Report 07-010, Fletcher FU24-950, ZK-DZG, in-flight vertical fin failure, loss of control and ground impact, 5 kilometres west of Whangarei (Pukenui Forest), 22 November 2005

Report 07-010

Fletcher FU24-950

ZK-DZG

in-flight vertical fin failure, loss of control and ground impact

5 kilometres west of Whangarei (Pukenui Forest)

22 November 2005

Abstract

At about 1142 on 22 November 2005, ZK-DZG, a Fletcher FU24-950 agricultural aeroplane was on a ferry flight to Whangarei Aerodrome with the pilot and a loader-driver on board when its vertical fin failed. The fin failure made the aircraft uncontrollable and it descended into trees, 10 kilometres from its destination. The aircraft was destroyed and both occupants were killed.

A pre-existing network of cracks in the leading edge of the vertical fin had reached a critical size and had reduced the structural strength of the fin to such a degree that complete failure resulted.

The safety issues identified included the design of the vertical fin and its ongoing maintenance requirements, and the adequacy of the supplemental type certificate process that allowed turbine engines to be fitted to the Fletcher aircraft. The New Zealand Civil Aviation Authority has undertaken a number of corrective actions to address the safety issues with the fin, which should help to prevent a recurrence of accidents of this nature. A safety recommendation was made to the Director of Civil Aviation that he also address the concerns raised regarding the supplemental type certificate process.

ZK-DZG
Walter turbine-powered FU24-950 Fletcher (image courtesy of Super Air Limited)

Content

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Abbreviations

AD	airworthiness directive
CAA	New Zealand Civil Aviation Authority
cm	centimetre(s)
ELT	emergency locator transmitter
GPS	global positioning system
hp	horsepower
km	kilometre(s)
m	metre(s)
MetService	Meteorological Service of New Zealand Limited
mm	millimetre(s)
PAC	Pacific Aerospace Corporation
PAL	Pacific Aerospace Limited
STC	supplemental type certificate
TC	type certificate
UTC	co-ordinated universal time

Glossary

Type certificate:

A type certificate (TC) is a design approval issued by the civil aviation regulator when the applicant demonstrates that a product complies with the applicable regulations. When issued, the certificate means a particular aircraft design meets standard criteria for production.

When the New Zealand Civil Aviation Authority (CAA) issues a TC, it includes:

- the type design
- the operating limitations
- the TC data sheet
- the applicable airworthiness design standards
- for an aircraft type, the flight manual
- any other conditions or limitations prescribed for the product.

Supplemental type certificate:

A supplemental type certificate (STC) is a TC issued when an applicant has received the regulator's approval to modify an aircraft from its original design. The STC, which incorporates by reference the related TC, approves not only the modification but also how that modification affects the original design.

Any additions to, omissions from or alterations to the certified aircraft layout, such as its built-in equipment, airframe and engines, initiated by any party other than the TC holder need an STC. They are issued for major and extensive changes to the original TC, but could include minor modifications. More substantial modifications may involve engine replacement or a complete role change for the aircraft. The STC belongs to the STC holder.

When the CAA issues an STC, it can include changes to:

- the TC category or type acceptance certificate category, or
- the type design, or
- the flight manual, or
- the operating limitations, or
- any special conditions prescribed on the TC or type acceptance certificate.

Empennage:

The entire tail section, or assembly, of an aircraft, including the vertical fin, rudder, horizontal stabilisers and elevators.

Data Summary

Aircraft registration:	ZK-DZG
Type and serial number:	New Zealand Aerospace Industries Fletcher FU24-950, 207
Number and type of engines:	one Walter M601D-11 turboprop
Year of manufacture:	1975
Operating company:	Super Air Limited
Date and time:	22 November 2005, 1142[1]
Location:	5 kilometres (km) west of Whangarei latitude: 35° 42.9´ south longitude: 174° 16.0´ east
Type of flight:	agricultural – ferry
Persons on board:	crew: one passengers: one
Injuries:	crew: one fatal passengers: one fatal
Nature of damage:	aircraft destroyed
Pilot's licence:	commercial pilot licence (aeroplane)
Pilot's age:	49 years
Pilot's total flying experience:	16 000 hours approximately (2382 on type)
Investigator-in-charge:	K A Mathews

[1] Times in this report are New Zealand Daylight Time (UTC + 13 hours) and are expressed in the 24-hour mode.

Synopsis

On the morning of 23 November 2005, the CAA was notified of the accident. Later that day the CAA advised the Transport Accident Investigation Commission (the Commission) of the known circumstances.

On the information available at the time, the Commission decided not to investigate the accident. The CAA opened its own investigation.

Subsequently, the aircraft TC holder, Pacific Aerospace Limited (PAL), expressed concern that the Walter turbine engine that had been retrofitted to the aircraft had brought about the failure of the vertical fin and the resulting loss of the aircraft. The turbine engine had been fitted in accordance with an STC issued by the CAA. The TC holder raised concern over whether the CAA had followed a proper process in approving the STC, and over whether it had properly considered the effects of such an installation on the empennage. The TC holder argued that the Commission, as an independent body, should examine the approval process to determine if it was adequate, including the reason for the fin failure.

After considering its submissions, the Commission in October 2007 elected to investigate the circumstances of the accident. The Commission engaged an independent aeronautical engineer to examine the STC approval process and report to the Commission.

The CAA continued with its investigation. Because of the length of time since the accident, the Commission has relied on some accident event and testing evidence that the CAA provided to the Commission for forming its determinations.

Factual Information

1.1 History of the flight

1.1.1 On 21 November 2005, the day before the accident, the pilot had completed a day of aerial topdressing in ZK-DZG, a New Zealand Aerospace Industries Fletcher FU24-950, then flown the aircraft with his loader-driver as a passenger to Whangarei Aerodrome. That evening the pilot contacted his operator's (the company's) chief engineer in Hamilton and said that the airspeed indicator in ZK-DZG was stuck on 80 knots. The chief engineer told him the pitot-static line for the indicator was probably blocked and to have a local aircraft engineer blow out the line.

1.1.2 Early the next morning, the day of the accident, the pilot flew ZK-DZG with his loader-driver on board to an airstrip 50 km north-west of Whangarei to spread fertiliser on a farm property. As the morning progressed, the weather conditions became unsuitable for aerial topdressing. At about 1020, the pilot used his mobile telephone to talk to another company pilot at Kerikeri, and told him that the wind was too strong for further work. The conversation included general work-related issues and ended about 1045, with the pilot saying that he was shortly going to return to Whangarei and go to his motel.

1.1.3 Before leaving for Whangarei, the pilot spoke with a truck driver who had delivered fertiliser to the airstrip about 1100. The driver commented later that the pilot said the wind had picked up enough to preclude further topdressing. After they had covered the fertiliser, the pilot told the driver that he and the loader-driver would fly to Whangarei. The driver did not recall anything untoward, except that the pilot had casually mentioned there was some electrical fault causing an amber light in the cockpit to flicker and that it would only be a problem if a second light came on. He said the pilot did not appear to be concerned about the light. The driver then left and did not see the aircraft depart.

1.1.4 The pilot used his mobile telephone to tell an aircraft engineer at Whangarei Aerodrome about the airspeed indicator problem and asked him if he could have a look at it and blow out the pitot-static system. The engineer believed the call was made from the ground at about 1130, but he could not be certain of the time. The engineer agreed to rectify the problem and the pilot said he would arrive at the Aerodrome about noon. The engineer said he did not know that the pilot had spent the previous night in Whangarei or that the aircraft had been parked at the Aerodrome overnight.

1.1.5 ZK-DZG was equipped with a global positioning system (GPS) and its navigation data was downloaded for analysis. From the data it was established that the aircraft departed from the airstrip at 1131 and flew for about 39 km on a track slightly right of the direct track to Whangarei Aerodrome, before altering heading direct to the aerodrome and Pukenui Forest located 5 km west of Whangarei city (see Figure 1).

1.1.6 A witness who had some aeroplane pilot flying experience, and was on a property close to the track of ZK-DZG, said he saw the aircraft fly past shortly after about 1130 at an estimated height of 500 feet. He watched it fly in the direction of Pukenui Forest for about 40 seconds before turning his head away. A short time later he turned again to look at the aircraft, which by then was just above the horizon about 2 ridges away. He said there was a strong, constant wind blowing from the right (south) of the aircraft, which appeared to be drifting sideways and rocking its wings. He then saw the aircraft enter a steep descending turn that seemed to tighten before it disappeared from view. He estimated it to have turned about 270 degrees.

1.1.7 Another witness near the aircraft track and accident site reported seeing the aircraft at about 1140 flying just above the tree line and thought it might have been "dusting" the forest. The aircraft then turned and disappeared behind some trees. Other witnesses who heard or saw the aircraft described the weather as squally throughout the morning with strong winds from the south, and said that near the time of the accident there was no rain.

1.1.8 The witnesses noticed nothing untoward with the aircraft itself, and at the time none was concerned that the aircraft may have been involved in an accident.

1.1.9 The local aircraft engineer said he was not concerned when ZK-DZG did not arrive at Whangarei, because from his experience it was not unusual for agricultural pilots to change their plans at the last minute and to not inform the engineers. He described his conversation with the pilot as being casual and said the pilot did not mention that he was finishing topdressing for the day because of the weather. He thought the pilot was just trying to fit in the maintenance work and that his plans had changed. The pilot had not asked him to provide any search and rescue watch, nor did the engineer expect him to because he could not recall any pilot having asked him to do so. There was no evidence that the pilot made any radio calls during the flight. The frequency to which the radio was selected and its serviceability could not be determined because of the accident damage.

1.1.10 At about 2200 a member of the pilot's family contacted the emergency services when she became concerned that there had been no contact from the pilot. An extensive aerial search began at first light the next morning, and at about 1120 the wreckage of ZK-DZG was located about 50 metres (m) below a ridge in a heavily wooded area of Pukenui Forest, at an elevation of 920 feet above sea level. Both occupants were fatally injured.

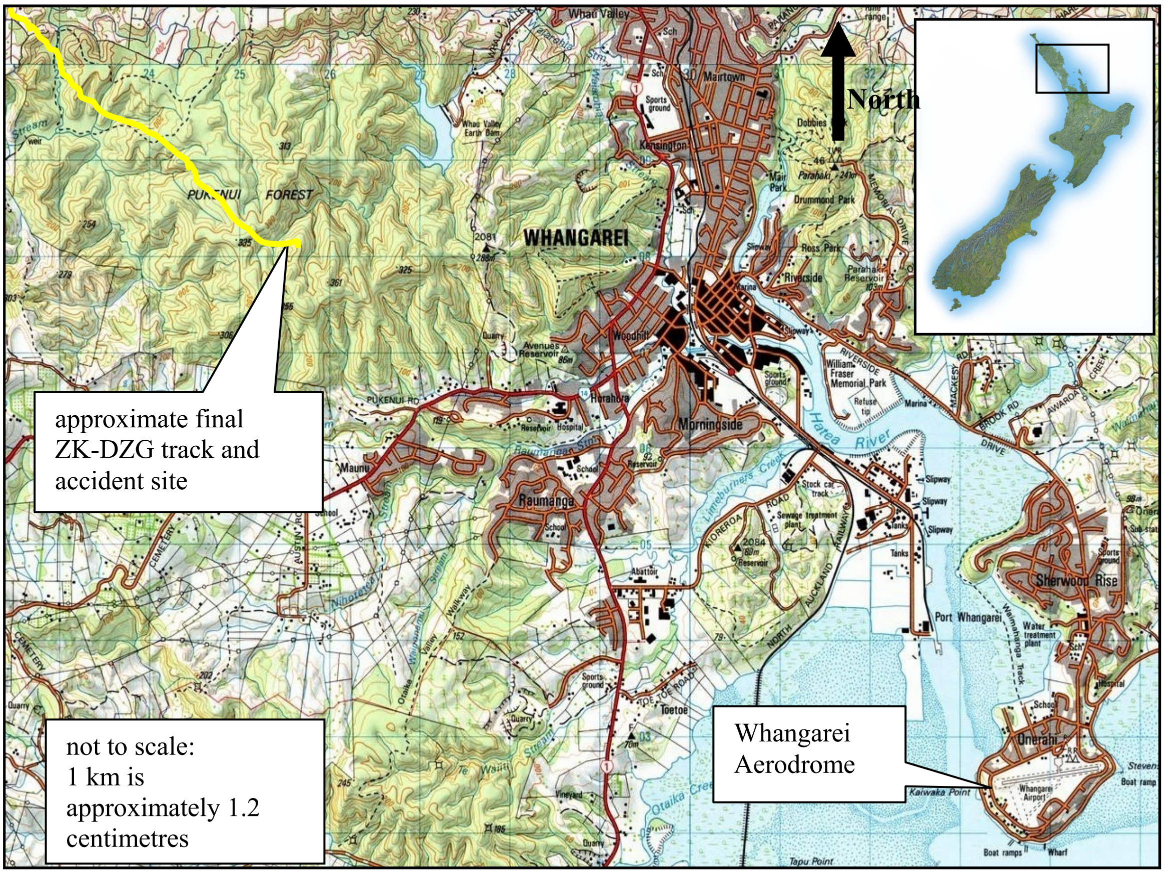


Figure 1
Location map

1.2 Wreckage and impact information

1.2.1 ZK-DZG was destroyed during the accident and had come to rest in an inverted, nose-down attitude, with the tail section folded around a tree trunk (see Figure 2). No fire occurred.

1.2.2 The vertical fin had detached and was situated on the ground a few metres away from the main wreckage. The rudder control surface was still attached to the aft fuselage by its torque tube. The wing root attachments had not broken and the inner sections of the wings were still attached to the fuselage. The outboard section of the left wing had detached from the main portion of the wing and there was damage consistent with the left wing leading edge striking a large tree. The hopper was empty.

Figure 2
Wreckage of ZK-DZG (image by CAA)

1.2.3 The strike marks on the trees along the flight path showed that the aircraft had entered the forest canopy at a high angle of bank, probably left wing low, and in a steep, nose-down attitude.

1.2.4 Significant energy had been dissipated by the aircraft striking the trees, and the evidence indicated it had been "slipping" along its lateral axis when it struck the forest floor. Even though there had been little forward velocity when the aircraft struck the ground, the engine and cockpit area had been forced to the left and compressed into the ground, significantly reducing the occupiable space in the cockpit area.

1.2.5 The propeller had separated from the engine because the reduction gearbox casing had broken apart during the ground impact. Damage to the propeller blades suggested that the engine was operating at a low power setting at the time of impact.

1.2.6 The primary flight-control surfaces were all accounted for at the accident site. The control runs to the flight-control surfaces were largely intact and the integrity of the flight-control systems was established. Reliable information about the position of the cockpit flight and engine controls could not be established because of substantial impact damage to the forward cockpit area. The flaps were in the retracted position.

1.2.7 Despite the fuel tanks being ruptured and an accurate assessment of the fuel on board at the time not being possible, there was fuel in the low-lying sections of the fuel tanks and the collector tank. The airframe fuel filter element and bowl contained fuel and a small amount of water and fine particles and debris.

1.2.8 The engine air-intake screen contained a significant amount of fibreglass debris and paint shards from the engine cowling, which showed that the engine had most likely been operating at the time of impact.

1.2.9 The 2 main landing gear oleos and wheels were separated from their attachments and were located near the wreckage.

1.2.10 There were paint and rubber transfer marks and impact damage on the left side of the aft fuselage (see Figure 3). These marks corresponded with the damage and marking on the vertical fin. Paint transfer marks and damage on the fin showed that the fin had been folded around the leading edge of the left stabilator[2].

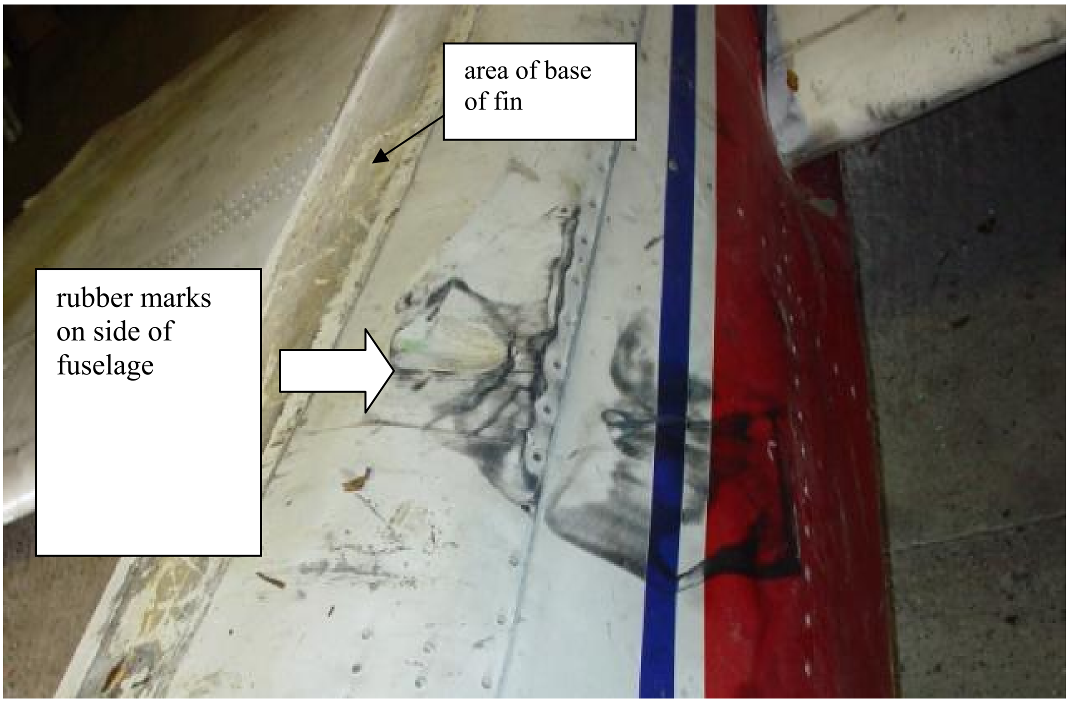


Figure 3
Aft fuselage witness mark (image by CAA)

1.2.11 A 30-centimetre (cm) high portion of the vertical fin's leading edge around the forward attachment fitting remained connected to the aircraft by its attachment bolt (see Figure 4). Further examination of this structure showed that a rectangular section about 4 cm long was missing from the fin leading edge skin (see Figure 5). There were 2 horizontal marks about 1 cm long inside the protective rubber anti-abrasion strip that covered the fin's leading edge. These marks were approximately in line with the upper and lower edges of the missing rectangular section. The skin on either side of the fracture surfaces had been bent back, showing that the fin had at some point in the failure sequence moved in a rearward direction. The damage to the fin rear-attachment support beam showed that the fin had folded to the left as it failed. The rudder was also bent towards the left side of the aircraft around its torque tube.

[2] The stabilator combined the stability function of a horizontal stabiliser with the pitch-control function of an elevator.

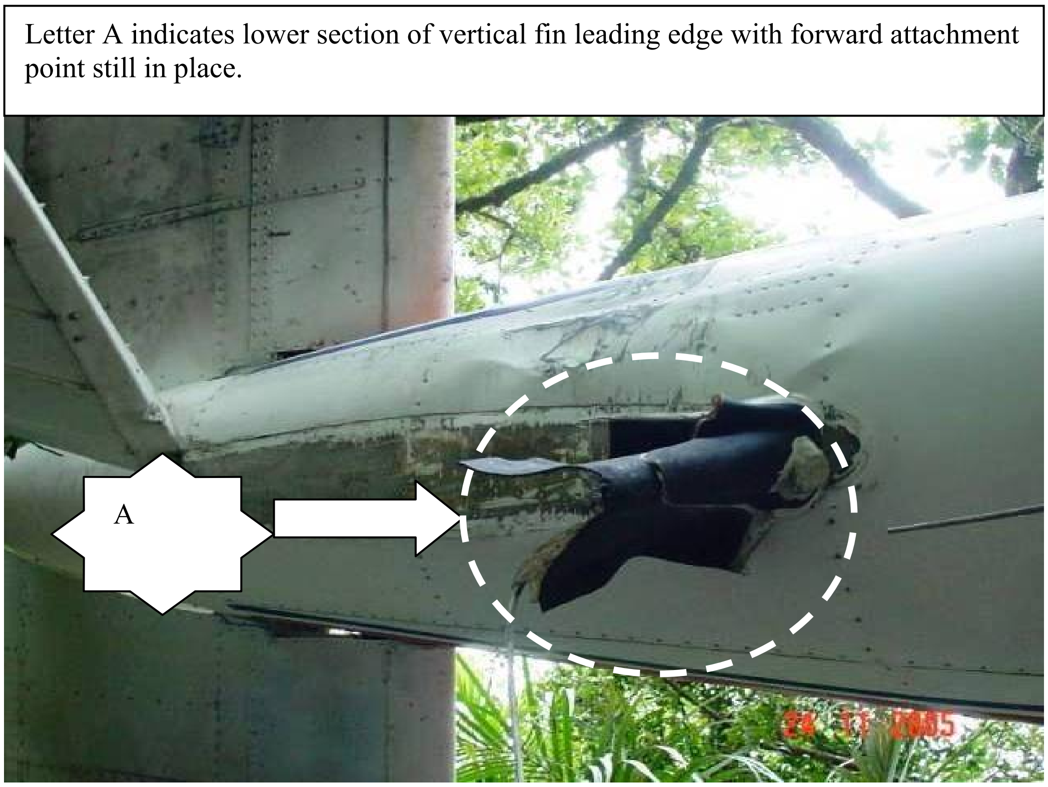


Figure 4
Forward attachment (from above) (image by CAA)

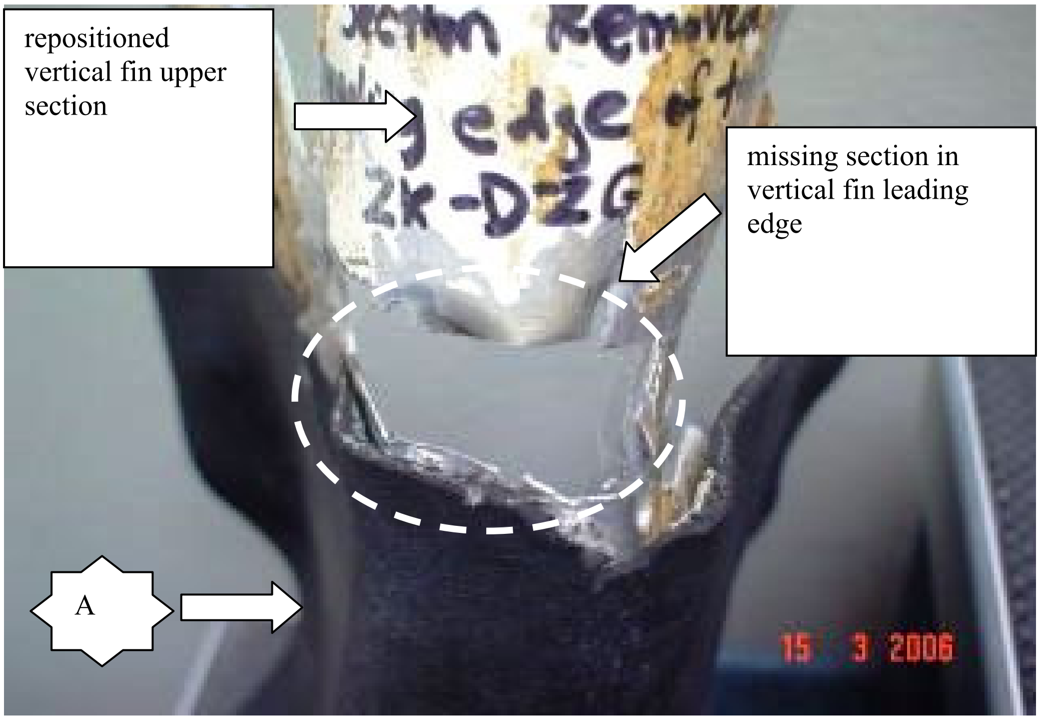


Figure 5
Missing section in fin leading edge (image by CAA)

1.3 Aircraft information

1.3.1 ZK-DZG was a New Zealand Aerospace Industries Limited Fletcher FU24-950 agricultural aeroplane, serial number 207, manufactured in 1975. On 22 November 2005, the aircraft had flown 10 597 hours.

1.3.2 The engine in the aircraft, a Walter M601D-11free turbine, serial number 852018, manufactured by Walter Engines a.s. in the Czech Republic, had completed 753 hours on 22 November, and had 1047 hours to run to overhaul. The engine was rated to provide 430 horsepower (hp) continuously and 550 hp for up to 5 minutes during take-off. The maximum available power was 620 hp.

1.3.3 The engine had been installed under Turbine Conversions Limited STC number 98/21E/15 (later transferred to Super Air Limited), approved in August 2000, and had replaced a 400 hp piston engine. An STC was issued when an applicant (in this case Turbine Conversions Limited but later taken over by Super Air Limited) received CAA approval to modify an aircraft from its original design. STCs belonged to the applicant and were issued for substantial changes to the original design, but could include minor modifications. On 19 February 2001, following the engine conversion, ZK-DZG was re-issued with a restricted category airworthiness certificate.

1.3.4 Since the original TC had been issued for the Fletcher aircraft type in the 1950s, the engines had been progressively upgraded from 225 hp piston-engine models to 550 hp turbine-engine models.

1.3.5 The Avia Hamilton Standard V508D-AG propeller, serial number 31-066-1780, had operated for 931 hours since overhaul on 22 November, and had 1069 hours to run until overhaul. Installation of the propeller had been in compliance with STC number 98/21E/15.

1.3.6 The previous aircraft annual review of airworthiness had been completed on 20 December 2004. Scheduled maintenance inspections were completed every 150 hours, in accordance with the CAA-approved maintenance programme. The most recent maintenance inspection had been completed on 22 June 2005 at 10 494.58 hours, and the aircraft had approximately 47 hours to run until its next inspection.

1.3.7 The vertical fin (see section 1.9) had a black rubber anti-abrasion strip fitted to its leading edge, in accordance with modification number JA/FU24/M258, which had been approved on 19 December 1975. Fitment of this strip was common industry practice to reduce leading edge damage from slipstream-blown debris. The fin was inspected each day during pilot checks and during scheduled inspections, but there was no requirement to remove this strip to inspect the fin leading edge surface. During scheduled inspections the strip usually remained attached, concealing the fin leading edge. A tactile examination carried out during such inspections might reveal any deformation under the rubber, but not necessarily any cracking or corrosion or minor damage, or the early stages of any buckling or deformation.

1.3.8 On 16 February 2001 at 7637 hours (2963 hours before the accident), the company had refurbished the vertical fin, which included replacing the leading edge skin.

1.3.9 On 29 April 2002 at 8530 hours (2070 hours before the accident), the fin skin was inspected in accordance with airworthiness directive (AD) DCA/FU24/173, reproduced below. The AD was issued following a fatigue failure of the vertical fin leading edge skin immediately aft of the forward attachment bulkhead. Score marks left in the skin during the leading edge protective rubber installation had initiated the fatigue.

DCA/FU24/173	**Forward Fin Structure - Inspection**
Applicability:	All model FU24, FU24A, -950, -950M and –954.
Requirement:	Pending the completion of the investigation into a recent accident where the fin separated in flight, accomplish the following:- Perform a detailed visual inspection of the forward area at the base of the fin for cracks. Pay particular attention to the skin in the area of the rivets that join the fin skin to bulkhead P/N 242305 and aft to the first vertical lap joint. Inspect from the bottom of the fin up to the first external strap. To accomplish this inspection, any rubber abrasion protection that is fitted in this area including any sealant, must be removed. The fin leading edge fairing, P/N 242321 must also be removed. If any structure is found cracked, it must be repaired before further flight and the CAA notified.
Compliance:	By 3 May 2002
Effective Date:	26 April 2002

1.3.10 On 1 June 2006, the CAA issued AD DCA/FU24/176, which required the completion of regular detailed visual inspections of the Fletcher FU24 aircraft vertical fin leading edge for any signs of damage. Subsequent versions of the AD required 50-hour inspections and the removal of all non-transparent protective coatings from the fin leading edge and advised that transparent protective tape could be fitted in place of the non-transparent coating. The AD that was current at the time of this report is included below.

DCA/FU24/176C	**Fin & Leading Edge – Inspection and Repair**
Applicability:	All model FU-24 aircraft **Note 1:** The content of this AD revised to clarify the intent.
Requirement:	To prevent the possible in-flight failure of the vertical fin, leading to loss of control of the aircraft, accomplish the following: 1. & 2. <u>Visual Inspection</u>: Inspect the fin for condition, security and damage in accordance with the requirements in chapter 05 page 25 of the FU-24-950 Series Maintenance Manual. In order to carry out this visual inspection all non-transparent protective coatings and their adhesive must be removed. This includes previously approved modifications such as, but not limited to, James Aviation modification JA/FU24/M258. 3. <u>Detailed Inspection</u>: Perform a detailed visual inspection of the leading edge skin in the area detailed in Figure 1 to detect cracking, corrosion, scratches, dents, creases or buckling. Inspect the entire leading edge down to the forward attach fitting. If the aircraft has been modified by the addition of dorsal fin extensions, these must be removed in order to inspect the obscured areas of the fin. Inspect the fin skin for corrosion and cracks paying particular attention to the center rib rivet holes and the skin joint at the fin base. Inspect the fin forward attachment point for corrosion and remove the fin tip and inspect the top rib for cracks at the skin stiffener cut outs. Inspection and maintenance requirements for the vertical stabilizer are detailed in the FU-24-950 Series Maintenance Manual, Chapters 05 and 55. Any damage must be repaired using an approved repair scheme <u>before further flight</u>.

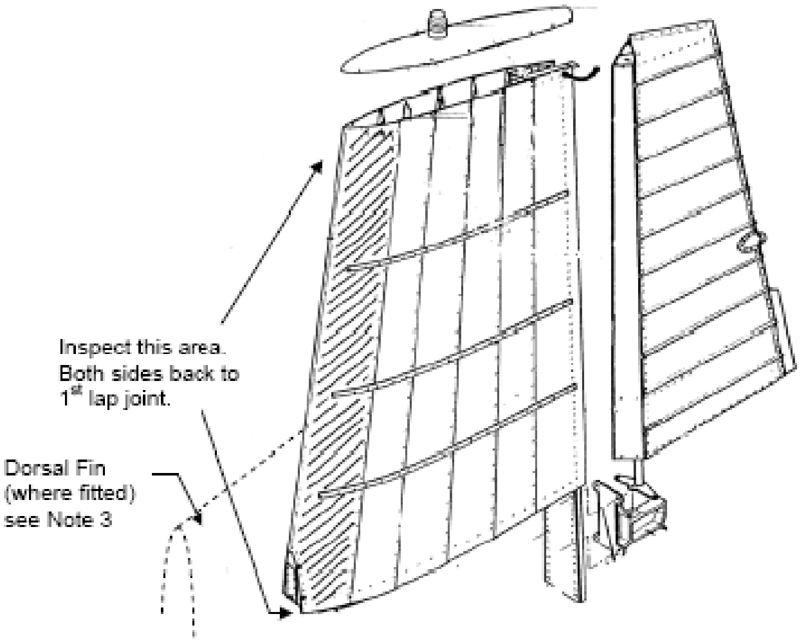


Figure 1: Fin Leading Edge Inspection

Note 2: For the purpose of this AD, a detailed inspection is an intensive examination of a specific item, installation, or assembly to detect damage, failure or irregularity. Available lighting is normally supplemented with a direct source of good lighting at an intensity deemed appropriate. Inspection aids such as mirror, magnifying lenses etc. may be necessary. Surface cleaning may be required.

Note 3: The following transparent polyurethane protective tapes have been assessed as suitable for use to re-protect the leading edge, and may remain in situ for subsequent inspections, provided they are sound, and in a condition to permit visual inspection of the skin beneath them.

Manufacturer	Product
3M	8591, or 8671, 8672 and 8681HS (aeronautical grade)
Scapa	Aeroshield P2604 (transparent)

Alternative high performance transparent polyurethane tapes may be used by application for an AMOC approval, on CAA form 24039/01. When applying protective films **DO NOT** trim product in situ, as score damage to the aircraft skin may lead to fatigue failure.

Note 4: This AD amplifies the Check 1 and Check 2 visual inspection requirements for the vertical stabilizer as detailed in chapter 05 page 25 of the FU-24-950 Series Maintenance Manual. The requirements of this AD take precedence over maintenance programmes approved under Rule Parts 119 or 91.607.

Compliance:

1. Visual Inspection by the Pilot:

   After every last flight of the day.

   Note 5: The visual inspection at every last flight of the day may be performed and certified under the provision in Part 43 Appendix A.1 (7) by the holder of a current pilot licence, if that person is rated on the aircraft, appropriately trained and authorised (Part 43, Subpart B refers), and the maintenance is recorded and certified as required by Part 43.

   Note 6: Add and record the visual inspection requirements of this AD in the tech log.

2. Visual Inspection by an Engineer:

   Within the next 50 hours TIS, unless previously accomplished, and thereafter at intervals not to exceed 50 hours TIS.

3. Detailed Inspection:

   Within 100 hours TIS, unless previously accomplished, and thereafter at intervals not to exceed 100 hours TIS.

Effective Date: DCA/FU24/176A - 31 May 2007

DCA/FU24/176B - 28 June 2007

DCA/FU24/176C - 27 September 2007

1.3.11 The aircraft flight manual stated that the maximum structural cruise speed, V_{NO}, during atmospheric turbulence was 116 knots indicated airspeed. This speed limit had been imposed to prevent the possibility of turbulence-generated wind gusts exerting excessive loads on the fuselage or fin. The aircraft was also limited to a maximum speed of 116 knots indicated airspeed with a deflector plate fitted for sowing, installed near the hopper door, as the aircraft was equipped.

1.3.12 Following the accident with ZK-DZG and information suggesting that agricultural pilots did not always observe the airspeed limitations, the CAA sent a letter, DW1114484-0, on 13 April 2006 to all agricultural aircraft operators, reminding them to ensure that their pilots observed all airspeed limitations.

1.3.13 Civil Aviation Rule 91.537 prescribed that an aircraft could not be flown if instruments and equipment specified as part of its TC airworthiness requirements, which included the airspeed indicator, were inoperative.

Flight recorder

1.3.14 The aircraft was fitted with a GPS unit (model AG-NAV®2), which was designed to provide directional guidance and navigation information to permit precise aerial application in the agricultural and forestry industries. The unit was operating in the "transit" mode during the flight, so recorded the aircraft's geographical position and altitude every 2 seconds. Its data was recovered using electronic topographical mapping software.

1.3.15 The GPS track data showed that the aircraft had flown slightly right of the direct track to Whangarei Aerodrome for about 23 km after departing from the airstrip. The aircraft then turned a further 7 degrees to the right, which it maintained for another 9 km. The aircraft at this point was about 3 km to the right of the direct track between the airstrip and Whangarei Aerodrome. The aircraft then turned 25 degrees to the left and followed this direction for 7 km. This track took the aircraft towards the highest point in the Pukenui Forest.

1.3.16 The last recorded GPS data plot at 1141:53 was 694 m to the south-west of the accident site at a height of about 800 feet above the ground. The GPS manufacturer advised that the unit most likely did not have sufficient time to save the last block of track data to its hard memory from its buffer prior to the accident, and therefore up to 40 seconds of its final track data were probably not recorded.

1.4 Personnel information

1.4.1 The pilot, aged 49, held a commercial pilot licence (aeroplane) first issued in 1993. On 8 September 2005 he was issued with a Class 1 medical certificate, which was valid until 8 March 2006. He also held a Class 2 medical certificate, valid until 7 September 2007. There were no conditions or restrictions associated with his medical certificates.

1.4.2 At the time of the accident the pilot had flown at least 16 000 hours, with 15 000 of these hours carried out in the agricultural role. He had completed an aircraft type rating for the FU24 Walter M601D conversion on 13 September 2002 and obtained a pilot chemical rating refresher on 10 October 2002. The pilot had completed a biennial flight review and annual currency check for single-seat agricultural operations on 14 March 2005.

1.5 Medical, pathological and survival information

1.5.1 A post-mortem examination showed that the 2 occupants of ZK-DZG had died from injuries consistent with a high-energy impact.

1.5.2 Examination of the pilot found no evidence of any pre-existing medical condition that could have resulted in incapacitation or affected his ability to control the aircraft.

1.5.3 The pilot was wearing a helmet and was restrained by a lap and shoulder harness. The loader-driver was not wearing a helmet, but was similarly restrained by a lap and shoulder harness. The severity of their injuries showed that the deceleration forces made the accident non-survivable.

1.5.4 The aircraft was fitted with a Pointer 3000-1 emergency locator transmitter (ELT) situated in the cockpit. The arming switch on the ELT was found in the off position. The connection to the ELT antenna had been severed in several places during the accident, preventing it transmitting any signal.

1.5.5 From 1 July 2008 the Civil Aviation Rules required more modern 406-megahertz ELTs to be fitted to aircraft, which allowed for a satellite fix in about 50 seconds when activated. The ELTs were designed to prevent their being easily deactivated, and Civil Aviation Advisory Circular 43-11 provided for ELT installation enhancements to improve the chances of a signal being transmitted following an accident.

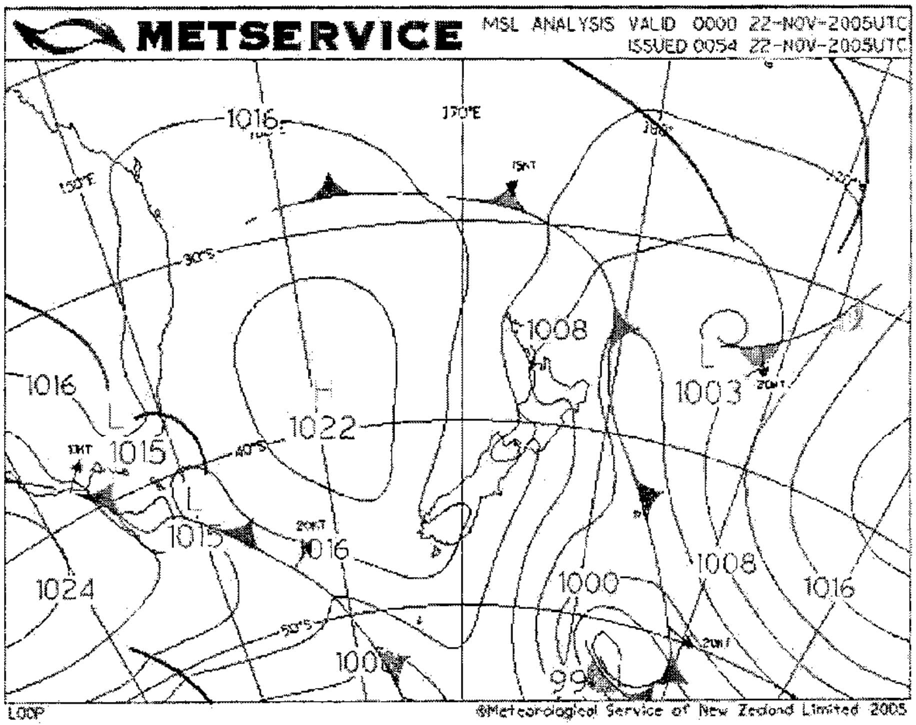
1.6 Meteorological information

1.6.1 The Meteorological Service of New Zealand Limited (MetService) provided the following weather information for the time around the accident. The information was based upon:

- MetService mean sea level analysis
- wind measurements inferred from Doppler radar data obtained by the weather surveillance radar at Mount Tamahunga (near Warkworth, about 75 km south-east of Whangarei Aerodrome)
- surface wind observations and reports at Whangarei Airport (5 km from the site).

1.6.2 The meteorological situation at midday on 22 November 2005 was as follows:

Meteorological Situation



At midday on 22 November 2005 an anticyclone was moving slowly northeast across the Tasman Sea, and a trough of low pressure to the east of New Zealand was moving away. A southwest air stream covered the northern half of the North Island following a cold front which had moved across the area 12 to 18 hours earlier.

1.6.3 MetService provided the following wind summary:

> At about 11:30am, about 5 kilometres west of Whangarei on 22 November 2005, the wind was blowing from the southwest with a sustained wind speed of 16 to 22 knots, and gusts of 25 to 30 knots.
>
> Considering the meteorological situation at the time it is very unlikely that there were severe wind gusts as high as 88 to 107 knots [response to question by CAA] in the vicinity of Whangarei on 22 November 2005.

1.6.4 Hourly weather observations at Whangarei at 1100 and 1200 on 22 November 2005 showed the visibility was 40 km in passing rain showers with scattered cloud at 3000 feet.

1.6.5 The aircraft engineer at Whangarei said that during the day there had been a stiff wind blowing at about 15 knots from the south-west. He said some squalls had passed through in the morning, with patches of rain. At about 1000 he had noticed dark weather to the north, with black cloud to the ground. About noon the dark weather had cleared and he believed the weather improved during the rest of the day, although the wind remained strong.

1.7 Tests and research

1.7.1 Laboratory analysis of the airframe fuel filter showed that most of the debris in the element was particulate and of geological origin (dirt, small stones and dust). The balance was predominantly metallic particulate such as aluminium, iron, copper and zinc.

1.7.2 The engine manufacturer did a strip-down and examination of the engine and its fuel-control unit. Some traces of water were found, but there was no evidence of any fault with the engine or its components that could have contributed to the accident.

1.7.3 The limited data from the simple engine-load monitor showed that the propeller had not feathered in flight nor had the engine failed. All other engine cycle and elapsed time readings were normal.

1.7.4 The engine performance trend-monitoring data recorded by the pilot was comparable with that of another aircraft of the same type and identified no cause for concern.

1.7.5 The power-lever paint had wear marks that suggested the lever might have gone beyond its de-rating stop. The stop approximately determined the maximum power for the engine. The CAA said that some other turbine-powered agricultural aircraft also had similar wear marks, and that discussion with industry pilots suggested that at times they advanced the lever past the stop. A pilot could go past the stop by pushing the lever to the side then forward, for example during an emergency situation. In such cases, power could exceed the maximum power for which the aircraft had been certified under STC 98/21E/15.

The fin

1.7.6 A metallurgical specialist examined the vertical fin leading edge and rear beam assembly. The specialist concluded that the leading edge material was similar to, and consistent with, aluminium alloy 2024-T3, the specification material for the fin. The material was slightly harder than new alloy but this was attributed to natural ageing and variations in material composition and manufacturing. The specialist concluded that any differences were insignificant, and that the skin of the failed fin was slightly stronger and thus slightly more resistant to fatigue than new alloy.

1.7.7 The specialist analysed a section of the rear beam assembly of the fin to determine its composition and hardness, and also examined the surface where it had fractured. He concluded that the beam assembly had been manufactured in accordance with its specifications from aluminium alloy 2024 with the correct hardness. The fracture surface was typical of tensile overload.

1.7.8 The specialist examined sections of the fracture surfaces of the fin leading edge aluminium alloy to determine the nature of the failure and whether fatigue cracking had been present. The specialist concluded that marks on the rubber anti-abrasion strip on the fin indicated the probable presence of 2 fractures in the leading edge skin prior to the fin failure. Each fracture showed wear from the mating surfaces rubbing together, which prevented determination of the age and propagation rate of the fractures. Optical and electron microscopic examination of the surfaces showed that fatigue cracking had probably been present in the area of the failure before the failure, but no initiation site could be determined. Extensive shear and tensile overload was present on the fracture surfaces either side of the fatigue region.

1.7.9 The Commission had a second independent metallurgical specialist examine the sections of the fracture surfaces of the fin leading edge aluminium alloy, using optical and electron microscopy. The specialist found that the fin leading edge had contained a network of cracks at the time of its failure. Extensive mechanical damage on the fracture surfaces meant that the presence of fatigue crack growth marks could not be confirmed. He reported that the damage had most likely occurred during the later stages of growth of the defects, when applied loads caused the fractured edges of the thin sheet metal to abrade repeatedly against and past one another. Crack networks of the observed type can develop in thin metal structural sections that are subjected to high-amplitude load reversals. In this case the fractures formed in an unsupported portion of the fin leading edge between adjacent stiffeners. The orientation of the fractures indicated that high local stresses from fin torsion and bending (aerodynamic and dynamic loads) were probably responsible for crack development.

1.7.10 While the second metallurgical specialist could not confirm a fatigue crack mechanism, the available evidence indicated that the initial defects near the fin leading edge apex grew relatively slowly to a chord-wise crack length of at least 110 millimetres (mm) prior to fin separation. No information on the crack growth rate could be extracted from the available material, but the evidence indicated that the cracks in the fin leading edge had been present for a period of time prior to the final failure. The form of 2 of the pieces examined indicated that the fin leading edge may have been affected by foreign object damage prior to the formation of the cracks. The specialist said any such damage, which would have been difficult to detect under the leading edge rubber abrasion strip, could have assisted local "oil canning" of the adjacent skin and accelerated fatigue damage in the area. He also said that if the leading edge had been locally deformed by a past overload event, fatigue cracking could have occurred in areas compromised by the deformation.

1.7.11 The second specialist concluded that the complex configuration of the cracks and the form of the damage on the fracture surfaces suggested that the cracks had been caused by metal fatigue in the fin leading edge.

1.7.12 Load tests carried out on a serviceable fin after the accident showed that excessive loads would cause the skin to buckle and crack around the leading edge in a similar position to the damage found in the fin of ZK-DZG. This demonstrated that structural loads on the fin were carried to some extent by the leading edge skin, as designed. The fin in the test met the calculated static strength requirements.

1.7.13 One party associated with the operation of ZK-DZG held the view that on the day of the accident the leading edge of the aircraft fin was serviceable but the rear beam assembly of the fin broke from a severe wind gust. The party held that view because the evidence showed that the fin had pivoted about the forward attachment fitting and folded around the leading edge of the left stabilator.

1.7.14 Stress calculations by an aircraft design engineer showed that a wind gust effect in the order of 88 to 107 knots would have been necessary to bring about a structural failure of the beam assembly. At 3 different weather stations near the accident site, the maximum gust recorded on the day of the accident was approximately 32 knots. The meteorological information did not indicate wind gusts of the magnitude necessary for a structural failure.

1.8 Organisational and management information

1.8.1 Following the accident with ZK-DZG, the Fletcher FU24 aircraft TC holder, PAL, expressed concern about STC-98/21E/15 that allowed installation of the Walter turbine engines to the aircraft. PAL questioned whether the CAA had followed an accepted process in approving the STC. Concern was also expressed that the Walter turbine installation itself, because of power levels, may have brought about the failure of the vertical fin on ZK-DZG, and that the regulator in approving the STC had not considered the potential effects such an installation may have on the empennage, especially the fin.

1.8.2 PAL had been incorporated in December 2006, after it acquired the assets of the FU24 TC holder Pacific Aerospace Corporation (PAC). The operating company's management changed along with the ownership. The former company PAC and its predecessors had been in business for many years and produced around 300 FU24 aircraft.

1.8.3 PAL's main concern was that the STC process had not taken sufficient account of the effects on the airframe of potential power and torque increases introduced by the turbine engine, and considered that the testing and analysis carried out had been inadequate. PAL had concerns that fatigue implications for the structure of the empennage and fin had not been given proper attention.

1.8.4 To address the above concerns, the Commission contracted a specialist independent aeronautical engineer to review the STC process carried out by the applicant, Turbine Conversion Limited (later transferred to Super Air Limited) and the CAA for installation of the Walter turbine engine in the Fletcher FU24-950 series aircraft. His review also examined other matters relevant to the safety of the operation of the aircraft. While the engineer's review focused on the Walter-powered Fletcher, many of his observations were relevant to any turbine- or piston-engine conversion that provided a power increase.

1.8.5 Specifically, the aeronautical engineer was requested to:

- determine whether the STC process used as the certification basis for the installation of the Walter turbine engine in the Fletcher aircraft was appropriate and correctly carried out, including whether fatigue and maintenance issues were duly considered in the process
- determine what, if any, changes to the STC process or any other relevant processes might be required to improve safety outcomes in this case and in general
- comment on whether the turbine conversion to ZK-DZG contributed to its fin failure and the subsequent loss of the aircraft.

1.8.6 In February 2008 the CAA held a Fletcher vertical fin engineering workshop. The workshop addressed safety concerns around the FU24 vertical fin and mitigation actions currently underway. The workshop demonstrated the methodology used by the applicant and by the CAA to justify the approval of the STC. The workshop also provided information on flight testing and analysis carried out subsequent to STC approval. The Walter Fletcher STC holder (Super Air Limited), the Commission and the aeronautical engineer, PAL and other parties attended this workshop.

1.8.7 After consultation with the CAA and other involved parties, the independent aeronautical engineer produced a comprehensive report for the Commission. That report is annexed to this investigation report. The engineer's report conclusions and recommendations are included below, but should be read in conjunction with the annexed report for a full understanding of the reasons for those conclusions and recommendations.

Conclusions, in part:

> The STC process used as the certification basis for the installation of the Walter turbine engine in the Fletcher Aircraft was appropriate and for the most part, correctly carried out. There is considerable room for judgment in deciding which FAA Advisory Circular should be used for guidance in the circumstances and what substantiation processes should be used for each requirement. In this case, I have concluded that the application of CAR3 and FAR23 with the guidance of AC23-14 was appropriate.

The STC process did not include evaluations (analysis and/or tests) of fatigue effects on the empennage and fin. The alternative approach of using a satisfactory history of operation of similar types including similar engine conversions is acceptable. However, there were areas of concern from past service experience of the FU24 fin structure that indicated a need for a more rigorous treatment of the Continued Airworthiness requirements than appears in the STC documentation.

Fatigue and maintenance issues are closely related. Considering the dependence placed on the Continued Airworthiness Inspection Programme as a backstop for potential fatigue problems, the documentation does not appear to provide sufficient emphasis on the importance of inspections under the Programme. In practice, evidence of ongoing analysis and fatigue tests carried out after the approval of the STC indicates that Super Air's execution of the Programme may have been more thorough than indicated in the STC documentation.

However, I consider that the Continued Airworthiness programme for the Walter Fletcher should be reviewed including the 150-hr maintenance periodicity to ensure that the lessons of several years of operation have been applied. The approach should be conservative. If the decisions that led to the 150 hour periodicity are properly documented such a review should be very straightforward.

The fact that a widespread, well-intentioned industry practice can arise where inspection-dependent fin structure can be covered by an opaque protective cover through which visual inspection is not possible, confirms the need for further analysis of the inspection programme to ensure that it is based on a logical consideration of the criticality of structure, service experience and risk.

The current redesign of the fin structure, being carried out by three separate companies, will markedly reduce safety risk and probably the ongoing cost of maintenance. This is undoubtedly the activity of most immediate importance to the structural integrity of the FU24 aircraft and it needs to be completed as soon as possible.

These actions in association with the outcomes of the Agricultural Aircraft Safety Review, and current FU24 AD's should be sufficient to mitigate foreseeable risks of fin structural failure.

While a comprehensive fatigue analysis of the Walter Fletcher (or all Fletchers for that matter) might help provide an indication of the location of probable future fatigue problems, a better investment of effort in the short term would be to analyse the problems that have shown up in many years of Fletcher operations and several years of actual operation of the higher powered versions including the Walter. This information should then be directed at improving inspection and maintenance programmes. Ongoing monitoring of aircraft defect and occurrence trends is a fundamental part of Continued Airworthiness programmes.

In recent years, the CAA has increased liaison with Type Certificate and major STC holders including regular visits and exchange of information. This is a very positive development.

Placarded limitations were in place to control operating envelopes. However, despite incredulity in some quarters, extra demands were being placed on older airframes by the increased performance provided by turbine engines. The turbine aircraft deliver more [tonnage] per hour and basic logic dictates that this comes at a price in airframe life. There is also demonstrable evidence that some operators are exceeding the placarded limits. This matter is being considered under the Agricultural Aircraft Safety Review but in any case, I would expect that such matters would also be addressed under the CAA's routine processes for education and enforcement.

The Agricultural Aircraft Safety Review and the Part 137 Rules rewrite are important reviews that have been given a high priority by the CAA and industry. They need to be completed quickly and some of the more important line items may need to be extracted for early attention. E.g. the agricultural overload provision.

There are a number of other issues that have been highlighted during the preparation of this report where changes could be made to systems to improve safety. It is probably reasonable to refer to these as "systemic safety issues". None of them is new and corrective action for most of them is already in hand through various CAA and industry initiatives including the Agricultural Aircraft Safety Review. In some cases, more urgent attention would be justified. These include observance of limitations, methodology for continued airworthiness programmes, agricultural overload provisions and modification programmes to improve the fin.

Within the limits of the information available to me, I have concluded that the Walter Fletcher Turbine Conversion was not the prime cause of the loss of ZK-DZG's fin and the subsequent loss of the aircraft. The extra power available to the aircraft may have been a contributory factor in the propagation of any damage that may have been present in the fin leading edge, but other factors are likely to be of more significance. E.g., the fin leading edge cannot be properly inspected when covered by an opaque anti-abrasive strip.

As is usual in any organization, there was a degree of compartmentalization in the CAA. The various units working more closely together would lead to better decisions in some instances.

There was a wide range of views on industry issues – some very strongly held. The conclusions of this report fall somewhere in the middle of industry opinion.

1.8.8 The independent aeronautical engineer included 4 recommendations in his report, which the Commission adopted. It recommended to the Director of Civil Aviation that he take action to address those recommendations.

1.8.9 Between the accident with ZK-DZG and concerns raised by PAL, the CAA began an engineering review of the structure of the tail fin of the Fletcher and an Agricultural Aircraft Safety Review.

1.8.10 On 22 May 2009 the CAA released on its web site www.caa.govt.nz its fin engineering review final report into its investigation of the structural integrity of the Fletcher aircraft vertical fin. The TC holder had completed a redesign of the vertical fin and issued service bulletin PACSB/FU/094, for implementation of the redesigned fin. The redesigned fin included a full-span leading edge spar and provided significantly improved strength and damage tolerance. The CAA planned to mandate the service bulletin by issuing an AD. On 12 February 2009 the CAA sent its proposed AD, DCA/FU24/178, to industry for consultation, with any submissions due by 15 March 2009. On 30 April 2009 CAA issued the AD requiring implementation of the service bulletin.

1.8.11 In October 2007 the CAA began an Agricultural Aircraft Safety Review to gather information and make recommendations about general agricultural aircraft design, continuing airworthiness, maintenance and operational practices and techniques that would improve safety in agricultural operations. In December 2008 the CAA released the Review findings, even though the CAA had still to go through the process of fully considering the Review findings. The early release was done to facilitate the consultation process planned during 2009, with the knowledge that there was a great deal of work to be done by the CAA and industry following the Review. The Review is available on the CAA website, www.caa.govt.nz.

1.9 Additional information

1.9.1 The Fletcher vertical fin design had remained the same since the aircraft had first been designed and issued with a TC more than 50 years earlier. The fin construction used a single-channel vertical beam assembly at the rear, and a single-point pivoting front attachment (Figure 6). The forward attachment point provided no redundancy, and any side loads on the fin were transferred to the stressed skin leading edge. A failure of the forward attachment point or leading edge skin would cause a transfer of aerodynamic loads to the rear vertical beam assembly. This could result in overload and failure of the beam assembly and loss of the fin.

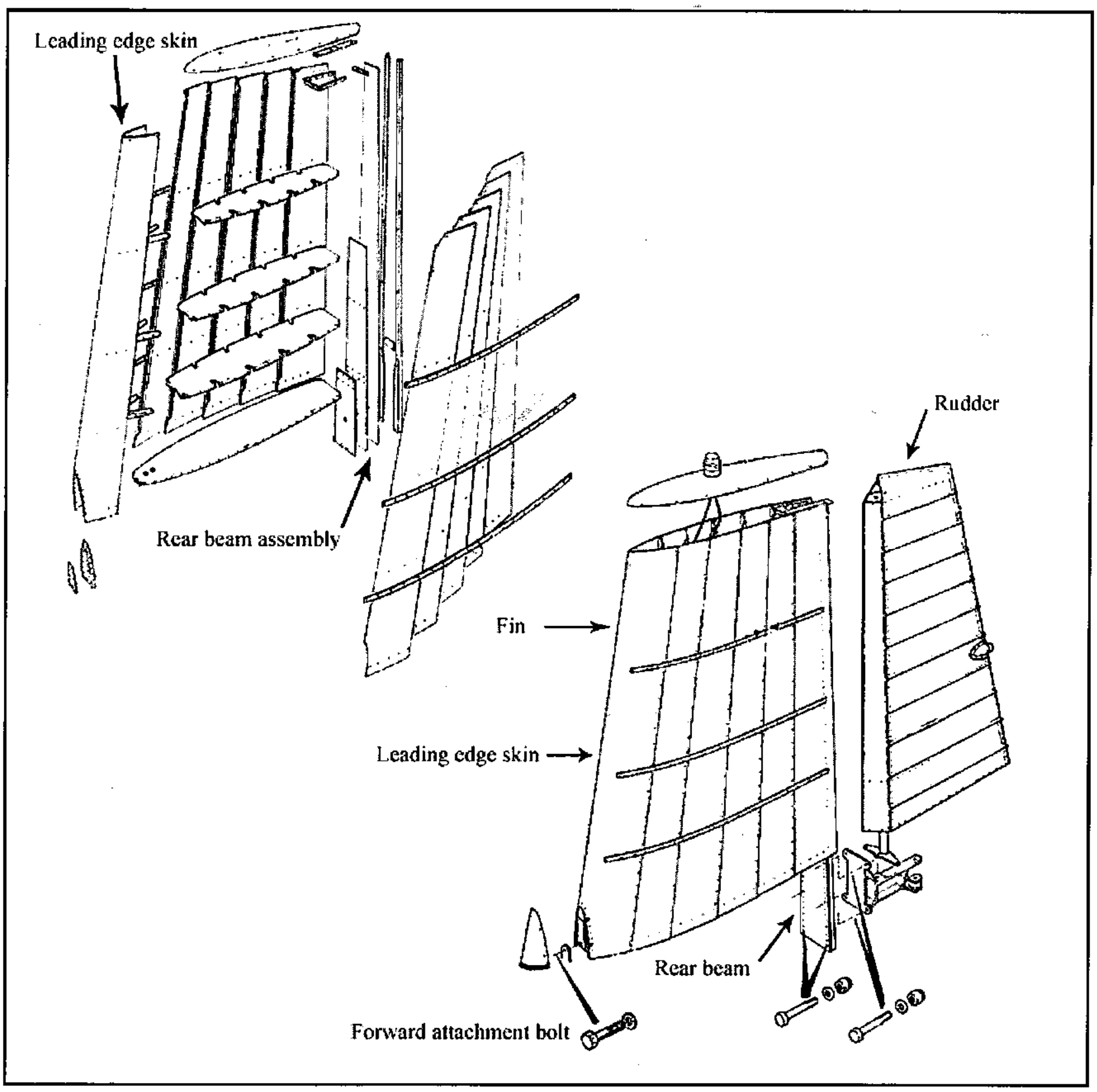


Figure 6
Fletcher FU24 fin structure (from a FU24 maintenance manual)

1.9.2 By comparison, the vertical fins on 2 other popular agricultural aircraft, the Air Tractor and Cessna Agwagon, were constructed with a forward and rear spar and 2 forward attachment points.

1.9.3 A review of CAA records showed that there had been 8 FU24-950 Fletcher vertical fin failures since 1970. Of these, 6 had involved piston-engine-powered and 2 turbine-engine-powered aircraft.

1.9.4 The first fin failure occurred on 8 May 1970 to a piston-powered aircraft when the fin separated and fell to the left, and was restrained only by the rudder. The failure was attributed to extensive corrosion of the rear beam assembly and forward attachment fitting.

1.9.5 The next 2 fin failures were to piston-powered aircraft on 17 November 1975 and 4 November 1976, and were attributed to corrosion-initiated fatigue failures of the forward attachment fitting. The first failure allowed the fin to twist around the rear beam assembly and bend the rudder and jam the stabilator. In the other failure the fin separated but remained jammed around the left stabilator.

1.9.6 The CAA's predecessor issued AD DCA/FU24/161 on 16 November 1976 and AD DCA/FU24/163 on 11 March 1976, for inspection and modification of the fitting to rectify the problem.

1.9.7 The next 2 failures also occurred to piston-powered aircraft, on 30 March 1982 and 16 February 1995. These were also attributed to corrosion-initiated fatigue failures of the forward attachment fitting. The first event allowed the fin to rotate through about 180 degrees, but although the rear beam assembly was twisted it remained attached. In the next event the fin departed the aircraft.

1.9.8 On 19 September 1995, the CAA issued AD DCA/FU24/161A, and on 29 September 1995 AD DCA/FU24/163A, to rectify the problem.

1.9.9 The next fin failure was on 20 September 2001 to a turbine-powered aircraft. This was again attributed to a failure of the forward attachment fitting, brought about by corrosion that was obscured by the skin. The fin did not depart the aircraft, but the pilot said the rudder locked in a fully deflected position.

1.9.10 On 25 October 2001 the CAA cancelled AD DCA/FU24/163 and replaced it with AD DCA/FU24/172 to address the issue with the strength of the forward attachment fitting.

1.9.11 On 18 April 2002, the first fatal accident following a fin failure occurred, on a piston-powered aircraft. The failure was attributed to fatigue of the leading edge skin aft of the forward attachment fitting because of score marks left in the skin during its leading edge rubber installation. The fin fell sideways onto the left stabilator, as well as rotating to the left and breaking the rear beam assembly before falling away from the aircraft.

1.9.12 On 26 April 2002, the CAA issued emergency AD DCA/FU24/173 for inspection of the forward fin structure.

1.9.13 On 22 November 2005 the accident involving ZK-DZG occurred.

1.9.14 On 1 June 2006 the CAA issued AD DCA/FU24/176 for inspection and repair of the fin leading edge (see 1.3.10). On 31 May 2007, the CAA issued AD DCA/FU24/176A, and on 28 June 2007 and 27 September 2007 issued AD DCA/FU24/176B and 176C respectively to clarify the intent of AD DCA/FU24/176A.

1.9.15 At the time of writing this report there were 64 Fletcher FU24 series aircraft registered in New Zealand.

2 Analysis

The accident

2.1 The day before the accident, the pilot had successfully completed a day of aerial topdressing, but some time during that day, or during the flight that evening to Whangarei, the aircraft airspeed indicator became stuck on 80 knots. Although the company's chief engineer advised the pilot to have a local aircraft engineer fix the problem, there was no evidence that the problem had been rectified before the pilot took off early from Whangarei Aerodrome on the day of the accident. His subsequent mobile telephone call to the local engineer showed that the indicator was unserviceable, at least at the start of the accident flight.

2.2 Experienced agricultural pilots would know the approximate airspeeds their aircraft would achieve at certain weights, configurations and power settings and consequently might not always closely monitor airspeed indicators. They might also reference GPS indicators for ground speed, but an accurate knowledge and assessment of the effect of the local wind velocity and direction would be necessary to determine the airspeed, and would make this impractical. Consequently the pilot may have considered that he could still safely operate the aircraft with an unserviceable airspeed indicator and, because of time constraints with the weather changing, complete a morning of topdressing before he had the airspeed indicator fixed.

2.3 In any event, as part of its TC airworthiness requirements, the aircraft was required to have a serviceable airspeed indicator before it could be flown. Despite the pilot's experience, he could not have known the exact airspeed of the aircraft without a serviceable airspeed indicator, and he could have inadvertently exceeded the aircraft's normal operating airspeed limitations for turbulent conditions.

2.4 Using data recovered from the GPS in ZK-DZG and information from other pilots, the actual airspeed of the aircraft was considered to have been about 120 knots prior to the accident. While this may have exceeded the maximum structural cruise speed (116 knots) in turbulent conditions by only some 4 knots, aerodynamic forces increase as the square of the airspeed. Consequently there may have been an increased risk of the aircraft sustaining some structural damage under turbulent conditions.

2.5 The CAA's safety action on 13 April 2006 in advising agricultural aeroplane operators to ensure their pilots were aware of the risks associated with exceeding airspeed limitations, and to observe those limitations, was an effective method for requiring compliance and helping to ensure that pilots observed such limitations.

2.6 An amber Beta[3] indicator light mounted above the instrument panel in the cockpit of the aircraft would illuminate when the Beta switch on the power lever was selected, along with a second green Beta light on the instrument panel. This Beta light was likely to have been the flickering amber light to which the pilot referred when talking to the truck driver just before the accident flight. The pilot did not appear to be concerned about the light, and there was no evidence from the testing and examinations that the propeller had moved into the Beta range.

2.7 The strong, gusty weather conditions at the time of the accident were unsuitable for aerial topdressing, but reasonable for a ferry flight to Whangarei. Because of the pilot's experience he would have encountered similar weather conditions before, and should have been able to assess the suitability of the conditions for a ferry flight. The fact that he continued towards Whangarei on the accident flight suggested that the weather was suitable for the ferry flight. No radio calls were received from the pilot, also suggesting that he had no major concerns during the flight, but this could not be relied upon because the radio serviceability and frequency could not be determined.

[3] Operational mode in which the propeller blade pitch is controlled by the power lever, including the range from zero to negative pitch.

2.8 From examination and an analysis of the available evidence, a structural failure of the vertical fin brought about the accident when the aircraft was over Pukenui Forest, 10 km from its destination (see "The fin failure" below). As the fin structure failed, the fin lodged against the left horizontal stabilator and made the aircraft uncontrollable, preventing the pilot taking any effective recovery action. There was no evidence that any other failure or pilot control inputs had contributed to the accident.

Survival

2.9 The accident was not survivable. Had the ELT activated, the aircraft might have been located up to 12 hours earlier, but that would not have affected the outcome. The ELT produced no signal because it was not armed and its antenna cable had been severed in the accident. Some agricultural pilots have been known to deactivate ELTs to prevent them inadvertently activating when operating from rough airstrips, so the pilot might have done this then forgotten to arm it for the ferry flight. However, the switch could also have been knocked to the off position amidst the disruption during the accident.

2.10 The 1 July 2008 Civil Aviation Rule change that required better installation of more modern ELTs to aircraft should help to improve the likelihood of a signal being generated and detected following an accident.

The fin failure

2.11 Evidence from the metallurgical specialists' examinations showed that the lower leading edge of the fin above the forward attachment fitting had a significant network of pre-existing cracks extending to some 55 mm either side of the leading edge. A section about 25 mm in diameter was found missing from the leading edge. The damaged area had been covered with a black protective rubber strip, which would have hidden the damage from anyone doing a visual inspection. Consequently the damage went unnoticed and the cracks progressively grew in length until they reached a critical size.

2.12 Side loads on the vertical fin would transfer to the stressed skin leading edge, and testing showed that such loads concentrated in the approximate area of the damage where the fin had failed on ZK-DZG.

2.13 Although the chafing damage to the crack edges prevented any determination of the cracks' likely propagation rates, the specialists concluded that the area had been damaged and thus weakened for some time before the accident. The last known comprehensive inspection of the fin had been 29 months and 2070 flying hours earlier, so the cracks most likely began within this period.

2.14 The metallurgical specialists concluded that metal fatigue was the most likely cause of the cracks. One specialist believed there was some deformation evidence suggesting that the area may have been struck and damaged some time earlier by a foreign object. If this were the case, it could help explain why the area developed a crack. Agricultural aircraft fly in a harsh environment and generally operate from short, rough airstrips with numerous turnarounds each hour. Because of this, foreign object strikes to the empennage, such as those from stones or clods, are not uncommon, and this was the reason why rubber protective strips had been applied to the leading edges of the fin and stabilators.

2.15 Specialist metallurgical examination of the rear vertical-beam assembly showed that it met its material specifications and had failed in overload. There was no evidence of any pre-existing damage, such as cracks or corrosion that could have contributed to its failure.

2.16 Apart from the fin, there was no evidence of any other system or structural failure that could have contributed to the accident.

2.17 From an evaluation of all the evidence, the hidden damage to the leading edge of the vertical fin put the fin in an unserviceable and structurally weakened state at the start of the accident flight. The fin had been in that state prior to the flight for an undetermined length of time since its most recent comprehensive inspection. During the flight, normal aerodynamic loads on the weakened fin, probably from a combination of airspeed, pilot inputs, sideslip and wind gusts, caused the fin to fail and bring about the accident.

2.18 The vertical fin failure began at the weakened section of the leading edge, and from aerodynamic loads the fin pivoted about the rear beam until it failed in overload, before finally tearing away from the leading edge. This combination allowed the fin to pivot and wrap itself across the leading edge of the left stabilator. The fin probably was held in that position for a short time by the rudder remaining attached to the top of the fin. From this point the pilot would have had little or no pitch control, and the drag would have caused the aircraft to yaw, roll and pitch, leading to a loss of control and the subsequent accident. This is consistent with a witness account of the aircraft entering a steep downward spiral.

2.19 One party believed that the rear beam needed to have failed first to have allowed the vertical fin to pitch forward and wrap around the left stabilator leading edge, and that the failure was caused by an excessive side load, such as from a wind gust. This theory was not supported because there was no evidence of such a side load, whereas all the evidence pointed to a structurally weakened fin leading edge and an initial failure at that point.

2.20 The certification design standards required a serviceable fin to be able to withstand all expected wind gust loads with a margin of safety. The vertical rear beam on ZK-DZG was structurally sound and serviceable before it failed in overload. Extensive meteorological evidence did not support wind gusts in the area of the accident of the magnitude necessary to cause a failure of a serviceable rear beam. There was also no history of any serviceable rear beams on the aircraft type failing from excessive gusts. Previous accident history showed that rear beam assemblies could fail in overload when the fin forward attachment fitting, or leading edge skin, failed.

The STC process and maintenance

2.21 The STC process that allowed more powerful turbine engines to be fitted to the aircraft was subject to some criticism by the aircraft TC holder. The certificate holder cited this as possibly being the cause of the accident with ZK-DZG because it believed the effects of such an installation on the empennage had not been properly considered during the process.

2.22 The in-depth review of the STC process by an independent aeronautical engineer found there was no evidence to support such a view, and that the process was generally robust and had been followed correctly. The review found that the extra power available to the aircraft might have been a contributory factor in the propagation of any existing fatigue damage in the fin leading edge, but other factors, such as continued airworthiness requirements that took account of the modifications, were more significant.

2.23 Although the turbine engine installation was considered not to have been the cause of the failure of the fin, it may have been a contributory factor once the fatigue cracks started. More significantly, because the turbine-powered aircraft could deliver more per hour and increase their turnaround cycles, the extra demands would have been at the expense of the airframe life.

2.24 The review did find some weaknesses in the process that the CAA applied in approving the STC, particularly in the treatment of fatigue considerations specified under the certification basis documents. The review found that a better evaluation of fatigue effects on the empennage should have been carried out, and that the in-service experience of the fin indicated the need for a more rigorous treatment of the continued airworthiness requirements than appeared in the STC documentation. Consequently, even though the fin was inspection-dependent to ensure its continued airworthiness, the approved maintenance programmes did not reflect this dependency and did not provide the necessary inspection criteria for the early detection of any fatigue issues.

2.25 Robust preventative maintenance is important for the early detection of fatigue damage and the prevention of fatigue-related failures. With ZK-DZG, undetected fatigue cracking of the fin leading edge skin was instrumental in the fin failure and the accident. Industry practice had allowed the inspection-dependent fin structure to be covered with a black rubber protective strip. With no requirement to remove the strip during routine inspections, effective visual inspections were not possible. This illustrated the need for further analysis of the inspection programme to ensure that it was based on proper critical considerations of the structure, service experience and risk. The step already taken by the CAA in issuing an AD for the replacement of the strip with a transparent strip and 50-hour inspections should go a long way to resolving the issue.

2.26 The continued airworthiness programme for the aircraft that allowed inspections to be extended from a 50- to a 150-hour periodicity also illustrated the need for further analysis of the inspection programme. This needs to be critically reviewed. The CAA's review work already underway should be completed as soon as practicable to ensure that operators' maintenance programmes are enhanced to help prevent any further fatigue-related failures.

2.27 The separate CAA Agricultural Aircraft Safety Review findings issued in December 2008 and the rewrite of the agricultural aircraft operations Civil Aviation Rules Part 137 are also important work, and once completed and the various safety issues addressed the safety of agricultural aircraft and that of the agricultural industry generally should be enhanced significantly.

2.28 The design of the vertical fin had remained unchanged since the aircraft type had first been constructed more than 50 years earlier, and although it had served its purpose it was not damage tolerant and had no failure redundancy in its structure. The early design of the fin that relied on the leading edge for its rigidity and structural integrity, its single load path attachment point, no failure redundancy, low threshold of damage tolerance and susceptibility to fatigue cracking illustrated that a redesign of the fin structure was long overdue.

2.29 The 8 known in-flight failures of the vertical fin and the fact that the loss of a fin could be catastrophic demonstrated the need for a redesign. The fact that the failures were evident in the piston-powered models before the turbine conversions were introduced, and the failures were mainly attributed to ongoing or incorrect maintenance issues, showed that regardless of the engine power the fin was inspection-dependent.

2.30 When fitment of the redesigned vertical fin by the TC holder in conjunction with the CAA is mandated and implemented, it should markedly reduce the inherent safety risk with the fin and provide a long-term solution to the risk.

2.31 If, as some paint scrapes and anecdotal evidence suggested, some pilots of turbine-powered Fletcher aircraft sometimes operated the engines past the maximum certified power setting, this could have imparted additional loads onto the empennage that had not been accounted for during approval. If this had been the case with ZK-DZG, it could have contributed to the propagation rate of the cracks in the fin. The CAA's Agricultural Aircraft Safety Review and investigation into the safety issues created by turbine-engined Fletcher aircraft operated above the certified engine power setting have addressed this issue.

3 Findings

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

3.1 The pilot was correctly licensed, experienced and authorised for the flight.

3.2 The pilot was operating the aircraft in an unserviceable condition because of a stuck airspeed indicator, which prevented him accurately assessing the aircraft airspeed. Consequently the aircraft could have exceeded its airspeed limitations by some degree in the turbulent conditions.

3.3 The structural integrity of the vertical fin had been reduced to such an extent by a cluster of unnoticed pre-existing fatigue cracks in its leading edge that eventual failure was inevitable. When the fin failed, it brought about an unrecoverable loss of control and the accident.

3.4 Although the early design of the vertical fin met recognised requirements, it did not provide for any structural redundancy and the leading edge of the fin (a structural component) was not damage-tolerant.

3.5 The cracks in the fin leading edge went unnoticed until the failure, most likely because an approved black rubber anti-abrasion strip along that surface had prevented any detailed examination of it.

3.6 The approved maintenance programmes did not reflect the inspection-dependent nature of the vertical fin for its ongoing airworthiness, with the inspection periods having been extended over the years without full consideration given to the importance of frequent inspections for timely detection of fatigue damage.

3.7 There was no evidence that the fitment of a more powerful STC-approved turbine engine, in place of a piston engine, had initiated the fatigue cracks in the fin leading edge. However, once started, the extra engine power might have contributed to the rate of propagation of the cracks.

3.8 The vertical fin defects and failures in the Fletcher aircraft over the years were not confined to turbine-powered aircraft.

3.9 The CAA's STC approval process for the turbine engine installation was generally robust and had followed recognised procedures, but the process should have been enhanced by an in-depth evaluation of the fatigue effects on the empennage.

3.10 Given the generally harsh operating environment and frequency of operations for the turbine-powered Fletcher, the continued airworthiness requirements of the fin were not scrutinised as robustly as they should have been during the STC approval process. Consequently the maintenance programmes had not been improved to ensure the ongoing structural integrity of the fin.

4 Safety Actions

4.1 Following the independent aeronautical engineer's inquiries and discussions with the company, and the company's discussions with the CAA, the company advised in July 2008 that it had taken the following actions:

- instituted a 100-hour check regime for its turbine aircraft fleet
- instituted a formal sign-in and sign-out process for aircraft on check
- "toolbox" [formal safety and hazard control] meetings in the hangar
- employed a dedicated Quality Assurance Manager.

4.2 The TC holder has redesigned the vertical fin for the Fletcher aircraft to overcome its inherent limitations, and issued service bulletin PACSB/FU24/094 for the replacement of the fin.

4.3 The CAA has taken the following actions:

- in April 2006 the CAA sent a letter to all agricultural aeroplane operators reminding them to ensure that their pilots observed aircraft airspeed limitations
- in May 2006 the CAA began an engineering review to examine the structural integrity of the Fletcher aircraft vertical fin. As a result the fin has been redesigned and on 30 April 2009 the CAA issued AD DCA/FU24/178 requiring implementation of the TC holder's service bulletin for fin replacement. The fin engineering review final report was released on the CAA website on 22 May 2009
- in June 2006 the CAA first issued AD DCA/FU24/176 that required the regular inspection of the leading edge of the Fletcher FU24 vertical fin. Subsequent versions of the AD required regular 50-hour inspections and the removal of all non-transparent protective coatings from the fin leading edge. Transparent protective tape could be fitted in place of the non-transparent coating
- in June 2006 the CAA began to review all approved agricultural aircraft maintenance programmes that allowed for scheduled maintenance programmes beyond the manufacturer's recommended inspection periods
- in November 2006 the CAA required an enhanced internal policy and procedure for the approving and amending of agricultural aircraft maintenance programmes
- in October 2007 the CAA began an Agricultural Aircraft Safety Review with a view to improving the general safety performance of that industry sector, and in December 2008 released the Review findings. Further consultation work with industry was planned for 2009 to address the findings
- in September 2008 the CAA began to investigate and establish the airworthiness safety issues created by turbine-engined Fletcher aircraft that were operated above the certified engine power setting.

5 Safety Recommendation

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

5.1 On 23 April 2009 the Commission recommended to the Director of Civil Aviation that he:

Take action to address the safety issues discussed in the recommendations of the specialist independent aeronautical engineer's review of the STC process, listed below.

> The CAA should make the introduction of a redesigned fin for all FU24's a very high priority.
>
> The Continued Airworthiness programme for the Walter Fletcher should be reviewed including the 150-hr maintenance periodicity to ensure that the lessons of several years of operation have been applied and that potential fatigue effects of operation with higher powered engines are properly accounted for. Any learning applicable to piston-powered aircraft should be disseminated widely. The Type Certificate holder should be involved where applicable.
>
> The CAA should clarify the divisions of responsibility for Continued Airworthiness of modified FU24 Aircraft between the original equipment manufacturer (PAL), STC holders, and design organizations.
>
> The Agricultural Aircraft Safety Review and the Part 137 Rules rewrite should be completed and acted on as soon as possible. (012/09)

5.2 On 17 April 2009 the Director of Civil Aviation responded to the preliminary safety recommendation and the CAA advised that this would be his comment on a final, similarly worded recommendation. The Director's response is included below in part:

> The CAA is actively working with the industry to introduce a redesigned tail fin, and anticipates that an Airworthiness Directive will be issued that will be effective from 30 April 2009;
>
> - The Airworthiness Directive will allow a compliance time of 18 months, giving the manufacturer (Pacific Aerospace) time to manufacture a sufficient number of new fins for installation by operators;
> - Until a new fin is fitted to an aircraft, an inspection programme is in place, which CAA monitors with respect to findings from the inspections;
>
> The CAA will review the Continued Airworthiness programme for the Walter Fletcher as a matter of priority;
>
> The findings of the Agricultural Aircraft Safety Review are being considered as part of the Part 137 rule rewrite, with the intention of having a revised rule before the Minister for his approval as soon as is practical; and
>
> The responsibilities for continued airworthiness are clear with respect to the original equipment manufacturer, STC holders and design organisations, although the effectiveness of the working relationships between the parties can be improved. The CAA is working with the various parties to help improve those working relationships.

Approved on 21 May 2009 for publication

Hon W P Jefferies
Chief Commissioner

Appendix 1

Ashton Technologies Limited's review of the supplemental type certificate process, STC-98/21E/15, for the Walter turbine-powered Fletcher aircraft.

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REPORT ASHTEC / TAIC 01/08

TO

THE TRANSPORT ACCIDENT INVESTIGATION COMMISSION

A REVIEW OF THE SUPPLEMENTAL TYPE CERTIFICATE PROCESS STC – 98/21E/15 FOR THE WALTER TURBINE POWERED FLETCHER AIRCRAFT

BY

DES ASHTON

ASHTON TECHNOLOGIES LIMITED

CARRIED OUT UNDER AGREEMENT DATED 13 FEBRUARY 2008

4 August 2008

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REPORT TO THE TRANSPORT ACCIDENT INVESTIGATION COMMISSION ON THE SUPPLEMENTAL TYPE CERTIFICATE PROCESS STC98/21E/15 FOR THE WALTER TURBINE POWERED FLETCHER FU24 AIRCRAFT

1. Introduction

Ashton Technologies Limited submits this report to the Transport Accident Investigation Commission (TAIC) under an Agreement dated 13 February 2008.

The Terms of Reference for the review are at Paragraph 3 below.

The TAIC has engaged Ashton Technologies as an independent consultant to carry out this review. The author of the report is Des Ashton an aviation consultant and company director. The CV at Annex A summarises relevant experience.

The report covers a review of the Supplemental Type Certificate (STC) process carried out by the STC Applicant / Holder Turbine Conversions Limited (later transferred to Super Air Limited) and the New Zealand Civil Aviation Authority (CAA) for the installation of the Czech manufactured Walter turbine engine in the Fletcher FU24-950 series aircraft (STC-98/21E/15). – (the “review” or the “report”)

The report also examines other matters relevant to the safety of the operation of FU24 aircraft and whether the turbine conversion carried out to Fletcher FU24-950 aircraft ZK-DZG directly bought about the failure of the fin and subsequent loss of the aircraft in a fatal accident on 22 November 2005.

The review has been carried out in parallel with TAIC Accident Investigation 07-010 (ZK-DZG)

The TAIC initiated the review and Accident Investigation 07-010 after representations by Pacific Aerospace Limited (PAL) to the CAA and to Government Ministers.

PAL (through its predecessors) is the manufacturer and holder of the New Zealand Type Certificate for the Fletcher FU24-950 aircraft powered by a piston engine.

PAL’s representations to the CAA and government ministers are detailed at Paragraph 5 below.

Prior to investigation by the TAIC under 07-010, ZK-DZG’s accident had been investigated by the CAA under Draft Aircraft Accident Report 05/3727 ZK-DZG (Reference C22)

As noted below, Fletcher FU24 aircraft have been fitted with several different types of piston and turbine engines over the lifetime of the aircraft. This report refers to the Fletcher FU-24 aircraft fitted with the Czech made Walter Turbine engine (by STC 98/21E/15) as the “Walter Fletcher”.

In this report, “fatigue” means the process of metal fatigue not the human condition.

Much of the report’s focus is on the implications of the STC for fatigue damage in the empennage and fin structure of the aircraft. Many of the issues raised by PAL relate to the fin and empennage and the Terms of Reference agreed with the TAIC include this matter. Fin defects and failures were also the focus of comment by people and agencies consulted in the preparation of the report. Along with the wing structure, loadings on the fin and other parts of the empennage are likely to change when aircraft are repowered.

The report does not address whether the Walter Turbine engine offers sufficient reliability and durability for use in Agricultural aircraft.

While the report focuses on the Walter Fletcher, many of the observations are relevant to any turbine or piston-powered conversion that provides a power increase.

The CAA, the industry including PAL, the AIA and the AAA have previously raised most of the issues covered by this report. The CAA and industry already have projects underway to improve safety in the agricultural aviation sector. While there are differing views on many issues including the repowering older airframes, there is wide support for efforts to improve safety in the sector.

There is also wide agreement with proposals to modify all Fletcher aircraft by fitting a redesigned fin with more damage tolerant characteristics.

The report examines the STC 98/21E/15 process in some detail. This may have application to future STC processes. It should be borne in mind, however, that the STC was approved several years ago. Since then the Walter Fletcher and similar aircraft have accumulated a large amount of actual operational service experience that can be drawn upon to make operational, maintenance and design changes to improve safety. This is likely to produce a bigger safety dividend than concentrating on the details of the STC process. The redesign of the fin is a case in point.

2. List of References and Documents Reviewed

Annex B lists documents reviewed in preparing the report.

Agencies and individuals including the CAA, TAIC, PAL, Super Air Limited, Aviation Design Solutions, Optimech, and the Defence Technology Agency provided these documents specifically for use in the review.

I have returned all documents not obtained through public sources to the TAIC.

3. People and Agencies Consulted in Compiling the Report

Annex C lists agencies and people consulted in compiling the report.

Consultation included formal and informal meetings and presentations, and communications by telephone and email. TAIC representatives Ken Mathews and / or Peter Williams were present at meetings with CAA, Pacific Aerospace, and Super Air.

I have received complete cooperation from all parties.

4. Terms of Reference

The Terms of Reference specified by the TAIC are:

Support of Commission's Purpose

The Consultant's role is in support of the Commission's purpose, which is to investigate and determine the circumstances and causes of accidents and incidents with a view to avoiding similar occurrences in the future, rather than to ascribe blame.

Professional Advice

In achieving this role, the Consultant is to provide the Commission with independent professional advice & services in the Consultant's field of expertise on matters as directed by the Chief Investigator of Accidents or Deputy Chief Investigator of Accidents. Work to be undertaken includes:

07- 010 Review of Fletcher Fin and Walter Turbine Conversion STC Process

- Determine whether the STC process used as the certification basis for the installation of the Walter Turbine Engine in the Fletcher Aircraft was appropriate and correctly carried out.
- This will include whether fatigue and maintenance issues were duly considered in the process.
- Determine what, if any changes to the STC process or any other relevant processes might be required to improve safety outcomes in this case and in general.
- This process will include a review of all relevant reports and would include meetings with CAA, PAL, and Super Air.
- Provide a written report and recommendations.

Additional Task Requested by TAIC Email (Ref A3)

- Provide a view on whether the turbine conversion to ZK-DZG directly brought about its fin failure and subsequent loss of the aircraft.

5. Submissions by Pacific Aerospace Limited to CAA and Ministers

A major factor leading to this report was PAL's representations to Ministers and to the CAA.

PAL is the current Type Certificate Holder of the of the Fletcher FU24 aircraft. The company also manufactures the Cresco agricultural aircraft the XL750, the CT4 Airtrainer and other aircraft types. PAL was incorporated in 2006 and acquired the assets of the FU24 Type Certificate holder Pacific Aerospace Corporation (PAC) in December 2006. The operating company's management changed along with the ownership.

The former company, PAC, and its predecessors had been in business for many years and produced more than 300 FU24 aircraft.

In 2007 PAL wrote to the Director of Civil Aviation, the Minister of Transport, and the Minister of Transport Safety, expressing "serious safety concerns" about the processes followed by the CAA and the STC Applicant in considering and approving STC 98-21R-15 for re-powered Fletcher aircraft (Refs B1, B2, B4 and B5)

PAL's initial correspondence referred to the Turbine powered Fletcher aircraft accident involving Walter Fletcher ZK-DZK at Pukenui Forest 22 November 2005.

Later correspondence referred to the loss of PT6 Turbine Powered Fletcher ZK-EGV near Opotiki 10 November 2007).

PAL's main concern was that the STC process did not take sufficient account of the effects on the airframe of power and torque increases introduced by the turbine engine. PAL considered that the testing and analysis carried out was inadequate. PAL had particular concerns that fatigue implications for the structure of the empennage and fin were not given due attention. PAL had other concerns arising from this basic position.

In support of the submissions, PAL commissioned studies by aviation experts:

- **Bernie Lewis** (Ref B6) – 20 August 2007 – A Review of the Draft CAA Accident Report 05/3727, ZK-DZG

- **D. Simons**, (Ref B7) – 7 September 2007
  Document Review – Loss of FU24-950 / M601D ZK-DZG

- **John Page and Zoran Vulovic** of Expert Opinion Services, University of New South Wales. (Ref B11) – 4 February 2008
  Critique of Optimech Report R705. (Optimech R705 reported on Fin Load Measurement Flight Trials on Walter and 400 Fletchers dated July 2007. - commissioned by STC holder Super Air at the request of the CAA)

PAL also cited a draft internal CAA Report obtained by PAL under the Official Information Act)

- **PJ Kirker** (Reference C12) then a CAA Safety Investigator – Review of the Certification Basis used for STC No. 98/21E/15.

This report forms the basis of many of PAL's submissions. It refers to "airworthiness safety issues that need urgent attention". While I do not agree with all the conclusions, it is a concise and useful report. The title does not fully reflect the full implications of the report. Issues such as the fact that DZG's fin and others were fitted with an anti-abrasive strip that made it difficult to inspect the fin are critical safety issues but are not a direct consequence of the STC Certification Basis.

PAL also expressed concern that in investigating the recent accidents the CAA would be investigating cases where its own performance may be an issue.

PAL proposed that the TAIC undertake independent investigations.

The TAIC has remedied part of PAL's concern by assuming responsibility for the investigation of the accidents involving ZK-DZG and ZK-EGV.

CAA's responses to PAL included a letter from the Director, Steve Douglas, dated 3 October 2007 (Ref B3) outlining current CAA action on three initiatives relevant to PAL's concerns:

- The CAA Engineering Review of the Structure of the Tail Fin of the Walter Fletcher;

- The CAA Accident Investigation 05/3727 ZK-DZG; and

- The CAA Agricultural Aircraft Safety Review. These initiatives are covered later in this report.

Since making the submissions, PAL has participated in a "Vertical Fin Engineering Workshop" held by the CAA on 2 February 2008. This workshop addressed safety concerns around the FU-24 Vertical Fin and mitigation actions currently underway. (Refs F1 to F3). It also demonstrated the methodology used by the applicant and by the CAA to justify the approval of the STC and it provided information on flight-testing and analysis carried out subsequent to the STC approval (Refs C13 to C17). Walter Fletcher STC Holder Super Air, the TAIC and other parties also attended this workshop.

I also understand that PAL is now meeting on a regular basis with the CAA.

These two initiatives should partly address a PAL concern on lack of engagement between PAL and the CAA in the engineering and modification activities involving aircraft for which PAL is the Type Certificate holder.

At Annex L, I have paraphrased PAL's questions and comments in PAL's letters to the CAA and to the Ministers of Transport and Transport Safety and have appended a comment on each issue. There is some repetition because information has been drawn from PAL's separate letters to the various parties.

PAL has invested considerable effort and financial investment in preparing their submissions and I have no doubt that the company's engagement will make a positive contribution to safety in the sector.

The TAIC has taken account of PAL's questions in setting the Terms of Reference for this review.

6. Background Information

The information below is included for context.

Annex D provides further detail.

a. History, and General Characteristics of the Fletcher FU24 Aircraft

The Fletcher FU 24 is an agricultural aircraft, manufactured in New Zealand used predominantly in New Zealand but also elsewhere in the world.

The Fletcher is the most numerous agricultural aircraft operating in New Zealand. Increasing numbers have been modified by the installation of turbine engines. CAA Quarterly flying hour returns (Ref H8) show that the hours flown by turbine powered FU24 aircraft has risen from zero in 1997 to more than 40 percent of total FU24 hours in 2007.

b. History of Power Increases through STC's for Fletcher FU 24 Aircraft

Since 1969, the Fletcher FU24 has been fitted with a number of different engines with greater power output than the 225HP piston engine originally fitted.

References K1, K2 and K3 list the evolution of these modifications. Most were developed in New Zealand and approved by the NZCAA or its equivalent at the time. The FU24 "Stallion" conversion that fitted the 665HP Garrett TPE331-101 engine was originally carried out in Australia and originally approved by the Civil Aviation Safety Authority of Australia (CASA).

The last "production standard" piston engine versions were the FU-950 and 954 with the 400HP Lycoming IO-720.

The fitting of these engines has been a process of evolution with each change drawing on information, test, and analysis from previous modifications. While the Walter engine clearly has greater available power than the originally fitted 225HP engine and the 400HP production piston engine, some of the turbine engine modifications that preceded it have greater power.

Annex E, produced by the CAA as part of the Vertical Fin Review is a history of Fletcher Aircraft engine installations and power ratings. This shows the power ratings of the various engines fitted including both piston and turbine engines. Various test and analytical methods have been used to determine the differing load cases resulting from these engine changes. In most cases, the analysis has been confined to static loads and extensive fatigue evaluations have not been carried out as part of the modification process. Fatigue effects have been accounted for by reference to satisfactory service of earlier versions, calculations showing that the stresses applied to various parts of the aircraft will not exceed the fatigue limit, satisfactory service experience of previous versions of the Fletcher and by reference to the "Continued Airworthiness Programme".

Annex E (History of Fletcher Aircraft Engine Installations and Power Rating) prepared by the CAA shows that there is considerable experience of the operation of FU24 aircraft with engines producing greater power and torque than the engines used in the original Fletcher that ranged from 225 hp to 285 hp. For example, the “Fletcher Stallion” conversion in Australia (CASA STC 209.1) mentioned by D. A. Simons, in Reference B7, installed a flat-rated 600 hp Honeywell TPE 331 engine. Mr Simons' notes in Reference B that a vibration survey of the horizontal stabilizer showed virtually no difference in frequencies of tail loads when compared with a piston-engined FU24. However, he points out that the installation of this engine involved a more detailed inspection schedule during the development phase and early operational use of the conversion.

c. The Nature of Metal Fatigue in Aircraft

Because many of the issues raised by PAL relate to relationship between the STC process and potential metal fatigue failures of the Walter Fletcher airframe, Annex F includes a brief explanation of metal fatigue for those unfamiliar with the process. For the same purpose, Annex F also includes two articles from the 1980’s describing aspects of metal fatigue.

I have observed over the years and during the course of this investigation that some in the industry are not fully aware of the nature of metal fatigue – for example the fact that a couple of years of operation will not necessarily provide a reliable indication of longer-term problems to come.

d. The Importance of Operational Demands, Inspection and Maintenance in Determining the Rate of Onset and Propagation of Fatigue Damage

From a fatigue perspective, the airworthiness and safe operation of aircraft depend on attention to detail in design, knowledge of and control of the way they are operated, the environment in which they operate and on inspection and maintenance. These factors are interdependent and good data is required to link them.

Of particular relevance to the Walter Fletcher and agricultural aircraft in general is the fact that the onset of fatigue problems can be accelerated by operation at heavy weights and by manoeuvre loads and ground-air-ground cycles made more likely by increased power and the “Agricultural Overload” provision.

To compensate for working aircraft harder there must be an appropriate inspection and maintenance programme in place. Modifications may be required. Also needed is regular monitoring of the way in which aircraft are being used and comprehensive reporting and analysis of defects, failures, occurrences, incidents, and accidents to pick up trends and react to them.

Much science and engineering effort has been applied to determining “fatigue lives” of aircraft and appropriate inspection intervals to prevent failures.

However, As John Page and Zoran Vulovic note at Reference B11 “in practice it is very difficult to predict fatigue failure either by analysis or experimentation. For light aircraft, the cost involved to ensure an acceptable level of safety is prohibitive and even in more sophisticated aircraft, weaknesses in the field of fracture mechanics make it hard to achieve. This has been overcome in modern aircraft design by using more robust structures where a single failure is not Cat C *(write-off of the aircraft)* provided an appropriate inspection regime is instigated.”

Even the well-funded US Air Force has recently permanently grounded many F-15 aircraft because of unexpected fatigue failures that are beyond economic repair. There are countless similar examples in New Zealand both civil and military.

As covered elsewhere in this report, in the case of the Fletcher FU24, the aircraft are ageing, they operate in a challenging environment, usage is difficult to monitor, and inspection and maintenance have sometimes been found wanting.

In the particular case of the FU24 fin, its design and the design of its attachment to the aircraft have been shown in service to be such that a single defect can cause potential catastrophic failure if not prevented or detected by maintenance action. Its structure is “inspection dependent”.

Fortunately, the fin structure is relatively easy to repair and recent redesign efforts will markedly improve its damage tolerance.

e. The Nature of the NZ Agricultural Aircraft Operating Environment

Agricultural aircraft operate in a challenging environment particularly in New Zealand where terrain is rugged, airstrips are often short, rough, and sloping, there is significant orographic turbulence, and aircraft mostly operate at low altitude. The combined effects of wet weather, chemicals, manoeuvre loads, gust loads, and sometimes less-than-ideal storage facilities mean that operating procedures and maintenance standards require greater attention than would be the case for aircraft operating in less demanding environments.

The “agricultural overload provision” dealt with elsewhere in this review adds another structural challenge.

The above factors apply to both piston and turbine FU24 aircraft.

f. Vertical Fin-Related Accident, Incident and Defect History of Fletcher FU24

There has been a history of defects and failures on the fins of Fletcher FU24 aircraft.

It is normal for any aircraft type to experience defects and failures in various parts of the structure over its lifetime. The important thing is that trends and weaknesses are recognized and corrective action is taken.

The CAA has carried out a comprehensive review of FU24 accidents, incidents, and defects. Various draft reports are at References F1 to F4. Annex H, a *DRAFT* CAA report titled “FU24 and Cresco Fin Failures and Occurrences Summary” dated 17 March 2008.shows that there have been regular failures and defects in the fins and attaching structure of Fletcher aircraft since 1972.

In the latter stages of preparation of this report, I was made aware of a parallel review of fin defects being carried out by Super Air in March 2008 (Ref M1). The report is still in draft. It covers similar ground to the CAA Fin Failures Summary but makes subtly different observations.

Most of the early reported defects were in the forward attachment fitting caused by corrosion, poor maintenance or both. In some cases, corrosion had initiated fatigue. It is likely that other incidents also involved fatigue but were not recognized or not reported at the time.

Regardless of the differences, both reports show that the design of the fin is not forgiving of inadequate maintenance.

A significant factor in some defects was the opaque leading edge anti-abrasion protective covering fitted by some operators. This had the effect of making an “inspection dependent” structure difficult to inspect.

All the early defects and failures involved piston-powered aircraft because initially there were no turbine-powered aircraft in service. Later, Turbine-powered FU24 aircraft were added to the fleet by modification of existing aircraft. The fin defect statistics reflect the change in fleet mix.

During its development and early service, the Cresco aircraft also suffered fin cracking and failures. Pacific Aerospace Corporation took corrective action at the time.

The data held by the CAA is likely to be incomplete. Fins have been repaired, replaced, or swapped in the field so not all failures and defects would be recorded. However, the CAA data probably includes the most significant incidents and accidents and recent efforts by CAA and the industry to collate the data have developed a reasonably comprehensive picture of the situation.

It is apparent from the history of failures that the current design of the fin and its attachment is neither "fail-safe" nor "damage-tolerant". It is in fact "inspection dependent". Damage or defects must be detected and corrected in time to prevent catastrophic failure.

It is also important to note that because the initiation points of most fatigue failures in the fin have been traced to corrosion or accidental damage this does not mean that fatigue failures will not occur in the absence of such factors. Initiation will just take longer.

CAA and industry have taken corrective action.

Firstly, CAA has issued Airworthiness Directives. These are listed below and included at References G1 to G5. DCA/FU24/175 relates to the wing and DCA/Cresco/13 to the Cresco aircraft. They are included for completeness.

- **DCA/FU24/172** 25/10/01 CAA
  Airworthiness Directive - Fin Forward Attachment- Replacement and Inspection - All Model FU24 Aircraft

- **DCA/FU24/173** 26/04/02 CAA
  Airworthiness Directive - Forward Fin Structure - Inspection - All Model FU24 Aircraft

- **DCA/FU24/175** 15/10/04 CAA
  Airworthiness Directive -Main (Wing) Spar- Inspection - All FU24 Aircraft *Fitted with Turbine Engines*

- **DCA/FU24/176C** 27/09/07 CAA
  Airworthiness Directive - Fin & Leading Edge - Inspection and Repair - All Model FU24 Aircraft (Note Rev A issued 31 May 2007 and Rev B issued 28 June 2007)

- **DCA/Cresco/13** 12/12/07 CAA
  Airworthiness Directive - Fin Leading Edge Inspection - Cresco 08-600 Series, All Serial Numbers (arose from Pacific Aerospace Limited Service Bulletin PACSB/CR/043

Secondly, three separate companies have completed, or are in the process of producing new damage tolerant fin designs. This will greatly reduce the risk of failure and reduce (but not eliminate) dependence on inspection. This activity is described elsewhere in this report.

The wings will require increased attention as the aircraft age.

Late in the preparation of this report, it was brought to my attention that in 2004 Super Air had carried out a Wing Spar Fatigue In-flight Strain Measurement Programme carried out by Optimech and an Analysis the Safe Life of the wing of the Walter Fletcher carried out by Murray McGregor (Refs M2 and M4). The analysis took account of an agricultural work flight spectrum including the agricultural overload provision. The latter included a requirement for the addition of straps to the wing spar under Modification SL/M/120. The recommended Safe Life of the wing of the Walter Powered FU24-950 with Modification SL/M/120 embodied was 10,000 hours. After this life, various wing components are called up for replacement.

g. Accident Rates of Repowered FU24 Aircraft Compared with Piston Fletchers -

Both piston and turbine powered Fletcher FU24 aircraft, have experienced accidents, incidents, in-flight failures and defects, over the years.

While comparisons are difficult, it is significant that the accident and incident rate for piston-powered aircraft from all causes is greater than that for turbine-powered aircraft.

At Annex J, the CAA has compared accident and incident rates of turbine and piston powered aircraft. The sample is small and the early data covers only piston powered aircraft. (Turbine conversions came later). There may be several reasons why the rates for piston aircraft are greater than for turbine-powered aircraft. For example, the greater power available to turbine-powered aircraft may enable pilots to manoeuvre their way out of trouble or more experienced pilots may fly turbine-powered aircraft. I have not attempted to analyze the trends in detail. The CAA is already carrying out this work as part of the Agricultural Aircraft Safety Review.

The most recent work by CAA shows that accident and incident rates of piston powered and turbine powered aircraft are statistically similar.

The point is that the safety question needs to be examined holistically. While the fatigue resistance and integrity of the fin and the rest of the structure are very important in the context of this review, other factors such as, say, training may be more significant in the overall safety picture.

h. Is it Safe to Fit Used FU24 Aircraft with More Powerful Turbine Engines?

Many industry observers question whether fitting turbine engines to aircraft with thousands of hours and cycles of service prior to modification and inevitable accumulated fatigue damage puts safety at risk.

The motivation for installing turbine engines is to access increased power, reliability, and flexibility over the piston engine previously fitted.

Anecdotal evidence indicates that the piston powered Fletcher FU24-950 will deliver 12 tonnes per hour and the turbine powered Fletcher (e.g. Walter Fletcher) 17 tonnes per hour.

From a fatigue damage perspective the additional productivity of the turbine means that on a per hour basis the turbine aircraft is carrying more, doing more cycles or a combination of both - probably because of take-off and climb performance and the ability to sustain manoeuvres at heavy weights. Additional work means more fatigue effects on the airframe if for no other reason than more cycles are being generated.

As noted elsewhere in this report, in a review of the STC 98/21E/15 the CAA notes that the STC modification did

> "not change the flight or (centre of gravity) envelopes of the aeroplane", and that "Therefore, in theory there should be no effects on the airframe. However, in practice, the performance of the turbine conversion allows the aircraft to use the full carrying capacity on a more frequent basis. Therefore, any weaknesses in the airframe will be shown up earlier, particularly in areas like the tailplane, undercarriage, and tyres that are more affected by operating weight and number of cycles."

In principle, provided the basic engine installation is sound (i.e. the engine does not pull out if its mountings etc) and operators observe load limits and other operating limitations, maintaining safety on a repowered aging aircraft should be an economic question. The operator must bear the increased cost and effort of inspection, maintenance, repair and modification to cope with the combined effects of increased performance and any extension of operating life that might be gained through the improved performance and other modifications.

An incidental consideration is that the extra power offered by the turbine almost certainly offers a safety benefit in some situations.

i. Observance of Engine and Airframe Limitations?

A consideration in the general safety question and in the question of whether the turbine installation might be a factor in any particular failure is whether operators observe placarded operating limitations. It would of course be unreasonable to expect an applicant or the CAA to take account of potential unprofessional operation in processing an STC.

There is anecdotal evidence that some FU24 operators do not observe operating limitations for the Walter engine.

Reference G6, an email report by Peter Kirker of CAA, reports that:

- Walter engineers advise that the M601D11-NZ engine can develop 620 hp if the pilot selects the maximum torque selection of 100%.

- There is evidence on some aircraft that the 89% (550shp) Flight Manual take-off power limitation has been regularly exceeded. He reports that this is apparent through a wear mark in the paint on the power lever arm caused by the pilots bending the lever arm around the adjustable limit (de-rate) stop.

- During normal operations, the adjustable stop is intended to allow the pilot to achieve the 89% (take-off) torque setting in varying atmospheric conditions.

- There appears to be no airworthiness instructions requiring pilots to document engine power exceedances.

If exceeding engine power limitations is not an isolated practice, it adds to the risk of fatigue failure of wings, empennages, engine mounts and other structural elements. The person who reaps the unfortunate result of such failures is often not the one who accumulated the damage in the first place.

j. Agricultural Aircraft Overloading

Agricultural aircraft overloading has been the practice in New Zealand for many years. The provision was originally introduced in USA under Civil Aeronautics Manual 8 (CAM 8), where it was applied in a relatively benign operating environment devoid of hills and with an accompanying requirement to limit manoeuvre loads and airspeed to protect the airframe and ensure safety. The provision was intended to allow aircraft not originally designed for the purpose to operate as agricultural aircraft subject to appropriate constraints.

There is anecdotal evidence that some NZ operators may not appreciate the long-term effect on the structure of the aircraft of failing to limit airspeed and manoeuvre loads when operating with the "CAM8" Agricultural Overload provision.

The effects of Agricultural Overload would be exacerbated by the use of turbine-powered aircraft that have the power to take advantage of the overload provision.

In 2005, the CAA commissioned a report on agricultural overloading by Mr Bernie Lewis. His report of 5 August 05 (Reference H1) provided ten recommendations to improve safety outcomes. His recommendations included that the fatigue life of old aircraft should be reassessed when they are fitted with turbine engines.

He also noted in his report that Murray MacGregor, the former chief designer at Pacific aerospace wrote to CAA 19 November 2000 stating that agricultural operations above normal category weights would only be acceptable if:

- There is a supporting engineering investigation that establishes aircraft fatigue characteristics at the higher weight;
- Operational limitations established as a result of the engineering investigation were made available to flight crew by means of a flight manual supplement covering operations under part 137; and
- Any change in airframe component lives and maintenance schedules established because of the engineering investigation should be available to maintenance organisations by means of a maintenance manual supplement.

As Mr Lewis notes in Reference H1 5 Aug 2005 report, at that time, there was no indication that Murray MacGregor's suggestions were acted upon.

However, the CAA has taken up the concerns of Mr Lewis and Mr McGregor since as part of the Agricultural Aircraft Safety Review commissioned by CAA with the involvement of industry. The Terms of Reference for that review are at Reference H2 dated 17 October 2006. This scope specifically includes a review of the recommendations of the 2005 Bernie Lewis report. Note that Mr. Lewis is also the author of an independent report supporting PAL’s submissions.

k. Inspection Requirements for Walter Fletcher Aircraft and Extension of Maintenance Periodicity to 150 hours

PAL and others have raised concerns regarding the extension of the maintenance periodicity in the Super Air Continuing Airworthiness Schedule for the Walter Fletcher to 150 hours where other Fletchers have a periodicity of 100 hours.

This periodicity was established in 2003 some years after the Walter Fletcher was introduced.

As noted elsewhere in this report, I understand from the CAA that the applicant established this periodicity through a structured process. Such an approach would normally require an analysis of the failure modes and consequences of failure of various components of the aircraft and determination of maintenance actions (if any) required to preserve airworthiness. It would also require feedback from in-service defects to be reported and analyzed and the programme adjusted if necessary.

There is sufficient justification from recent fatigue failures and from in-service experience of aircraft operation to prompt a review of this periodicity. For example, while there would have been very good reasons for fitting the opaque anti-abrasive strip on the leading edge of Fletcher Fins the fact that it was fitted to a part of the aircraft that in retrospect required regular inspection showed that there was at least one weakness in the overall inspection philosophy.

Such a review may show that 150 hours is a perfectly adequate periodicity, provided well directed inspections are carried out. If adequate written records are available showing how the 150-hour periodicity was established a review should be a straightforward task.

l. Redesign of FU24 Fin

There are currently three separate redesigns of the FU 24 fin either completed or underway. I understand that in all three cases, it is the failure history of the current fin and the recognition that it does not have inherent redundancy that has prompted the redesigns.

The redesign activity has been commissioned and /or carried out separately by

i. Super Air Ltd (by Aircraft Design Services)

ii. Pacific Aerospace Ltd (PAC Engineers - peer reviewed by Norm Taylor); and

iii. Wanganui Aerowork Ltd. (by Murray MacGregor)

All these designs incorporate a forward spar providing a much improved and forgiving load path. One has a removable non-structural fibreglass leading edge as well as a new attachment to the fuselage that includes a redundant load path providing a measure of fail-safe configuration. In all cases, the new fins would be a significant improvement on the original design. However, as with any such redesign it should not be assumed that all fatigue problems will go away forever or that new ones will not arise in their place.

The redesign activity is a sensible and responsible approach from all three parties.

Probably commercial imperatives have led to three separate redesigns being carried out concurrently. A collaborative approach might have been better but improved safety will result in any case.

Of all the actions currently underway, the replacement of the fin offers the most definite means of improving the structural integrity of all FU24 aircraft

m. Agricultural Aircraft Safety Review (Refs H1 to H4 and H8)

The CAA General Manager General Aviation Group commissioned the Agricultural Aircraft Safety Review 12 February 2007. It involves the CAA and a cross section of the industry. It aims – ‘to gather information, authenticate anecdotal stories as far as possible and make recommendations regarding currently operated agricultural aircraft design, continuing airworthiness and operational practices and techniques that would improve the safety of performance of the industry sector”.

The preamble to the Terms of Reference notes increasing concerns in the CAA and in some sectors of the agricultural aviation industry regarding the use of and re-powering of ageing aircraft and the lack of awareness amongst some agricultural pilots on the need to reduce speeds, manoeuvre loadings and G loadings at high all-up-weights. (i.e. agricultural overload provision.

The review is taking a commendable holistic view of the challenges laid down by the ageing fleet – a wider view than the detailed matter of the STC process.

The scope of the review is to:

- Review the Bernie Lewis report commissioned and completed in 2005 and to review the resultant recommendations.

- Review all New Zealand Civil Aviation Authority documented safety occurrences, findings, and open actions relating to agricultural aircraft.

- Review NZ airworthiness schedules for all agricultural aircraft types currently in operation or under certification.

- To conduct a study in association with NZ agricultural aviation operators and pilots to further quantify possible unreported incidents, occurrences, defects and structural failures and structural fatigue.

- Consider the airworthiness and operational implications of operating modified agricultural aircraft where old airframes are being fitted with more powerful turbine engines.

- Consider the implications of current non-terminating certificates of airworthiness in the agricultural context. (i.e. vs. 4 yearly and 8 yearly rebuilds of days past)

- Review NZCAA policy of the re-use of data plates from crashed aircraft.

- Discuss with Industry broader operational safety concerns such as hopper size, compliance with Limitations, Appendix B Overload provision.

- Consider the available technology to assist the measuring, recording and retrieval of hopper loads

Assuming the anecdotal problems identified in the scope are confirmed to be real and that they are quickly addressed, the Agricultural Aircraft Safety Review should markedly improve safety outcomes in the sector.

It is apparent that the resources of parts of the CAA are stretched. However, it appears that the Agricultural Aircraft Safety Review along with the Part 137 Rules rewrite below have high priority.

Priority action will be taken on any items identified as so urgent that they cannot wait for completion of the review(s).

n. **Part 137 Agricultural Aircraft Rules Rewrite Project (Refs H5 to H7)**

This project involves the MOT, CAA, AIA, AAA and wider industry representatives. Again, this project seems to have good industry support. Its Statement of Intent is to:

- Raise the existing standards and / or set new standards for agricultural aircraft operations to maintain lower accident and incident rates, and enable improved safety targets.

- Update areas of the rule that that have lost relevance due to changed equipment and technologies, and operating environments.

The project covers some of the same ground as the Agricultural Aircraft Safety Review including the aircraft overloading issue.

It is significant that a rewrite of any of the CAA rules can take up to five years by the time that all mandated processes are followed. This includes the time taken for consideration and approval by government.

o. CAA Defect, Occurrence and Failure Data Collection and Analysis and Involvement of the Aircraft Manufacturer in this Process.

The proper collection, investigation, analyzing, sharing and reporting of information relating to defects, incidents and accidents is fundamental to a well-functioning continuing airworthiness system. CAA Rules such as Part 12 and Part 146 cover the requirement.

In the case of the Walter Fletcher, good data is very important because the Continuing Airworthiness Maintenance Programme is cited as the method by which unexpected or early fatigue failures will be detected.

It is significant that part of the scope of the Agricultural Aircraft Safety Review is to "conduct a study in association with NZ agricultural aviation operators and pilots to further quantify possible unreported incidents, occurrences, defects and structural failures and structural fatigue." This study may not reveal any shortcomings but either way it is important that both the industry and the CAA operate based on good data and preferably the same data.

The CAA has recently upgraded its own procedures for categorization and analysis of information reported to or otherwise obtained by the CAA so that important trends can be recognized and acted upon.

The collation of failure data for the Annex H, CAA "Summary of Fin Failures and Occurrences" is an example of information that has been difficult for the CAA to collate in the past but is now easier to assemble.

While there are commercial sensitivities involved, it is important that the aircraft manufacturer remain in the loop for relevant defect and failure data. PAL contends that this has not always been the case for the FU24.

Whether flying hours are the right measure on which to base maintenance operations of agricultural aircraft is debatable. This is a question for others. The nature of the agricultural aircraft task is such that airframe and engine damage will most likely be a function of cycles. Flying hours are a suitable measure if there is a reasonably predictable relationship between cycles and hours and provided this relationship have been taken account of in design.

p. Descriptions of a Typical STC Process

Annex G provides for explanatory purposes, two flow charts showing examples of typical Supplemental Type Certificate Processes.

7. NZCAA Certification Basis of the Supplemental Type Certificate STC/98/21E/15 for Walter Fletcher Aircraft

The Certification basis used by the applicant TCL and the CAA to process, substantiate, and approve STC/98/21E/15 is recorded in a substantial set of drawings, test reports, stress reports and other documents.

I have examined the STC records held by the CAA. They are a well-organized record of the process

Relevant documents are listed in the References.

- References C1 to C10 are documents directly related to the original STC process.
- References C11 to C23 are later documents covering a range of relevant subjects including internal comment the STC process, the draft CAA accident report for DZG, additional testing carried out to substantiate fin loads etc.

- Reference C20 is a list of all relevant documents held in the CAA's data package for the STC.
- References D1 to D3 are background documents on maintenance programmes.
- References E1 to E6 are NZ and FAA Regulations and Advisory Circulars either used as the basis of the STC certification or cited by PAL or others as relevant to the process.

a. CAA Type Certification Requirements for STC No 98/21E/15 dated 2 Jul 98

CAA document "Type Certification Requirements, STC No 9/21E/15" (Reference C1) prescribed the requirements and processes to be used by Turbine Conversions Limited to certify the fitting of the Walter M601D engine in the FU24-950 Series aircraft.

Annex J 5 is a copy of the Type Certification Requirements for STC No 98/21E/15

It lists the following applicable documents. I have added comments in italics for clarity.

i. **US Civil Air Regulation 3 (CAR 3) amended to 16 May 1953**; *(CAR3 is the predecessor of FAR 23, which is the basic standard for Normal Category Airplanes).*and

ii. **FAR 23, effective February 1, 1965,** including Amendments 23-1 through 23- 52 to 27 March 1996 only as applicable to turboprop engine installation.

A list of FAR 23 paragraphs to be considered was attached to the document as Appendix 1. This list followed the recommendation of FAA Advisory Circular AC 23-14 Type Certification Basis for Conversion from Reciprocating Engine to Turbine Engine-Powered Part 23 Airplanes. As. is standard practice, this list formed the basis of a checklist used by the Applicant Turbine Conversions Limited to show compliance.

iii. Per **CAR 3.415,** the engine shall have been type certificated. The airworthiness standard shall be that listed in NZCAR Part 21 Appendix C. (The Walter M601D or M601D-1 certificated to FAR Part 33 under Czech Type Certificate No. 90-04 would be acceptable to the CAA); and

iv. Per **CAR 3.416,** the propeller shall have been type certificated. The airworthiness standard shall be that listed in NZCAR Part 21 Appendix C. (The Avia-Hamilton Standard VJ8.508D or VJ8.508D-AG certificated to FAR Part 35 under Czech Type Certificate No. 91-01 would be acceptable to the CAA.) The propeller shall also be shown to be a compatible installation with the engine and airframe; and

v. Any special conditions established in accordance with **NZCAR §21.23**.

Note. NZCAR §21.23 Special Conditions - states: "The Director may prescribe special conditions for a product to establish a level of safety equivalent to the airworthiness design standards specified in Appendix C if the Director determines that the airworthiness standards do not contain adequate or appropriate safety levels because— (1) the product has novel or unusual design features relative to the design practices on which the applicable airworthiness design standards are based; or (2) the intended use of the product is unconventional)

The "List of FAR Part 23 Paragraphs Applicable to a Turboprop Installation" at Appendix 1 to the Certification Requirements for STC 98/21E/15 includes a note:

> "The following list is based on the assumption that the original flight envelope and maximum weight limitations are retained and any power increase is small, and no approval is sought for flight in known icing conditions.(For further reference see FAA Advisory Circular 23-14)."

The rest of the document covers the Applicant's design responsibilities, the design approval and certification process, the documentation, and structural test required, as well as the ground inspection and flight test requirements.

It includes a statement requiring the Applicant to provide Continuing Airworthiness Support for the aircraft to all owners, and all national airworthiness authorities in countries in which the aircraft is officially operated. It requires that the Applicant demonstrate that it has the procedures and system in place to achieve this.

b. CAA Summary Report for STC 98/21E/15 8 August 2000 Walter Fletcher Conversion

The CAA Summary Report (Reference C5) reviewed and approved the STC process carried out by TCL including the test programme, Continuing Airworthiness Schedule, Equivalent Safety Findings for the Fuel Tank Filler, the Ice Protection, and the Speed Warning Device and approved the STC as compliant with FAR 23 amendment 23-52.

c. CAA (Updated) Summary Report 2/21E/17 8 May 2002 for Walter Fletcher Upgrade

A later CAA Summary Report (Reference C9) reviewed and approved an amendment to the STC to include a new model of propeller, the Avia V508E-AG/99B. This propeller offered better thrust at low speeds.

The document also reviewed a number of reported defects on aircraft with the STC embodied. Most of these defects related to the forward part of the aircraft. However, there were problems reported with damage to horizontal stabilizers and heavy-duty axles that were also investigated at the time.

This report also noted that the STC modification did

> "not change the flight or c.g. envelopes of the aeroplane", and commented that "Therefore, in theory there should be no effects on the airframe. However, in practice, the performance of the turbine conversion allows the aircraft to use the full carrying capacity on a more frequent basis. Therefore, any weaknesses in the airframe will be shown up earlier, particularly in areas like the tailplane, undercarriage, and tyres that are more affected by operating weight and number of cycles."

This is a salient comment that indicates the need to ensure that the inspection and maintenance requirements called up in the Continued Airworthiness Programme are capable of detecting defects resulting from such "weaknesses" in time to prevent them leading to catastrophic failure.

8. Turbine Conversions Limited Compliance Process for STC 98/21E/15

Turbine Conversions Limited (TCL) followed the CAA approved Certification process described above. TCL produced relevant drawings, analysis, reports, and documents (again listed at Reference C23) including:

- **Programme for Preliminary Restricted Category. - Agricultural Operation for ZK-JSW , ZF-EUF, ZK-BDS, ZK-CBA (FU24 -950 Series / Walter M601D Series) Revision 3 dated 6 August 1999**; (Reference C2) provided a programme to allow on-going monitoring of the modified aircraft over a shake-down or trial period on the return to service. The objective was to refine the design change through highlighting defective components and suggesting practical improvements to the modification components, their usage, and method of operation. The reference includes the comment that should concern be raised over any part of the modification, the operating procedures, engine and propeller maintenance procedures or appearance of defects, which may directly affect the airworthiness of these aircraft, the concern should be reported immediately to the project designer, and that aircraft grounded until the further notification by the project designer. The document provides reference to the revised flight manual supplement for the engine modification.

This monitoring programme was intended for detecting, monitoring, and correcting major deficiencies in the modification. It was not intended as substitute for the long-term surveillance required from the Continuing Airworthiness Programme.

- **Extract From TCL FU24-950 Series / M601D Flight Manual and Operators Handbook 30 August 1999**. (Reference C3). This extract provides guidance to pilots on power plant limitations; types of operations permitted, and airspeed limitations.

  In general, the limitations that it imposes mean that the aircraft is supposed to be operated within the same envelope as the 400 hp FU24-950.

  This is a fundamental assumption on which the CAA has based the STC process as it would be for all such STC's

  The Walter Fletcher, however, does have greater take-off, climb, and manoeuvre performance than the FU24-950. The aircraft is capable of carrying the maximum allowable load more frequently and of sustaining manoeuvres for longer.

- **Compliance Checklist for FU 24-950 Series / Walter M601D-1 Series Report – TCL-01-013R dated 8 August 2000** (Reference C4) This CAA approved checklist shows the means of compliance for installation of the Walter M601 series engine and Avia-Hamilton Standard VJ8.508D-AG propeller in the Fletcher FU24-950 Series aircraft. Against the applicable Federal Aviation Regulation paragraph numbers, it shows how the TCL has satisfied each requirement through the STC process - by test procedures, ground run trials, flight test, inspection, demonstration that the part of the design has not changed and the original means of compliance is not affected, or by reference to the Walter Fletcher flight manual etc.

  Three non-compliances are listed in the document and are shown to have been certified by "Alternative Means of Compliance" or "Equivalent Levels of Safety". These relate to:

  - FAR 23.973 – Fuel Filler Tank Filler Connection;
  - FAR 23.1093(b) Induction System Icing Protection; and
  - FAR 23.1303(e) Speed Warning Device.

  The justifications for these Alternative Means of Compliance are sound and consistent with accepted international practice.

  PAL's correspondence and reports by aviation consultants Mr. Lewis and Mr Simons and Mr Kirker of CAA have drawn attention to one paragraph of the Compliance Checklist .FAR §23.572(b)(3) Fatigue – Wing, empennage and associated structures. The checklist showed closing action for this paragraph as "Not Specifically Established" with the comment "See Note 3".

Note 3 in turn stated:

> "While the wing, empennage, and associated structure are currently not fatigue limited any effects from increased slipstream loading and vortex impingement on the structure will be monitored as detailed in the Continuing Airworthiness Maintenance Schedule, Section 5."

Again, this statement places reliance on the Continued Airworthiness Programme to provide adequate monitoring of the structure to detect impending failures. This dependence coupled with the extended 150-hour periodicity is the basis one of PAL's concerns regarding the STC.

- **Walter Fletcher Installation Instructions etc for the PAC Ltd FU24 Series with a Walter M601D Series Engine and Avia-Hamilton VJ8.508D-AG Propeller** (Reference C8) These instructions include the requirements for cockpit placards including "Max. Man. Speed $V_{A\,=}$ 116 KIAS" and "CAUTION This is an agricultural aircraft. Avoid severe flight manoeuvres. Do not exceed the maximum authorized weight. Disregard of this notice will greatly reduce fatigue life and may result in structural failure".

These placards should leave operators in no doubt of the influence of manoeuvre, weight, and airspeed on structural integrity.

9. Further Flight Testing – Including Tests Carried out in 2007 to Compare Fin Loads on FU24-950 Series 400 hp Piston Powered Fletcher and Walter Fletcher "Optimech Report"

a. Test Flight by Tony Morris CAA ACU Test Pilot

Supplemental flight-testing was carried out by CAA Air Certification Unit contracted test pilot Tony Morris in May 2001. Tony Morris is an Australian professionally qualified as a test pilot. His report noted that only one flight was carried out in one weight and centre of gravity configuration. The purpose of the flight was to determine if any significant safety-of-flight issues existed with the Walter-powered Fletcher, given that the STC for the modification had already been issued.

Mr. Morris noted that the installation of the Walter power plant had not "further degraded the flying qualities of the aircraft" (in reference to the fact that he judges that the original aircraft would have difficulty passing a full and comprehensive assessment under current FAR-23 requirements). He paid particular attention to the likelihood of the Vne of 145 knots being exceeded in normal operations. He concluded that the fundamental design of the aircraft tends to naturally limit speed in normal operations. Mr. Morris examined other relevant flight regimes. He noted that "for future programmes of this type CAA should plan for a more formal and structured flight test review to ensure compliance (or otherwise) with the requirements of FAR23".

b. Additional Flight Testing Programme to Compare Fin Loads on FU24-950 Series and Walter Fletcher (Optimech Report)

Reference C13 to C17 cover an additional flight-testing programme carried out in 2007 to compare the fin loads on the Walter Fletcher and the 400hp piston powered FU24-950 including design cases. This programme involved the CAA, Aviation Design Services, Optimech, and Super Air.

This programme appears to have been prompted by the investigation of the ZK-DZG accident. The data gathered is a useful comparison within the constraints of the test specification. The results were reported in Reference C16, Optimech Services R705 "Fletcher Fin Load Measurement Report" by Rod Mackay. In short, the report concluded that the loads on the fins of the Walter Fletcher and the FU24-950 Fletcher are very similar and in some flight conditions, the "vibration levels" in the FU24-950 exceeded those of the Walter Fletcher.

As noted in the next section John Page and Zoran Vulovic of Expert Opinion Services, claim that the Optimech report does not clearly state purpose of the flight-test programme and the flight profiles do not reflect what happens in operational service.

It is true that apart from take-off and climb performance at full power the Optimech flight tests do not measure the full effect of the excess power available on the Walter Fletcher nor the influence of this power on the frequency and duration of manoeuvre loads applied to the aircraft. It was not the intention of Optimech nor the CAA to carry out a comparison over the full spectrum of operation but rather to compare the magnitude and frequency of loads between the two different aircraft configurations.

On the other hand, the tests do measure specific load cases, some of which are greater than one would expect to see in day-to-day operation.

In short, the Optimech report was not intended to provide comprehensive information on the fatigue effects on the structure of the actual operation of the Walter Fletcher and the piston powered FU24-950. However, it provides useful information comparing the loads on the structure of the two aircraft under similar flight conditions.

10. Expert Opinion Services Comment on Optimech Report

PAL commissioned a report by John Page and Zoran Vulovic of Expert Opinion Services University of NSW dated 4 Feb 2008 titled Critique of Optimech Report. (Reference B11) This critique questioned many aspects of the Optimech report. Some of the points raised are summarized below.

Mr. Page and Mr. Vulovic point out that manoeuvre loads depend on the amount of excess power and if this remains constant as in the flight-test so does the manoeuvre loading. Their critique concludes by saying:

> "Though the limited amount of data indicates this, the large transients, though mentioned, are not investigated. It is these large loads occurring only occasionally that usually do the structural damage, especially when they remain undetected by tests like this.
>
> It is not clear what the objectives of this study were. It seems to do little to assist in determining whether the modification of exchanging the piston for a turbine engine resulted in the fin experiencing a more damaging load environment.
>
> There is a traditional approach, though somewhat outdated, which this approach may have been based on, of finding the maximum load and designing for a low stress level. If the maximum stress is kept below a certain value, it is assumed the structure will be safe from fatigue for a certain number of cycles, hours, or flights. The maximum stress level selected determines the expected time before failure. This fatigue protection strategy is based on

experience but has no theoretical base and is thus today regarded as a risky strategy. The data obtained could be aimed at this approach but there is no attempt to determine the maximum load by combining static, dynamic, and aerodynamic loading.

The flight test procedure is not appropriate to establishing aircraft loads. The tests conducted appear to be based on proofing trials. To obtain a permit to fly an aircraft produced as one of a number of similar aircraft has to be shown to conform to the type certificate. That is, it has to show, within an acceptable tolerance, it conforms to the vehicle or vehicles the testing of which led to the type certificate being issued. To achieve this, a number of flight tests are conducted to examine differences not absolutes. This procedure only works if the test aircraft and the one it is being compared with are close to identical. Theless identical, the less significant the comparison. It would, of course, be nonsense to compare an airliner with an agricultural aircraft or even one agricultural aircraft to one of a different manufacture. The error in these tests is to assume both aircraft were the same when in fact the modified aircraft was substantially different due to the power increase. If this had been a true forward of firewall modification without significant power change the test would, however, of been quite appropriate.

In practice, it is very difficult to predict fatigue failure either by analysis or experimentation. For light aircraft, the cost involved to ensure an acceptable level of safety is prohibitive and even in more sophisticated aircraft weaknesses in the field of fracture mechanics make it hard to achieve. This has been overcome in modern aircraft design by using more robust structures, where a single failure is not catastrophic provided an appropriate inspection regime is instigated. "

In short Mr Page and Mr. Vulovic suggest that more attention should have been paid to possible fatigue effects arising from the actual performance and use of excess power available to the Walter Fletcher and they reinforce the view that design and appropriate inspection are essential to the airworthiness process.

11. Was the STC Process Used as the Certification Basis for the Installation of the Walter Turbine Engine in the Fletcher Aircraft Appropriate?

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a. Civil Aviation Regulation in New Zealand

To place this report in context, it is important to understand regulation of civil aviation in New Zealand.

In common with other states, New Zealand's civil aviation regulation follows the principles and standards of the International Civil Aviation Organisation, an organ of the United Nations. These principles and standards are given effect in New Zealand by the Parliament through the Civil Aviation Act. The Act provides the duties (and accountabilities) of the participants, viz. the Minister of Transport, the Civil Aviation Authority (CAA) and the document holders. This last group includes both persons and organisations.

In brief, the Minister issues the Rules, the CAA administers (permits entry of persons and product, audits for compliance and conformity, investigates occurrences and ensures corrective action) and enforces the Rules. Persons and organisations undertake the activities by exercising the privileges of their aviation documents in compliance and conformity and when necessary, applying for changes to their documentation or exemption from the Rules.

The nature of NZ civil aviation regulation is 'light handed'; safety performance requires a dedicated commitment from each and co-operation between the three parties. It depends on a regulator that enables and promotes the well-being of those who provide services and safety of those who use them. An understanding regulator and a responsible industry are essential ingredients to a safety performance that is acceptable to the public.

The NZCAA is the Airworthiness Authority for aircraft operating on the New Zealand Civil Register. In general, the CAA follows similar practice to other National Authorities particularly when dealing with aircraft imported from those jurisdictions.

b. NZCAA Rule Part 21 Certification of Products and Parts

NZCAA Rules Part 21 prescribes the requirements for the issue of documents for products, their components, and appliances to allow for their use in the New Zealand aviation environment. Part 21 is based on the New Zealand airworthiness requirements previously contained in New Zealand Civil Airworthiness Requirements and those equivalent requirements of the US Federal Aviation Administration (FAA) and the European Joint Aviation Authority (JAA).

Of particular relevance to STC 98/21E/15, Part 21 includes coverage of the requirements for the issue and ongoing revision of type certificates, the approval of modifications, repairs, and the issue of Supplemental Type Certificates.

Paragraph 21.113 provides for the issue of Supplemental Type Certificates for changes to the original type certificate category, type design; the flight manual; the operating limitations; or any special conditions prescribed on the type certificate or type acceptance certificate.

Part 21 provides for the Director to issue an STC provided:

- he is satisfied that the applicant meets the applicable requirements of Part 21;
- it is not contrary to the interests of aviation safety;
- any airworthiness requirement that is not complied with is compensated for by a factor that provides an "Equivalent Level of Safety;" and
- there is no feature or characteristic of the changed product that makes it unsafe for the intended use, if it is operated in accordance with the correctly amended flight manual or other specified limitation.

Part 21 also provides for the Director to require other conditions that he considers appropriate.

Appendix C to Part 21 lays down applicable airworthiness design standards that may be used for Standard and Restricted Categories of Aircraft.

The permitted Standard Category airworthiness design standards include:

- most of the relevant USA Federal Aviation Regulations including Part 23 — Airworthiness Standards: Normal, Utility, Acrobatic, and Commuter Category Aeroplanes;) **or**
- a set of airworthiness design standards that the Director determines comply with ICAO Annex 8; and provide an equivalent level of safety to the FAA airworthiness design standards...

The permitted Restricted Category (included Agricultural) airworthiness design standards are the same as those for the Standard Category except that the Director may determine that some of the standards (e.g. relating to noise and emissions) may be inappropriate for the purpose for which the aircraft is to be used;

Again, Annex C to Part 21 allows the Director to specify under the Restricted Category

- a set of airworthiness design standards that the Director determines appropriate for the purpose for which the aircraft is to be used.

Note: There is no obligation in Part 21 for the Director to make the conditions for a restricted category aircraft more or less stringent than for a Standard Category Aircraft.

In both the Standard and Restricted Category cases, Annex C Part 21 requires provision of a flight manual containing the operating limitations and other required information in the form of a manual, markings, or placards etc.

In short, apart from the flexibility to exercise engineering judgment (and other forms of judgment) that already exists in the FAR's and the associated Advisory Circulars that the Director may choose to use, the Director has considerable scope to determine the airworthiness standards to be applied to STC's and other airworthiness related documents.

A salient consideration is the need to ensure there is no feature or characteristic of the changed product that makes it unsafe for the intended use, if it is operated in accordance with the correctly amended flight manual or other specified limitation.

c. Was the CAA's Choice of Certification Requirements for the STC 98/21E/15 Appropriate?

There are two questions here.

"Was an STC the Correct Instrument for Turbine Conversions Ltd. to apply for a design change to the Fletcher FU24-950 series of agricultural aircraft?

As noted above under Rule Part 21 provides rules governing the approval of a design change.

At 21.73, a design changes may be approved by –

- including it in an Airworthiness Directive (AD); or
- the approval of a modification; or
- the approval of a change to a type certificate or type acceptance certificate under Subpart D; or
- the issue of a supplemental type certificate under Subpart E.

At 21.79, a design change may be approved by the issue of an airworthiness certificate.

The use of an AD would be inappropriate. The change to a type certificate or type acceptance certificate would be inadmissible because the applicant is not the certificate holder (cf Advisory Circular AC21-1 at page 6) This AC requires the 'designer' of any identified change and who is not the holder of the type certificate to apply for a supplemental type certificate. The use of an airworthiness certificate would be inappropriate because the applicant wished to have the design change apply to the FU24-750 series of aircraft not limited to an individual aircraft (cf 21.79 (b)).

The approval of the proposed design change can only be made on the basis of a modification or the issue of a supplemental type certificate.

Design changes are acceptable if they are –

- described by the technical data listed in Appendix D; or
- accepted by the issue of an airworthiness certificate.

Approving the modification's technical data under 21.505 shall approve a modification.

An STC will be issued if the applicant provides, *inter alia*, –

- 21.33 - the type design data; and
- 21.35 – inspection and test programme; and
- 21.505(a) – Form CAA 337 approval of technical data; and
- 21.32 – affect on noise and emissions.

It is clear that the STC is the more demanding of these last two processes and, therefore, it is an appropriate certification basis for the design change.

"Were the appropriate airworthiness requirements specified as part of the STC process?"

Paragraph 8 of AC 23-14 that was used for guidance, includes the statement "an STC or amended TC application for turbo-propeller engine installation, the type certification basis should include the applicable prior certification basis regulations of the airplane being modified plus at least the latest amendment (through amendment 23-45) of the following sections of part 23 as they apply to the airplane modifications."

The original certification basis for the Fletcher FU24-950 was US CAR 3 amended 16 May 1953.

On this basis, the use of CAR 3 and the FAR 23 as the certification basis for the STC was appropriate.

The list of FAR Part 23 paragraphs specified by the CAA at Appendix 1 to the Type Certification Requirements for STC98/21E/15 applicable to a turboprop installation was also appropriate.

This list follows the guidance of FAA Advisory Circular 23-14 - Type Certification Basis for Conversion from Reciprocating Engine to Turbine Powered Engine – Part 23 Airplanes issued on 30 September 1993.

As noted in the preamble to AC23-14, "The Advisory Circular (AC) provides information and guidance concerning an acceptable means, but not the only means of showing compliance with part 23 through amendment 23-45 of the Federal Aviation Regulations (FAR) applicable to replacing reciprocating engines with gas turbine engines (turbo-propeller, turbojet, or turbofan). Accordingly, this material is neither mandatory nor regulatory in nature and does not constitute a regulation."

12. Was the Process Used as the Certification Basis for the Installation of the Walter Turbine in the Fletcher Aircraft under STC 98/21E/ 15 Correctly Carried Out ?

The rules governing the issue of a Supplemental Type Certificate (STC) and the responsibilities of a holder of a STC are at Subpart E of Rule Part 21 – Certification of Products and Parts.

The STC may be used to change the category of the type certificate, the type acceptance certificate category, the type design, the flight manual, the operating limitations, or any special conditions prescribed on the type certificate or the type acceptance certificate.

A high-level examination of the rule requires the applicant, putting the administrative details aside, to complete form CAA 2402/09 along with the information requested in

- 21.33 i.e. all the technical data associated with the type design and compliance with the accepted design standards; and
- 21.35 i.e. the inspections and tests that have or will be carried out and those that will be demonstrated; and
- 21.505(a) i.e. approval of technical data;
- 21.32 provision of aircraft noise and emission certification; and

- such further particulars relating to the design change as may be required by the Director as indicated on the form.

There is no CAA advisory circular relating to this Subpart, however, as noted above the US FAA Advisory Circular 23-14 "Type Certification Basis for Conversion from Reciprocating Engine to Turbine Engine-Powered Part 23 Airplanes" 30 September 1993 provides information and guidance.

The 'Type Certification Requirements STC 98/21E/15' makes reference, at Appendix 1, to the 'FAR Part 23 Paragraphs Applicable to a Turboprop Installation'.

This list constitutes the 'airworthiness standards' to be used for the design change. These sections of FAR part 21 are extracted from FAA AC 23-14.

FAA AC 23-14 also refers to other 'Related Regulations and Documents at Para. 2 and, in particular, FAR 21.19 and FAR 21.113.

> *FAR 21.19 Changes requiring a new type certificate.*
> *Each person who proposes to change a product must apply for a new type certificate if the Administrator finds that the proposed change in design, power, thrust, or weight is so extensive that a substantially complete investigation of compliance with the applicable regulations is required.*

> *FAR 21.113 Requirement of supplemental type certificate*
> *Any person who alters a product by introducing a major change in type design, not great enough to require a new application for a type certificate under 21.19, shall apply to the Administrator for a supplemental type certificate, except that the holder of a type certificate for the product may apply for amendment of the original type certificate. The application must be made in a form and manner prescribed by the Administrator.*

However, as demonstrated above, CAA only permits a design change to a type certificate if the applicant is the holder of that type certificate.

Turbine Conversions, the applicant, through its design organisation, Aviation Design Solutions, prepared the design based on the type design data and the 'Type Certification Requirements STC 98/21E/15'. It is understood that Turbine Conversions had purchased the type design data from the Type Certificate Holder, PAC and that the CAA supplied the type certification requirements.

As required by 'Type Certification Requirements STC 98/21E/15' the applicant is required to provide the Director with a statement of compliance provided by a design organisation certificated in accordance with Part 146 (Aircraft Design Organisations – Certification) stating that the technical data meets the airworthiness requirements, inter alia, of rule 21.31 (Airworthiness Requirements). Turbine Conversions prepared and submitted 'Compliance Checklist for FU24-950 series/Walter M601D-1 Series'- dated 8 August 2000.

A fundamental question in this review, at least in determining whether the rules were applied correctly, is whether the aircraft modification involved a "power increase". This is dealt with further in the next paragraph but is discussed in isolation here and in Annex M.

The last paragraph of AC23-14 states:

> "If engine power, airspeed limits, propeller rotational speed (revolutions per minute), or number of propeller blades are changed, the applicant should provide substantiating data showing that the vibratory response of the horizontal tail assembly to the propeller slipstream environment will not result in fatigue failures. [§§ 23.251, 23.572(a)(1), and 23.572(b)(3)].

The significant airworthiness standards relating to fatigue provided in 'Type Certification Requirements STC 98/21E/15' are -

23.251 Vibration and buffeting.

There must be no vibration or buffeting severe enough to result in structural damage, and each part of the airplane must be free from excessive vibration, under any appropriate speed and power conditions up to V_D/M_D. In addition, there must be no buffeting in any normal flight condition severe enough to interfere with the satisfactory control of the airplane or cause excessive fatigue to the flight crew. Stall warning buffeting within these limits is allowable.

§ 23.572 Metallic wing, empennage, and associated structures.

(a) For normal, utility, and acrobatic category airplanes, the strength, detail design, and fabrication of those parts of the airframe structure whose failure would be catastrophic must be evaluated under one of the following unless it is shown that the structure, operating stress level, materials and expected uses are comparable, from a fatigue standpoint, to a similar design that has had extensive satisfactory service experience:

(1) A fatigue strength investigation in which the structure is shown by tests, or by analysis supported by test evidence, to be able to withstand the repeated loads of variable magnitude expected in service; or

(2) A fail-safe strength investigation: or

(2) A damage tolerance investigation. *(not all three)*

§ 23.572 Metallic wing, empennage, and associated structures.

§ 23.572(b)(3). This requires each of the above investigations and evaluation to include typical loading spectra (e.g. taxi, ground-air-ground cycles, maneuver, and gust) account for any significant effects due to the mutual influence of aerodynamic surfaces; and consider any significant effects from propeller slipstream loading, and buffet from vortex impingements.

§ 23.627 This requires the structure to be designed, as far as practicable, to avoid points of stress concentration where variable stresses above the fatigue limit are likely to occur in normal service.

The compliance checklist for STC 98/21E/15 does not include § 23.572(a)(1) as a requirement but the fact that § 23.572(b)(3) is listed indicates that that an Applicant is expected to provide substantiation of fatigue effects:

The foregoing provides the basis of certification with relation to fatigue and buffet and contained in the 'Type Certification Requirements STC 98/21E/15' and derived from the references. However, there is an assumption made in Appendix 1 by the CAA. This assumption is that the original flight envelope and maximum weight limitations are retained, any power increase is small, and no approval is sought for flight in known icing conditions.

The STC Data Sheet (98/21E/15) issued for the modification does not specify any change to the design speeds or the centre of gravity limits so the assumption is correct in that element. The Data Sheet does not specify any changes to the weight limitations so that assumption is correct. Approval for flight in icing conditions was not sought so that is not a matter for concern either. However, the assumption that 'any power increase is small' requires further exploration.

I have explored with the CAA, the logic that led to the conclusion that there was justification to treat the Walter Fletcher installation as a "no power increase" or "small" power increase.

As background information, compared with the piston engines it replaced, the Walter engine has a lower engine speed but higher torque. (Torque and engine speed are measured - power is calculated).

Plainly, the take-off power offered by the Walter Turbine at 550 hp is more than that offered by a 400 hp Lycoming reciprocating piston engine.

The FU24-750 is the baseline aircraft since the STC is applicable only to models in that range. The FU24-750 was fitted with the Lycoming IO-720-AIA piston engine developing 400 shp. A range of Hartzell propellers could be fitted. The maximum take off weight was 5431 lb.

The Walter M601D-11NZ may be used up to its rated power of 410kW (550shp) but a cockpit placard limits this to Take-off and Climb. The power requirement, with the aircraft in level flight, will be such that the thrust provided by the M601D-11NZ powerplant is no different from the Lycoming IO-720-AIA/Hartzell installation. However, the additional power will be available to the pilot when the aircraft is accelerating or turning.

An aircraft involved in agricultural topdressing experiences a high number of take offs (accelerations) and high rate turns in normal operations. In theory, additional power applied during the take off run will increase the load on the vertical fin/rudder and the tailplane/elevator through increased propeller wash, increased torque effect, and possibly increased gyroscopic precession. This last factor will be relieved by the lighter weight of the Walter engine and it is worth noting that the Optimech report did not measure significantly increased loads on the fin of the Walter Fletcher during take-off. Any increase in the rate of turn is accompanied by in increase in load on the empennage. Turboprop installers claim that turboprop powered aircraft are more productive because of the greater number of cycles (missions) that may be achieved.

All of the above would lead to the conclusion that the Walter Fletcher conversion results in a power increase and that the assumption made in CAA document 'Type Certification Requirements STC 98/21E/15' that 'any power increase is small' is not valid. However, the last paragraph states that –

> *If engine power, airspeed limits, propeller rotational speed (revolutions per minute), or number of propeller blades are changed, the applicant should provide substantiating data showing that the vibratory response of the horizontal tail assembly to the propeller slipstream environment will not result in fatigue failures*
> [§§ 23.251, 23.572(a)(1), and 23.572(b)(3)].

Looking at the stipulations of this paragraph –

Changes to –

- Engine power – additional shaft horse power (plus jet efflux) is available;
- Propeller rotational speed – rotational speed is lower;
- Number of propeller blades – no change.

The requirement states that if any of the stipulations are changed then the applicant should *'provide substantiating data showing that the vibratory response of the horizontal tail assembly to the propeller slipstream environment will not result in fatigue failures'*. References are then made to Sections 23.251, 23.572(a)(1), and 23.572(b)(3).

Sections 23.251 and 23.572(b)(3) are called up in Appendix 1 of 'Type Certification Requirements STC

98/21E/15'. Reference 23.572(a)(1) is not included in Appendix 1. A careful reading of 23.572(b)(3) shows that it defines the loading spectra for 23.572(a)(1) so the requirements of this last reference would have to be met if the CAA had decided that a fatigue strength, failsafe or damage tolerance analysis had been necessary. However, 23.572(a)(1) is not relevant in this case where the applicant and the CAA have chosen to show that "the structure, operating stress level, materials and expected uses are comparable, from a fatigue standpoint, to a similar design that has had extensive satisfactory service experience" The CAA's assessment was that there were no adverse effects due to slipstream loading or vortex buffet and that this has been confirmed by the Optimech Load Comparison Review.

If the substantiation provided by the applicant fulfilled the expectations of 'Type Certification Requirements STC 98/21E/15' then the assumption regarding the power increase being small was of no import.

In the report 'Compliance Checklist for FU24-950 series/Walter M601D-1 Series', referred to earlier, the means of compliance is stated to be –

- Section 23.251 – Reference is made to the Flight Test Schedule Report TCL – 01- 008 at Part 4.In the absence of any evidence to the contrary, the writer believes this to be a qualitative test.

- Section 23.572(a) (1) – It will be recalled that the CAA did not call up this subsection.

- Section 23.572(b) (3) – 'Not specifically established – See Note 3'.

Note 3 states –

'While the wing, empennage and associated structure are currently not fatigue limited, any effects from increased slipstream loading and vortex impingement on this structure will be monitored as detailed in the Continuing Airworthiness Maintenance Schedule, Section 5.'

It was argued above, that the assumption that the power increase was small was not important provided that the requirements of Section 23.251, Section 23.572(a) (1), and Section 23.572(b) (3) were carried out. It may be seen from the statement above (Note 3) that proof of compliance with Section 23.572(b) (3) was not provided. It has been noted that Section 23.572(a) (1) defines the evaluations with Section 23.572(b) (3) providing the envelope (scope) of the 'evaluations'.

This chapter of the Rule Part deals with 'Fatigue Evaluation' with Section 23.571 dealing with 'Metallic pressurized cabin structures' and Section 23.572 dealing with Metallic wing, empennage, and associated structures.

An analysis of Section 23.572 reveals that the requirement is to demonstrate that any 'parts of the airframe structure whose failure would be catastrophic' must be evaluated to demonstrate the integrity of that part of the structure by a number of options –

- Section 23.572 (a) 1 i.e. a fatigue strength investigation using tests or analysis and tests that the subject structure is able to withstand the repeated loads of variable loads expected in service, **or**

- Section 23.572 (a) 2 i.e. a fail-safe investigation using tests or analysis and tests that catastrophic failure is not probable after fatigue failure, or obvious partial failure of a principal structural element …. **or**

- Section 23.572(a) 3 i.e. by reference to Section 573(b), a damage tolerance evaluation establishing the probable locations and modes of damage due to fatigue, corrosion, or accidental damage. The evaluation must incorporate repeated load and static analyses supported by test evidence. The crux of this methodology is that when the damage is at a degree where it is detectable there is sufficient strength in the structure not to fail catastrophically.

- Section 23.572 (a) offers another option, i.e. by showing that that the structure, operating stress level, materials and expected uses are comparable, from a fatigue standpoint, to a similar design that has had extensive satisfactory service experience.

By reference to Note 3, it would seem that the Design Organisation is saying that because '*…the wing, empennage and associated structure are currently not fatigue limited'* that the absence of a hard life dictated by fatigue considerations is absent then compliance has been demonstrated Section 23.572 (a), in the first instance, and that any '*effects from increased slipstream loading and vortex impingement'* will be monitored by the maintenance schedule. As noted above, I understand that the Design Organisation took the approach in Section 23.572 (a) that offered the option of recognising the service experience of the FU24-950 and other FU-24 variants and determining that it was satisfactory.

It is worth evaluating if this approach is sustainable. The first matter to note is that, contrary to the Design Organisation's statement (i.e, the lack of a hard fatigue life limit), the FAA has placed a life on parts of the wing structure (cf FAA Type Certificate Data sheet A9PC of 7,200 flight hours). While the FAA limitation is probably for administrative reasons and no limitation has been placed on the aircraft in NZ this limitation is worthy of note.

The second matter is the assumption that the service experience of the aircraft has been satisfactory in the area of fin integrity. The history of accidents and occurrences (both in flight and in maintenance) suggests that the experience of the fin structure had not been particularly 'satisfactory'. A number of the accidents, incidents, and defects prior to the engine conversion programme gave the cause as 'corrosion'. The true cause of any occurrence, so the adage goes, is not established until the question 'Why?' has been asked five times. The first 'Why?' would produce 'not found during maintenance', the second 'Why?' might produce 'maintenance periodicity too infrequent' or 'maintenance check scheduled but not able to be seen' or 'maintenance check scheduled but not carried out'. Any of the foregoing gives potential cause for concern. It is not clear how much of this information was available to the design authority at the time or what scrutiny it received. On the other hand, various remedial actions had been put in place over the life of the FU24 that were intended to prevent recurrences of each of the reported defects and failures. On that basis the Applicant and the CAA judged that service history was satisfactory.

The Applicant's Design Organisation offered no evaluation (analysis or tests) for the fin structure

The Applicant instead chose to substantiate this part of the STC on the basis that:

> "the structure, operating stress level, materials, and expected uses are comparable, from a fatigue standpoint, to a similar design that has had extensive satisfactory service experience."

In principle, this is a reasonable approach provided satisfactory service experience is demonstrated. As noted earlier there is substantial in-service experience with re-powered FU24 variants. While the FU24-950 is the baseline aircraft since the STC is applicable only to models in that range, several other repowered FU24 variants can provide comparative data for substantiation. Paragraph 6.b. above and Annex E provide a "History of Power Increases through STC's for Fletcher FU 24 Aircraft".

The argument and supporting test data for this approach was presented at the Vertical Fin Workshop at CAA on 5 February 2008 (References F1 to F3).

At the time of applying for the STC, the Applicant had purchased relevant data from PAC and had employed Pat Monk, former chief designer from PAC, a person highly familiar with the Fletcher in all its forms.

It is also relevant that the CAA (the Director) has the discretion to exercise good judgment in such matters and FAA AC 23-14 is an advisory document.

The CAA ACU contends that:

- All other performance and handling aspects were addressed as part of the STC;
- The increase in power was small, 10%. - the 37% increase over a Fletcher FU24-950 is a take-off condition, which was to be used only for a maximum of 5 minutes per flight intended to give better takeoff and climb performance only; and
- The permitted increase in power was based on a progressive approval process, which included previous turbine conversions of much higher power, and the earlier V8 STC.
- The important fact was that the basic operating envelope was going to be unchanged.

Taking into account the logic applied by the CAA and the analysis carried out by the Applicant, the treatment of the power increase through the installation of the Walter Fletcher engine in the FU24-950 under STC-98/21E/15 as a "no power increase" modification compared with previous designs was a reasonable judgment at the time.

The overall STC process used as the certification basis for the installation of the Walter Turbine Engine in the Fletcher Aircraft was adequate.

On the basis that the correct judgments had been made that the power increase was small and that previous similar variants had an extensive satisfactory service history reliance on the Continued Airworthiness Programme was also reasonable.

Reliance on the current Continued Airworthiness Programme alone for the long term airworthiness of the fin and empennage requires regular revisiting. As covered below the CAA and industry have addressed this through various AD's and industry participants have proposed three separate redesigns of the fin structure. This work also has application to other FU24 aircraft besides Walter Fletchers.

In cases such as STC 98/21E/15 where the certification basis relies on assumptions of usage and previous similar experience to cope with possible fatigue effects it is important that the Continued Airworthiness Programme is afforded continued attention.

13. Were Fatigue Issues Duly Considered in the STC Process?

The answer to this question has for the most part been answered by the previous paragraphs.

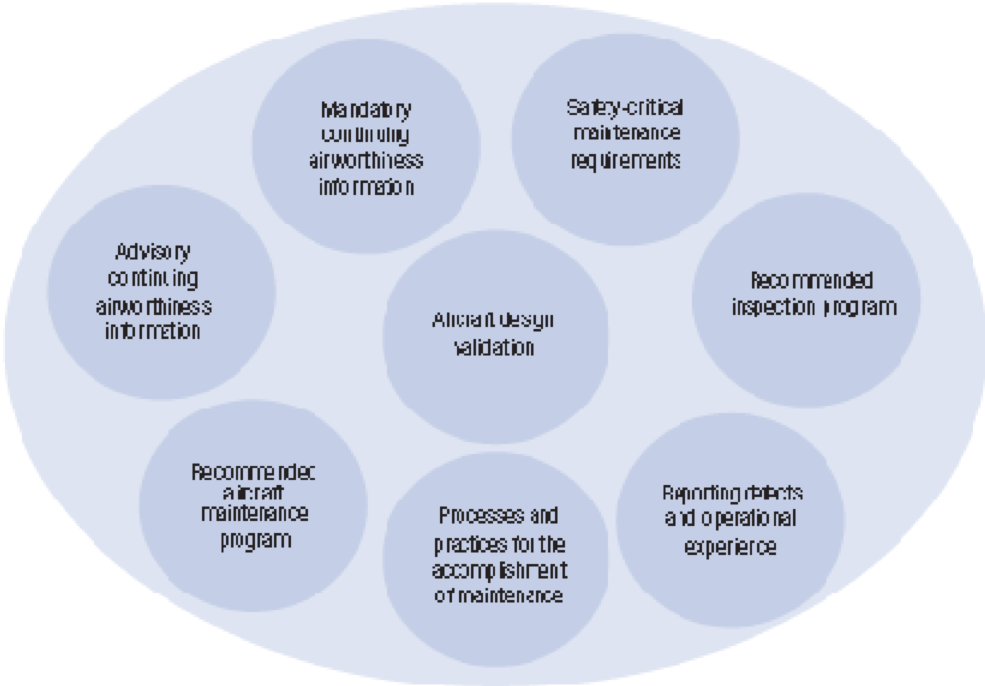
Effectively, STC 98/21E/15 substantiated fatigue compliance by a combination of showing that "that the structure, operating stress level, materials and expected uses are comparable, from a fatigue standpoint, to a similar design that has had extensive satisfactory service experience:" and by reference to the Continuing Airworthiness Programme.

14. Continued Airworthiness Programme and Responsibility

The Continued Airworthiness system is essentially a communication system among all the organisations responsible for the design, manufacture, regulation, operation, and maintenance of an aircraft type. The Figure below (from the Australian Transport Safety Bureau) is a representation of the elements of the system.

Within this system, fatigue and maintenance issues are always closely related. The approach usually taken to protect against the safety and cost effects of fatigue failures involves good design and materials, establishing through analysis, test and in-service experience the probable locations of failures and theneither redesigning the area or putting in place preventative maintenance, component life limits and inspection programmes. Inspection programmes need to be set up so that will have several chances to detect cracks before they lead to failure.

Basic elements of the continuing airworthiness system



This is certainly the case with the empennage and fin of the Walter Fletcher where the STC– 98/21E/15 process cited the Super Air Continuing Airworthiness Programme (inspection programme) as providing protection against the potential early onset of fatigue.

The Super Air Limited Walter Fletcher Maintenance Schedule (Section 5 is now Section 6 through insertion of a new Section 3) specifies that the airframe with some exclusions (- fuel system, engine mounts, instrumentation, controls, induction system, and lower NLG etc) is to be maintained to the Pacific Aerospace Corporation FU24 Series Maintenance Manual. i.e. The Super Air Continuing Airworthiness Maintenance Schedule for the Walter Fletcher does not call out any special inspections for the empennage or wing structure.

This of course indicates that under STC 98/21E/15 the same inspection criteria for potential fatigue issues was applied to the Walter Fletcher as to the FU24-950 and (I assume) all other repowered Fletchers through the inspection requirements of the standard PAC Maintenance Manual. However, as noted below, except where required by Airworthiness Directives, inspections are being carried out less frequently on Walter Fletchers than other variants because the Super Air Maintenance Programme is based on a 150 hour periodicity.

Three other factors are worthy of comment.

- The inspection periodicity of the Super Air Continuing Airworthiness Programme has extended inspections to 150 hours with CAA approval. This is a separate issue from the STC. As noted elsewhere, as part of a total package of inspections, monitoring and preventative maintenance a 150-hour interval may be quite appropriate. However, I have not seen the analysis that led to the

150-hour periodicity and I believe that the CAA should require Super Air to carry out an analysis to re-substantiate it.

- The fact that the PAC Maintenance Manual was specified for the Walter Fletcher is of concern to PAL because PAL contends that PAC was not adequately consulted on the Walter conversions. However, some of the original consultation took place two iterations of PAC management prior to the current management. I have dealt with this contention at Annex L. As a rule, it is highly desirable to keep the aircraft manufacturer \ Type Certificate Holder in the loop on all matters pertaining to aircraft manufactured by them. I have not attempted to dig into history on this matter. Suffice it to say that liaison should be maintained between the CAA, PAL, and other operators of the FU24. The Director should exercise his prerogative to require this liaison. I also note that part of the PAC Maintenance Manual pertaining to the fin has not been amended for 30 years. This is surprising considering the number of defects that have occurred.

- As noted below the leading edge of the fin had been fitted with an opaque rubber anti-abrasion strip that made visual inspection difficult.

'Type Certification Requirements STC 98/21E/15', at para.12 page 4, states that the applicant 'shall be responsible for providing continuing airworthiness support for the aircraft to all owners and all national airworthiness authorities in countries in which the aircraft is officially operated, in accordance with NZCAR 21.123(a)(1) and 146.61. The applicant shall demonstrate that they have (sic) the procedures and system in place to achieve this.' Emphasis added.

The applicant is not the aircraft Type Certificate Holder so it cannot provide airworthiness support for the aircraft. It may be argued that the applicant, at the time, Turbine Conversions Limited, is not qualified to provide airworthiness support at all because the design is the product of a Design Organisation, Aviation Design Solutions Limited. Making reference to 146.61 'delegates' the duty to the Design Organisation. Providing a solution is beyond the scope of this work but the anomaly needs to be addressed.

Civil Aviation Rules define an 'Airworthy condition' to mean the condition of an aircraft, including its components, fuel, and other materials and substances essential to the manufacture and operation of the aircraft, that complies with all the requirements prescribed by the Civil Aviation Rules relating to design, manufacture, maintenance, modification, repair, and safety:

The following Rule Part contain rules governing continued airworthiness –

Part	Description
21	Certification of Products and Parts
43	General Maintenance Rules
91	General Operating and Flight Rules
119	Air Operator – Certification
135	Air Operations – Helicopters and Small Aeroplanes
145	Aircraft Maintenance Organisations – Certification
146	Aircraft Design Organisations – Certification

Civil Aviation Rules further define 'Maintenance' in relation to an aircraft or aircraft component, means all work and inspections performed to ensure the continued airworthiness of the aircraft or aircraft component, and all modifications.

The 'work and inspections' that are required to be performed are contained in a maintenance manual that define the 'how' (i.e. the practices, tooling, limits, etc) and 'when' (i.e. the programme or schedule) of maintenance activities.

For completeness, the definition of a maintenance manual means an approved manual containing limitations within which the aircraft may be considered airworthy, and instructions and information necessary to ensure the aircraft is in an airworthy condition.

The award of a certificate of airworthiness demonstrates that the regulatory authority is satisfied that the design complies with relevant regulations and the issue of an approval to release an aircraft for service demonstrates conformity with the airworthiness certificate.

As stated above the document 'Type Certification Requirements STC 98/21E/15' required the applicant to provide continuing airworthiness support in accordance with 21.123(a) (1) and 146.61

Section 21.123 governs the responsibilities of certificate holder and requires the holder of the supplemental type certificate to undertake the continued airworthiness responsibilities required by 146.61 in respect of the change to a type-certificated product.

Section 146.61 defines the requirements, specifically for the granting of a design organisation certificate but in this case, to be used by a certificate holder. These requirements require the establishment of procedures to collect, investigate, and analyze information relating to defects in the design. There is also an obligation to distribute the information to other parties using the design, any other party that receives the design and the CAA under Rule Part 12.

In addition, through the use of Section 146.61 Turbine Conversions is required to establish procedures to distribute and provide any purchaser of the product with a copy of a 'set of instructions for continued airworthiness' i.e. a maintenance manual.

As may be seen above, the continued airworthiness requirement was limited to 21.123(a) (1). If this had been extended to 21.123(a) (2), it would require the supplemental type certificate holder to 'upon *the Director's request, provide the Director with evidence of appropriate liaison with the holder of the type certificate of the product'.* This might not have been an unreasonable and responsible request.

Turbine Conversions (or Super Air) provided the 'Walter Fletcher Continuing Airworthiness Maintenance Schedule' as proof of compliance with the requirements of 21.123(a) (1) and 146.61. Fundamentally, it provides for the airframe, apart from parts modified by the design and which are identified, to be maintained in accordance with the Pacific Aerospace Corporation FU 24 series Maintenance Manual.

The Walter Fletcher Maintenance Schedule does not appear to cover the requirement of 146.61 referring to the establishing of procedures for the collecting, investigating, and analyzing information relating to defects arising from the STC.

In short , at the time that STC 98/21E/15' was processed the obligations placed on the applicant (STC holder) to provide continuing airworthiness support for the aircraft relative to the obligations of the aircraft Type Certificate holder (manufacturer PAC) were not as clear as desirable.

While the CAA follows international practice in this regard, the net result was that until recently no one agency held a complete picture of the defect history of the fin and empennage of the FU 24 fleet.

As noted elsewhere, the CAA has subsequently put a commendable effort into gathering and analyzing available industry data on fin failures (Reference J4 - FU24 and Cresco Fin Failures and Occurrences Summary). This has largely resolved earlier shortcomings.

15. Did the Turbine Conversion to ZK-DZG Directly Bring About the Fin Failure and Subsequent Loss of the Aircraft?

In commenting on this question, I am dealing with the balance of probability and not certainty.

I have concluded that the Turbine conversion to ZK-DZG did not directly bring about the fin failure and subsequent loss of the aircraft.

The extra take-off, climb and manoeuvre performance of the turbine engine would certainly mean that the aircraft would have been working harder, delivering more product per hour and generating more cycles per hour than the piston-powered equivalent. This would in turn result in more frequent loads on the aircraft structure and accelerated crack propagation in the leading edge of the fin once any crack(s) initiated. Commonsense says as much.

However, while the extra power made available by the turbine engine may have been a contributing factor it would have been of less significance than other factors including the opaque anti-abrasion protection fitted to the leading edge of the fin that prevented visual inspection of the structure.

This follows from the probability that at least some of the damage propagation in the leading edge of the fin resulted from fatigue or other pre-existing damage, and that part of the leading edge of the fin failed or at least was significantly distorted, before failure of the rear spar of the fin occurred.

The current fin leading edge structure and its attachments are not "fail-safe" or "damage tolerant." In fact, like much aircraft structure they are "inspection dependent".

Had the leading edge been visible and the subject of a regular daily inspection then any accidental damage or significant cracking from fatigue or other causes may have been detectable before normal operation would cause failure.

As usual, it is likely that a combination of factors led to this accident. Apart from the engineering and maintenance aspects, there may also have contributions from operational factors and weather (gusts). I will not comment on those aspects.

The two separate experts in the field of structural failure who inspected components of the failed fin (MPT Solutions – Reference I3 and P. Conor, DTA – Reference F8) concluded that it was very probable that the leading edge of the fin had damage that existed for "some time" before the failure. Neither expert could determine with certainty whether the initial pre-existing damage was initiated by corrosion, accidental damage or impact damage (dents, scratches etc), from pure fatigue initiation of from other causes. However, both concluded that it was most likely that once it was initiated, the damage had propagated by metal fatigue, at least to some degree. Again, neither expert could state with certainly exactly how long the damage had taken to propagate from initiation to catastrophic failure.

Assuming that these two experts are correct and my opinion is that on the balance of probability, they are, then the accident would not have happened if any pre-existing damage present had been detected by inspection prior to the flight in question.

I understand that it was many flying hours since an engineer or pilot had the opportunity or obligation to inspect the fin leading edge structure of ZK-DZG with the protective rubber anti-abrasion strip removed.

In retrospect, the inspection requirements for the fin were inadequate. The CAA has now raised Airworthiness Bulletins to take account of these characteristics including requiring removal of the opaque anti-abrasion strip.

The 150-hour inspection periodicity applied to the Walter Fletcher may have been a factor but again not a direct cause of the accident. Most inspection programmes for critical structure would be designed to provide at least three chances of finding a fatigue crack between initiation and ultimate failure. Assuming the quality of inspection is the same (and where leading edge abrasion strips are installed that is in doubt); a 100-hour inspection cycle is more likely to detect a propagating crack before ultimate failure than a 150-hour cycle. This does not mean that the 150-hour inspection cycle is not acceptable when coupled with other more frequent inspections but as noted elsewhere in this report I believe that the 150-hour inspection cycle should be re-substantiated.

In short, I do not think that the Turbine Conversion was the direct cause of the loss of the aircraft. Nor do I think it probable that in the case of DZG an undamaged fin failed through damage incurred during one flight. More likely is a combination of pre-existing damage, lack of inspectability, a non damage tolerant design, and possibly the flight conditions at the time of the accident.

Note that Super Air has drawn attention to damage on DZG's antenna that may indicate evidence of a wire strike at some stage prior to the accident. This raises the possibility of pre-existing damage to the fin from a wire strike. This possibility should be considered by the TAIC in the accident investigation.

16. Changes to STC Process to Improve Safety Outcomes

I have been asked to comment on whether any changes might be made to the STC process to improve safety outcomes.

In general, the STC process used by the CAA is sound. It has been recognized as such, through mutual recognition arrangements with the FAA and other airworthiness agencies.

The CAA does not carry out many STC's of the scope of STC98/21E/15. The CAA has assured me that it takes account of broad operational and maintenance implications of STC's such as this by applying an "airworthiness board" approach. This brings broad experience to bear on the process and requires that final approval includes scrutiny from senior management of the responsible branches.

While I recognize the challenges of engaging the aircraft manufacturer in a process that might result in the production of a competitor for the manufacturer's products, it is highly desirable that the aircraft manufacturer should be aware of developments in an STC such as this. This should be the default position particularly in cases where the manufacturer and TC holder is a New Zealand Company.

A comprehensive review of the relevant defect history of the aircraft type should always be part of the STC process.

In the case of this STC the CAA would have been aware of the fleet service experience. However, the STC process took place prior to certification of the general aviation sector, and reporting occurrences in the field may have been the exception rather than the norm. It should be noted that the 'life cycle' model on which the 'light handed' regulator undertakes its business requires the 'learning' from investigated reported occurrences to be available to designers, maintainers and regulators comprehensive, freely available and acted upon.

17. Changes to Other Processes to Improve Safety Outcomes

Most of my discussions with industry members have served to confirm only that most of the aims of the Agricultural Aircraft Safety Review are relevant and the review needs to be completed as soon as possible. The same applies to the rewrite of Part 137.

Completion of these reviews should turn some anecdotal evidence into facts. There is a wide range of views and understanding in the industry regarding such issues as the effect of extending maintenance periodicity, the effect of operating aircraft in the agricultural overload provision, and the nature of aircraft metal fatigue and the factors that accelerate it. There is still the view that because an aircraft appears to be built like a brick outhouse and has operated satisfactorily four years that it will continue to do so forever. This is not the case in theory or in practice. As always, more education is required.

There is a need to continue work in the CAA towards an integrated approach to common goals. The internal CAA letter, which partly prompted this TAIC review, contained valid questioning of internal CAA processes. It would have been better if this type of scrutiny had resulted from a routine internal CAA audit or review, rather than in response to an aircraft accident investigation. Perhaps some form of peer review is justified if it does not already exist.

Working on the basis that "you manage what you measure", it is important that the CAA continues its drive to improve data collection and management processes. The Fletcher fin engineering review is a very useful piece of work. However, in the ideal world, this type of important information would be routinely available and the CAA is aiming to achieve that.

18. Conclusion

a) The STC process used as the certification basis for the installation of the Walter turbine engine in the Fletcher Aircraft was appropriate and for the most part, correctly carried out. There is considerable room for judgment in deciding which FAA Advisory Circular should be used for guidance in the circumstances and what substantiation processes should be used for each requirement. In this case, I have concluded that the application of CAR3 and FAR23 with the guidance of AC23-14 was an appropriate option.

b) The STC process did not include evaluations (analysis and/or tests) of fatigue effects on the empennage and fin. The alternative approach of using a satisfactory history of operation of similar types including similar engine conversions was used and is acceptable. However, in retrospect there were areas of concern from past service experience of the FU24 fin structure that indicated a need for more a more rigorous treatment of the Continued Airworthiness requirements than appears in the STC documentation.

c) Fatigue and maintenance issues are closely related. Considering the dependence placed on the Continued Airworthiness Inspection Programme as a backstop for potential fatigue problems, the documentation does not appear to provide it with sufficient emphasis. However, in practice evidence of ongoing analysis and fatigue tests indicates that Super Air's execution of the programme may in fact have been more thorough than indicated in the STC documentation.

d) I consider that the Continued Airworthiness programme for the Walter Fletcher should be reviewed including the 150-hr maintenance periodicity to ensure that the lessons of several years of operation have been applied. The approach should be conservative. If the decisions that led to the 150 hour periodicity are properly documented such a review should be very straightforward

e) The fact that a widespread, well-intentioned industry practice can arise where inspection-dependent fin structure can be covered by an opaque protective cover through which visual inspection is not possible confirms the need for further analysis of the inspection programme. This should ensure that the programme is based on a logical consideration of the criticality of structure, service experience and risk.

f) The redesign of the fin structure being carried out by three separate companies will markedly reduce safety risk and probably the ongoing cost of maintenance. This is undoubtedly the activity of most immediate importance to the structural integrity of the FU24 aircraft and it needs to be completed as soon as possible.

g) These actions in association with the outcomes of the Agricultural Aircraft Safety Review, and current FU24 AD's should be sufficient to mitigate foreseeable risks of fin structural failure.

h) While a comprehensive fatigue analysis of the Walter Fletcher (or all Fletchers for that matter) might help provide an indication of the location of probable future fatigue problems, a better investment of effort in the short term would be to analyse the problems that have shown up in many years of Fletcher operations and several years of actual operation of the higher powered versions including the Walter. This information should then be directed at improving inspection and maintenance programmes. Ongoing monitoring of aircraft defect and occurrence trends is a fundamental part of Continued Airworthiness programmes.

i) In recent years, the CAA has increased liaison with Type Certificate and major STC holders including regular visits and exchange of information. This is a very positive development.

j) Placarded limitations are in place to control operating envelopes. However, despite incredulity in some quarters, extra demands are being placed on older airframes by the increased performance provided by turbine engines. The turbine aircraft deliver more per hour and basic logic dictates that this comes at a price in airframe life. There is also demonstrable evidence that some operators are exceeding the placarded limits.

k) The Agricultural Aircraft Safety Review and the Part 137 Rules rewrite are important reviews that have been given a high priority by the CAA and industry. They need to be completed quickly and some of the more important line items may need to be extracted for early attention. e.g. the Agricultural overload provision.

l) There are a number of other issues that have been highlighted during the preparation of this report where changes could be made to systems to improve safety. It is probably reasonable to refer to these as "systemic safety issues". None of them is new and corrective action for most of them is already in hand through various CAA and Industry initiatives including the Agricultural Aircraft Safety Review. In some cases, more urgent attention would be justified. These include observance of limitations, methodology for continued airworthiness programmes, agricultural overload provisions and modification programmes to improve the fin.

m) Within the limits of the information available to me, I have concluded that the Walter Fletcher Turbine Conversion was not the prime cause of the loss of its fin and the loss of the aircraft. The extra power available to the aircraft may have been a contributory factor but other factors are likely to be of more significance. E.g., the fin leading edge cannot be properly inspected when covered by an opaque anti-abrasive strip.

n) The CAA people I dealt with in the preparation of this report were highly professional and cooperative. As is usual in any organisation, there is a degree of compartmentalization in the CAA and continued management awareness is needed to ensure that the best decisions are made. I would be pleased to elaborate on this comment if required.

o) Industry people were also extremely forthcoming and helpful. There is a wide range of views on industry issues – some very strongly held. The conclusions of this report fall somewhere in the middle of industry opinion.

19. Recommendations

a) The CAA should make the introduction of a redesigned fin for all FU24's a very high priority.

b) The Continued Airworthiness programme for the Walter Fletcher should be reviewed including the 150-hr maintenance periodicity to ensure that the lessons of several years of operation have been applied and that potential fatigue effects of operation with higher powered engines are properly accounted for. Any learning applicable to piston-powered aircraft should also be disseminated widely. The Type Certificate holder should be involved where applicable.

c) The CAA should clarify the divisions of responsibility for Continued Airworthiness of modified FU24 Aircraft between the OEM, STC holders, and design organisations.

d) The Agricultural Aircraft Safety Review and the Part 137 Rules rewrite should be completed and acted on as soon as possible – I am aware that both are receiving high priority.

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4 August 2008

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