Air Accidents Investigation Branch

Department of Transport

Report on the accident to Boeing 747–136 G–AWNB on Runway 28R London (Heathrow) Airport on 15 November 1986

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Department of Transport
Air Accidents Investigation Branch
Royal Aircraft Establishment
Farnborough
Hants GU14 6TD

12 January 1988

The Rt Honourable Paul Channon
Secretary of State for Transport

Sir,

I have the honour to submit the report by Mr D F King, an Inspector of Accidents, on the circumstances of the accident to a Boeing 747–136, G–AWNB, which occurred on Runway 28R London (Heathrow) Airport on 15 November 1986.

I have the honour to be
Sir
Your obedient Servant

D A COOPER
Chief Inspector of Accidents

Contents

Air Accidents Investigation Branch

Aircraft Accident Report No. 8/87
(EW/C993)

Owner and Operator:		British Airways PLC
Aircraft:	*Type:*	Boeing 747–136
	Nationality:	British
	Registration:	G–AWNB
Place of Accident:		Runway 28R London (Heathrow) Airport
		Latitude: 51° 28′ N
		Longitude: 000° 27′ W
Date and Time:		15 November 1986 at 0620 hrs
		All times in this report are UTC

Synopsis

The accident was notified by the London (Heathrow) Airport Air Traffic Control (ATC) at 0650 hrs on 15 November 1986 and an investigation was commenced by the Air Accidents Investigation Branch (AAIB) the same morning.

The aircraft was engaged on a scheduled international passenger flight from New York, John F Kennedy International Airport, to London (Heathrow) Airport with a total of 259 persons on board. The flight had proceeded normally until, at about 44 minutes before landing whilst still in cruising flight, the flight crew noticed that the No 2 engine turbine gas temperature (TGT) gauge indication had dropped to 130° Celsius (C). After checking the continuity of the electrical supplies to the gauge and that all other parameters appeared to be normal, it was suspected that the TGT gauge was at fault and the engine was allowed to continue running. A normal approach and landing at Heathrow's runway 28R was carried out, however, approximately 13 seconds after touch-down, with reverse power selected on all engines, there was a No 2 engine fire warning. The flight crew carried out the laid down drill and the fire warning cancelled.

The accident, an uncontained failure of the No 2 engine, resulted in minor damage to the wing flaps, fuselage fairing and the No 1 engine. The non-containment was caused by complete failure of the anti-rotation pins restraining the third stage low pressure (LP) turbine stator vanes. Inadequate design strength of the pins and the failure of an Airworthiness Directive (AD) to prevent recurrence of a known problem were major contributory factors.

1. Factual Information

1.1 History of the flight

The aircraft was engaged on a scheduled international passenger flight from New York, John F Kennedy Airport to London (Heathrow) Airport with 242 passengers and a crew of 17. The aircraft departed from New York at 0029 hrs on 15 November 1986. The flight was uneventful until 0536 hrs when engine power was being increased following a descent from 35,000 feet to 31,000 feet. At this stage it was noticed that the No 2 engine TGT gauge indication had dropped from its previous reading of 616° C to 130° C. After recycling the TGT gauge electrical circuit breaker and checking that all other engine parameters appeared to be normal, a TGT indicator fault was suspected and the engine was allowed to continue running. The flight data recorder (FDR) read-out confirmed the drop in TGT indication and that, after minor disturbances, all other engine parameter indications were normal and consistent with the indications from the three other engines.

A standard let-down towards London (Heathrow) was carried out followed by a normal instrument landing system approach and landing on runway 28R. Shortly after touch-down, and 13 seconds after reverse power was applied, there was a No 2 engine fire warning. Reverse thrust was cancelled and the flight crew carried out the laid down emergency drill. They informed ATC of the situation and a full response from the emergency services was immediately initiated. The No 2 engine fire warning indication cancelled immediately the fire handle was pulled and, with the engine shut-down, the aircraft was turned off the runway and parked. After the commander had received a damage report from the airport fire services, the aircraft was taxied to the terminal area where the passengers disembarked through the normal exits.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	—	—	—
Serious	—	—	—
Minor/none	17	242	

1.3 Damage to aircraft

There was substantial damage to the No 2 engine LP turbine module and engine cowlings. Release of debris resulted in minor damage to the aircraft's left wing flap sections and lower fuselage. There was also evidence of some minor ingestion of debris by the No 1 engine.

1.4 **Other damage**

Nil

1.5 **Personnel information**

1.5.1	*Commander:*	Male, aged 50 years
	Licence:	Airline Transport Pilot's Licence valid until 28 February 1990
	Aircraft ratings:	Auster variants, Viscount, VC10, Boeing 747
	Instrument rating:	Valid until 7 January 1987
	Medical examination:	Class I, renewed 21 July 1986 valid until 31 January 1987
	Certificate of Test:	Dated 20 July 1986
	Flying experience:	
	Total flying hours:	12,870
	Total flying hours in command:	7828
	Total flying hours on type:	4755
	Total flying hours in last 28 days:	65
1.5.2	*Co-pilot:*	Male, aged 39 years
	Licence:	Airline Transport Pilot's Licence valid until 20 November 1989
	Aircraft ratings:	PA28/32, Vanguard, Boeing 707/720, Boeing 737, Boeing 747
	Instrument rating:	Valid until 28 April 1987
	Medical examination:	Class I, dated 31 July 1986 valid until 31 July 1987
	Certificate of Test:	Dated 5 March 1986
	Flying experience:	
	Total flying hours:	6085
	Total flying hours on type:	938
	Total flying hours in last 28 days:	20

1.5.3 *Flight Engineer:* Male, aged 42 years

Licence:	Flight Engineer's Licence valid until 30 August 1988
Aircraft ratings:	VC10, Boeing 747
Medical examination:	30 September 1986 and valid until 30 September 1987
Flying experience:	
Total flying hours:	7787
Total flying hours on type:	3700
Total flying hours in last 28 days:	30

1.5.4 *Rest and duty periods*

Each crew member had been on duty for 7 hours and 20 minutes at the time of the accident. Before reporting for duty at New York, each crew member had a rest period in excess of 24 hours.

1.6 Aircraft information

1.6.1 *General Information*

Type:	Boeing 747–136
Registration:	G–AWNB
Serial number:	19762
Date of manufacture:	1970
Registered owner:	British Airways PLC
Certificate of Airworthiness:	Transport Category (Passenger) issued 16 August 1984 and valid until 15 August 1988
Total airframe hours:	60,039
Total airframe landings:	15,148
Type of engines:	4 Pratt and Whitney JT9D–7cn turbofans

1.6.2 *Aircraft weight and centre of gravity*

The maximum permitted take-off weight was 332,900 kg and the maximum landing weight was 265,300 kg. The actual weights were 278,900 kg and 216,000 kg respectively.

At the time of take-off from New York, the centre of gravity of the aircraft was within the prescribed limits and remained so throughout the flight.

1.6.3 *Engines*

The engines fitted to G–AWNB were Pratt and Whitney JT9D–7cn turbofans. The turbine section of the engine comprised 2 high pressure (HP) and 4 LP stages. The LP turbine stators were manufactured as individual vanes, but during the normal construction process, most were bonded together in groups of three to provide structural rigidity and improve engine efficiency. There were 35 groups of three and 3 individual vanes in the third stage.

The vanes incorporated mounting feet (see Appendix A) which located in the LP turbine case. The forward feet were inserted into a slot in the casing which contained 108 anti-rotation pins in the case of the third stage. Slots in the forward feet engaged on the pins to react the rotational loading due to the gas flow. The aft feet were located in a shallow groove and held in place by a locking ring which was itself retained by the third stage turbine air seal.

Six thermocouple probes were fitted to the engine to measure the TGT. These were inserted through the LP turbine case and into the ring of third stage stators where they measured the gas temperature at approximately the mid-point of the gas flow annulus. Any rotational movement of the third stage stator ring would therefore eventually result in bending and/or shearing of the probes.

1.6.4 *Maintenance*

The aircraft possessed valid Certificates of Airworthiness, Registration, and Maintenance. A review of the maintenance records for the No 2 engine, serial number 662334, showed that it had run a total of 48,562 hours/12,374 cycles since new and 4934 hours/977 cycles since installation on G–AWNB on 12 September 1985.

The failed turbine module, serial number 62881, was fitted to the engine in September 1985, at which time it received a relatively brief visual inspection. It had a total time since new of 34,939 hours/7671 cycles and had last been overhauled in October 1982 since when it had run for 9734 hours/1971 cycles. The operator's approved maintenance schedule specified a "straight overhaul life" of 12,500 hours. The overhaul of the module included inspection of the anti-rotation pins for condition, but Service Bulletin (SB) 5292, concerning modification of the anti-rotation pins, (see paragraph 1.17.1) had not been incorporated.

Examination of the aircraft's Technical Log showed that the flight crew had recorded the apparent failure of the No 2 engine TGT gauge as the indication fell to 130° C, whilst noting that all other parameters were normal. A review of the entries for the 3 months prior to the accident did not reveal any other significant entries relating to this engine.

1.7 **Meteorological information**

After the accident the Meteorological Office, Bracknell, provided an aftercast of the weather at London (Heathrow) for the relevant period. The aftercast contained the following information:

General situation:	A weak flat ridge of high pressure was predominant over south east England
Weather:	Nil
Visibility:	In excess of 10 kilometres
Cloud:	Shallow stratus, base 3000 feet
Surface wind:	240°/06 knots

The details of the actual weather broadcast by the Automatic Terminal Information Service which the flight crew had received before commencing their approach to land were:

Surface wind:	230°/03 knots
Cloud:	No significant low cloud
Visibility:	In excess of 10 kilometres

Meteorological conditions were not a factor in this accident which occurred during the hours of darkness.

1.8 **Aids to navigation**

Not relevant

1.9. **Communications**

Communication on all the very high frequency channels used throughout the accident were satisfactory. Recordings and transcripts of all relevant radio-telephony messages were available.

1.10 **Aerodrome information**

London (Heathrow) Airport has three runways available for normal operations: 28R/10L, 28L/10R, and 23/05. At the time of the accident, 0620 hrs, single runway operation was in force using runway 28R for both take-offs and landings because of the temporary closure of runway 28L due to work in progress. As soon as G—AWNB reported the emergency to Heathrow ATC, an inspection of runway 28R was ordered and the runway was closed immediately that debris was found. Three aircraft, inbound for runway 28R, were instructed to go-around and await further flight clearance. The work in progress on runway 28L was ordered to cease and that runway was declared open for all operations at 0637 hrs. The three aircraft that had been instructed to go-around subsequently landed on runway 28L and the accident caused no disruption to other air traffic movements.

1.11 Flight recorders

1.11.1 *Flight data recorders*

A Plessey PV1910 FDR system was fitted to the aircraft. The accident protected part of the system was a Penny and Giles type D800 re-cycling digital FDR which used stainless steel tape as the recording medium. This recorder is of the twin-spool 8 track type, with serial data recorded on sequential tracks, and the recorder alternating its direction at the end of each track. The record duration was approximately 30 hours. A total of 33 parameters were recorded plus 71 discrete (switch) positions.

A satisfactory replay of the data recorded shortly before and upto the TGT run-down was obtained, this being from track 3 of the recorder. However, approximately 3.5 hours of data recorded in the immediately preceding track (track 2) had been erased. This was most likely due to a fault in the reed switches controlling part of the record circuitry, such that when the recorder switched direction and track changed from 2 to 3, the appropriate reed switches did not operate. This meant that the record head for the previous track was continuously energised, resulting in identical data being recorded on both tracks 3 and 2 simultaneously, that on track 2 being recorded in the reverse direction to that which it would normally be running when recording. Tests at British Airways workshops verified the fault as intermittent and strip examination revealed that the three reed switches controlling the read/write head for track 2 were intermitttent in operation.

As part of the system a "quick-access" cassette recorder was also fitted and this recorded a number of additional parameters; in total 77 parameters plus 81 discretes. This was replayed using the British Airways facilities with no problems. Copies of the relevant portions of this replay were passed to AAIB and provided useful additional information.

1.11.2 *Cockpit voice recorder*

A Fairchild A100 four track cockpit voice recorder (CVR) was installed in the aircraft. This used plastic based tape as the recording medium and was of the normal endless loop type with a duration of 30 minutes.

Due to this short duration the earliest information recorded was as the aircraft taxied into the stand after the incident. No useful information was therefore obtained from the CVR.

1.12 Examination of wreckage

1.12.1 *Preliminary examination*

The aircraft was examined on stand 10 of Terminal 4 at London (Heathrow) and later at the operator's maintenance facility. It was clear that the No 2 engine had suffered an uncontained failure in the region of the HP/LP turbine. The cowlings exhibited circumferential gashes around their lower segment in the plane of the third stage turbine stator vanes, caused by parts being released at some speed. There was severe damage to the LP turbine components visible from the exhaust duct. (See Appendix B.)

A considerable quantity of third stage stator vane groups, exhibiting varying degrees of damage, was recovered from the south side of runway 28R between blocks 13 and 15 inclusive. The airframe had evidently been struck by some of this debris, but damage was confined to relatively minor impacts on the trailing edge of some aft flaps, a flap fairing and the wing/fuselage fairing. Evidence of hard object damage to the No 1 engine, in the form of minor nicks in 5 fan blade leading edges, was also attributed to uncontained debris from the No 2 engine.

Upon removing the damaged core cowlings, it was apparent that the LP turbine case had separated completely from the rest of the engine carcass. A relatively clean circumferential fracture of the case had occurred just aft of the TGT probes (See Appendix B) which were inserted through holes in the ring of third stage turbine stator vanes. This had allowed the aft part of the casing to sag, opening up a gap through which the vanes had been released. It was noted that the gap was wider at the bottom than the top because of a yoke located on top of the engine which had restricted rearward movement of the top of the case. This would appear to have been the reason why the vanes were released in a predominantly downward direction ie, they had not "burst through" the casing but had rather been permitted to escape as the case parted.

There was no evidence of any sustained fire on the engine, but the lower accessories and piping in the region of the casing fracture showed some scorching as did the inner surface of the hinged access cowling and the fire detection elements. Such damage would be expected due to the release of hot gas or residual fuel.

The engine was removed and despatched to the operator's overhaul facility, where a strip of the LP turbine module was undertaken under AAIB supervision.

1.12.2 *Strip examination of No 2 engine*

Uncontained failure of stator vanes is an unusual event. It was appreciated at an early stage that this accident was associated with a known problem with the JT9D engine whereby the failure of the anti-rotation pins allows the stator vanes to rotate at high speed (see paragraph 1.17.3).

The nature of the casing fracture of the No 2 engine was typical of a previous accident, investigated by AAIB, in which the casing had been worn away by the locating feet of the stator groups (see paragraph 1.17.3). The feet of the stators also showed evidence of gross rotational wear and had lost nearly 12 mm of material (see Appendix A). There was no sign of the six TGT probe sheaths, although the mounting blocks were found detached from the casing but hanging from the wiring looms. The fracture face of the casing exhibited heavy smearing and scoring, indicating that the vanes had departed whilst rotating in a counter-clockwise direction viewed from the rear (ie, the opposite direction to the turbine rotation), although a small amount of debris appeared to have been released in a clockwise direction.

There was damage to all of the second stage turbine blades and the third stage air seal had broken and was lying loose in the engine. The third stage turbine rotor blades had also come adrift and caused severe damage to the remaining stages of the LP turbine. The LP shaft showed scoring due to trapped debris. Two holes in the exhaust duct were noted, apparently caused by turbine rotor blade or vane penetrations.

The rotation of the third stage stator vanes had caused a high degree of frictional heating and thus the locating groove for the stator feet in the casing was virtually filled with fused material, obliterating all traces of the anti-rotation pin fracture surfaces. No pieces of pin material were recovered. Following the strip of the module, it could be seen that the pins from the remaining stages were all intact, although many showed wear to varying degrees. The distribution of worn pins appeared to be random, occurring singly or in groups with some pins exhibiting wear on both contact faces.

1.13 Medical and pathological information

Not applicable.

1.14 Fire

The No 2 engine fire warning indication was initiated by the disintegration of its LP turbine section, which allowed hot gases to be released around the engine's fire detection system. As soon as the emergency fire drill had been completed by the flight crew, and the fuel supply to the engine had been cut off, the cockpit fire warning cancelled. The Airport Fire Service responded immediately to the emergency call-out and a full complement of fire appliances had positioned around the aircraft within 2 minutes. After examination of the damage to the No 2 engine and the under-side of the aircraft, the chief fire officer informed the aircraft commander that there was no immediate fire hazard and the aircraft was taxied to the terminal area, accompanied by a back-up of fire vehicles.

1.15 Survival aspects

Not applicable.

1.16 Tests and research

Nil.

1.17 Additional information

1.17.1 *Pratt and Whitney Service Bulletin No 5292*

SB No 5292 was first issued in June 1981. At that time the engine manufacturer was aware of nine incidents of LP turbine damage occurring since 1976 due to stator vane anti-rotation pin failure. The degree of damage is not mentioned although it would appear to have been limited to air seal rub and consequential damage but without rupture of the casing. The SB introduced anti-rotation pins made from nickel alloy instead of the pre-modification stainless steel material, and also reduced the free length projection of the pin out of the turbine case. The problem was cited as "wear of pin can lead to pin rupture or shearing" and the cause stated as "shearing of pins is due to extensive bending stress and/or caused by pin bending due to creep of material".

It is evident from the SB that accomplishment of the modification can cause problems because of difficulty in removing the old pins. Several methods are suggested for pin removal.

The SB was applicable to several marks of JT9D engine, including the -7cn fitted to G–AWNB, with SB 5507 being the equivalent modification to other marks of the engine. The original Pratt and Whitney compliance category for SB 5292 was 5 : "Optional – accomplish at a period based on an operator's experience with prior configuration". Revision No 3, dated 24 June 1985, raised the compliance to category 3B : "Recommended – Pratt and Whitney considers the work outlined herein desirable but not urgent and recommends accomplishment when engine or module is disassembled sufficiently to afford access to affected part".

1.17.2 *FAA Airworthiness Directive 86–09–01*

FAA AD 86–09–01 became effective on 13 May 1986. It called for mandatory embodiment of SB 5292 or SB 5507 as appropriate. Compliance was required at the next removal of the LP turbine rotor from the LP case and vane assembly, but not later than 31 December 1989.

1.17.3 *Previous incidents of anti-rotation pin failure*

It was not uncommon for engine overhaul workshops to find one or more anti-rotation pins broken upon strip of the LP turbine module.

On 23 January 1981 a British Airways Boeing 747–136, registration G–BDPV, fitted with Pratt and Whitney JT9D–7J engines, experienced unreliable TGT indications on its No 3 engine occurring over two sectors. On the second sector the indication fell to 155° C in the climb and reduced further in the cruise. Upon inspection after landing without incident, it was found that the TGT probes had been sheared off by rotation of the third stage stator vanes. The stage had evidently not spun at high speed, and damage was mainly limited to distortion and wear of the third stage inner air seal shroud. It was thought at the time that a possible explanation for the failure was some form of interference between the shroud and associated knife-edge seal which put excessive torque into the stator ring, failing the anti-rotation pins.

On 1 August 1985 a Boeing 747, registration 4X–AXC experienced an LP turbine case rupture due to failure of the fourth stage stator anti-rotation pins. The aircraft was landing at London (Heathrow) and the failure apparently occurred after reverse thrust was selected. The aircraft suffered similar, but more severe, damage than G–AWNB and was the subject of a field investigation which was reported in AAIB Bulletin 1/86.

Following this accident British Airways asked Pratt and Whitney for a summary of their experience of anti-rotation pin failures which incurred secondary damage. Their reply, dated 15 January 1986, stated that they were aware of a total of 23 "pin shear events" which caused secondary damage and a further 10 events in which no secondary damage resulted. It would appear that, prior to the accident to G–AWNB, there had been 2 similar uncontained failures of the LP turbine stators due to pin failure.

It was also noted that, of the 23 "pin shear events", 5 had occurred to the third stage stators, 10 to the fourth stage stators and 8 to the fifth stage stators. There had been no reported complete failures of the sixth stage pins, although some failed pins had been found and it was for this reason that they were included in the SB.

The "pin shear events" were analysed by LP turbine case part total time and part total cycles. It was found that the events occurred between 7,000 and 35,000 hours and between 1,000 and 12,000 cycles and to 12 different operators. It was concluded from this that there was no correlation between time/cycles and number of events, and that pins with relatively low hours/cycles were just as prone to failure as high time items.

1.17.4 *British Airways' compliance with SB 5292*

Following the incident to G–BDPV in January 1981, British Airways received details of SB 5292 and commenced spares provisioning. Their compliance target was to replace all worn or broken pins with the modified part. In June 1984, the decision was made to upgrade this by requiring replacement of all pins when the LP turbine module was stripped sufficiently to afford access to the pins.

In May 1985, it was decided to further upgrade the compliance to require pin replacement when the LP turbine module was removed from the engine for any reason. By then, mainly through problems in removing the old pins, British Airways were having difficulties in accomplishing the modification and very few engines had been completely modified.

Following the accident to 4X–AXC on 1 August 1985 (see paragraph 1.17.3) and, knowing that an AD on the subject was imminent, British Airways again upgraded the compliance to require pin replacement on all engines entering the overhaul facility for any reason. This decision was taken in May 1986 and between then and the date of the accident to G–AWNB, some 60% of their JT9D engines were fully modified to SB 5292 standard. After the accident to G–AWNB, compliance was further accelerated and all British Airways engines were scheduled to be modified by 31 May 1987.

2. Analysis

2.1 Sequence of failure of No 2 engine

The first indication of any abnormality of the No 2 engine occurred as the crew increased power following a descent from 35,000 feet to 31,000 feet, when the indicated TGT fell from its normal reading of about 600°C to 130°C. The FDR recorded this decrease and also confirmed that, after a brief fluctuation, the other engine parameters stabilised at indications consistent with those of the other engines. It therefore appears that the loss of TGT indication was caused by damage to, or severance of, the TGT probes by partial rotation of the third stage ring of stators. The engine then continued to operate normally and it is reasonable to assume that major disruption did not occur until high reverse power was selected after touch-down.

At this point it would appear that the increased mass flow of the engine overcame the frictional forces preventing rotation of the stators. Once rapid rotation had begun, the locating feet of the vanes started to "machine away" the LP turbine case whilst also losing material themselves. As the casing thinned, pressure loads caused it to rupture circumferentially and release the rapidly spinning stator vanes. Rearward movement of the LP turbine case, although partially restrained by the yoke at the top of the engine, caused collisions between the remaining LP stators and rotors resulting in massive damage.

2.2 Anti-rotation pin failure

Due to the degree of damage to the pin fracture faces of the No 2 engine it was not possible to examine any in detail for metallurgical information. There is, however, no reason to believe that the failure mechanism was any different from that reported on the previous occasions, both of total or partial failure of the pins retaining any particular stage.

In the absence of any correlation between part total hours/cycles and failure occurrences, there would appear to be other factors which are not purely time dependent. The information regarding the causes of pin failure as described in SB 5292 is somewhat brief, but further discussion with the manufacturer led to the conclusion that the pre-modification pins are of inadequate strength to withstand certain adverse cases which can occur during engine build and operation. It is possible that these could be a combination of build and manufacturing tolerances, surface finish, vibration, and other factors. These would make it extremely difficult to estimate accurately the loads felt by any given pin and, therefore, to predict when pin failure could be expected. Additionally, the manufacturer believes that the primary mechanism of failure of the pins is "stress rupture" and that this is also dependent upon time-at-temperature as well as the applied stress.

The modification introduced by SB 5292 provides stronger pin material coupled with reduced projection length of the pin from its socket, hence reducing possible bending stress. The manufacturer had reported no failures of post-modification pins up to April 1987.

2.3 FAA Airworthiness Directive 86–09–01

Pratt and Whitney SB 5292 was upgraded to category 3B in June 1985 but, as with any manufacturer's SB, was not mandatory. The AD issued on 13 May 1986 was largely prompted by the incident to Boeing 747, registration 4X-AXC, on 1 August 1985. The date of 31 December 1989 specified in the AD was imposed to ensure that operators eventually incorporated the modification. However, because it would have been difficult to predict that further cases of total pin failure were unlikely, the reason for specifying such a long compliance time in the AD could only have been based on achieving the minimum economic penalty to operators.

The manufacturer had devised a radiographic inspection which is designed to inspect engines in situ for broken anti-rotation pins, although this is not capable of detecting cracked or worn pins. Guidance is given to operators regarding subsequent actions, or re-inspection intervals, depending upon how many pins are found to have failed. Early indications are that this inspection is effective in detecting broken pins. It is considered that the AD should be amended to incorporate the radiographic technique. This inspection could also be applied to engines fitted with modified pins to monitor the effectiveness of the modification.

3. Conclusions

(a) *Findings*

(i) The aircraft possessed a valid Certificate of Airworthiness and its documentation was in order.

(ii) The aircraft had been maintained in accordance with an approved maintenance schedule and all relevant Airworthiness Directives had either been actioned or awaited implementation within the compliance timescale.

(iii) The flight crew were properly licenced and experienced.

(iv) The accident occurred when the No 2 engine suffered an uncontained failure of the low pressure turbine releasing third stage stator vanes and rotor blades. Liberated debris caused minor damage to the flaps, fuselage fairing and the No 1 engine.

(v) The non-containment of the stator vanes was caused by failure of their anti-rotation pins which allowed the entire stator stage to rotate at high speed. This rotation caused rapid wear of the low pressure turbine case, which failed circumferentially and released the rapidly spinning vanes.

(vi) Final failure of the anti-rotation pins probably occurred between the departure from New York and the descent towards London. The loss of a sensible turbine gas temperature indication for the No 2 engine was probably associated with this event.

(vii) Rapid rotation of the vanes probably did not occur until the crew selected reverse thrust after touch-down.

(viii) There was no indication of a sustained fire occurring after the case ruptured, although some evidence of overheating was found which could have triggered the engine fire warning system.

(ix) The problem of failure of all the stator vane anti-rotation pins in either stages 3, 4, or 5 of the low pressure turbine was a known problem and the subject of both a manufacturer's Service Bulletin and a Federal Aviation Authority Airworthiness Directive. The accident engine was un-modified but within the compliance requirements of the Airworthiness Directive.

(x) The compliance instructions contained in the Service Bulletin and the Airworthiness Directive were inadequate to prevent a further uncontained failure of an engine, despite the operator's policy of implementation well within the respective compliance dates.

(xi) The mechanism of failure of the anti-rotation pins makes it impossible to predict when a failure is likely to occur. It would appear that pin breakage occurs progressively and, therefore, any form of inspection which can detect the numbers of broken pins in an engine could be used to identify engines which are at risk from total pin failure.

(b) *Cause*

The accident, an uncontained failure of the No 2 engine, resulted from complete failure of the anti-rotation pins restraining the third stage low pressure turbine stator vanes. Inadequate design strength of the pins and the failure of an Airworthiness Directive to prevent recurrence of a known problem were major contributory factors.

4. Safety Recommendations

It is recommended that:

4.1 The Pratt and Whitney radiographic inspection procedure for broken anti-rotation pins should be incorporated into the Airworthiness Directive to ensure that broken pins are detected pending embodiment of Service Bulletin 5292.

4.2 The performance of modified anti-rotation pins should be monitored to ensure that the modification is effective.

D F KING
Inspector of Accidents

Air Accidents Investigation Branch
Department of Transport

December 1987

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