Smoke emergency and oil loss, Boeing 777, N796UA

Micro-summary: **This Boeing 777 experienced a complete loss of oil on the #1 engine and a smoke emergency in the cabin.**

Event Date: **1998-07-29 at 1433 UTC**

Investigative Body: **Aircraft Accident Investigation Board (AAIB), United Kingdom**

Investigative Body's Web Site: **http://www.aaib.dft.gov/uk/**

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Boeing 777, N796UA

AAIB Bulletin No: 9/99 Ref: EW/C98/7/10 Category: 1.1

Aircraft Type and Registration:	Boeing 777, N796UA
No & Type of Engines:	2 Pratt & Whitney PW4090 turbofan engines
Year of Manufacture:	1998
Date & Time (UTC):	29 July 1998 at 1433 hrs
Location:	London Heathrow
Type of Flight:	Public Transport
Persons on Board:	Crew - 17 - Passengers - 272
Injuries:	Crew - None - Passengers - None
Nature of Damage:	Internal damage within No 1 engine and heating damage within nacelle
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	59 years
Commander's Flying Experience:	18,500 hours (of which 603 were on type)
	Last 90 days - 165 hours
	Last 28 days - 41 hours
Information Source:	AAIB Field Investigation

The aircraft, with 17 crew and 272 passengers on board, was engaged on a scheduled service from London Heathrow to San Francisco. Engine start and the taxi out to the holding point for Runway 27L were normal. The aircraft's all up weight (AUW) was 570,826 lb and the crew had planned for a reduced thrust take off using an assumed temperature of 43°C and an associated engine pressure ratio (EPR) of 1.39

The aircraft was cleared for take off at 1432 hrs and became airborne one minute later at 1433 hrs. At 1434 hrs the Heathrow tower controller instructed the crew to change to the London Control frequency of 119.775 MHz. The commander, who was the pilot flying (PF), reported that the first sign of a malfunction was shortly after rotate when smoke was seen to emanate from the air vents on the flight deck. The commander instructed the crew to don their oxygen masks and continued to fly the aircraft manually. The crew did not don their smoke goggles for although smoke was present their view of the instruments was not impeded. A few moments later the cabin attendants in both the 'first class' and 'coach class' cabins contacted the flight deck advising that their cabins were also filling with smoke. There were no associated messages on the electronic indication and crew alerting system (EICAS). At 1,500 feet the auto throttle reduced engine thrust to climb power and at the same time the crew heard a 'bang' from the left engine and noticed that the left engine N1 and oil quantity had reduced to zero.

When the crew checked in on the London Radar frequency they transmitted 'OKAY WE'VE GOT SMOKE IN THE COCKPIT WE'RE GONNA NEED TO COME BACK AROUND FOR A LAND BACK AT HEATHROW'. The controller's response was '...SORRY SAY AGAIN'. The crew repeated their transmission by saying 'DECLARING AN EMERGENCY WE'RE GONNA NEED TO COME BACK TO LONDON HEATHROW'. The radar controller acknowledged this transmission and cleared the aircraft to climb to 6,000 feet. The crew however stated that they wished to maintain 2,000 feet and that they were already in a turn onto a downwind heading. The controller cleared the aircraft to turn onto a heading of 090°. By now the landing gear and flaps had been retracted and fuel dumping had been initiated. At or about this time the crew also carried out the emergency drills for 'Smoke in the Cockpit' followed by 'Engine Severe Damage/Separation'.

ATC then asked the crew '...CAN YOU TELL ME WHAT THE PROBLEM IS'. The crew replied 'WE'VE GOT AN ENGINE FIRE'. At 1435:30 hrs they were transferred to the London Area and Terminal Control frequency of 120.400 MHz. After initial contact ATC advised the crew that they were downwind for Runway 27R. The crew replied 'OKAY WE'RE VECTORS FOR 27 RIGHT WE'VE GOT AN ENGINE FAILURE SIR NEED TO GET BACK ON'. Moments later ATC advised the crew of the ILS frequency for Runway 27R and asked them if they were able to make an ILS approach. The crew did not reply but repeated the ILS frequency when it was transmitted again by ATC. They were then asked how many track miles they needed from their position which was 5 nm south of Heathrow. Their reply was to be positioned on finals at 10 nm. The crew then asked to climb to 3,000 feet. At 1437:30 hrs ATC transmitted that Runway 27L was available, gave the crew the ILS frequency, and stated that 27L would now be their landing runway. With 12 track miles to run ATC asked the crew if they intended to evacuate the passengers on landing. The crew replied 'RIGHT NOW WE DO NOT PLAN TO EVACUATE THE RUNWAY...WE'RE GONNA LEAVE THE RUNWAY BUT WE'RE NOT PLANNING TO EVACUATE AT THIS TIME BUT WE DO WANT THE TRUCKS ROLLED'.

The aircraft established on the centreline for Runway 27L at 9 nm from touchdown. At 1441:30 hrs the crew called 'HEATHROW IN SIGHT'. ATC cleared the aircraft to land on either 27L or 27R at the crew's discretion. At 3.5 nm from touchdown the crew were transferred to the Heathrow Tower frequency.

The aircraft landed uneventfully at 1443:30 hrs, 85,000 lb above its maximum normal landing weight, having jettisoned approximately 25,000 lb of fuel. Fire vehicles pre-positioned for the emergency followed the aircraft after landing. As the aircraft vacated the runway the crew asked ATC if the fire crews could see anything. ATC advised the crew to contact the fire crews directly on frequency 121.6 MHZ. The fire crews advised the tower that all was well and followed the aircraft to stand where the passengers disembarked normally.

At no point was there an Engine Fire indication on the flight deck and thus the flight crew did not discharge any fire bottle into the engine.

Flight recorders

The CVR (Cockpit Voice Recorder) had overrun its 30 minute duration and was not, therefore, replayed. The DFDR (Digital Flight data Recorder) was removed from the aircraft and was replayed, satisfactorily, at the AAIB. The resulting technical data from the event were supplied to the NTSB, the operator and the engine manufacturer.

Technical examination

Initial examination of the No 1 engine (serial number 222049) shortly after the event showed oil-wetting around the lower casing of the fan and substantial heating damage around the forward upper portion of the engine, within the fan case. This damage included sooting, melting of wire insulation, burned wire wraps and burned wires. Initially, the N1 rotor could not be moved by hand. Before the engine was removed from the aircraft a borescope inspection showed heat damage to the 'No 1 to 2' bearing compartment and failure of the No 1.5 and No 2 carbon seals.

The engine was removed and transported to the engine manufacturer's facility at East Hartford, Connecticut, for detailed examination and strip under the supervision of the NTSB. This examination confirmed that the initial failure had been of the No 2 carbon seal. In the P&W 4000 series of turbofans, the 'No. 1 to 2' bearing compartment contains the engine's No 1 and 1.5 bearings, which support the front end of the N1/LP rotor, and the No 2 bearing, which supports the front end of the N2/HP rotor. The No 2 carbon seal is located just forward of the No 2 bearing and its purpose is to prevent airflow from entering the compartment between the N1 and N2 rotors.

As a result of the seal's failure the engine oil contents had rapidly reduced from 17 US quarts to 0, leading to the further damage and heating within the 'No 1 to 2' compartment and the subsequent heating damage within the nacelle, exterior to the engine. The data from the DFDR confirmed the corruption of the N1 signal, the rapid oil loss and the engine surge before the fire handle was pulled and the engine shut down. It also confirmed that there were no flight deck messages relating to the fire overheat warning system. The technical examination also revealed that the corruption of the N1 signal had been due to a displacement of the N1 probe, which measures the passage of gear teeth on the LP shaft. Corruption of the signal from the N1 probe, inadvertently simulating an overspeed, would trigger the 'overspeed' fuel solenoid, reducing the fuel to minimum flow for this engine, and the DFDR data confirmed that this 'overspeed' solenoid had, indeed, been energised.

During the examination it was found that a small section of conduit within the bearing compartment had melted during the brief internal fire, allowing the heating within the nacelle around the forward upper portion of the engine. The conduit was made of a conventional Aluminium alloy and the engine manufacturer states that a change of material, to a steel conduit, is under consideration.

Carbon seal design change

The manufacturer was aware of a number of previous failures of the No 2 carbon seal and had been taking action to cure the problem. The initial design of the No 2 carbon seal used a 'dry face' assembly, with a carbon element running on a dry seal plate, and the remedial action changed this to a 'wet' face assembly, creating an oil film at the seal plate. This change was promulgated in the manufacturer's Service Bulletin PW4G-112-72-138, dated January 1998. In the meantime, performance of the seal was checked by trend monitoring of the engine's oil pressure and temperature parameters (special instruction 75-F-98) and by borescope inspection of the No 2 seal at each engine A-check (500 hour inspection). This particular engine (serial number 222049) was scheduled for removal to have this Service Bulletin incorporated on its next visit to the operator's maintenance base at San Francisco, California, and this flight, on 29 July, would have been its last sector before modification. This engine had been monitored but the trend monitoring and borescope inspections had provided no warning of this failure. The engine had accumulated 1,830 hours since new, with an A-check at 1,388 hours.

Nacelle overheat and fire detection

The 777 aircraft design also includes a nacelle overheat and fire detection system with 3 dual-element detector assemblies wired in series to form two detection loops connected to the aircraft's electronics. The detector assemblies are located in the upper aft, lower aft and lower forward areas of the engine compartment.

The fire and overheat warning loops were examined at their manufacturer's facility in North Carolina. This examination showed that all the elements of the system were working correctly. This led the aircraft manufacturer to conduct a design audit of the Fire Detection system, including a review of the location of the detector elements. The audit concluded that, despite the intensity of the internal engine fire, the external fire had been of low intensity and short duration and the lack of a fire warning was reasonable. The design audit also considered that, had the external fire continued at that intensity, a fire warning would have resulted.