AAIB BULLETIN No: 7/95 Ref: EW/A94/11/1 Category: 1.1

INCIDENT

Aircraft Type and Registration:	Boeing 747-436, G-BNLA
No & Type of Engines:	4 Rolls-Royce RB211-524 H turbofan engines
Year of Manufacture:	1989
Date & Time (UTC):	10 November 1994 at 1906 hrs
Location:	Buenos Aires, Argentina
Type of Flight:	Public Transport
Persons on Board:	Crew - 20 Passengers - 240
Injuries:	Crew - None Passengers - None
Nature of Damage:	Substantial to No 4 engine
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	53 years
Commander's Flying Experience:	14,000 hours (of which 1,300 were on type) Last 90 days - 185 hours Last 28 days - 95 hours
Information Source:	AAIB Field Investigation

The aircraft departed Buenos Aires, from Runway 11 at 1900 hrs (1600 hrs local time), for its non-stop flight to London Heathrow. The weather at the time was fine with a temperature of 24°C, calm winds and CAVOK conditions. The aircraft was being operated with a 'Heavy Crew' complement which included an additional captain and first officer.

At approximately 1,300 feet and at a speed of 190 kt during the initial climb the crew heard a series of loud bangs sounding similar to severe engine surging. The commander noticed the EGT strip instrument for No 4 engine rise and turn red as it exceeded the limits. As he retarded the thrust lever for No 4 engine the EICAS (Engine Indication and Crew Alerting System) indicated 'FIRE ENGINE No 4' and the fire warning bell sounded. The commander initiated the recall items from the engine fire checklist by closing the thrust lever, selecting the fuel lever to shut off and firing the first fire extinguisher bottle. Thirty seconds later, with the fire indications still present, he fired the second extinguisher bottle. Sensing the engine failure the automatic flight system indicated a level acceleration whereupon the flaps were retracted on the speed schedule. During the 'clean up' the first officer, who was the flying pilot, transmitted a 'MAYDAY' to the tower. Once 'clean' the aircraft took up a heading for the first waypoint and was climbed to 6,000 feet, a height above sector safe altitude and the minimum height for fuel jettison.

Shortly after the initial fire warning the second captain entered the flight deck and, with the agreement of the commander, started the fuel dumping procedure. At this stage the aircraft was 100,000 kg above its maximum normal landing weight. The second first officer, who was now also present on the flight deck, was sent by the commander to carry out a visual inspection of the No 4 engine from the rear of the cabin as a fire indication was still showing on the EICAS. The SCCM (Senior Cabin Crew Member) was also summoned to the flight deck and was told that the aircraft would be landing immediately. He returned to the cabin and broadcast the pre-recorded 'emergency landing' public address. Some moments later the second first officer returned to the flight deck and reported that no fire was visible on the No 4 engine. The commander now decided not to return to land immediately but to continue jettisoning fuel down to the maximum normal landing weight. This took approximately 1 hour and was carried out in VMC conditions at 6,000 feet over the River Platte estuary clear of built-up areas. During this time a cabin crew member was briefed to remain at door R5 to observe and report on the condition of No 4 engine.

With the fuel jettison complete the crew manoeuvred the aircraft to commence a procedural three engine autoland approach onto Runway 11 which was carried out without further incident. The emergency services and the resident company engineer attended the aircraft as it landed to examine the engine and brakes. With no further apparent problems the aircraft was escorted by the emergency services as it taxied to the stand. The passengers and crew deplaned normally.

The commander reported that although the emergency procedures could have been carried out adequately by the two flight deck crew alone, the presence of the 'heavy crew' was a bonus and led to greater flexibility in resource management.

Initial Examination by the Operator

On initial examination, the engine was found to have suffered an internal failure leading to burning through of the panels forming the outer fairing of the engine core within the bypass duct and the leaking combustion gases had torched across the bypass airflow region of the duct before damaging the cold nozzle and elements of the thrust reverser which, in normal operation, form the inner skin of the duct. No externally visible damage to the engine cowl was present and the remainder of the aircraft was undamaged.

A propulsion specialist was dispatched by the operator to Buenos Aires to examine the aircraft. He carried out an assessment of the internal condition of the damaged No 4 engine to determine its remaining structural integrity and hence its suitability to remain on the wing for a proposed ferry flight.

Inspections were carried out on the remaining three engines in order to confirm that they were still in the condition predicted by the operator's condition monitoring programme. It was confirmed that there was no evidence of an increased likelihood of premature failure on any of them. A decision was then made to carry out a three-engine ferry of the aircraft back to the UK.

The visible damage on the internal faces of the bypass duct was patched with aluminium alloy panels and speedtape and the fan blades were all removed. A blank was fitted to the intake of the engine core. A return flight to London Heathrow, using a ferry-qualified crew, was carried out utilising two intermediate stops en route.

Examination of Aircraft on Return to the United Kingdom

Examination of the aircraft on its arrival at London Heathrow by AAIB and the operator confirmed that major burn damage had occurred at approximately the 4 o'clock position (looking forward). On removal of the temporary repair panels covering the core engine damage within the bypass duct, the blades of the high pressure (HP) turbine could be seen through the hole in the casing.

Detailed Examination

The power unit was removed and transported to the premises of the operator's overhaul contractor. A strip examination was carried out in the presence of the operator's propulsion specialists, representatives from the manufacturer and an Engineering Inspector from the AAIB. It was established that the engine inner casing had burnt through in the region of the trailing edge of the 1st stage nozzle guide vanes (NGVs) and the tip seal of the HP turbine, as a result of a gas flow occurring in an approximately tangential direction on exit from the NGVs centred in approximately the 3-30 position.

This had initially allowed combustion gases to escape into the cooling air cavity before burning through the outer casing of the engine core and locally destroying the metal panels forming the fairing of the core within the bypass flow. In addition, the inner skin of the cold nozzle and elements of the thrust reverser (ie skins forming the outer boundary of the bypass flow) was locally heat damaged. Severe burning, holing and cracking of the Intermediate Pressure (IP) turbine casing and cooling air manifold had also occurred, together with local damage to the HP/IP support structure. Although extensive mechanical damage to most of the turbine stages was found, it was considered that this was all associated with debris from the original burn through area passing through the turbines and becoming trapped between the blades and the nozzle guide vanes.

Examination of the combustion system revealed that a section of the meterpanel at the upstream end of the combustion liner had become displaced in such a way that the faces of the heat shields were angled towards the outside of the engine rather than lying at right angles to the flow direction. This displacement was the result of circumferential cracking occurring between a group of adjacent cooling air slots at the inner circumference of a section of the meterpanel, allowing the latter to distort under the influence of the gas path load. This resulted in complete or partial disengagement of fuel spray nozzles from positions 3 to 7 and modification of the downstream flow pattern such that the hotter areas near the centre of the flame pattern came into contact with the outer wall of the gas path. This, in turn, resulted in loss of the outer platforms of two HP NGVs and local burn through of HP turbine seal segments.

No defects or damage were found upstream of the meterpanel, although small deposits of an apparently organic substance were found on most of the fan blades. No corresponding deposits were found on any of the compressor blades or stators, or elsewhere in the core engine. The deposits from the fan blades were analysed by specialists of the Bird Strike Avoidance Team of the Central Science Laboratory of the Ministry of Agriculture Fisheries and Food to establish whether any biological evidence of a bird strike existed. They were found not to be consistent with bird remains but were believed rather to be the result of insect ingestion.

Laboratory Examination

The damaged section of the meterpanel area was cut away from the combustion liner and was examined by the materials laboratory of the engine manufacturer, as were a number of corresponding sections removed from in-service examples of other engines which exhibited cracking in similar areas. It was determined that the components were all dimensionally and materially correct. It was also established that the cracking phenomenon was the result of a low cycle thermal fatigue effect which, when sufficiently developed, allowed a high-cycle fatigue mechanism to become dominant.

Other Service Experience

Most meterpanels in this type of combustion liner develop some degree of in-service cracking in the area of the cooling air slots (ie the area of origin of this failure). These do not, however, normally inhibit the continued use of the component, without any displacement of the meterpanel occurring, for some 20,000 hours or 3,000 cycles. The component involved in this incident, however, had only completed some 12,918 hours and 1,741 flight cycles. A similar displacement of a meterpanel has been found to have occurred on another unit with a different operator in which the combustion liner had completed fewer hours and cycles than the incident component but no in-flight problem was experienced.

Engine Condition Monitoring

A retrospective study of recorded modular performance data not used for routine engine trend monitoring revealed two rapid short-term parameter changes, the first of which, beginning approximately 90 flight cycles before the incident, was thought to be the result of the alteration of the flame pattern as a result of the initial displacement of the meterpanel. The parameters affected included Turbine Gas Temperature (TGT). This parameter is recorded by all operators of the engine type and its change during the 90 cycles up to the incident exceeded that normally expected during 1,000 cycles of operation.

Fire Detection

The damage to the engine also resulted in destruction of wiring associated with the fire warning and overheat detection systems. The logic of the aircraft warning system interpreted the open circuit condition of this wiring as being a continuation of the fire after it was, in fact, successfully extinguished. The EICAS flight deck fire warning thus remained present throughout the flight.

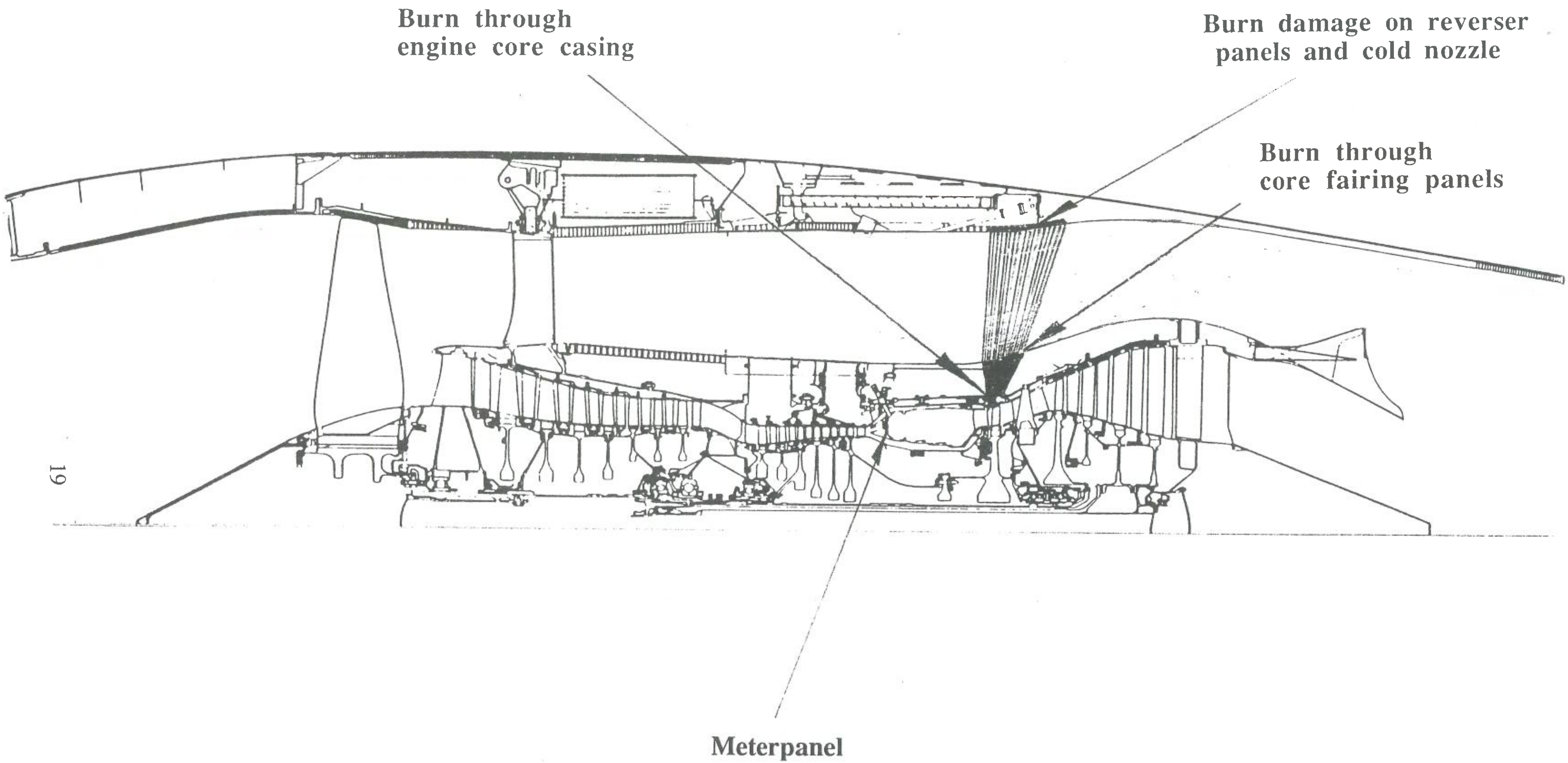
Fire Protection Considerations

The burn-through occurred in a radial position such that the resulting torching occurred harmlessly into the bypass duct, only impinging on the inner surface of the cold nozzle and onto thrust reverser panels. Consideration was given to the possibility and consequences of such a burn through occurring at the 12 o'clock position, ie in line with the pylon and the interservices fairing. It was established that a firewall separates all flight critical components mounted in the 12 o'clock position from the engine core. It was also understood that the engine has been shown to satisfy the certification requirement calling for this firewall to be effective for the total time period normally assumed to separate the start of flame break-out and completion of crew post-fire actions.

Airworthiness Follow-Up Action

The manufacturer has produced a Non Modification Service Bulletin (NMSB) for circulation under its CAA approval system to all users of the engine type and closely related types (ie all RB211-524 G and H and a small number of RB211-524D4 engines; the latter have a similar combustor but operate at a lower rating and are not thought to be subject to the problem). The NMSB details an internal borescope inspection technique to detect any displacement of the heat shields/meter panel and calls for its implementation at all routine inspections otherwise undertaken and at any time that an excessive shift in TGT trend is detected. The NMSB calls for removal of any engine within five flights of an abnormality in the meterpanel and/or disengagement of a fuel spray nozzle from the burner seal being observed.

The manufacturer has also recently introduced into production a modified combustor head manufactured from C 263, in place of the existing Nimonic 75 material. The meterpanel, which is attached to the head, is already manufactured from C 263, but the opportunity has also been taken to incorporate within it some minor changes to the arrangement of cooling air holes and some slight geometric alterations. Although this design change, which is detailed in Service Bulletin 72-9764, was made for reasons unrelated to the problem of meterpanel failure, it is thought that the design will reduce the tendency for cracking to occur in the area of the cooling air slots and reduce or eliminate the possibility of this type of failure.



SECTION OF RB 211 524 H ENGINE SHOWING POSITIONS OF MAJOR BURN DAMAGE AND DISPLACED METERPANEL

DETAILED VIEW OF COMBUSTOR AND HP TURBINE AREA AT APPROXIMATELY 3 0-CLOCK POSITION