No: 3/84 Ref: EW/C861

Aircraft type and registration:	Boeing 747-100 N656PA (multi-jet public transport aircraft)	
Year of manufacture:	1971	
Date and time (GMT):	18 January 1984 at 1410 hrs	
Location:	London Heathrow Airport	
Type of flight:	Scheduled Passenger	
Persons on board:	Crew – 15	Passengers – 392
Injuries:	Crew – Nil	Passengers – Nil
Nature of damage:	Rupture to No 3 engine diffuser casing causing damage to the engine cowlings, pylon skin and adjacent leading edge flap	
Commander's Licence:	Air Transport Rating	
Commander's Age:	57 years	
Commander's total flying experience:	20,172 hours (of which 4,142 were on B 747 types)	

Pan American flight 'Clipper One' was scheduled for a 1330 hrs departure from London Heathrow Airport to J F Kennedy Airport, New York. The forecast weather and resultant problems at New York necessitated a last minute fuel uplift which delayed the departure until 1352 hrs. Following an entirely normal start up, the aircraft taxied out to runway 28R, was cleared to line up at 1406 hrs and was cleared to take-off at 1409 hrs.

The Commander, who was the handling pilot, opened the throttle to a nominal 1.1 EPR and checked that all the engines had spooled up. Having ascertained that this was the case, he opened the throttle to take-off power (1.44 EPR), let the brakes off and was in the process of passing throttle control to the engineer when there was a loud bang on the right hand side of the aircraft. The Commander closed the throttles and abandoned the take-off but, because of the very low speed which the aircraft had attained, it was not necessary to apply either reverse thrust or severe braking. At 1410 he taxied the aircraft off the runway at the first available exit.

There was no smoke or indication of fire to the crew so, having completed the engine shutdown drills and the after landing checks, they taxied the aircraft back to the terminal where the passengers disembarked.

The nature of the emergency and the absence of any sustained indications of smoke or fire to onlookers made it unnecessary to involve the airport emergency services and the event was initially classified as an incident. Subsequent detailed examination of the aircraft, however, revealed explosion damage to the slat leading edge attachment brackets immediately inboard of engine No 3, pylon skin deformation, damage to one fan blade on engine No 4 and a cut tyre. This re-categorised the event as a reportable accident.

The cockpit voice recorder (CVR) had remained active until the ground engineers pulled the circuit breaker some ¾ hour after the accident. The ½ hour relevant to the accident had therefore been erased. The only engine data provided by the Digital Flight Data Recorder (DFDR) were the EPR readings for each engine. These recorded an engine No 3 EPR of 1.57, a 13% increase on the desired maximum selection of 1.44 attained by other engines.

Initial examination of the No 3 JT9D.7 engine revealed that a major rupture had occurred to its casing. This had caused both inner cowl doors to be torn off together with the engine starter motor, oil tank and some pneumatic ducting. These parts and some minor debris were scattered over a localised area at the end of the runway.

After replacement of the engine and airframe repairs, calibration tests were carried out on the engine instrumentation with no significant abnormalities being detected.

The damaged engine was transferred to the operator's overhaul facility for a detailed strip examination. This revealed that the primary failure had occurred in the diffuser module and that all other observed damage was consistent with having been caused by failure of the case, ref. Figure 1.

The rupture was confined to the diffuser case/outer combuster case area and extended from the high pressure compressor case/diffuser case mating flange (K) through the diffuser case/outer combuster case mating flange (L) and terminated at the outer combuster case/high pressure turbine case mating flange (M). The primary rupture had occurred over an axial distance of 33 inches at the 5–6 o'clock position (viewed

from the rear) with secondary circumferiential ruptures occurring around the 2–10 o'clock position in the region of K flange. The widest separation of the case occurred at M flange and measured 15".

The fracture surfaces exhibited a fresh greyish appearance throughout with the exception of an area in the vicinity of the diffuser rear rail;* adjacent to a boss at the engine 6 o'clock position. This area was discoloured a dull brown over a length of 4.80", which extended forward and aft of the rear rail. A previously welded crack repair was co-incident with a 2.8" section of the discoloured fracture surface, 1" of this being forward and 1.8" aft of the rear rail centre-line, ref. Figure 2.

Metallurgical examinations of the fracture surfaces, conducted by the engine manufacturer and the AIB have determined that the 4.8" discoloured area exhibited evidence of fatigue, from multiple origins, whilst the remainder were consistent with having suffered failure from direct overstressing. It was apparent that the weld repair co-incident with the discoloration was sub-standard (ref. JT9D Engine Manual, Section 72-41-01), this being characterised by incomplete fusion of the weld, voids, cold shuts and poor surface finish, ref. Figure 3.

At the time of the accident the diffuser case had accumulated 35,153 hours/9646 cycles since being manufactured in 1970, 7462 hours/1352 cycles since its last inspection and repair at the operator's overhaul base. At that time a total of 21 cracks were detected and weld repaired. It did not prove possible from the available records, presented by the manufacturer and operator, to determine when and where the particular repair had been carried out.

The diffuser case, in common with many parts on the JT9D, is an 'on condition' item and had been subject to a visual on wing inspection by the operator as part of a general engine inspection, every 2000 hours.

However, due to the difficult of access to the lower segment of the case on a fully dressed engine, this area was not inspected on these occasions. Full inspection of the diffuser case was being conducted only when the engine had been removed and partially or completely stripped, for other reasons.

Three previous diffuser case failures in this area are known to have occurred since 1977 to different operators, of which one event was investigated by the manufacturer. This investigation showed a near identical type of fatigue failure adjacent to, but on the opposite side from, the boss at the 6 o'clock position. This failure had also propagated from a repair weld to the rear rail, the fatigue crack extending to a length of 5.7" before a rupture of 13" total length occurred. The failure which occurred on N656PA, however, was more extensive and associated with a shorter pre-existing crack than that described above. It is possible, therefore, that this failure was precipitated earlier, in terms of hours/cycles, than it would have occurred otherwise, by the engine inadvertently achieving an EPR value of 1.57, as indicated by the DFDR.

In 1980, a non-mandatory service Bulletin, SB 5055, was introduced by the manufacturers which detailed extensive modifications to the diffuser case. One of the objectives of this was to reduce stress levels in the boss/rear rail transition areas and thereby increase the cyclic life to crack initiation. The case from N656PA was not so modified.

Since the accident the engine manufacturer has recommended, amongst other checks, that a once off on wing inspection be carried out on all diffuser cases, with particular attention to be paid to the 6 o'clock boss location, using a flexible borescope. Both the operator and manufacturer of the engine have now shown this to be possible without the removal of any engine components.

In addition, they are requesting all JT9D operators to initiate record keeping such that a diffuser case crack repair data base may be established. Information on crack size, location, case total time and cycles, time and cycles since last full inspection/repair, and time and cycles since incorporation of SB 5055, if applicable, is being sought.

The attention of the CAA has been drawn to this accident.

*The rear rail is one of two circumferential integral thickened-sections around the outside of the diffuser case, interconnecting the various bosses/mounting pads.

a Diffuser case

b Outer combustor case

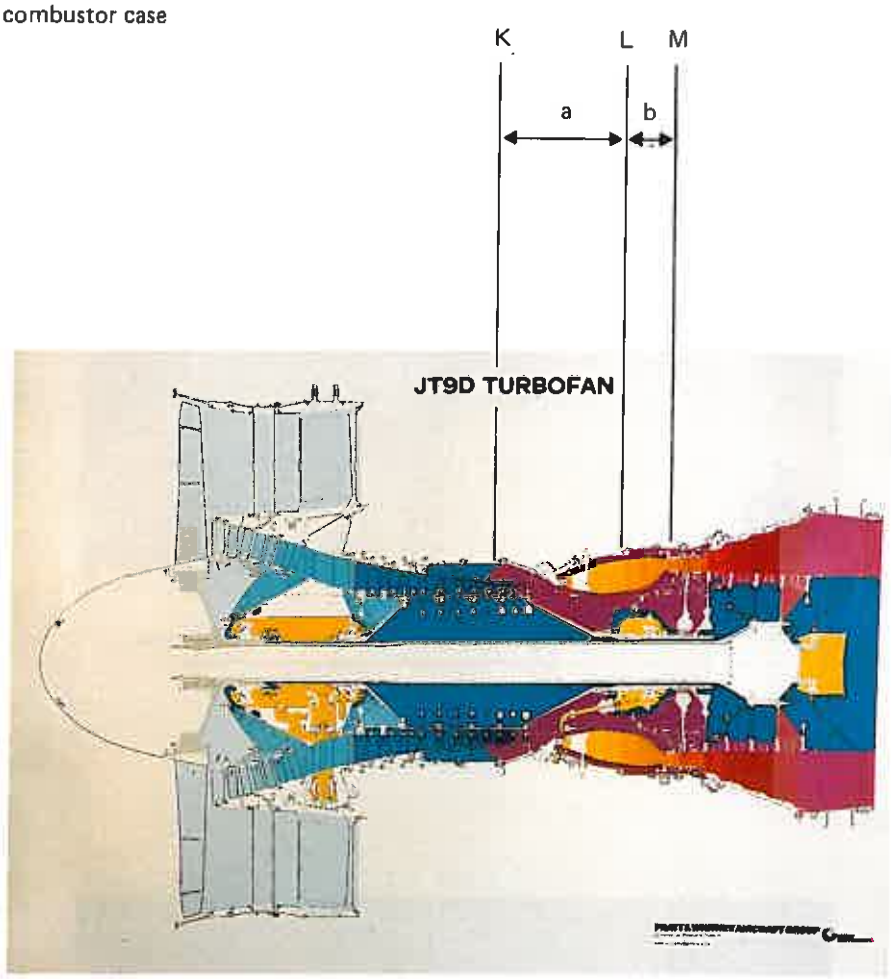

FIG 1 Colour cross-sectional diagram of JT9D with diffuser case and outer combustion case annotated in addition to flanges K, L and M

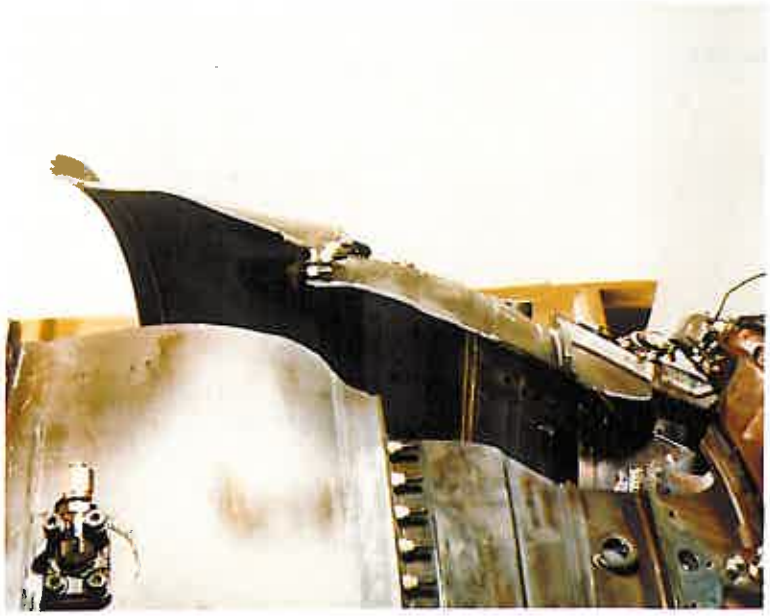

FIG 2 Colour reproduction of photo showing casing split, with discoloured area and rear rail indicated

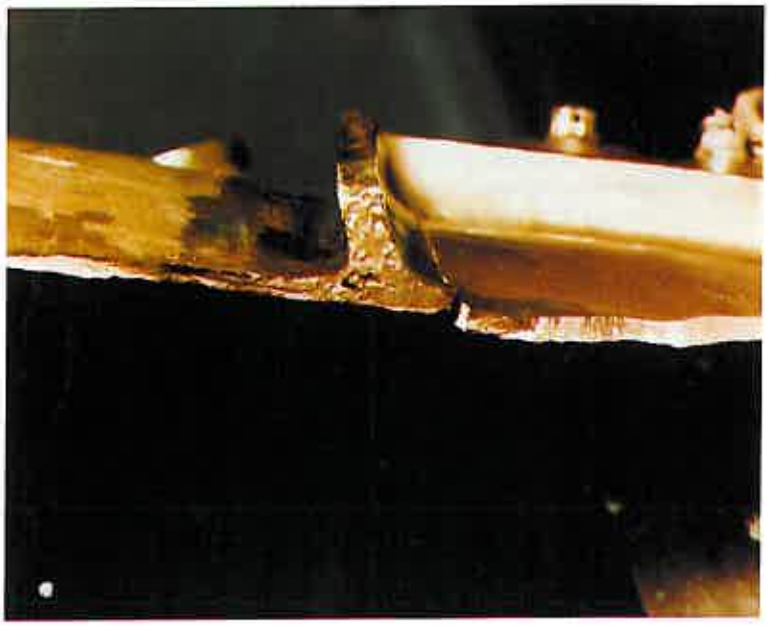

FIG 3 Colour reproduction of close-up photo of fatigue/weld area. Extent to fatigue highlighted