

INCIDENT

Aircraft Type and Registration:	BAe 146-300, G-JEBC	
No & Type of Engines:	4 Lycoming ALF502R-5 turbofan engines	
Year of Manufacture:	1990	
Date & Time (UTC):	6 September 2007 at 1248 hrs	
Location:	En route from Belfast	
Type of Flight:	Commercial Air Transport (Non-Revenue)	
Persons on Board:	Crew - 4	Passengers - 0
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	None	
Commander's Licence:	Air Transport Pilot's Licence	
Commander's Age:	52 years	
Commander's Flying Experience:	10,842 hours (of which 5,083 were on type) Last 90 days - 162 hours Last 28 days - 46 hours	
Information Source:	AAIB Field Investigation	

Synopsis

During a positioning flight from Belfast, the flight crew became aware of an unusual smell. There was no smoke or haze. The commander elected to put the crew on oxygen. He declared an emergency and diverted back to Belfast. The commander later described how he felt as similar to being inebriated and that he found it difficult to concentrate. The co-pilot initially felt she had a reduced capacity to fly the aircraft, but this feeling quickly passed. One cabin crew member felt light-headed, sick and distressed. The other cabin crew member felt tired and slightly sick. The origin of the fumes was traced to the forward toilet and was probably due to a chemical in the toilet. The fumes may have been as a result of formaldehyde, released as a degradation product of a toilet chemical added during maintenance at Exeter. It

was not possible positively to determine to what extent the symptoms of the crew were a result of the fumes, or of the stress associated with the in-flight fumes emergency, or a combination of both.

History of flight

The aircraft had recently completed a major maintenance 'C' check at Exeter on 4 September 2007. It was flown to Belfast City Airport, the flight being described as normal other than, during the flight, the yaw damper failed. When the crew selected the engine air bleeds ON in the climb, there was a smell of "sweaty socks". This smell was described as "normal when the aircraft has been standing for a while". The smell quickly dissipated and gave the crew no cause for alarm.

On 6 September the aircraft was required at Southampton to replace an unserviceable aircraft, for a scheduled flight to Nice, so it was prepared for a non-revenue positioning flight. The pre-flight procedures were all described as normal and the crew, consisting of the two flight crew and two cabin crew members, went out to the aircraft. The cabin crew performed their security checks, which included a check of the toilets, and they reported that everything appeared, and smelt normal. The aircraft had carried no cargo, or passengers since its 'C' check, and hence the toilets had not been serviced, and the cabin had not yet been prepared for a revenue flight.

The co-pilot was the pilot flying (PF) for the sector and so she completed the internal checks whilst the commander performed the external walkround. The co-pilot noted that, shortly after she selected the APU bleed air ON, she was aware of an unusual smell. She described this as "not being one of the normal smells that you get used to flying the 146". The commander completed his walkround, and he noticed nothing unusual. When the commander returned to the flight deck the co-pilot mentioned to him that she had smelt something unusual. He could not smell anything, and the start up and taxi then continued without any significant events.

When the aircraft lined up for departure, the commander attempted to engage the Thrust Management System (TMS) but it would not engage, indicating that there was a fault with the system. After a short period of troubleshooting the commander elected to continue the flight without the TMS. He planned to have the fault rectified at Southampton.

The takeoff, at 1239 hrs, was a normal, reduced thrust, takeoff with the APU air bleed on, and, as expected, the yaw damper failed. The after takeoff checks were performed passing the minimum sector altitude (MSA)

of 3,800 ft, and the engine air bleeds were selected ON whilst the APU air bleed was selected OFF. Shortly after this the commander became aware of an unusual smell. He also described the smell as not one that he normally associated with his experience of operating the 146. The commander called one of the cabin crew forward and asked her if she could smell anything, but she could not. Passing FL100 the commander turned up the heating and a little while later he again smelt something unusual.

The commander instructed the co-pilot to go onto oxygen. He then called a cabin crew member forward, and instructed her to put both cabin crew members onto oxygen. The cabin crew member could now smell "something".

The commander went onto oxygen, and declared a PAN to Scottish Radar. He requested a descent, initially to FL100, then further to 8,000 ft. He then went through the smoke and fumes checklist although he later described cockpit communications as difficult using masks.

The aircraft diverted back to Belfast City Airport uneventfully and was met by fire crews who assisted the crews in exiting the aircraft. The crew were all taken to hospital, and tested for carbon monoxide poisoning. The tests were all negative and the crew were released.

Medical

The commander described feeling a sensation in the aircraft like being drunk. He felt it was difficult to concentrate, and he felt "fuzzy". He subsequently felt a little faint at one point, shortly after having got out of his seat to open the cabin door to allow the fire service to board the aircraft. The next day he was suffering from a headache, and he felt "woolly-headed". The commander had been involved in a serious fumes incident eight years earlier.

The co-pilot felt she was operating at reduced capacity and she had difficulty in concentrating for the first few moments after putting on her mask, thereafter she felt more normal.

One of the cabin crew smelt nothing unusual. She felt tired, and a bit sick when on oxygen. She had no ill effects the next day.

The second cabin crew member did not smell anything unusual up to the point where the commander asked her for the second time if she smelt anything. At that point she smelt what she described as “sweaty socks”. After going onto oxygen, she felt light-headed and sick. She was also very concerned about the situation and that the flight crew were on oxygen (the cockpit door was open). After landing she needed assistance from the fire crews to get into the ambulance. She was very anxious about the incident and her doctor advised her to spend “a couple of weeks away from the environment” (off work). She had been involved in a fumes incident three months earlier, about which she was still upset.

Examination of the aircraft

Upon entering the aircraft after the incident there was no distinctive smell evident to the investigators. A full examination of the engines and the APU was carried out, including an internal check, using a borescope. These did not show any signs of oil leakage or seal degradation. Previously there had been issues concerning ALF-502 engines and cabin air quality; these engines, in G-JEBC, had been modified with improved seals.

Both air-conditioning packs were also examined; the faces of the heat exchangers were clean and there were no signs of contamination of any of the ducting. The ducting further downstream from the air-conditioning packs was also examined and found to be clean.

A full engine and APU run at various temperatures was carried out with no signs of any unusual odour, or indeed any sign of fumes or smoke in the aircraft.

Due to the report in the technical log of the smell being of a ‘chemical nature’, the toilets were checked as a potential source. On opening the forward toilet door, a very strong odour was immediately apparent; a similar odour was evident in the rear toilet. The surfaces in the toilet were clean and did not show any signs of a spilt chemical. The only area within the toilet compartment which was suspected was the toilet water, due to the use of chemicals within it; samples were taken from both toilets for later testing.

The flight crew of the incident flight were invited back to the aircraft. When the crew were exposed to the air in the forward toilet compartment, the commander reacted to the smell and identified it as being similar to the smell he had experienced in flight. The co-pilot also confirmed that the smell seemed similar to that she had smelt during the flight.

Flight Recorders

The aircraft was equipped with a flight data recorder (FDR) and a cockpit voice recorder (CVR), capable of recording a minimum duration of 25 hours of data and 120 minutes of audio respectively.

Recorded information

The FDR and CVR were removed from the aircraft and successfully replayed at the AAIB. The incident flight, from before engine start to aircraft shutdown, was recorded by the CVR.

Toilet description

The toilets fitted to G-JEBC were of a recirculating chemical type, each with a capacity of 45 litres. The

toilet is initially charged with 13 litres of a chemical deodorising fluid, usually a diluted mixture of water and chemical. A four litre fluid reservoir is connected at the bottom of the main tank, and is used for the toilet flush. A filter screen separates the main tank from the reservoir. When the toilet is flushed, air enters a fluid reservoir which forces fluid through the flush pipe and around the bowl of the toilet, before the fluid drains back into the main part of the tank.

For toilet servicing, on the ground, a pipe is connected to a ball valve at the bottom of the tank. The service vehicle connects to the outlet of the pipe, via an external connection on the side of the fuselage and the ball valve is opened. The contents of the main tank then empty into the service vehicle. To empty the reservoir, the flush has to be operated whilst the ball valve is still open and the vehicle is connected. Once the toilet is emptied the ball valve is closed.

Replenishment of the 13 litre charge is carried out in two ways. If a service vehicle is available then a fresh water hose is connected to a fill connection at the toilet service panel, which then feeds the fresh water to the toilet tank. A sachet of the deodorising chemical is then put into the toilet tank via the toilet bowl.

If a servicing vehicle is not available, water is poured into the toilet tank via the toilet bowl with the deodorising chemical added, either as a sachet or a dilution of the chemical in the added water.

Toilet compartment ventilation

The toilet compartments on the BAe 146 are ventilated by air supplied from the air-conditioning packs. The conditioned air enters the compartment via an air outlet. The air is only vented from the compartment during flight, when the differential pressure between the cabin

and the outside air is above about 1 psi. The air is vented overboard, through a controlled pressurisation leak, with air taken from around the top of the toilet pan.

A test of the toilet ventilation on G-JEBC found it to be working correctly once the cabin began to pressurise.

Aircraft maintenance

As noted above, the aircraft had undergone a major maintenance 'C' check input at Exeter, which was completed on 4 September 2007. The incident flight was the second flight of the aircraft following this maintenance input, having initially positioned from Exeter to Belfast. Prior to these two flights, the toilets had not been serviced (using normal 'line' equipment) since the 'C' check.

During the 'C' check the toilets were removed from the aircraft as complete modules. The modules were then sent for deep cleaning in workshops and involved the use of a cleaning agent 'Honeybee 76'. When the toilet modules were refitted, the chemical toilet was recharged. As there was no service vehicle available during the maintenance input, the toilets were charged (manually) by adding water and a dilute mixture of the deodorising chemical. The aircraft was still in the hangar at Exeter at this stage and the 'C' check was completed on 2 September 2007. The deodorising chemical used was 'Aqua Kem Blue' which was supplied in liquid form (rather than sachets), and was used at a dilution of 60 ml to 1 litre of fresh water.

Following the incident, and under AAIB supervision, a service vehicle serviced the toilet. The amount of fluid removed from the forward toilet was 16 litres.

After the fresh water had been added, the usual toilet chemical applied to aircraft toilets at Belfast, known

as 'Honeybee Pak 44', was used. This was supplied as a sachet of predetermined quantity, and added to the 13 litres of fresh water charge that had been pumped into the toilet.

Sample testing

The samples were taken to a forensic laboratory for testing. Included with these samples was a sample of neat 'Aqua Kem Blue' and a diluted sample provided by the maintenance organisation at Exeter.

The results of the tests revealed that the three diluted samples, that is those from the toilets on the aircraft and the diluted 'Aqua Kem Blue', were very similar. The only difference was some additional olfactory 'notes' in the pine-like odours given off from the toilet samples. These additional 'notes', however, were not similar to those given off from formaldehyde and were not identified. All the liquids, including the neat 'Aqua Kem Blue', were positive for oxidising agents. Methanol was not detected in any of the samples, suggesting that formulated formaldehyde was not present in the samples in any significant quantity. It was not possible to identify if any other chemical substance was present in the toilet samples, over and above the 'Aqua Kem Blue' which had already been added at Exeter.

The AAIB Inspector who experienced the odour in the toilets at Belfast compared it to the odour from vapours given off from a sample of formaldehyde. Although not conclusive, the smell was very similar.

One of the active ingredients of 'Aqua Kem Blue' is '2-Bromo-2-nitro-2.3 propenediol', commonly known as 'Bronopol'. This chemical is known as a formaldehyde releaser and can produce low concentrations of formaldehyde when it degrades in alkaline aqueous solutions or at elevated temperatures. 'Bronopol' is

commonly used as a preservative in cosmetics, shampoos, medicinal products and toilet sterilisers.

Formaldehyde is a reducing agent used to sterilise biological matter and kill germs. The chemical is used in domestic cleaners, such as washing-up liquid. It is also commonly used as embalming fluid as it fixes the body tissues. The chemical is usually formulated in water with 37% by weight of formaldehyde and 10-15% of methanol. Formaldehyde produces a very distinct strong and acrid odour and is noticeable at low concentrations. As atmospheric pressure drops, such as in the aircraft cabin during climb, the chemical becomes more volatile so fumes would become more noticeable. In low concentrations, formaldehyde does not pose a toxic risk, but it can cause a feeling of light-headedness and irritation to nose, throat, mouth and eyes.

Analysis

The source of the fumes that were detected by the aircraft's crew was most likely from a chemical within the forward toilet. The chemical could not be positively identified in the sample taken from the toilet; however the smell was similar to that of formaldehyde. As formaldehyde and methanol were not detected in the samples taken from the toilet it is unlikely that a product containing formulated formaldehyde had been used. It is possible, however, that formaldehyde was produced as a result of degradation of the chemical 'Bronopol' contained in the 'Aqua Kem Blue' toilet chemical that had been added during maintenance at Exeter. However, the introduction of an additional unknown substance to the toilet cannot be discounted. Similarly, the addition of another substance, such as one containing an alkaline, could have precipitated the release of formaldehyde from the 'Bronopol' in 'Aqua Kem Blue'.

The gas given off from the chemical probably built up

in the forward toilet compartment, whilst the aircraft remained closed up and on the ground at Belfast. It is also possible that during this period the 'Bronopol' in the 'Aqua Kem Blue' degraded, liberating formaldehyde. As formaldehyde is volatile it would have become gaseous and entered the atmosphere of the toilet. The air in the toilet compartment would have remained undisturbed until the toilet door was opened or the air-conditioning packs were switched on. The action of putting the air-conditioning packs to ON would have stirred the air, dispersing the gas through the ventilation paths, including some air entering the cockpit. As the aircraft climbed, the pressure drop in the cabin would have made the chemical more volatile, thereby releasing more fumes.

The CAA Aeromedical Section confirmed that the symptoms suffered by the crew were consistent with the effects of a fumes event, such as would be experienced by a crew experiencing a low concentration of formaldehyde.

The CAA Aeromedical Section were asked if there could be any alternative explanation for the symptoms suffered by the crew. They considered that a possible induction of motion sickness could be caused by the

inoperative yaw damper and lack of a thrust balancing system (TMS), and that this could, possibly, predispose a crew to anxiety. The cabin crew's symptoms may have been exacerbated by hyperventilation.

The CAA report added that, in this case, there was no indication that any of the crew members would have had a particular predisposition to anxiety; feelings of anxiety would have been normal during an event such as this.

In summary, it is likely that this crew suffered from the effects of a low concentration of formaldehyde and it is possible that a normal anxious reaction to the unusual situation aggravated their symptoms.

Safety action

As a result of this investigation, the maintenance organisation has put in place a procedure which requires the chemical toilets on all aircraft to be flushed and serviced following maintenance and prior to any flight. They are also discontinuing the use of 'Aqua Kem Blue'. The operator uses 'Honeybee 76' when deep cleaning the toilet and 'Honeybee 20' when servicing the toilet whilst the aircraft is in maintenance. Neither of these products is believed to contain formaldehyde or 'Bronopol'.