Report 09-004, Britten Norman BN2A-Mk III Trislander, ZK-LOU loss of engine propeller assembly, near Claris, Great Barrier Island, 5 July 2009

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Britten Norman BN2A-Mk III Trislander

ZK-LOU

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Trislander ZK-LOU
(Airliners.net 2005)
(used with permission)

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Abbreviations

CAA	Civil Aviation Authority of New Zealand
CAR	Civil Aviation Rule
DTA	Defence Technology Agency
kg	kilogram(s)
TBO	time between overhaul
UTC	coordinated universal time

Data Summary

Aircraft registration:	ZK-LOU
Type and serial number:	Britten Norman BN2A-MkIII Trislander, 322
Number and type of engines:	3 reciprocating Textron Lycoming 0-540-E4C5
Year of manufacture:	1972
Operator:	Great Barrier Airlines
Date and time:	5 July 2009, 1305[1]
Location:	near Claris, Great Barrier Island latitude: 36° 12.83´ south longitude: 175° 26.13´ east
Type of flight:	scheduled air transport
Persons on board:	crew: one passengers: 10
Injuries:	crew: nil passengers: 3 minor
Nature of damage:	extensive to fuselage, right engine and propeller
Pilot's licence:	Commercial Pilot Licence (aeroplane)
Pilot's age:	24
Pilot's total flying experience:	868 hours (28 hours on type)
Investigator-in-charge:	K Mathews

[1] Times in this report are New Zealand Standard Time (UTC+12 hours) expressed in the 24-hour mode.

Executive Summary

Shortly after take-off at approximately 1305 on 5 July 2009, the right engine propeller assembly of ZK-LOU, a 3-engine Trislander, separated from the engine crankshaft and struck the side of the aeroplane. Nobody was seriously injured, but the aeroplane fuselage was extensively damaged and a passenger door was removed, leaving a large opening adjacent to some passengers.

Undetected corrosion of the propeller flange had led to extensive cracking and its eventual failure.

Safety issues identified included the need for detailed checking of overseas component records to ensure their reported in-service hours were accurate and for periodic crack checking of propeller flanges for corrosion damage. A safety recommendation regarding component record-checking was made to the Director of Civil Aviation, and the Civil Aviation Authority issued a Continuing Airworthiness Notice regarding inspections of crankshaft flanges for corrosion.

(Note: this executive summary condenses content to highlight key points to the reader and does so in simple English with less technical precision than the remainder of the report to ensure its accessibility to a non-expert reader. Expert readers should refer to and rely on the body of the full report.)

1. Factual Information

1.1 History of the flight

1.1.1 At about 1300 on Sunday 5 July 2009, ZK-LOU, a 3-engined Britten Norman BN2A Mk III Trislander operated by Great Barrier Airlines (the company), took off from Great Barrier Aerodrome at Claris on Great Barrier Island on a regular service to Auckland International Airport. On board were 10 passengers and a pilot, all of whom were wearing their seat belts
(see Figure 1).

1.1.2 That morning the pilot had flown a different Trislander from Auckland International Airport to Claris and swapped it for ZK-LOU for the return flight because it was needed for pilot training back in Auckland. Another company pilot had that morning flown ZK-LOU to Claris from North Shore Aerodrome. He had completed a full engine run-up for the first departure of the day, as was usual, and said he noticed nothing unusual with the aeroplane during the approximate 30-minute flight.

1.1.3 For the return flight the pilot said he completed the normal after-start checks in ZK-LOU and noticed nothing abnormal. He did not do another full engine run-up because it was not required. He taxied the aeroplane to the start of sealed runway 28, applied full power while holding the aeroplane on brakes and rechecked that the engine gauges were indicating normally before starting the take-off roll.

1.1.4 The aeroplane took off without incident, but the pilot said when it was climbing through about 500 feet he heard an unusual “pattering” sound. He also heard the propellers going out of synchronisation, so he attempted to resynchronise them with the propeller controls. He checked the engine’s gauges and noticed that the right engine manifold pressure and engine rotation speed had dropped, so he adjusted the engine and propeller controls to increase engine power. At that time there was a loud bang and he heard a passenger scream. Looking back to his right the pilot saw that the entire propeller assembly for the right engine was missing and that there was a lot of oil spray around the engine cowling.

1.1.5 The pilot turned the aeroplane left and completed the engine failure and shutdown checks. He transmitted a distress call on the local area frequency and asked the other company pilot, who was airborne behind him, to alert the local company office that he was returning to Claris.

1.1.6 The company office manager and other company pilot noticed nothing unusual with ZK-LOU as it taxied and took off. The other pilot was not concerned until he saw what looked like white smoke and debris emanate from the aeroplane as though it had struck a flock of birds.

1.1.7 Despite the failure, ZK-LOU continued to climb, so the pilot said he levelled at about 800 feet and reduced power on the 2 serviceable engines, completed a left turn and crossed over the aerodrome and positioned right downwind for runway 28. There was quite a strong headwind for the landing, so the pilot elected to do a flapless landing and keep the power and speed up a little because of the possibility of some wind shear.

1.1.8 The pilot and other personnel said that the cloud was scattered at about 2500 feet, that there were a few showers in the area and that the wind was about 15 to 20 knots along runway 28. The visibility was reported as good.

1.1.9 After landing, the pilot stopped the aeroplane on the runway and checked on the passengers before taxiing to the apron. At the apron he shut down the other engines and helped the passengers to the terminal, where they were offered drinks. The company chief executive, who lived locally, and a local doctor attended to the passengers. Three of the passengers received some minor abrasions and scrapes from shattered Perspex and broken interior lining when the propeller struck the side of the fuselage (see Figures 2 and 3).

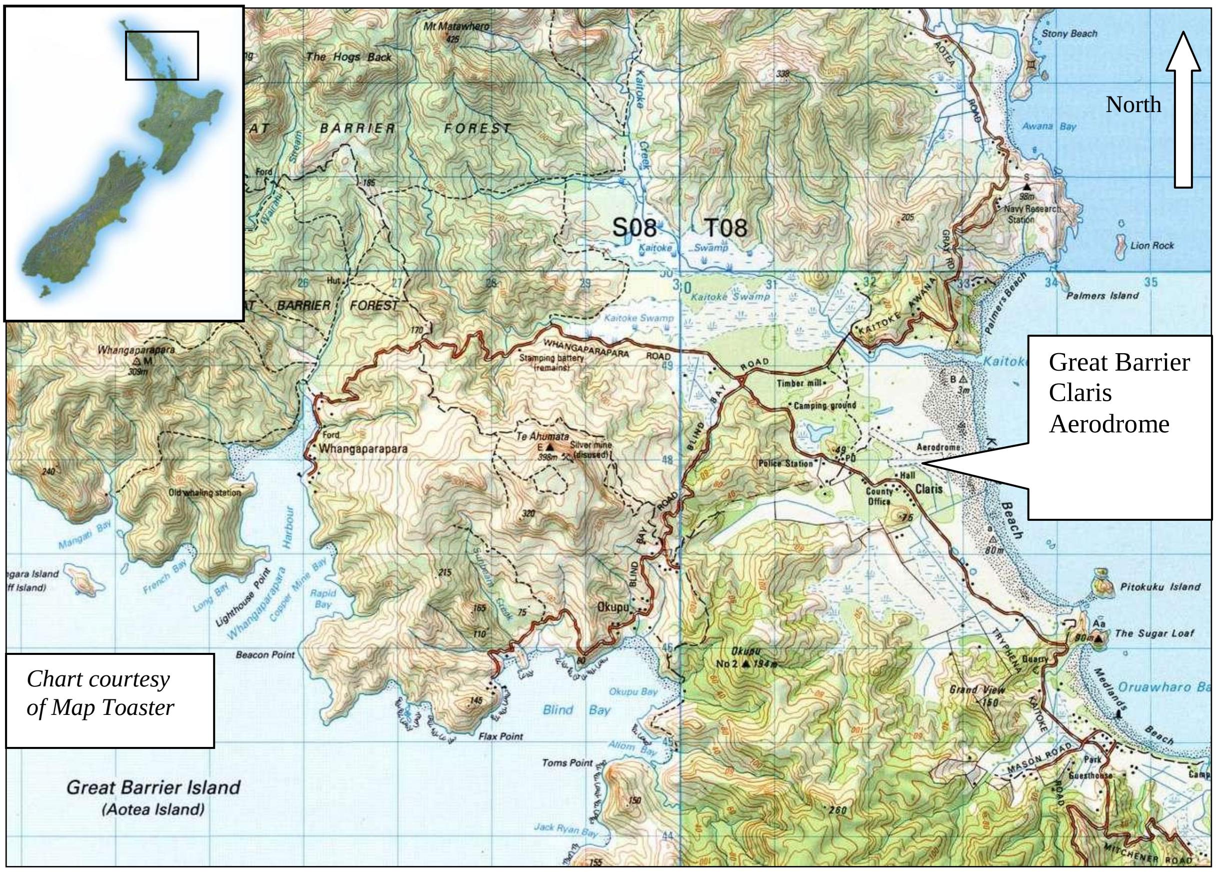

Figure 1
Great Barrier Island and Great Barrier Claris Aerodrome
(MetaMedia Ltd 1997-2009)

1.2 Damage to aircraft

1.2.1 The right engine crankshaft flange that attached to the propeller hub had fractured through lightening holes in the flange. The complete propeller assembly had released from the fractured crankshaft flange and struck the side of the fuselage adjacent to the engine, substantially damaging the fuselage. The fuselage skin had been penetrated in places and a passenger window Perspex had shattered, but nobody was seated in that passenger row. Immediately behind the window the propeller assembly struck a passenger door next to which a passenger had been seated. The door hinges were damaged and the door fell from the aeroplane, leaving a large hole in the side of the fuselage by the passenger (see Figure 2).

1.2.2 No part of the propeller assembly entered the cabin, but the cabin interior lining and insulation were damaged and pushed inwards onto some of the passengers (see Figure 3).

Figure 2
ZK-LOU right side showing damage and missing propeller

Figure 3
ZK-LOU interior showing cabin lining damage

1.3 Aircraft information

1.3.1 ZK-LOU was a Britten Norman BN2A-Mk III Trislander, serial number 322, 3-engined aeroplane fitted with fixed undercarriage and seating for 16, including one or 2 pilots. The aeroplane had been manufactured in the United Kingdom in 1972 and approved for single-pilot operation.

1.3.2 At the time of the accident the aeroplane had flown 18 289.2 hours. The most recent check recorded was a 50-hour inspection of the aeroplane and its major components on 3 June 2009 (Civil Aviation Authority of New Zealand [CAA] 2004).

1.3.3 The aeroplane was not equipped with any flight recorders, nor was it required to be (CAA 2008).

Engine

1.3.4 Three Textron Lycoming 0-540-E4C5 engines were fitted to the aeroplane, one on each main wing and one on the vertical fin. Each engine was rated at 260 horsepower.

1.3.5 The left engine, serial number L-18420-40A, had accrued 1419.7 hours since overhaul at the time of the accident.

1.3.6 The rear engine, serial number L-12327-40A, had accrued 807.9 hours since new at the time of the accident.

1.3.7 The right failed engine, serial number L-6341-40, had most recently been overhauled in the United States by Lycoming, on 23 October 1997. According to Lycoming, the crankshaft fitted at overhaul would not have been the original but would have been one taken from a pool of overhauled components. The crankshaft fitted to the engine was part number 71639-70, serial number 10238, and Lycoming advised it would have been manufactured in 1970.

1.3.8 After overhaul the engine re-entered service on 19 February 1998 when it was fitted to a Trislander in Bali Indonesia, for air transport operations. That aeroplane was retired from service on 31 October 1999 and put into storage in a hangar because its main wing spar had reached its service life. The engine remained on the aeroplane but was not inhibited (protected for long-term storage).

1.3.9 In mid-2004 the company purchased the engine and had it shipped to New Zealand, where a CAA-approved engine overhaul facility at Ardmore received it for inspection. The company chief engineer advised that he did not know the engine history after it had gone into storage in Bali. The Indonesian engine records showed that the engine had accrued 47.4 hours since its previous overhaul.

1.3.10 The CAA provided guidance and reference material in Advisory Circular 00-1, Acceptability of parts, 24 July 2007, to help ensure that components to be used on aircraft were acceptable for use. One section dealt with foreign sources and outlined the factors to be considered when obtaining components from overseas, such as record accuracy, cross-checking of records and component condition (CAA 2007).

1.3.11 The company also later purchased as scrap the time-expired airframe to which the engine had been fitted and had it shipped to New Zealand for breaking down for use as spare parts.

1.3.12 The New Zealand overhaul facility advised that because the engine was well under the maximum permitted operating hours and had about half the calendar life before overhaul was due, it was not overhauled. The facility removed all the engine accessories, cylinders, rear covers and the sump for a thorough evaluation of the engine condition, including a top overhaul of the cylinder assemblies, before releasing the engine to service.

1.3.13 The engine crankcase was not split and the crankshaft was not removed, but the facility inspected the crankcase internals and the crankshaft for serviceability and found their condition to be satisfactory. From the evaluation the facility had no concerns that the engine condition showed the reported hours to be incorrect. There was little internal corrosion but some minor external corrosion on some cylinders. The valves, which are a good indicator of usage, showed minimal wear. The facility had seen corrosion in the carburettors of some similar engines from overseas, but found that the carburettor from this engine was free of corrosion. Some corrosion was found on the crankshaft flange but it was considered not excessive. The corrosion was polished out and the surface protected by etching and painting. No other damage or any evidence of any cracking was found on the flange. After the facility had completed its inspection, repair work and reassembly, the engine was released to service on 31 October 2004.

1.3.14 On 9 November 2004 the engine was fitted to Trislander ZK-LGR. The engine remained on that aeroplane and was operated successfully for 1220.9 hours until 22 July 2008 when it was fitted to the right wing of ZK-LOU. The engine operated for another 569.5 hours until the failure on 5 July 2009 when, according to its records, it had accrued 1837.8 hours since overhaul. There was no evidence that the engine had been damaged or subject to a sudden stoppage when fitted to either of the company aeroplanes.

1.3.15 After the accident the company chief engineer perused entries in an Indonesian aircraft record log book that had accompanied the scrap airframe to which the engine had been fitted. In doing so he discovered an entry that indicated the engine had probably accrued 439.8 hours when the company received it, not the 47.4 hours the engine records suggested it had accrued.

1.3.16 Assuming the aircraft record log book entry to be correct, the chief engineer amended the New Zealand engine log book records. This added 392.4 hours to the engine life, which meant that at the time of the failure the engine had accrued 2230.2 hours since overhaul.

Overhaul and inspection requirements

1.3.17 Lycoming Service Instruction No.1009AT, effective 9 May 2008 (Textron Lycoming 2008), which superseded Service Instruction No. 1009AS, listed the recommended established time between overhaul (TBO) periods for its range of piston engines. The Service Instruction included a statement saying:

> Because of variations in the manner in which engines are operated and maintained, Lycoming can give no assurance that any individual operator will achieve the recommended TBO.

The TBO recommended for the 0-540-E4C5 engine was 2000 hours. A note contained the following statement:

> If an engine is being used in <u>"frequent"</u> type service and accumulates 40 hours or more per month, and has been so operated consistently since being placed in service, add 200 hours to TBO time.

The Service Instruction also stated that engines that did not accumulate the hourly period of time between overhauls should be overhauled in the 12th year.

1.3.18 The CAA-accepted company maintenance exposition (CAA 2008b) listed the aircraft that were to be maintained in accordance with the requirements of the exposition, which included ZK-LOU and ZK-LGR. The exposition stated that engines complying with the requirements of Lycoming Service Instruction No. 1009 could have the TBO extended by 200 hours.

1.3.19 In addition the exposition approved an escalation programme to extend the hourly overhaul period for operation of its piston engines, propellers and components over the manufacturer's recommended operating life (the manufacturer's recommended operating life included compliance with all service letters and instructions).

1.3.20 The exposition outlined procedures and guidelines to manage the escalation programme. As long as the procedures were followed, the engine or component life could initially be extended over the recommended operating life by 10%, and thereafter by a maximum of 10% over the current operating life. This meant that in theory a 0-540-E4C5 engine could operate initially to 2200 hours, then to 2420 hours and then to a maximum of 2662 hours.

1.3.21 The listed procedures that needed to be followed for an engine to meet the escalation requirements included:

> the engine needed to have been overhauled under the operator's control and operated for its full life by the operator;
>
> all the manufacturer's instructions were to be complied with;
>
> only one engine on a multi-engined aircraft could be being maintained under the escalation programme at any one time.

1.3.22 The 2 other engines on ZK-LOU were not being maintained under the escalation programme at the time of the failure of the right engine, nor were any engines fitted to other company aircraft being maintained under the programme.

1.3.23 On 29 July 2009, because of the failure with ZK-LOU, the CAA removed its approval for the operator's TBO escalation procedure as part of its approved maintenance programme, until such time as certain requirements had been met and a re-evaluation carried out (see section 1.6).

1.3.24 All the airworthiness directives for the engine were signed off in the engine log book as being not applicable, found embodied or embodied. A number of airworthiness directives and manufacturers' maintenance requirements applied to the crankshafts fitted to some Lycoming engines that called for certain inspections or crankshaft replacements. None applied to the crankshaft fitted in the right engine of ZK-LOU.

1.3.25 Crankshaft flange cracking was a known problem in some models of Lycoming engine. Flanges with lightening holes had been affected in IO-360 engines in Twin Comanche aircraft (Avco Lycoming 1967) and in 360 and 540 series engines fitted to aerobatic aircraft (Avco Lycoming 1985). The problem was also known to have occurred in plain flanges in AEIO-540-D engines subjected to aggressive aerobatic flying (Textron Lycoming 1988) and was thought to be caused by the high gyroscopic forces that can be induced by rapid propeller centreline angular acceleration at high engine speed. The service bulletins indicated that these high gyroscopic loads induced crack growth from the rear face of the flange. Crack growth of this type was a feature of some of the fractured flange webs from the failed right engine in ZK-LOU (DTA 2009).

1.3.26 The United States Federal Aviation Administration advised the Transport Accident Investigation Commission (the Commission) that it knew of no events of similar propeller flange cracking on non-aerobatic engines.

1.3.27 As recorded in its log book, the most recent check of the engine was a 50-hour inspection on 3 June 2009, when the engine had accrued 1816.1 hours. When corrected for the error from Indonesia, it had accrued 2208.5 hours on that date.

Propeller

1.3.28 A 2-bladed Hartzell HC-C2YK-2CU constant speed propeller, hub serial number AU9951B, had been fitted to the right engine. The propeller assembly had accrued 1973.6 hours since its previous overhaul on 17 March 2006. After overhaul the propeller was fitted to the right engine of ZK-LOU on 27 March 2006, and refitted on 22 July 2008 to engine serial number L-6341-40 when the previous engine was replaced. The propeller remained fitted to engine serial number L-6341-40 until the failure. The most recent propeller inspection had been a 50-hour check on 3 June 2009.

1.3.29 The last opportunity to examine the mating surface of the propeller hub and the engine crankshaft flange to which it attached was during the engine replacement on 22 July 2008. Other than good general engineering practice, there was no maintenance requirement that called for a specific inspection for cracks of the flange during propeller replacement. The maintenance log books had no entries that indicated there were any issues with the hub or flange at that time. The company chief engineer advised that during the replacement the condition of the components would have been checked visually.

1.3.30 A 2-bladed Hartzell HC-C2YK-2CUF constant speed propeller, hub serial number AU12970B, was fitted to the rear engine. The propeller assembly had accrued 1022.4 hours since its previous overhaul on 13 December 2006. Its most recent inspection had been a 50-hour check on 3 June 2009.

1.3.31 A 2-bladed Hartzell HC-C2YK-2CUF constant speed propeller, hub serial number AU9223B, was fitted to the left engine. The propeller assembly had accrued 1973.6 hours since its previous overhaul on 28 March 2006. Its most recent recorded inspection had been a 50-hour check on 3 June 2009.

1.3.32 Each propeller had a 6-year calendar life and a nominal TBO of 2000 hours (Hartzell Propeller Inc 2009).

1.4 Pilot information

1.4.1 The pilot held a New Zealand Commercial Pilot Licence (Aeroplane) with a class 1 medical certificate valid until 2 August 2009.

1.4.2 The pilot held a type rating for the Britten Norman BN2A-Mk III Trislander. His total flight time was 867.5 hours with 27.8 hours on the aircraft type. In the 90-day period before the accident he had flown 73.6 hours, including 17 hours on the Trislander. In the 30-day period before the accident he had flown 27 hours, and in the 7-day period he had flown 8.1 hours. His most recent check had been an operator's instrument flight check the day before the accident on 4 July 2009 in a multi-engine BN2A Islander. He had been off duty on 2 and 3 July.

1.5 Tests and research

1.5.1 Under the Commission's supervision an independent overhaul facility disassembled the engine and removed the crankshaft for further evaluation. The 2 rear-most cylinder piston heads, valves and tappets were found damaged by valve bounce that would typically have occurred during an engine over-speed associated with a propeller being lost from the engine. Apart from the failed crankshaft flange, no other damage or failure was found that could have contributed to the engine failure. The engine propeller governor tested normally during a rig test.

1.5.2 The independent overhaul facility also disassembled the propeller hub and evaluated its condition, including before disassembly a check of the preload of each blade and any blade looseness. There was no blade looseness and the preload was within limits. No failure or defect was found that could have contributed to the flange failure. One propeller blade pitch change knob had bent and fractured but, from impact markings on the associated blade and its bending, the facility believed the fracture was impact damage caused when the blade struck the fuselage or ground. The propeller manufacturer and the overhaul facility both advised that it was common for the knobs to fail from overload when blades struck solid objects during accidents.

1.5.3 The New Zealand Defence Technology Agency (DTA) provided specialist science and technology support, advice and solutions to the New Zealand Defence Force. Under the provisions of a memorandum of understanding the Commission engaged DTA to examine the failed crankshaft end, including the fractured propeller pitch change knob, to determine the likely failure mode and to report its findings to the Commission. The DTA report (DTA 2009) is summarised below.

The examination of the bent propeller blade that had a bent and fractured pitch change knob determined that the damage implied the blade root had been exposed to high shear-reaction loads when its tip was bent. The fracture of its pitch change knob was caused by high shear loads probably induced by blade impact after the propeller left the engine. There was no evidence of fatigue, fretting damage or corrosion in the knob.

The crankshaft had an end flange that contained 6 lightening holes separated by web spokes [see Figure 4]. The crankshaft also had a pair of counterweights at the rear to act as vibration dampers.

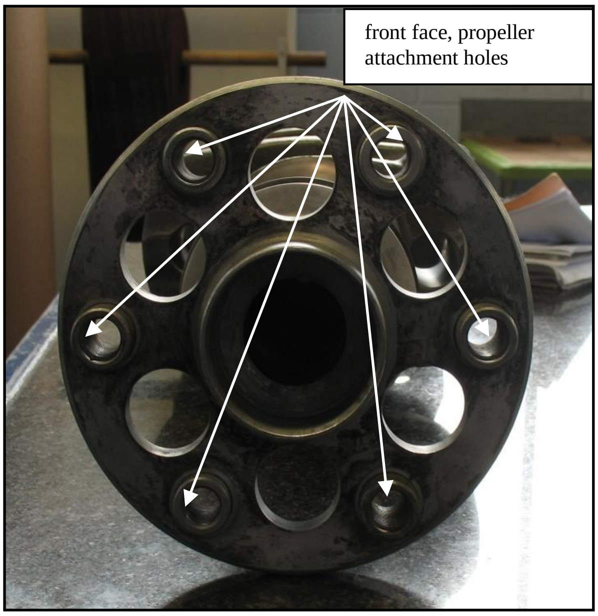

Figure 4
A serviceable crankshaft flange with lightening holes

The crankshaft bearing surfaces were corroded in places, most obviously at the location of the forward main bearing where the corrosion was concentrated on one side of the shaft surface. Some scoring of the nitrided bearing surfaces was also evident.

There was no evidence of any abnormality of the crankshaft material.

There was no indication that the propeller attachment bolts had been loose, or incorrectly tightened prior to the incident.

In the vibration damper counterweights there was evidence of wear at the pin contact zones of the bushings. Pitting, caused by corrosion or wear was evident on some of the loaded bushing surfaces. The counterweight pins were also worn, reducing the effectiveness of the dampers.

The flange had fractured through the spoke web sections separating the 6 lightening holes [see Figure 5]. Five of the webs had fractured at or near the fillet between the flange and the crankshaft. The rear face of the flange retained its paint coating but some corrosion was evident on the webs near and in some of the lightening holes. The corrosion, visually evident as patches of rust, had penetrated the cadmium protective plating beneath the paint and affected the underlying steel surface. Close inspection indicated that the corrosion had pitted the steel in places. The forward face of the flange was also rust-stained in isolated areas. Cadmium plate covered much of the surface but it had been abraded and fretted locally. Traces of paint were also present in a few places on the front surface. The crankshaft stub section projecting forward from the flange was extensively and irregularly fretted and its rim was bent inwards across one sector. This deformation was likely to have occurred as the propeller pitched and rotated off the flange in the final stage of the failure sequence.

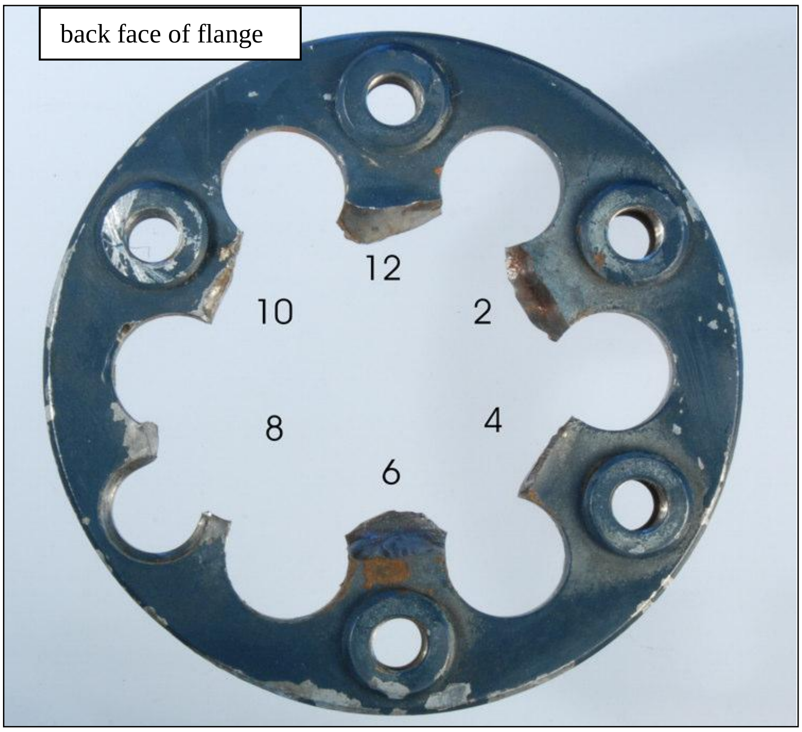

Figure 5
Broken crankshaft flange that was attached to the right engine propeller hub
(DTA 2009)

Figure 6
Fractured rear face of flange centre (machined off the crankshaft)
(DTA 2009)

Inspection showed that 5 of the 6 fracture surfaces had clear signs that metal fatigue had played a critical part in their failure. The remaining web element that also went through a bolt hole [see position 8 in Figures 5and 6] had failed by ductile shear which was likely to have occurred during the final stages of propeller separation.

Two of the fatigue fractures, at Positions 6 and 2 [see Figures 5 and 6] appeared relatively old, being discoloured and fretted to the point of having lost all microscopic surface detail. However, crack surface beach-markings indicated that the cracks had initiated on the rear face of the flange, at the fillet between the flange and shaft. Both cracks had grown forward and inwards towards the fillet at the front of the flange. The fracture at Position 6 had initiated in a region of extensive corrosion pitting. Multiple corrosion pits up to 0.2mm in size were found in this area. Some corrosion was also evident at the initiation point of the fracture in the Position 2 web.

Two other fractures, at Positions 4 and 10, had received severe surface damage during the final phases of flange breakup. Both had some signs of fatigue crack development from the rear face of the flange but one of them (at Position 10) showed extensive crack growth rearwards from the forward face towards the top of the fillet blend on the rear face. The fracture in the web at Position 4 had a similar configuration.

The fatigue crack surfaces at Position 12 were relatively fresh. The fractures were only locally fretted and were largely uncorroded. Clearly-defined beach marks were evident in places. These markings showed that the crack had initiated at the rear of the flange from the web corner loaded in tension by crankshaft torque. This fracture also ran inwards towards the front web/shaft fillet.

Electron microscopy of the fracture at Position 12 revealed well-defined fatigue striations, typically with a spacing of 2.5 microns. The large number, regularity and configuration of these striations indicated that they were probably caused by the loads induced by crankshaft rotation, each striation likely to have been induced by one shaft revolution.

Detailed inspection of a zone of corrosion damage near the blend radius on the web at Position 8 showed that while the corrosion had initially seemed to be relatively superficial, there was widespread pitting in the area. Numerous small cracks had developed in these corrosion pits. Similar corrosion pitting was associated with cracking initiation sites on other flange webs.

All the cracked webs showed signs of defect initiation on the rear of the flange at or near the point where the fillet intersected the flange surface. Three of the defects had grown forward and inwards to intersect the front fillet on the flange while the two other cracks had cut across the web.

The form of the oldest cracks indicated that the crankshaft flange had been subjected to loads with a significant fore-aft bending component which induced cracking primarily from the rear face of the flange. The configuration of the cracks also indicated that they were caused by high cycle fatigue from relatively high frequency load fluctuations rather than low cycle fatigue from engine start/max power/stop cycles.

The corrosion pitting damage on rear faces of the some of the webs most likely triggered crack initiation. The corrosion had evidently occurred after local failure of the paint coating, followed by penetration of the cadmium plate covering the surface. The observed corrosion pitting would have compromised the fatigue resistance of this highly loaded area of the crankshaft.

The presence of the lightening holes in the flange meant that stress levels in the remaining web elements would have been higher than in the solid flanges used in the heavier crankshafts which have come into service more recently.

The heavily fretted condition of the initial fatigue cracks indicated that they had been present for some time before the flange failed but the extent of the damage on their surfaces meant that the duration of the initial phase of the failure sequence could not be estimated. The final phase of the failure occurred relatively quickly. At the full power engine speed of 2,700 rpm, the fatigue crack in the web at Position 12 would have taken approximately 3 minutes to grow across the available cross section of the web. The relatively good condition of the surfaces of this crack indicated that the assembly failed soon after the crack cut through the web.

The worn condition of the crankshaft vibration dampers suggested that torsional vibration in the crankshaft would have been higher than the manufacturer's design intent. Some of the shell markings on the fatigue cracks indicated that torsional vibration had been present during fatigue crack initiation and growth and may have contributed to the failure. However, there was no evidence that torsional vibration loads dominated the fatigue stress spectrum at the crankshaft flange.

1.5.4 A check of CAA records in the past 20 years showed no evidence of flange failures and loss of propeller assemblies from other aircraft.

1.6 Organisational and management information

1.6.1 Great Barrier Airlines was established in 1983 and operated out of Auckland, North Shore, Whangarei, Whitianga, Claris and Matarangi Aerodromes. The company employed about 25 staff and operated a fleet of 9 aircraft, including Islander, Trislander, Partenavia, Chieftain and Cherokee 6 types.

1.6.2 The CAA had renewed the company's Airline Air Operator Certificate, effective from 1 February 2009, authorising it under the provisions of Civil Aviation Rule (CAR) Part 119[2] to perform air operations and other associated activities in accordance with CAR Part 125[3] and Part 135[4] as defined in its Operations Specifications and the organisation's exposition. Certificates were normally issued for up to 5 years, but in accordance with standard practice the company's Certificate was renewed initially for a shorter period,

[2] Part 119 prescribes the certification requirements for operators to conduct air operations and the operating requirements for the continuation of this certification. Air operations include Air Transport Operations and Commercial Transport Operations.
[3] CAR Part 125 prescribes the operating requirements for air operations conducted by a holder of an Airline Air Operator Certificate issued in accordance with Part 119 using an aeroplane that has (1) a passenger seating configuration of 10 to 30 seats; or (2) a payload capacity of 3410 kilograms (kg) or less and a maximum certified take-off weight of greater than 5700 kg; or (3) a single engine and is carrying passengers under instrument flight rules.
[4] CAR Part 135 prescribes the operating requirements for air operations conducted by a holder of an Airline Air Operator Certificate or a General Aviation Air Operator Certificate issued in accordance with Part 119 using (1) an aeroplane that has a seating configuration of 9 seats or fewer, excluding any required crew member seat, and a maximum certified take-off weight of 5700 kg or less, except for a single-engine aeroplane used for an air operation carrying a passenger under instrument flight rules; or (2) a helicopter.

until 31 October 2009, so that after successful surveillance checking it could be further renewed. The CAA subsequently renewed the Certificate from 1 November 2009 until 13 July 2013.

1.6.3 A service provider listed in the Air Operator Certificate was Great Barrier Airlines (Engineering) Limited, a certified maintenance organisation owned by the operator that carried out maintenance of the operator's aircraft. The organisation was approved in accordance with CAR Part 145 that prescribed rules governing the certification and operation of aircraft maintenance organisations.

1.6.4 The company was subject to routine CAA surveillance. The most recent CAA safety audit report documented the results of the safety audit carried out on 30 July 2009 on Part 119 Maintenance (CAA 2009). The report stated that the previous internal audit of maintenance control had been reviewed and it was noted that the audit had been carried out in depth and findings issued wherever required, and that the internal audit programme appeared to be functioning well. The company aircraft were maintained to the respective manufacturers' maintenance programmes using the manufacturers' maintenance schedules. The audit report also noted that the records of maintenance and annual review of airworthiness of aircraft had been reviewed and found to be satisfactory.

1.6.5 From the audit, 2 findings resulted in 2 actions raised (see paragraphs 1.6.7 to 1.6.9). The report noted that one finding was of a minor nature; that the planning extension used for a 50-hour check on a different Trislander was exceeded by 0.4 of an hour, because of an error in the transmission of data. The other finding related to the accumulated hours of the Lycoming O-540 engine fitted to a single-engine Piper PA32 aircraft. The engine had accrued a total of 2025.5 hours without meeting the requirements of Lycoming Service Instruction 1009AT (see 1.3.17). The engine had not accumulated the minimum 40 hours per month for April, May and June and therefore its TBO of 2000 hours had been exceeded by 25 hours. The other aircraft engines were found to be operating below the 2000-hour TBO.

1.6.6 The audit report noted that the 25-hour TBO overrun resulted from an incorrect interpretation of the Service Instruction requirement and therefore the use of the aircraft when its engine was beyond its overhaul limit. The operator had thought that the 40-hours-per-month usage requirement could be an average and did not necessarily have to be consecutive. The CAA corrected this interpretation with the operator, advising it that to meet the requirements for TBO extension it had to operate an engine for at least 40 hours each month. The CAA subsequently confirmed that no other company aircraft engines were over the 2000-hour TBO limit and that the company had accepted the CAA's view of the monthly hour requirement.

1.6.7 The company in its submission to the Commission said that although the engine mentioned in the audit had not met the manufacturer's service letter extension requirements, the CAA had misunderstood that the company was following the escalation programme, and the engine had been within the first 10% extension allowed for when it accumulated 2025 hours. In the company's closing action to the CAA regarding the audit finding, the company stated that its and the CAA's interpretation of the 40-hour usage differed, but that the engine would be removed for overhaul at its existing hours and other engines would be monitored for hours' usage.

1.6.8 The company had removed the engine for overhaul the day after it received the CAA's letter withdrawing its approval of the escalation programme, which was the day of the audit.

1.6.9 In a subsequent letter to the CAA the company advised that following discussions with the auditor it accepted that using the engine manufacturer's service letter as a method of overhaul extension would not be appropriate, because its average monthly usage of aircraft sometimes fell below the 40-hour minimum consistency requirement.

2 Analysis

2.1 During the climb out from Great Barrier Aerodrome, the right engine propeller assembly was lost from the engine when the crankshaft flange on which the propeller was mounted failed, because high-cycle fatigue cracks had reached a critical level and the remaining material failed in overload from normal operating loads.

2.2 Following the failure, the unrestrained propeller struck the side of the fuselage, sliced into the fuselage skin and removed a passenger door. That nobody was seriously injured or the aeroplane flight controls not compromised was fortunate because separated propeller blades have the potential to penetrate the fuselage skin and enter the cabin, or even disrupt control linkages.

2.3 The flange crack initiation occurred from corrosion pitting damage on the rear faces of some of the flange webs, in the stressed region at the top of the flange fillet between the lightening holes. The fluctuating loads on the flange responsible for crack growth acted primarily in a fore and aft direction and implied the presence of dynamic loads that induced variation of the axial bending moment on the flange webs as the propeller rotated normally. Any abrupt pitching and yawing from turbulence or other sources from time to time could have added to the bending moment and crack growth.

2.4 No evidence of material deficiency or any pre-existing physical damage was found with the crankshaft that might have contributed to its failure. The crankshaft bearing surfaces had some uneven surface corrosion and the torsional vibration damper bushings had some wear, which could have induced increasing levels of vibration as the engine neared the end of its service life. Although these 2 factors might have contributed to the fatigue damage in the corroding flange, there was no evidence that torsional vibration loads dominated the fatigue stress spectrum at the flange. Corrosion damage was the dominant factor in the crack initiation.

2.5 When the corrosion damage had started could not be accurately determined, but the specialist examination determined that the cracking had been present for some time before the failure. The engine had been examined in New Zealand by an approved overhaul specialist before its release to service on 31 October 2004 and some minor corrosion on the flange had been removed and the area protected with etching and painting at that time. However, some time later the protection was compromised and the corrosion started.

2.6 Although the engine was subject to routine inspections, it was not possible to inspect thoroughly the crankshaft flange with the propeller hub attached and there was no reason to remove the hub at each inspection. The most recent opportunity to do a thorough visual examination of the flange had been on 22 July 2008, a year before the failure, when the engine was fitted to ZK-LOU and the propeller refitted. Although the flange was probably visually inspected in accordance with good engineering practice, there was no requirement to do a detailed examination or crack check, so any corrosion could have either gone unnoticed or been considered insignificant. Therefore it cannot be ruled out that corrosion damage had already begun and the cracking initiated by that time. Had there been a requirement to do specific periodic crack checking of the flanges with lightening holes, such as when propellers were removed, the opportunity to detect any cracking would have been enhanced. Had this been the case with ZK-LOU, any hidden cracks could have been detected a year earlier and the failure might have been prevented. To help reduce the risk, on 15 December 2009 the CAA issued a Continuing Airworthiness Notice (CAA 2009) to advise operators and maintainers of Lycoming engines fitted with crankshafts with lightening holes in the propeller flange to inspect the flanges for corrosion.

2.7 Because corrosion can lead to cracking, as demonstrated in this case, any corrosion that is found around crankshaft flanges should be removed and the area specifically checked for cracking and protected as advised in the Continuing Airworthiness Notice.

2.8 Although some Lycoming crankshaft flanges with lightening holes were prone to cracking when fitted to aerobatic aeroplanes, the cracking was from different circumstances. The cracking came about because of the varying gyroscopic forces associated with such manoeuvres and not from corrosion such as that found with the flange from the engine of ZK-LOU. Lycoming advised that the lightweight crankshafts with flanges with lightening holes were old-style crankshafts that since about 1970 had been progressively replaced by those with heavier flanges and were being phased out altogether by shafts with solid flanges much less prone to cracking. As a safety measure after the failure, the operator checked its fleet and established that it had no other engines with lightening holes in the crankshaft flanges. The CAA advised that although it had no record of engines that might be operating with such crankshafts, it was unlikely there were many in service given the time since that version had last been produced.

2.9 The company was operating in accordance with the provisions of an Air Operator Certificate at the time of the engine failure. As well, CAA approval allowed the company to extend the overhaul intervals of its engines beyond the manufacturers' recommended TBOs, in accordance with an escalation programme. However, no engines had been operating within the programme, except that, inadvertently, the accident engine had exceeded the TBO because of an anomaly in its recorded operating hours. The anomaly was detected only after the accident when the separate aircraft record log book was perused. As a safety measure following the accident, the CAA removed the approval for the operator to follow an escalation programme.

2.10 Had the company known the real operating hours, the engine should have been overhauled 230 hours before the failure because it met neither the manufacturer's requirements to allow the overhaul period to be extended by 200 hours to 2200 hours, nor the documented escalation programme requirements for an extension of the overhaul period. Amongst the listed requirements that allowed an engine to be included in the escalation programme was the need for the engine to have been overhauled under the company's control and operated for its full life by the company, which it had not. However, because of the anomaly in the hours recorded before the importation to New Zealand, its New Zealand log book showed that at the time of the failure the engine had 162 hours to run to its 2000-hour overhaul. Had the crankshaft not failed, the engine could have operated for 2392 hours before overhaul, assuming the calendar limit of 12 years, due in October 2009, was not reached first.

2.11 The flange failure occurred when the engine had passed the end of its normal hour service life and was within 3 months of its maximum calendar life. There was no history of similar flange failures with other engines in New Zealand or notified to the United States Federal Aviation Administration. Had the failed engine been overhauled within the manufacturer's recommended time of 2000 hours, or even within 2200 hours had it met the manufacturer's 200-hour extension requirements, the overhaul would have occurred before the flange cracking had reached a critical stage and the crankshaft should have been scrapped.

2.12 The anomaly in the Indonesian engine records meant the engine had 392 recorded hours fewer than actual, which was only discovered when the records for the aeroplane to which the engine had been fitted were examined and compared with the engine records. This was only made possible because the company later purchased the aeroplane and had its records available. However, the anomaly highlighted the need for parties always to scrutinise thoroughly all overseas records, including cross-checking, or for the records to come from known, trustworthy sources, to ensure recorded component hours were authentic, as recommended in CAA Advisory Circular 00-1.

2.13 Because the engine had relatively few operating hours since overhaul and during its time in Indonesia, this could have alerted the company to more thoroughly cross-check all the records. However, the company's use of the overhaul facility to disassemble and inspect thoroughly the engine alleviated any concern that the engine records might be inaccurate.

2.14 Although a finding of the most recent CAA audit of the company showed in error that on a different company aeroplane its engine overhaul period had been exceeded by 25 hours because it had misunderstood the manufacturer's monthly operating hour requirements, this was an issue of CAA interpretation. The company explained that it was following its CAA-approved overhaul escalation programme at the time, not the manufacturer's programme to which the audit referred. This was a different circumstance from the recorded hours' anomaly with the accident engine, but it illustrated the need for continuous diligence to ensure that engines were overhauled at the correct time. The CAA's withdrawal of its approval for the company to follow the escalation programme prevented the possibility of further escalation extensions. Because the company's schedules would not allow the required 40-hour-per-month engine operating hour consistency, no overhaul extensions could be planned for under the manufacturer's programme.

3 Findings

Findings are listed in order of development and not in order of priority.

3.1 The engine propeller assembly separated from the right engine of ZK-LOU in flight and struck the fuselage when the crankshaft failed at the flange that connected it to the propeller hub.

3.2 High-cycle fatigue cracking on the flange that had developed during normal operations from undetected corrosion had reached a critical stage and allowed the flange to fail in overload.

3.3 The crankshaft had inadvertently passed its overhaul service life by around 11% when the failure occurred, but the company had not realised this because of an anomaly in the recorded overseas service hours prior to importation of the engine to New Zealand. Ordinarily, the crankshaft would have been retired before a failure was likely.

3.4 The crankshaft was an older design that has since been progressively superseded by those with flanges less prone to cracking.

3.5 There was no requirement for a specific periodic crack check of the older-design crankshaft flanges, but this has been addressed by the CAA issuing a Continuing Airworthiness Notice on the issue.

3.6 The CAA audit of the company had examined whether its engine overhaul periods were correct, but the audit could not have been expected to discover the anomaly in the overseas-recorded engine hours.

3.7 This failure highlighted the need by potential purchasers of overseas components to follow the guidelines outlined in CAA Advisory Circular 00-1 to scrutinise overseas component records to ensure that the reported in-service hours are accurate.

4 Safety Action

4.1 On 15 December 2009 the CAA issued Continuing Airworthiness Notice 85-005 advising operators and maintainers of the potential for cracking of Lycoming engines fitted with crankshaft propeller flanges with lightening holes because of corrosion, and the need to inspect periodically the flanges for corrosion damage.

5 Safety Recommendation

Safety recommendations are listed in order of development and not in order of priority.

5.1 On 22 April 2010 the Commission recommended to the Director of Civil Aviation that he address the following safety issue:

> The continuing need for parties involved in importing overseas components to thoroughly scrutinise all available records in accordance with AC-001 to ensure the accuracy of the reported component service life. (010/10)

On 20 May 2010 the Civil Aviation Authority replied to the Safety Recommendation as follows;

> The Civil Aviation Authority intends to include a synopsis of the 09-004 Transport Accident Investigation Commission occurrence report in a future copy of the Vector Safety Magazines in order to highlight the need to scrutinize all records in accordance with AC-001.

Approved on 25 March 2010 for Publication

Mr John Marshall QC
Chief Commissioner

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