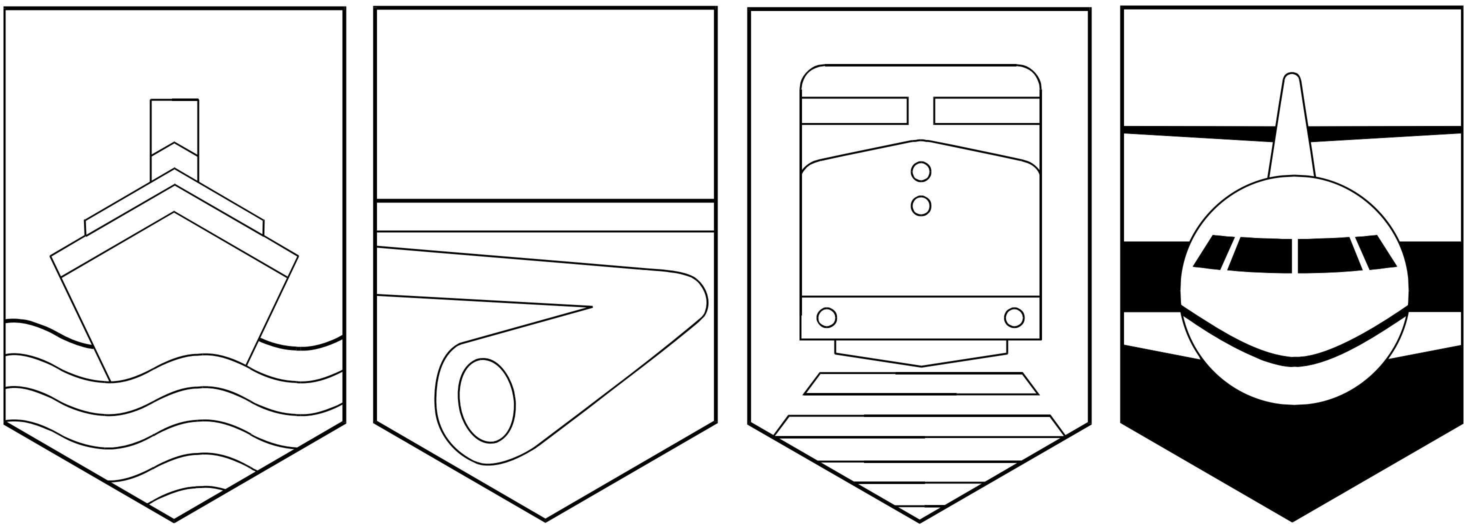
Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada



AVIATION OCCURRENCE REPORT

ENGINE COMPONENT FAILURE/INTENTIONAL SHUTDOWN

AIR NOVA
BRITISH AEROSPACE BAe-146-200 C-GRNV
NEWARK, NEW JERSEY, U.S.A.
29 DECEMBER 1994

REPORT NUMBER A94A0252

Canada

MANDATE OF THE TSB

The Canadian Transportation Accident Investigation and Safety Board Act provides the legal framework governing the TSB's activities. Basically, the TSB has a mandate to advance safety in the marine, pipeline, rail, and aviation modes of transportation by:

- conducting independent investigations and, if necessary, public inquiries into transportation occurrences in order to make findings as to their causes and contributing factors;
- reporting publicly on its investigations and public inquiries and on the related findings;
- identifying safety deficiencies as evidenced by transportation occurrences;
- making recommendations designed to eliminate or reduce any such safety deficiencies; and
- conducting special studies and special investigations on transportation safety matters.

It is not the function of the Board to assign fault or determine civil or criminal liability. However, the Board must not refrain from fully reporting on the causes and contributing factors merely because fault or liability might be inferred from the Board's findings.

INDEPENDENCE

To enable the public to have confidence in the transportation accident investigation process, it is essential that the investigating agency be, and be seen to be, independent and free from any conflicts of interest when it investigates accidents, identifies safety deficiencies, and makes safety recommendations. Independence is a key feature of the TSB. The Board reports to Parliament through the President of the Queen's Privy Council for Canada and is separate from other government agencies and departments. Its independence enables it to be fully objective in arriving at its conclusions and recommendations.

Aviation Occurrence Report

Engine Component Failure/ Intentional Shutdown

Air Nova
British Aerospace BAe-146-200 C-GRNV
Newark, New Jersey, U.S.A.
29 December 1994

Report Number A94A0252

Synopsis

The BAe-146-200 aircraft (C-GRNV), operating as ARN896, was on a scheduled international flight from Newark, New Jersey, U.S.A., to Halifax, Nova Scotia, Canada. During the climb-out from Newark, as the aircraft was climbing through 9,000 feet above sea level to flight level 190, a vibration, in excess of the maximum allowable, developed in the No. 4 engine. The engine was subsequently shut down and, after consultation with company maintenance, dispatch, and operations departments, the decision was made to continue the flight to Halifax, where an uneventful landing was carried out.

The Board determined that a third stage turbine blade failed, causing excessive vibration which prompted the flight crew to carry out a precautionary shutdown of the No. 4 engine. The third stage blade failed as a result of the overload extension of a high-cycle fatigue crack which originated near the blade's leading edge.

Ce rapport est également disponible en français.

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1.0 Factual Information

1.1 History of the Flight

The BAe-146-200 aircraft (C-GRNV), operating as ARN896, was on a scheduled international flight from Newark, New Jersey, U.S.A., to Halifax, Nova Scotia, Canada. As the aircraft was climbing through 9,000 feet above sea level (asl)[1] out of Newark, the No. 4 engine vibration light illuminated, and the vibration gauge indicated 3.0 inches per second (ips). The crew reduced power on the No. 4 engine, and the vibration level decreased to below 1.2 ips. The crew then carried out the engine vibration checklist; however, as the aircraft levelled at flight level 190, the vibration level had increased again above the maximum allowable 1.2 ips. The crew secured the engine as per their procedures.

The crew consulted with company maintenance, dispatch, and operations departments, and the decision was made to continue the flight. The aircraft was landed uneventfully at Halifax with Emergency Response Services (ERS) standing by.

The incident occurred at latitude 42°44'N and longitude 073°48'W[2], at 1348 eastern standard time, during the hours of daylight.

1.2 Injuries to Persons

	Crew	Passengers	Others	Total
Fatal	-	-	-	-
Serious	-	-	-	-
Minor/None	5	48	-	53
Total	5	48	-	53

1.3 Damage to Aircraft

There was no damage to the aircraft other than internal damage to the No. 4 engine.

1.4 Other Damage

There was no damage to other property or objects.

1.5 Personnel Information

1 See Glossary for all abbreviations and acronyms.

2 Units are consistent with official manuals, documents, reports, and instructions used by or issued to the crew.

	Captain	First Officer
Age	31	32
Pilot Licence	ATPL	ATPL
Medical Expiry Date	01 Dec 95	21 Feb 95
Total Flying Hours	8,845	9,700
Hours on Type	1,200	800
Hours Last 90 Days	167	150
Hours on Type Last 90 Days	167	150
Hours on Duty Prior to Occurrence	8	8
Hours Off Duty Prior to Work Period	16	16

The flight crew was certified and qualified for the flight in accordance with existing regulations.

1.6 Aircraft Information

Manufacturer	British Aerospace
Type and Model	BAe-146-200
Year of Manufacture	1989
Serial Number	E2133
Certificate of Airworthiness (Flight Permit)	Valid
Total Airframe Time	12,669 hr
Engine Type (number of)	Lycoming ALF-502R-5 (4)

Propeller/Rotor Type (number of)	N/A
Maximum Allowable Take-off Weight	42,184 kg
Recommended Fuel Type(s)	Jet A, Jet A-1, Jet B
Fuel Type Used	Jet A

Documentation indicates that the aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures. The weight and centre of gravity were within prescribed limits.

1.7 Meteorological Information

The following weather conditions existed at the time of the occurrence:

Newark - Clear skies and the winds were 320 degrees at 20 knots gusting to 33 knots.

Halifax - 600 scattered, ceiling 1,500 overcast, the visibility was six miles in rain showers and snow showers, and the winds were 240 degrees at 15 knots gusting to 25 knots.

1.8 Flight Continuation to Halifax

The decision to continue the flight to Halifax was based on the facts that the aircraft had just passed through an extensive area of moderate turbulence and low level wind shear which was associated with strong surface winds in the New York area, and that the weather conditions in Halifax were more suitable for a three-engine landing.

1.9 Engine Examination

A teardown of the No. 4 engine (Lycoming ALF-502R-5, serial number LF-05483A) revealed a fractured third stage turbine blade. This was the third incident of this type involving the same aircraft (C-GRNV) in less than a year. The three incidents involved re-bladed engines, with the last repair prior to the failure being their modification according to Service Bulletin (SB) ALF 72-270R1.

The third stage turbine disc and shaft were sent to the TSB Engineering Branch for failure analyses and to determine possible commonality in the three failures (LP 03/95 refers). Failure analyses of the two previous third stage turbine blade failures were also carried out at the TSB Engineering Branch; the findings are contained in Engineering Reports LP 31/94 and LP 89/94.

1.10 Engineering Branch Examination

1.10.1 Third Stage Turbine Blade

One of the blades from the third stage disc had separated approximately 12 millimetres (mm) above the platform. The second blade clockwise from the broken blade had its tip shroud knocked off. The damage to other blades consisted of chipped trailing edges near the blade tips. Visual and liquid penetrant inspections were performed on all blades in search of cracks in the same general area as the fracture occurred; no cracks were detected. To facilitate a detailed examination using optical and scanning electron microscopy, the broken blade and two neighbouring blades were removed from the disc. The fractured blade bore the identification 2079, which corresponds to the heat lot number.

The blade had broken in a chordwise manner 12 mm outboard of the platform, and the fracture surface was more or less perpendicular to the longitudinal blade axis. There were two distinct regions visible on the fracture. The first region extended approximately 10 mm from the leading edge and appeared flatter and brighter than the rest of the fracture. Right at the leading edge, there was a very small region which reflected light differently. When viewed from the side, a "V" type notch was discernible. This kind of fracture topography is consistent with Stage I and II fatigue crack propagation. The darker appearing fracture beyond the 10 mm zone reflects the rapid final separation.

Scanning electron microscope examination confirmed the Stage I fatigue crack propagation characterized by pronounced crystallographic facets. Isolated pockets of microporosity were also detected in the Stage I fatigue crack region. Further into the fracture, Stage II fatigue crack propagation, with its typical beach marks and striations, became prevalent. Successive grinding and polishing into the origin disclosed no presence of large metallurgical discontinuities; however, scattered microporosity was intercepted within the origin region on the third polish. The microporosity was so small that it would undoubtedly have met the manufacturer's acceptance criteria.

The microstructure of the failed blade was typical of the cast nickel base superalloy. Comparison of the microstructure of the failed blade with that of the two neighbouring blades did not disclose any metallurgical deviations. Similarly, hardness readings taken on the longitudinal sections of the failed blade and two neighbouring blades were practically identical. Energy dispersive X-ray analysis of the blade material verified that the alloy conformed to the manufacturer's specification for M3617R.

The third stage turbine assembly had been modified to carry out SB ALF 72-270R1. The modification involved machining a redesigned blade root slot profile that alleviates disc broach slot cracking. The material removed by this modification is replaced by an insert. In other words, the blade roots retain the original configuration. All blades, including the failed one, were sitting firmly in their respective slots, and the tip shroud gaps were checked by the operator and found to be within limits. The blades had accumulated 4,103 hours and 3,836 cycles between the time of the modification and the time of the failure.

1.11 Previous Third Stage Turbine Blade Failures

Following concerns expressed by operators, Transport Canada invited Allied Signal (formerly Textron Lycoming) to give a briefing about the ALF 502 series engines' in-service difficulties. The meeting was held on 19 January 1995 in Ottawa.

The third stage turbine blade failure problems first appeared in 1991 (Air Wisconsin); since then, there have been four more occurrences (one at Air BC, three at Air Nova). All turbine blade failures involved re-bladed engines and were contained. Allied Signal indicated that the lower-than-desired life after re-blade resulted from re-blading the turbine wheel at overhaul with used blades. The used blades met replacement specification at the time of installation; however, following its investigation into the blade failures, the engine manufacturer determined that the tip shroud gaps between neighbouring blades were excessive. The excessive tip shroud gaps were caused by in-service wear of the high spots on the fretted shroud surfaces of the used blades. The manufacturer concluded that the excessive gaps resulted in reduced damping and led to high-cycle fatigue failure.

2.0 Analysis

2.1 Failure Analysis - Third Stage Turbine Blade

This third stage blade failure bears a striking resemblance to the failure investigated last year (LP 89/94). In that occurrence, as in this case, Stage I and II fatigue cracking were detected, with no particular material deficiency at the initiation site. In the present case, there was some scattered microporosity present at the origin. It is believed, however, that the microporosity merely served to locate the crack origin, rather than cause it. The respective blades came from the same supplier but had different heat lot numbers, so the problem does not seem to be batch related.

There was no obvious connection between the modification to the third stage turbine disc and the development of this failure.

The first of the three third-stage blade failures on this aircraft was discussed in Engineering Branch Report LP 31/94. In that case, the blade failed through the platform by fatigue which established itself in an area of clustered porosity judged to be in excess of the manufacturer's acceptance criteria. Therefore, no connecting link has been established between the first failure and the two that followed.

In this occurrence, the third stage blade failed as a result of an overload extension of a high-cycle fatigue crack which originated near the blade's leading edge. It is possible that re-blading with used blades resulted in excessive tip shroud gaps between neighbouring blades, which then resulted in reduced damping and the high cycle fatigue cracking.

2.2 No. 4 Engine In-Flight Shutdown

The No. 4 engine turbine blade failures were contained and caused vibration to exceed the allowable 1.2 ips. The excessive vibration prompted the flight crew to carry out a precautionary in-flight shutdown of the No. 4 engine according to procedure.

3.0 Conclusions

3.1 Findings

1. The third stage blade (engine S/N LF-05483A) failed as a result of an overload extension of a fatigue crack which originated near the blade's leading edge. With the exception of scattered microporosity intercepted in the Stage I fatigue region, no other material deficiencies or damage were in evidence to explain the failure initiation mechanism.

2. The third stage blade material is considered to be in compliance with the chemical composition and porosity limits as per manufacturers' specification M3617.

3. There does not appear to be any connection between the modifications carried out on the third stage turbine disc and the development of the failure.

4. The third stage failure closely resembles a failure investigated last year (LP 89/94). While the failure mechanism was identical, it was not possible to find a common underlying cause.

5. All previous occurrences of third stage turbine blade failure involved re-bladed engines, with the blades failing in high-cycle fatigue. It is possible that the lower-than-desired life after re-blade resulted from re-blading the turbine wheel at overhaul with used blades, with excessive tip shroud gaps between neighbouring blades.

6. The No. 4 engine turbine blade failure was contained and caused vibration to exceed the allowable 1.2 ips.

7. The excessive vibration prompted the flight crew to carry out a precautionary shutdown of the No. 4 engine as per procedure.

3.2 Causes

A third stage turbine blade failed, causing excessive vibration which prompted the flight crew to carry out a precautionary shutdown of the No. 4 engine. The third stage blade failed as a result of the overload extension of a high-cycle fatigue crack which originated near the blade's leading edge.

4.0 Safety Action

4.1 Action Taken

Allied Signal is developing shroud reconditioning procedures to alleviate the problem. Transport Canada is monitoring Canadian and other operators who use the ALF 502 engines for in-flight shutdown rates and engine reliability.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson John W. Stants, and members Zita Brunet and Maurice Harquail, authorized the release of this report on 08 January 1996.

Appendix A - List of Supporting Reports

The following TSB Engineering Branch Reports were completed:

LP 03/95 - Third Stage Turbine Disc Blade Failure;
LP 89/94 - Turbine Blade Failure Analysis; and
LP 31/94 - Third Stage Turbine Blade.

These reports are available upon request from the Transportation Safety Board of Canada.

Appendix B - Glossary

asl	above sea level
ATPL	Airline Transport Pilot Licence
ERS	Emergency Response Services
hr	hour(s)
ips	inches per second
kg	kilogram(s)
LP	laboratory project (Engineering Branch report)
mm	millimetre
SB	Service Bulletin
S/N	serial number
TSB	Transportation Safety Board of Canada
°	degree(s)
'	minute(s)

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