No: 1/89 **Ref: EW/C1075** **Category: 2c**

Aircraft Type and Registration:	Bell Model 206L Long Ranger, G-OLDN
No & Type of Engines:	1 Allison 250-C20B turbine engine
Year of Manufacture:	1977
Date and Time (UTC):	6 July 1988 at 1045 hrs
Location:	Folyats, Fyfield, Essex
Type of Flight:	Public Transport
Persons on Board:	Crew - 1 Passengers - 6
Injuries:	Crew - None Passengers - None
Nature of Damage:	Both landing skids deformed and tail-boom buckled
Commander's Licence:	Airline Transport Pilot's Licence (Helicopters)
Commander's Age:	41 years
Commander's Total Flying Experience:	3300 hrs (of which 1800 were on type)
Information Source:	AAIB Field Investigation

1 HISTORY OF THE FLIGHT

G-OLDN had been chartered to fly a party of six from a private residence at Fyfield, Essex, to Newmarket race course. The helicopter departed its operational base at Stansted Airport and flew to the pick-up point, which was a paddock on the periphery of the grounds surrounding the charterer's house. This site was used regularly by helicopters, but had not been visited previously by the pilot of G-OLDN. The passengers were embarked at the upwind corner of the paddock, the engine was started normally and the aircraft took off, at or close to the maximum permitted take-off weight.

A normal lift-off was made at about 76-78% torque, without the use of the water methanol injection system, and a gradual transition into forward flight was made using about 98-99% torque. The pilot felt translational lift take effect and began to climb away when suddenly "at about 40 kts and 40 ft" there was a loud bang and a violent yaw, accompanied by the engine-out warning. The pilot reported that, with no time to enter autorotation, he corrected the yaw and kept the collective lever at its existing position. A stout wooden fence across the far end of the paddock necessitated a turn to the left and an attempt was made to cushion the touch-down with a slight flare, and use of the remaining collective pitch.

The aircraft landed heavily at low speed some 10 metres before the fence, travelling towards it at an angle of approximately 40 degrees but with a rate of yaw to the left which resulted in it coming to rest facing at 90 degrees to its take-off track, parallel with the fence, and some 6 metres forward of the initial touch-down. The pilot shut off the fuel and battery master switch, and applied the rotor brake. However, although the throttle twist grip was closed, the "baulk" button was not pressed to allow full movement from flight idle to the fuel cut-off position.

The impact grossly deformed both landing gear skids, particularly on the right side, allowing the skid belly-attachments to contact the ground.

Additionally, both aft footsteps were knocked off the fuselage, the tail boom was buckled as a result of inertial 'spring back' loading, and there were indications of main gearbox movement sufficient to bring the swash plate into contact with the adjacent fairings. There were no tail or main rotor strikes and the tailboom did not contact the ground. The aircraft remained upright, although leaning appreciably to the right.

None of the occupants was injured by the impact. However, they ignored the pilot's instruction to remain on board the aircraft until it was safe to leave and exited from both sides beneath the still turning rotors. Because of the sideways tilt of the aircraft and the low body position caused by the deformed skids, the tips of the teetering rotor could have descended to within 5 ft of the ground on the right side of the aircraft as they flapped during run-down, creating an extremely hazardous evacuation path.

There were 380 lbs of fuel on board at the time of the accident and the water/methanol tank was 3/4 full. A moderate rain shower was falling and the wind, recorded at Stansted, was 180/10-15 kts.

2 ENGINE EXAMINATION

Examination of the engine on-site revealed bulging of the compressor case in the region of the 3rd/4th stage of the axial compressor, together with several splits in the casing.. These splits had not opened significantly and no debris had penetrated the compressor casing. However, numerous very small pellets of steel and 'steel filings', evidently compressor blade fragments which had been ejected from the compressor bleed valve, were distributed over the engine decking. Debris had also passed through the compressor centrifugal impeller and into the turbine section of the engine, dimpling the compressor discharge ducts where debris had struck the internal walls of the tube. No other damage to the engine was evident externally, and no abnormalities were noted affecting the engine's installation or ancillary equipment.

The aircraft was recovered to the operator's engineering base where the engine was removed, taken to the main overhaul agency and strip-examined under AAIB supervision, with a representative from the engine manufacturer in attendance.

Strip examination

Dismantling of the engine revealed a major breakup of the axial compressor assembly, initiating in the region of the 3rd/4th stage axial rotors, which had resulted in the loss of all blades from the 3rd, 4th and 5th stage rotors and substantial damage to the 6th stage rotor blades. There were indications that the compressor had surged, almost certainly as a result of the damage, leading to the ejection and re-ingestion of small pieces of debris. The 2nd stage rotor blade trailing edges were damaged and the 1st stage rotors had several small nicks on both the leading and trailing edges. Light tip-rubbing was also evident. The vanes at the "eye" of the centrifugal impeller were bruised by debris, but the remainder of the impeller was substantially undamaged.

The compressor case was extensively damaged by breakup debris. All stator vanes were "wiped off" except those between the 1st-to-2nd stages, which were largely undamaged, and the 2nd-to-3rd stage vanes which were intact but had suffered leading and trailing edge damage. The plastic liner material had been torn out behind the 2nd stage, but was present forward of the break-up area although some gouging damage was evident, together with recent tip-rubbing, which was clearly a result of the break-up. In addition, a general pattern of cracking together with some 'machining' of the plastic material was also evident, which was clearly long-term and not associated with the break-up. These pre-existing features were not considered by the overhaul agency or the manufacturer to be unusual. A small amount of corrosion was evident beneath the plastic liner material, particularly around the stator vane roots in the areas where cracking of the plastic appeared prevalent. This was also considered to be normal.

Debris had passed into the turbine section, causing damage to both the gas producer and power turbines, and jamming both rotors. All bearings were in good condition, the magnetic plugs were normal and the oil filter screen was clean.

No evidence of significant abnormality was found anywhere in the engine except for the damage directly associated with the compressor failure.

3 METALLURGICAL EXAMINATION OF THE COMPRESSOR

A majority of the missing blades on the compressor rotor were found to have separated as a result of rapid, low cycle/high stress fatigue-cracking from multiple origins on the blade flanks, and numerous similar partial cracks were also found adjacent to the main fractures. This damage clearly stemmed from the failure, being caused by abnormal loads generated during the breakup process, rather than being a part of the causal mechanism.

In contrast to this general mode of blade failure, one of the blades on the 3rd stage wheel had separated as a result of slower, high cycle/low stress fatigue-cracking, involving many millions of load cycles, which appeared to have grown from multiple origins on the concave side of the blade, in an area approximately 25% outboard from the root. The precise nature of the origins could not be determined because of secondary damage. However, there is little doubt that the fracture was pre-existing and that the separation of this weakened blade during the period of high load on climb-out initiated the compressor failure sequence which caused the accident. A second blade from this wheel also exhibited signs of long term fatigue in three small regions on the convex side of the blade, near the trailing edge.

Corrosion pitting was found in the region forward of the blade leading edges, in the gas path between stages. Because of the destruction of the blades, it was not possible to assess the extent to which the corrosion pitting may have extended to the blades themselves.

Etched microsections of the material showed that the casting was of good quality, with no evidence of intergranular carbides or other imperfections. The material hardness was within the manufacturer's specification.

It was concluded that the engine failure was caused by the separation of a 3rd stage compressor blade as a result of fatigue, which probably initiated from corrosion pits on the concave side of the blade, at approximately 25% span.

4 PREVIOUS HISTORY: G-OLDN

(i) Oil pressure fluctuations

On the day prior to the accident, the engine oil pressure had fluctuated during a flight from Stansted to Bath. A precautionary landing was carried out at Wycombe Aerodrome and the pilot telephoned his engineering base, which advised him that low oil contents could produce such symptoms. The oil level was checked and found to be very low, requiring 3 quarts to bring the oil level up to normal. On start-up, the oil pressure was found to be normal and the flight to Bath and the return to Stansted were carried out without further incident, as was the outbound flight from Stansted to the accident location.

No evidence was found of burning or seepage from any of the seals or bearings during the post accident strip examination of the engine and it is not considered that the oil loss played any part in the accident.

No satisfactory explanation has been found for the apparently sudden loss of oil. No reference has been made concerning unusual smoking or oil contamination of the aircraft exterior, and there were no signs of external leakage from either the engine or airframe pipework. However, the maximum normal oil consumption of Allison 250-C20B series engines is 0.05 Gals (US) per hour, at which rate 3 quarts would be consumed every 18 hrs. The total flight time between the last maintenance check (when the oil level would have been checked/topped up) and the onset of oil pressure fluctuations due to low oil level was approximately 18 hrs. During this period no oil replenishments were recorded in the technical log.

(ii) Compressor failure:

Some 430 hrs prior to the accident (in 1985), the same pilot had experienced a compressor failure on G-OLDN. On that occasion, the symptoms were unusual noises on start-up and shut-down. This was followed, after a few flights, by slow acceleration to idle.

During the flight to his maintenance base to have the engine checked, the pilot also noted an increased turbine outlet temperature (TOT). Removal of a compressor half-casing revealed that single blades had become detached from each of the 4th and 5th stages, and lodged in the bleed valve area, without causing further damage.

The maintenance organisation which repaired the compressor did not comment upon the fracture surfaces of the detached blades, but did note that the plastic liner had lifted in the area forward of the failed blades and expressed the opinion that a segment of liner had lifted and fouled a compressor blade, causing it to "break off".

5 HISTORY OF COMPRESSOR FAILURES ON ALLISON 250 SERIES ENGINES:

Some 50% of the total number of compressor failures affecting the axial stages of Allison 250 series engines have been examined by the manufacturer, who states that of these, 65% were caused by fatigue originating from corrosion pits; 26% were caused by cracks the origins of which were obscure, but where there was evidence of corrosion on the affected wheel; 2% were caused by fatigue cracking, not associated with corrosion; and the remaining 7% failed for reasons which could not be established.

Corrosion pitting of the axial compressor blades on Allison 250 series engines operating in corrosive environments has been recognised as a threat by the manufacturer for many years. In common with most other manufacturers of similar sized engines, Allison recommends daily compressor rinsing when operating in such environments. This is supported by evidence of very significant improvements in the failure rates of engines in specific fleets of aircraft, operating in hostile (maritime) environments, subsequent to a policy of daily rinsing being introduced. However, the practical aspects of compliance with the Allison recommendations, particularly for owner-operators and small-fleet operators, are such that compressor rinsing in accordance with Allison's intentions is seldom carried out, unless the aircraft is operated regularly in an obviously hostile environment. In common with most operators based inland, G-OLDN was not subject to a daily program of compressor rinsing. The reasons why the rinse recommendation is not widely adopted are manifold, but appear to fall principally into the following principal areas:

a) A lack of awareness of the Allison recommendations: Allison has used the engine maintenance manual and 'Commercial Service Letters' as the media through which to promulgate their recommendations concerning compressor rinsing, rather than insertions in the flight manuals of the affected aircraft. This results in maintenance organisations being the initial recipients of Allison's advice, rather than the pilots and operating personnel directly. The operation of many aircraft remote from the maintenance base, as in this case, must reduce considerably the impact which this advice has on pilots and operators.

b) The operator's perception of the level of threat to his aircraft: Allison's definition of a hostile engine environment in the 'Engine Operation and Maintenance' manual dated 1985 was "salt water areas". This was expanded to "salt water or other chemically laden atmospheres (including pesticides contamination)" in 1986, and again expanded in the Service Letter revision No.1, dated February 15th 1988, to include "...industrial pollutants, sulfur laden atmosphere, pesticides, herbicides, etc".

A note contained in both Service Letters points out that "... salt laden air may be encountered for 75-150 miles inland under certain weather conditions" (AAIB italics) although it does not say specifically what those conditions are. It recommends a daily water rinse if in any doubt.

Whilst this note provides clear information on the chemical constituents of atmospheres regarded as hazardous, it does not offer guidance as to how an individual pilot or operator is supposed to form a judgement in practice.

(c) The time penalty involved, and the difficulty of carrying-out the procedure single handed: Allison specifies that the following process is carried out:

i) The engine is to be allowed to cool to a temperature which allows hand contact on the engine case, but it must not be allowed to become cold.

ii) The bleed valve is wedged into the closed position.

iii) The engine is subjected to a controlled water spray into the intake whilst being motored on the starter (with the ignition circuit breaker pulled to prevent a start).

iv) The bleed valve is restored to normal.

v) The engine is started and allowed to run at idle for 5 minutes to allow the engine to dry thoroughly.

Estimates of the time taken to accomplish this complete cycle vary from 20 minutes (Allison) to 50 to 60 minutes (most operators). The task can be undertaken single-handed by a pilot if the aircraft is fitted with an optional spray ring for connection to the wash water reservoir. The need for a drying run, during which rotors would be turning, dictates the need for a pilot to be present.

d) The penalty of 1 extra start cycle (per day in many cases): Depending on the type of operation, the additional start cycle could lead to the engine 'starts limit' being reached before the 'life (hours) limit'.

The AAIB has investigated several compressor failures affecting the Allison 250 series engines and has confirmed the potential for corrosion pitting on compressor blades to initiate fatigue cracks. As a result of that earlier work, and in the light of an apparently high rate of compressor failure affecting Allison 250 engines in the UK compared with the corresponding failure rate in the USA (UK failure rate appears to be approximately ten times higher), the AAIB wrote to the CAA in May 1988 summarising the problems of corrosion induced fatigue and recommending that:

"..the CAA clarify the situation in the UK concerning compressor rinsing of Allison 250-B17/-C18/-C20 engines, particularly with regard to the extent of the atmospheric hazard in the UK. This information should be promulgated to UK owners, operators and pilots in the most direct and expeditious form, such as Flight Manual amendments and letters to operators of the affected aircraft types."

In response, on the 21st July 1988, the CAA wrote to all operators/owners of the affected engine types asking them how they decide whether compressor washing is justified (with regard to the environment in which they fly), whether their frequency of washing is in accordance with Allison recommendations, and whether the fluids and methods used differ from those prescribed. The issue of compressor rinsing, as opposed to washing,was not directly addressed.

It is considered that the original AAIB recommendations of May 1988 have been given added weight by this accident, and it is recommended that the CAA should encourage the wider adoption of water rinsing amongst operators, with a view to giving added force to the existing Allison recommendations. It is also recommended that the CAA letter requesting information on compressor washing is clarified, in so far as its intention to gather information about rinsing is concerned, since compressor washing and rinsing are quite different processes.

6 NEW SPECIFICATION COMPRESSOR WHEELS

In response to the corrosion problem affecting the axial compressor wheels on the 250 series engines, Allison has introduced an improved wheel, which is essentially the same as the original wheel but has, in addition, a diffused alloy coating which it claims will improve resistance to corrosion pitting.

It is understood that the new coated wheel has now superseded the old wheels as a direct replacement item (the original wheels are no longer available). The intention is that this new wheel will, once the appropriate agency approvals have been granted, be cleared for re-coating. However, coating of original non-coated wheels will not be approved.

It must be pointed out that Allison states that the coating, which is intended to act as sacrificial barrier, does not remove the need for compressor rinsing when operating in corrosive environments, and the requirement for the CAA and operators to address the need for an effective rinsing policy will therefore remain for the foreseeable future.

7 HAZARDS FROM TURNING ROTORS DURING EVACUATION

The evacuation from the damaged aircraft beneath the still turning rotors was extremely hazardous.

It is difficult to lay down specific guidelines concerning the relative risks involved in remaining on board a crashed helicopter compared with the risks associated with evacuation under turning rotors. However, it would appear that many who fly as passengers in helicopters imagine the main rotor to turn rigidly about its axis and do not appreciate that it is actually flying with a considerable freedom of movement, particularly in the flapping (up and down) axis.

As a rotor slows down, the control over the path of the blades through the air is reduced and 'blade sailing' is likely to occur. In an accident, the possibility of damage to the rotor pitch control systems, distortion of gearbox mountings and rotor head geometry, together with unusual body angles, increases greatly the risk of a rotor going out of control, creating a very serious hazard for evacuees. Further risks arise from the potential for blades to strike the ground, the tail-boom or some other obstruction during or immediately after an accident which can cause the aircraft to roll over.