INCIDENT

Aircraft Type and Registration:	Boeing 757-236, G-BPEE
No & Type of Engines:	2 Rolls-Royce RB211-535E4-37 turbofan engines
Year of Manufacture:	1991
Date & Time (UTC):	12, 16 and 23 November 2004
Location:	En-route, various sectors
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - Not known Passengers - Not known
Injuries:	Crew - 3 (Minor) Passengers - None
Nature of Damage:	None to aircraft
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	43 years
Commander's Flying Experience:	12,000 hours (of which 6,000 were on type) Last 90 days - 155 hours Last 28 days - 65 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and subsequent enquiries by the AAIB

Synopsis

The aircraft experienced several incidents, on different flights, of fumes in the cockpit and cabin and in some cases this produced symptoms in the flight and cabin crew. Although evidence was found of leaking hydraulic fluid having migrated inside a bleed air supply duct, the various investigations failed to definitively establish if this was the source of the fumes.

History of flight

Incident of 12 November 2004

This was the aircraft's first flight following a major maintenance check. On the outbound sector of a return flight from London Heathrow to Nice, the flight crew detected fumes in the cockpit. Passengers in the forward cabin and cabin crew in the rear galley also reported smelling fumes.

After landing, the flight crew contacted the company's Flight Operations department for advice before deciding to operate the return sector to London Heathrow. After engine start, they smelt a "strong but short burst" of "contaminated air" in the cockpit when the left air-conditioning pack was selected on, but this quickly cleared. Once airborne, they experienced four or five further occasional "sharp bursts" of contaminated air in the cockpit, but as these also cleared quickly, they did not consider it necessary to don their oxygen masks. The problem appeared to be associated with the left air-conditioning pack, which tripped on and off line occasionally during the flight, the contaminated air seeming to coincide with the left air-conditioning pack coming back on line.

During the descent into London Heathrow, both flight crew members became aware of a stronger and more persistent smell in the cockpit. At this point the commander had considered going onto oxygen as he was feeling a little unwell and "a bit spacey", but did not do so. The Cabin Services Director was asked to visit the cockpit to provide an independent opinion on the fumes and confirmed the presence of the odours. Both flight crew members then donned oxygen masks before declaring a 'PAN' and carrying out the relevant Quick Reference Handbook (QRH) drills. The approach and landing were uneventful. The odours were confirmed by a fireman from the Airport Fire Service who attended the cockpit after landing. The captain reported feeling slightly unwell for three days after the flight, causing him to consult his doctor.

Incident of 16 November 2004

This was the aircraft's first flight since the incident of 12 November. When boarding the aircraft for a flight from London Heathrow to Stockholm Arlanda, the crew commented on a strong smell inside the cabin. The APU was not running at the time. On takeoff a "warm aromatic" smell was present in the cockpit. The QRH procedure for '*SMOKE OR FUMES AIR CONDITIONING*' was actioned after flap retraction, with the flight crew donning their oxygen masks. When the right air-conditioning pack was selected off, the air cleared, allowing the crew to remove their oxygen masks. Given that there were no reported symptoms amongst any of the crew or passengers, the flight was continued, although the possibility of a return to Heathrow was discussed.

In the early part of the cruise, odours were again detected in the cockpit, prompting the flight crew to don their oxygen masks again. The Cabin Services Director confirmed the smell and advised that it could be detected faintly throughout the cabin. The captain described the odour as being a "warm sweet smell, but slightly burnt". Suspecting that the source of the smell might be the left air-conditioning pack, this was turned off and the right-hand pack was switched back on. Within seven minutes, the smell had cleared from inside the cockpit and, with no symptoms amongst the crew, the flight was continued.

Approximately 80 minutes into the flight, the Purser at the Door 4 station reported that she and a colleague had sore throats. The Cabin Services Director investigated and reported that the air seemed to be irritant at the rear galley only. This was confirmed later by the captain who visited the area.

During the descent the co-pilot started to get a "buzzy head and body", although he did not report it at the time. At 3,000 feet in the descent, both flight crew members noted an "oily-sewage" smell and the co-pilot voiced his feeling of buzziness. At 2,000 feet, the captain felt "slightly spaced" and found it an effort to concentrate, although he reported his breathing was normal. The aircraft was configured for a triple-channel autopilot approach and a manual landing was completed without further incident.

After the flight, the flight and cabin crew visited a paramedic at Stockholm Airport with their symptoms being recorded as including headaches, a sore throat, coughing, nausea, burning sensation in the lungs, and a "slightly spaced" feeling. On the advice of the paramedic the crew saw a doctor, who gave them the 'all clear' to return to the UK. The aircraft was ferried back to London Heathrow on completion of troubleshooting at Stockholm.

Incident of 23 November 2004

A further occurrence of fumes in the air supply on this aircraft was reported on 23 November, whilst en-route from London Heathrow to Milan Malpensa. During the flight the flight crew were aware of an unusual background smell, which was confined to the cockpit. The smell came and went during the descent. No unusual smells were noted during climb and cruise on the return sector but the smell returned in the descent, this time more strongly. Selecting the left air-conditioning pack and bleed-air sources off caused the smell to dissipate. The smell returned when the left pack and bleed-air were selected on again for the approach. Cross-feeding the left pack from the right bleed supply during taxi-in did not cause the smell to dissipate.

Two further event of oil fumes were recorded, one on 9 December 2004, but no definitive cause was identified, the other on 16 January 2005.

Boeing 757 pneumatic and air conditioning systems

The cabin pressurisation, air conditioning and various other systems require pressurized air, which is sourced from the engines. Depending on the engine power setting, high pressure air is bled from either the second or the sixth stage of the High Pressure Compressor (HPC) of each engine, denoted HP2 or HP6, to supply the pneumatic system. The bleed air is cooled by precoolers and pressure-regulated prior to being fed to the various user systems.

There are two air conditioning packs, a left and a right unit. These are supplied with air from the pneumatic system and their function is to provide pressurised air for the cabin which has been cooled and conditioned for passenger comfort. The left pack receives pneumatic air supplied by the left engine and the right pack receives air from the right engine. The conditioned air from both packs is combined within a mix manifold, together with a certain amount of recirculated air from the cabin, before being supplied to the cabin. The cockpit receives its own dedicated supply of conditioned air which is tapped off the supply duct between the left air-conditioning pack and the mix manifold. The aircraft is normally operated with both air conditioning packs selected on although it is permissible to operate with either pack inoperative, subject to some operational restrictions.

Service experience shows that, mostly, on aircraft types fitted with turbine engines, because the conditioned air is sourced from the engine compressors, it is vulnerable to contamination from engine oil leaks that allow oil to enter the compressor air path.

Engine oil servicing

The AAIB is investigating an event of fumes in cockpit/cabin on another Boeing 757, G-CPER, from the same operator that occurred on 7 September 2003. During this investigation it was found that maintenance engineers were not servicing the engine oils consistently in accordance with the Aircraft Maintenance Manual (AMM) procedure. Failure to comply with the specified time limits for checking the oil level can result in an incorrect level indication on the oil tank sight glass. This is so as there is a tendency with time for oil in the tank to slowly drain down into the engine gearbox, causing the oil level on the sight glass to drop. If the oil level is not checked within the specified time period, there is a danger that too much oil may be added.

Overfilling the engine with oil can cause the oil separator in the vent system to become partially blocked with oil, causing an increase in the air pressure in the bearing chambers. Oil may then be forced out past the compressor seals, and centrifuged outwards in the compressor drum. If the leak is sufficiently large, an oil mist is released into the compressor air path. This may be ingested into the HP2 and HP6 bleed-air off-takes, resulting in oil fumes entering the cabin air supply.

Following the G-CPER incident, the operator amended their engine oil servicing procedures to ensure compliance with the AMM requirements and specific training was given to maintenance staff on the correct procedure for servicing the engine oils. There has been a significant reduction in the rate of reporting of air contamination events since these changes were implemented.

Engineering investigation

After the incident of 12 November, a standard troubleshooting procedure was carried out, involving checking various areas of the aircraft where oil might leak into the bleed air supply path and contaminate the air supply. The engine oil quantities were checked and found to be acceptable, with 17 and 18 litres in the left and right engines respectively. (The full graduation on the oil tank represents a quantity of 20 litres; however the operator fills to below this level to reduce the chances of overfilling.) The fan blades were inspected for oil that might indicate a leak from the front bearing housing, but none was found. The APU was inspected and, although the area was found to be oily, no leaks were found. Some evidence of hydraulic fluid seepage was found at the base of the rudder, but this was remote from the APU air intake and no leaks were found in any of the rudder hydraulic components. When engine ground runs were performed, no unusual smells were noted inside the aircraft. The left air-conditioning pack control valve was replaced to correct the problem of the left pack tripping off line.

During troubleshooting after the incident of 16 November, a slight odour was detected inside the aircraft when the left air-conditioning pack was supplied with bleed air from the right engine. The oil pump assembly from the right engine was replaced as a precaution, as poor oil scavenging due to a faulty pump is a potential cause of oil contamination of the air supply. Examination of the APU and engines, including boroscope inspections of the engine compressors did not reveal any oil leaks, although chemical analysis of swabs taken from the right-hand engine compressor identified traces of Mobil Jet II engine oil.

During this examination, evidence of burnt hydraulic fluid was found on the exterior of a bleed air duct (Part Number 312N5306-1) on the left engine. This duct supplies HP2 compressor bleed air to the pneumatic system, which provides air for the cabin air supply system. A leak was found in a hydraulic pipe in the thrust reverser retract line (Item 205 in 757 Illustrated Parts Catalogue Chapter 78-31-01-01), which is located above the HP2 duct. Chemical analysis of swabs taken from the inside of the HP2 duct suggested that hydraulic fluid had migrated inside the duct. According to the aircraft manufacturer, the most likely leak path would have been through the carbon seals in the spherical flex joint in the duct. The duct is pressurised with air when the engine is running. The thrust reverser hydraulic pipes in the pylon area are located within tubes or shrouds, which provide cooling air for the hydraulic pipes and are also designed to allow any leaking fluid to drain out of the pylon area safely. The removed hydraulic pipe and shroud were not available for examination and so their condition could not be determined.

A flight test was completed with no reports of fumes and the aircraft was released for service.

Following the incident of 23 November, the engine oil levels, when checked within 20 minutes of engine shutdown, were noted to be 17 and 18 litres in the left and right engines respectively. Chemical analysis of swabs taken from the compressors on both engines revealed traces of Mobil Jet II engine oil in one of the swabs from the left engine. Traces of Skydrol LD4 hydraulic fluid were found in both engines. The left engine, serial number 31207, was removed for strip examination at Rolls-Royce Derby. It had completed 7,237 hours and 5,473 cycles since the previous shop visit. During this examination, no evidence was found of any leaks that might have allowed oil to enter the bleed air system.

Discussion

There have been numerous other reports of oil smells in the cockpit and/or cabin of the Boeing 757 and some of these events have been the result of genuine oil leaks from the engine or APU compressor oil seals. In other cases, no definitive source of the fumes could be identified. However, service experience shows that overfilling the engines with oil can produce fumes in the aircraft interior. Since the G-CPER incident, the operator has taken extensive measures to ensure that the engine oil is serviced correctly and, in the particular case of G-BPEE, no evidence was found to suggest that the engines had been over-serviced.

It was possible that the fumes may have been caused by contamination of the HP2 bleed air duct by hydraulic fluid from a leak in a thrust reverser hydraulic pipe, as evidenced by the presence of burnt hydraulic fluid on the outside of the duct and the analysis of the swabs from its interior. However, given that the thrust reverser hydraulic pipes are enclosed in tubes or shrouds designed to contain any leak and allow fluid to drain away safely, and that the HP2 duct is pressurised with bleed air when the engine is running, the amount of hydraulic fluid that could have found its way inside the duct would probably have been small. What is not known, however, is how much hydraulic fluid would be required to leak into the duct to produce fumes inside the aircraft.

Hydraulic fluid has a characteristic sharp, acrid, chemical smell, but different crews described the contamination as "warm aromatic", "warm sweet….. but slightly burnt" or like "oily-sewage". This seems inconsistent with the characteristics of hydraulic fluid. Although the hydraulic leak cannot be ruled as insignificant, there remains doubt as to whether it was the source of the fumes.

The problem of fumes in the cabin is not new and is currently the subject of much industry discussion. AAIB Formal Report 1/2004 presents the findings of an extensive investigation into the problem of contamination of cockpit/cabin air supply by engine oil fumes and includes the results of studies into the physiological effects of such fumes. In December 2000, The UK CAA issued Flight Operations Department Communication (FODCOM), number 17/2000, providing valuable safety advice on the use of flight crew oxygen masks in the event of smoke or fumes entering the cockpit. Further updated safety advice was provided in FODCOM's 14/2001 and 21/2002.