supply tube running between the high pressure (HP) fuel pump and the fuel flow governor (Figure 1). This fuel tube had been installed during the C-check as part of a recommended Service Bulletin, RB.211-73-G230. This Service Bulletin recommends the replacement of earlier standards of fuel tube that were the source of previous fuel leaks; the AAIB report on G-TCBA, published in AAIB Bulletin 4/2011, refers to one such incident.

When the fuel supply tube was removed from the engine, one of the two bolts that attached the flange to the HP fuel pump body was found to be only finger-



Figures courtesy of Rolls-Royce and Boeing

Figure 1

Location of the supply and overspill fuel tubes between the HP fuel pump and fuel flow governor, including detail of the supply tube's flanged end fitting

tight and the flange's O-ring seal was damaged, with a section missing (Figure 2). Both attachment bolts were new items that had been fitted during the installation of the fuel tube, however the bi-hex head of the lower bolt exhibited an unexpected degree of galling (Figure 3), consistent with a socket slipping off the head of the bolt during tightening of the bolted-flange joint.

The threads on the lower bolt were found to be damaged, as was the start thread of the wire-thread insert in the pump body which had been displaced upwards slightly, and metallic debris was present on the insert's threads.

Examination of the damaged thread forms showed that the bolt had not been cross-threaded, rather that the start thread of the wire-thread insert had 'picked up' during insertion of the bolt, causing a progressive rounding-over of the bolt's threads as the bolt was tightened. A subsequent trial at the HP fuel pump manufacturer's overhaul facility, using a new bolt in the same hole, showed that whilst similar damage occurred to the bolt threads, the bolt torque specified in the Service Bulletin, 102 lbf-in, was only achieved when the flanged joint was fully fastened. It is therefore unlikely that the damaged wire-thread insert caused the lower bolt to remain only

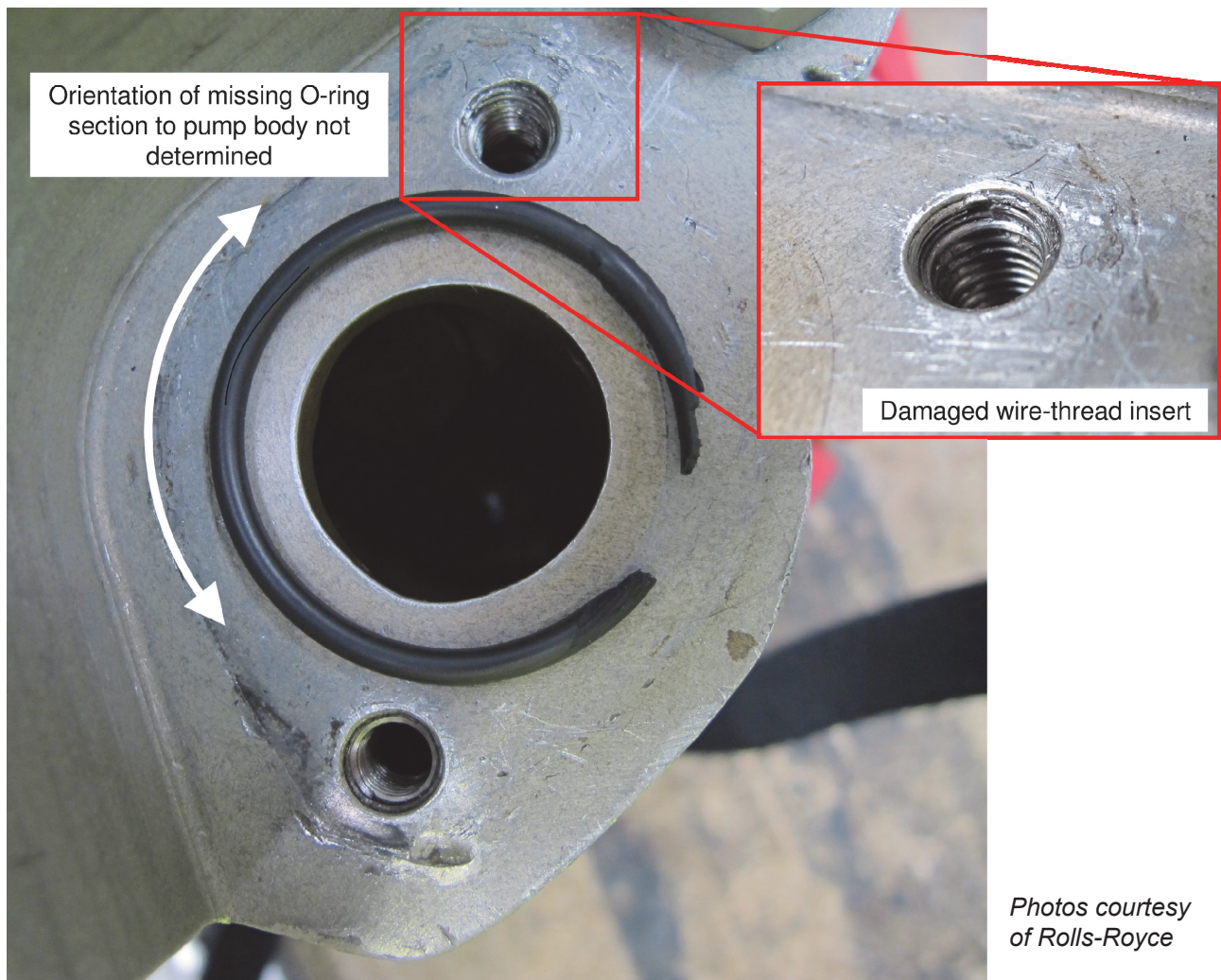


Figure 2

Damaged O-ring seal, pump body and wire-thread insert



Figure 3

Lower bolt showing damaged threads and galling marks on head

partially inserted, despite the required bolt torque value being applied during assembly of the tube to the fuel pump. The torque wrench used during the installation of the fuel tubes was checked, determined to perform within calibration limits, and was declared to be serviceable.

The face of the pump body, to which the fuel tube adjoins, exhibited fresh galling and scratch marks around the lower bolt hole and around the periphery of the fuel tube flange interface, indicating that a degree of difficulty was experienced in assembling the fuel tube to the pump body.

Maintenance actions preceding the incident

In order to progress the planned maintenance activity on the aircraft, embodiment of the Service Bulletin had taken place whilst the right engine was removed from the aircraft and installed in a transport cradle, as both of the aircraft's pylons had been removed for other, unrelated, maintenance purposes. The lower parts of the engine, including the area where the fuel tubes were to be replaced, were close to the ground and partially obstructed by the cradle's steel framework. These restrictions made access significantly more difficult than if the engine had been mounted on its pylon, or in an engine overhaul fixture.

The Service Bulletin was accomplished in a hangar by a mechanic and inspected by a licensed engineer, both of whom were familiar with the task. The mechanic described the access to the fuel tubes and the visibility of the fuel tube's flanged joints at the HP fuel pump as "not good". He experienced initial difficulty in retaining the fuel tube O-rings when using fuel as a lubricating and retaining fluid and applied 'Nyco 65' petroleum grease to retain the O-rings within their grooves. Whilst Nyco 65 was effective in retaining the O-rings, it is not an approved material for use in the engine fuel or oil systems as it does not readily dissolve in fuel or oil, and may block small metering orifices in fuel control systems.

The mechanic installed and tightened the fuel tube bolts in accordance with the Service Bulletin instructions; for each fuel tube this required tightening three bolts at the fuel flow governor end of the tube before then tightening the two bolts at the HP fuel pump. He reported that the flanged joints on both fuel tubes appeared to be properly seated and flush, as did the licensed engineer who inspected and certified the task. On completion of the C-check the aircraft's engines were ground run at full power and no leaks were detected from either engine. The aircraft was subsequently flown to Norwich Airport for repainting before returning to the

maintenance provider's base and no fuel leaks were experienced on either of these sectors.

Engine manufacturer's investigation

Following the incident the engine manufacturer conducted an investigation into the installation difficulty of both the supply and overspill return fuel tubes as specified in the Service Bulletin. This activity showed that for both fuel tubes, it was significantly easier for a mechanic to align and torque the HP fuel pump flange bolts before then tightening the fuel flow governor flange bolts, which is the reverse of the bolt tightening sequence specified in the Service Bulletin. Retention of the O-rings within the grooves in the fuel tube flanges was also identified as a problem, particularly at the HP fuel pump ends where access and visibility are limited. Application of a viscous assembly fluid to specification OMat 1069, which is approved for use on fuel system components, was identified as a suitable measure to retain the O-rings during assembly of the joints.

Analysis

The nature of the damage to the fuel supply tube's O-ring was consistent with it becoming partially displaced and subsequently pinched during the assembly of the tube's joint to the HP fuel pump. The failure of the O-ring was insidious in that no leak occurred during the full power ground run and eventual failure of the O-ring under fuel pressure loading occurred only after 4 hours and 20 minutes of flight had elapsed. The detachment of the pinched section of O-ring reduced the end load on the fuel tube flange, causing the upper attachment bolt to appear to be only finger-tight immediately after the diversion to Newcastle Airport.

The galling damage observed on the lower flange bolt and pump body, together with the damaged wire-thread insert suggests that difficulties were experienced

during alignment of the flange's bolt holes to the fuel pump body. The investigation conducted by the engine manufacturer confirmed that tooling and visual access to both pairs of flange bolts at the fuel pump is limited, and that locating and tightening the bolts was made additionally difficult by the assembly sequence specified in the Service Bulletin.

Conclusion

The fuel leak was caused by the fuel supply tube's O-ring seal becoming trapped in the joint between the tube and the HP fuel pump body during assembly, before subsequently failing under fuel pressure load during flight. Two contributory factors were identified in the investigation: embodiment of the Service Bulletin whilst the engine was mounted in a transport cradle, which made access to the fuel tubes more difficult than if the engine had been mounted on its pylon, and the bolt-tightening sequence specified in the Service Bulletin, that exacerbated the difficulty of aligning the fuel tube to the HP fuel pump and therefore increased the probability of displacement the O-ring from the tube's flange groove.

Safety actions

The engine manufacturer is revising the Service Bulletin and engine manual to require that the fuel flow governor supply and overspill return tubes have their bolts tightened in the opposite order to that presently specified. The modified Service Bulletin text will also include a recommendation to apply a viscous assembly fluid to OMat 1069 specification to aid, during assembly, retention of the O-rings within their grooves in the tube end flanges.

The maintenance organisation is drafting a Quality Advisory Notice to its staff to communicate the findings of this investigation in addition to similar findings

from an internal MEDA investigation carried out following the fuel leak event. The organisation has also classified the Service Bulletin as a '*Flight Safety Sensitive Task*', requiring independent inspection during

the critical stages of the task including installation of the O-ring seals, lubrication with viscous assembly fluid, installation of the fuel tubes and torque tightening of the attachment bolts.