BAe 146-200, G-MANS

AAIB Bulletin No: 2/2004	Ref: EW/G2003/08/57	Category: 1.1
Aircraft Type and Registration:	BAe 146-200, G-MANS	
No & Type of Engines:	4 Lycoming ALF502R-5 turbofan engines	
Year of Manufacture:	1987	
Date & Time (UTC):	1 August 2003 at 0800 hrs	
Location:	Belfast City Airport. Northern Ireland	
Type of Flight:	Public Transport (Passenger)	
Persons on Board:	Crew - 5	Passengers - 53
Injuries:	Crew - None	Passengers - 1 (Minor)
Nature of Damage:	No damage to aircraft. Possible oil leak in APU	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	52 years	
Commander's Flying Experience:	9,600 hours (of which 730 were on type)	
	Last 90 days - 64 hours	
	Last 28 days - 21 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

History of the Flight

The aircraft was about to commence a scheduled flight to Manchester from Belfast City Airport with a crew of 5 and 53 passengers. The 5 crew had boarded the aircraft and started the APU, which was used to provide an air supply to the air conditioning packs as well as electrical power for the aircraft systems during a turn round. The passengers were boarded through the forward door and the cabin was secured for departure. Push back and engine start clearance were obtained from ATC and the aircraft was reversed by the tug from Stand 5 through 90° from the stand heading of 130° and brought to a halt on a heading of about 040°. The surface wind was from 240° at 8 kt and during the 'push back' the main engines were started whilst the cabin crew gave the safety brief. In order to start the engines, the air conditioning packs and APU bleed air were switched off.

As the safety brief was completed, the cabin crew became aware of a smell of fumes and could see smoke appearing which seemed to be worst towards the rear of the cabin. The aft cabin attendant moved to the forward galley immediately behind the flight deck to discuss the situation with the Senior Cabin Crew Member (SCCM). The SCCM contacted the aircraft commander on the interphone and reported the presence of the smoke and fumes and also explained that the passengers were aware but were not alarmed. No smoke or fumes were present on the flight deck. The First Officer (FO) informed ATC of the situation and that the aircraft would be holding its position. The commander switched off both air-conditioning packs which had been re-selected 'ON' after engine starting and informed the SCCM of his actions. He also warned her that if the situation did not improve, an emergency evacuation order may be issued. The commander then asked the SCCM to update him on the situation and asked if the cabin crew were happy to taxi back to the parking stand. The report from the SCCM indicated that the situation was getting worse, that the passengers were becoming agitated and the cabin crew were not happy to taxi back to the stand. The commander warned the SCCM to be ready for an emergency evacuation, instructed the FO to carry out the

emergency evacuation drill and completed his own memory items which included a public address announcement ordering the evacuation.

The SCCM disarmed the main left door electing to use the airstairs and having opened it, turned around to find a passenger stood in the forward galley supporting a wheel chair passenger whom he wished moved first. In order to get the evacuation flow moving, the SCCM took hold of the passenger's legs and assisted the standing passenger to carry the wheelchair passenger clear of both the aircraft and the evacuation path. The SCCM then returned to the base of the airstairs to assist passengers who were exiting the aircraft under the supervision of another cabin crew member. The aft position cabin crew member made her way back to the rear of the aircraft with some difficulty. However, a passenger had opened the rear right door and its slide had deployed with passengers being assisted by airport staff to move clear of the aircraft.

The airport Rescue and Fire Fighting Service (RFFS) quickly arrived at the aircraft and the aircraft commander established that there were no external signs of fire. The aft cabin crew member, having disembarked the passengers, moved back through the cabin to confirm it was clear. The aft cabin crew member briefed fire officers who had entered the cabin on the nature and location of the smoke before joining the other cabin crew outside the aircraft.

On the flight deck the emergency evacuation drill items were repeated using the emergency checklist and confirmed complete. The commander then entered the cabin to assist with the evacuation as the last passenger was leaving the aircraft, which had cleared of smoke. He therefore returned to the flight deck and completed the remaining shut down checks before both pilots vacated the aircraft and joined the passengers and cabin crew a safe distance from the aircraft.

The passengers were moved to the terminal building and the crew returned to the aircraft, which was towed back onto stand. One passenger was thought to have suffered a minor back injury and was removed to the local hospital for assessment but was released later the same day.

APU examination

The APU had been installed in the aircraft following an overhaul and had been in service for several months, having operated for more than 500 hours. After removal the unit was returned by to the APU manufacturer's UK agent for examination. This 'tear down' examination revealed general oil deposits and staining on the compressor rotor and in the air intake. There was also evidence of a recent and more significant oil loss indicated by areas where clean oil had washed away dirt deposits on the compressor bearing housing. These indications were symptoms of oil leaking from the compressor carbon seal into the air path. Minor leakage is not atypical for this type of APU but a small leak was unlikely to have caused the sudden increase in smoke and fumes in the cabin.

Close examination of the carbon seal and roller bearing concluded that although there were signs of uneven wear on the carbon seal and micro-pitting of the seal rotor face, there had been no sign of overheating or bearing failure. Oil supply to the bearing was assessed as normal with all areas wetted and no carbon build-up. However, an 'O' ring seal was missing from the bearing retainer assembly yet there was no sign of the missing seal in the gearbox oil tank.

Analysis

In this instance, dismantling of the APU revealed that the compressor carbon seal had, for some time, been leaking oil into its air inlet. If the leak rate was sufficient, this oil could pass through the APU and into the aircraft's air conditioning packs. Moreover, the recent oil washing of the compressor area showed that there had been a sudden increase in the rate at which oil was leaking from the compressor bearing. This rapid oil leak was a potential source for the smoke and fumes in the aircraft cabin.

The underlying reason for the sudden increase in oil leakage was attributed by the manufacturer's agent to a compressor surge. Compressor surge causes the rotor assembly to move aft due to poor air flow through the power section. This in turn causes the spring washer that supports the main rotor ball bearing to be heavily loaded, and thus compressed. The movement of the main rotor also moves

the seal rotor aft, which in turn bears against and compresses the compressor carbon seal bellows. After the surge dissipates, the main rotor returns to its original position and the seal bellows relaxes. Repetition of this process unseats the compressor carbon seal allowing oil to escape. (NB oil is directed at the seal rotor at approximately 35 psi.) Once the APU returns to normal operation, the compressor carbon seal re-seats.

The 'O' ring, found missing from behind the main rotor roller bearing prevents oil returning to the gearbox prematurely. After consultation with the APU manufacturer it was concluded that its absence would not have affected the oil leak.

Although the aircraft was holding with its tail into wind, the commander deduced that the extent of the problem described by the SCCM was not the result of re-circulating APU or engine exhaust gasses. He was familiar with previous incidents of smoke and fumes in the cabin that had been attributed to a faulty APU oil seal and he considered that the symptoms reported by the SCCM were consistent with an APU fault. Consequently, he switched off the air conditioning packs and informed ATC that the aircraft would be holding its position until the matter was resolved. When the commander again contacted the SCCM, from the lack of dissipation of the smoke and the concerns expressed by the cabin crew, he considered the possibility that the APU may not have been the source of the air contamination and that a fire might have existed. Therefore, he decided that the aircraft should be evacuated.

Whilst the commander considered opening the flight deck door to assess the smoke, he thought this action might delay the evacuation and such an assessment was not called for in accordance with the QRH '*Aircraft Emergency Evacuation Drill*'. The SCCM had deliberately decided to use the forward airstairs instead of the evacuation slide at the main left door because that was the easiest and safest method of evacuating the 'carry on' (disabled) passenger and a baby. The opening of doors at both ends of the cabin coupled with shutting down the APU had allowed the smoke and fumes to dissipate during the evacuation.

APU modifications

The embodiment of modifications SB-49-7076 Rev 1 issued by the APU manufacturer and SB-49-47-36162A introduces changes to the APU exhaust connection and gearbox breather. These changes ensure that an oil leak from the compressor carbon seal will be 'captured' by negative pressure within the gearbox. With these modifications embodied, after an oil seal leak the APU should eventually shut down due to low oil pressure, or be removed from service due to high oil consumption, before smoke is evident in the cabin.