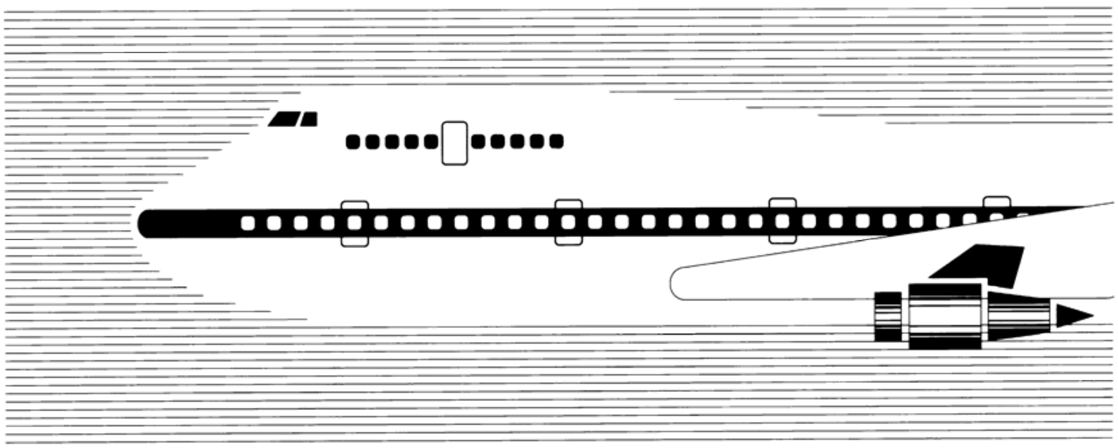

A V I A T I O N   O C C U R R E N C E   R E P O R T

05-008 **Cessna U206G, ZK-WWH, loss of control on take-off, Queenstown Aerodrome** **10 August 2005**

TRANSPORT ACCIDENT INVESTIGATION COMMISSION
NEW ZEALAND

Report 05-008

Cessna U206G

ZK-WWH

loss of control on take-off

Queenstown Aerodrome

10 August 2005

Abstract

On Wednesday 10 August 2005, at about 0845, ZK-WWH, a Cessna U206G, took off from Queenstown Aerodrome for Mount Cook Aerodrome with a pilot and 5 passengers on board. Just after take-off, the pilot encountered control difficulties that culminated in the aircraft striking the runway with its left wing tip and failing to remain airborne. The aircraft was substantially damaged, but no one was injured.

Although the pilot had taken action to remove frost from the aircraft, a layer of frost remained on the wing upper surfaces for the take-off. It was possible that wake turbulence from a preceding Cessna 206 initially upset ZK-WWH, but the frost on the wings was considered to be the main reason for the loss of control. In addition, the centre of gravity position was probably aft of the rear limit for take-off.

Safety issues identified included:

- the need to ensure critical aircraft surfaces are completely free of contaminants, such as frost, before flight
- pilots' awareness of wake turbulence and the need to report severe wake turbulence encounters
- the specification of all relevant conditions in weight and balance calculations
- the accuracy of safety briefing information provided to passengers
- the proper restraint of baggage and cargo.

Safety recommendations were made to the operator and to the Director of Civil Aviation, as appropriate, to address these issues.

ZK-WWH after the accident

Contents

Figures

Abbreviations

agl	above ground level
AIA	Aviation Industry Association
AOPA	Aircraft Owners and Pilots Association
ATC	air traffic control
ATSB	Australian Transport Safety Bureau
^{o}C	degrees Celsius
CAA	(New Zealand) Civil Aviation Authority
CAR	Civil Aviation Rule(s)
CG	centre of gravity
ELT	emergency locator transmitter
ft	foot/feet
GAP	Good Aviation Practice, a CAA booklet
ICAO	International Civil Aviation Organisation
IFR	instrument flight rules
kg	kilogram(s)
KIAS	knots indicated air speed
kt	knot(s)
m	metre(s)
MCTOW	maximum certificated take-off weight
NTSB	National Transportation Safety Board
OM	Operations Manual
POH	Pilot's Operating Handbook
RFS	rescue fire service
RPM	revolutions per minute
sec	second(s)
UTC	coordinated universal time
VFR	visual flight rules

Data Summary

Aircraft registration:	ZK-WWH
Type and serial number:	Cessna U206G, U20603550
Number and type of engines:	one Teledyne Continental IO-520F
Year of manufacture:	1976
Operator:	Fiordland Experience Group Limited
Date and time:	10 August 2005, 0845[1]
Location:	Queenstown Aerodrome latitude: 45° 01.1´ south longitude: 168° 45.1´ east
Type of flight:	air transport, passenger
Persons on board:	crew: 1 passengers: 5
Injuries:	nil
Nature of damage:	substantial to left wing, landing gear, propeller and engine compartment
Pilot's licence:	Commercial Pilot Licence (Aeroplane)
Pilot's age:	43
Pilot's total flying experience:	1858 hours (570 on type)
Investigator-in-charge:	P R Williams

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

1 Factual Information

1.1 History of the flight

1.1.1 On Wednesday 10 August 2005, the operator provided 2 Cessna 206 aircraft, ZK-WWH and ZK-TFW, to fly 10 foreign tourists from Queenstown to Mount Cook. Another company provided a BN2 Islander aircraft to carry other members of the tourist group. The 3 flights were to be flown under visual flight rules (VFR).

1.1.2 Neither Cessna had flown since the previous Monday, and both had been parked outside since then. The operator had not fitted frost covers over the aircraft wings because no frost had been expected, but overnight on Tuesday 9 August the air temperature dropped to minus (–)2^{o} Celsius (^{o}C).

1.1.3 On the Wednesday morning, the pilot of ZK-WWH (the pilot) arrived at the aerodrome at about 0730. After completing a pre-flight inspection of ZK-WWH, he performed an engine run-up then added some fuel. He taxied the aircraft to the terminal apron and shut it down. While he waited for the passengers, the pilot prepared the cabin and cleaned the exterior of the aircraft. These duties were probably completed by 0800.

1.1.4 In his incident report to the operator, the pilot said that he had swept "the leading edges of all control surfaces to free a small amount of frost". He later said that he had used a broom to sweep the wings, tail and control surfaces, and that he had cleaned the wing upper surface by standing on the fuselage refuel steps, and by reaching forward from the wing trailing edge. He said that when he had finished cleaning, there was "absolutely no ice on the wing" and the tail plane "was completely clear".

1.1.5 An airport worker later said that he had seen the pilot cleaning frost from ZK-WWH. The Islander pilot said that he had seen ZK-TFW, but not ZK-WWH, being cleaned, but he had parked next to the 2 Cessna aircraft at the terminal and had not noticed frost on either aircraft.

1.1.6 The pilot of the other Cessna 206, ZK-TFW, said that he had twice brushed his aircraft, with a broom, to remove the frost from the wings and control surfaces. The pilot of ZK-WWH then recalled that he, too, had twice swept his aircraft clean: once prior to the engine run-up, and again after parking outside the terminal before meeting his passengers.

1.1.7 A local company arranged the tourists' travel, and their agent said that he had heard the runway at Mount Cook was affected by early-morning ice, so there was no hurry to depart. The passengers arrived at the terminal at 0810 and 5 of them boarded ZK-WWH at about 0840. The pilot drew the passengers' attention to safety briefing cards written in their own language.

1.1.8 The pilot had loaded 5 sets of ski boots into the baggage area of ZK-WWH, behind the rear row of seats. There were tie-down rings on the floor, but no net was carried on the aircraft for securing baggage. The operator did have some nets available at the Queenstown Aerodrome. A set of skis was placed, unsecured, in the centre of the cabin between the seats and butted against the bottom of the instrument panel centre pedestal.

1.1.9 The pilot had completed the operator's passenger manifest, also referred to as the load sheet, using a standard weight of 83 kilograms (kg) per passenger. The boots and the set of skis were estimated to weigh 30 kg. The calculated take-off weight was 1590 kg, compared with the maximum certificated take-off weight (MCTOW) of 1633 kg.

1.1.10 The 3 aircraft taxied at about the same time. The duty aerodrome controller (the controller) cleared all 3 aircraft to line up on runway 05 at the intersection with taxiway A (see Figure 1). The use of multiple line-ups was an air traffic control (ATC) procedure that was often used at Queenstown when many VFR light aircraft departed in a stream. ZK-TFW was lined up first, just to the left of the runway centreline. ZK-WWH was behind, near the left side of the runway, and the Islander was further back, right of the runway centreline.

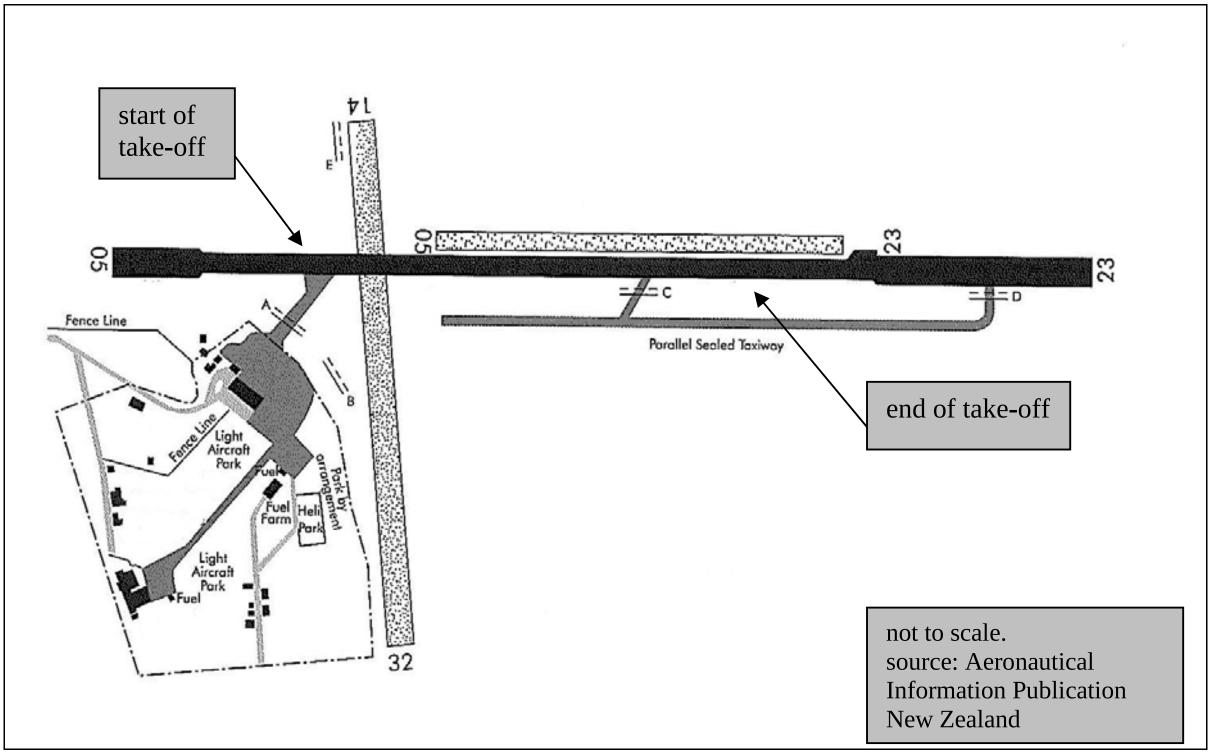

Figure 1
Queenstown Aerodrome plan

1.1.11 The aerodrome conditions recorded at 0834 and broadcast to traffic were wind from 010° magnetic at 4 knots (kt), visibility 70 kilometres, air temperature -1°C, dew point[2] -3 °C, and air pressure 1014 hectoPascals. There was a broken layer of cloud at 2000 feet (ft), and the forecast 2000 ft wind was 230° at 15 kt.

1.1.12 At 0844, the controller cleared ZK-TFW for take-off. ZK-WWH was cleared to take off in turn. The pilot set the flaps to 10° and performed a check of the flight controls. The elevator and rudder trims were set as normal. The pilot said he estimated that when he started his take-off, ZK-TFW was about 100 ft (30 m) above ground level (agl). A trainee controller said that ZK-TFW had passed taxiway C and was well airborne before ZK-WWH started its take-off roll.

1.1.13 The pilot said that the engine delivered full power and the aircraft accelerated normally. Once the controls felt light and the aircraft wanted to fly, he held the nose down until 60 kt indicated air speed (KIAS) and then gently applied aft elevator. He said that the aircraft got airborne after a ground roll of about 300 m, well before taxiway C, but almost immediately began to yaw and roll, quite violently, to the right. The pilot said that full application of aileron was required to oppose the roll, but then the aircraft yawed and rolled to the left. The pilot said that he felt that the aircraft "waffled all over the place" and that the controls felt "sluggish", but not restricted.

1.1.14 None of the passengers could see ahead through the windscreen during the take-off, but they described the aircraft's movement as a sharp roll to the right, followed by a roll to the left. The front seat passenger recalled seeing the pilot making lots of control inputs. The passengers said that they thought the aircraft climbed no more than a few metres above the runway, and that the wheels hit the runway twice before the aircraft tipped forward onto its nose.

[2] Dew point is the temperature at which air becomes saturated with contained water vapour. When the air temperature is cooled to its dew point, water vapour condenses out.

1.1.15 The passenger in the left rear seat had made a video recording that included most of the take-off. The take-off segment of the recording began after the take-off roll had commenced, with the camera generally aimed between the left wing tip and directly abeam the aircraft. It was not always possible to differentiate camera movement and aircraft movement, but a touchdown was apparent. The left wing tip was seen to hit the runway 18 seconds (sec) into the segment. At that stage, it could be seen that the aircraft had drifted across to the right side of the runway. For the rest of the recording, the camera was pointed at the cabin floor. The engine note was steady throughout the 25-sec recording, which ended with a sound of an impact.

1.1.16 The pilot said that the stall warning horn did not sound. He said that when he felt the aircraft was uncontrollable, he closed the throttle, pulled the mixture to shut-off, and turned off the master electrics switch. The aircraft remained upright and came to rest on its nose in the grass, facing southeast, about 5-10 m off the southern side of the runway.

1.1.17 The pilot and 3 of the passengers exited the aircraft through the pilot's door. The 2 passengers in the rear row tried to use the right rear cargo door, through which they had boarded the aircraft. Their exit was slowed by the forward half of the door binding on the wing flap, which was partly lowered for take-off. The pilot assisted them from outside the aircraft after he had ensured the other passengers were out. He then returned to the cockpit and checked that the engine shutdown checks were complete and that the fuel selector was off.

1.1.18 The Islander pilot said that when ZK-WWH took off, the sun was to the left of the runway direction and obscured by cloud. There was no wind. The Islander pilot observed ZK-WWH make a normal take-off before it began to yaw right, then left, when about 20-25 ft (6-8 m) agl. The aircraft drifted from left to right across the runway. A violent "wing rock" developed and the aircraft nose went high. The left wing then dropped violently and the aircraft pitched down.

1.1.19 A local pilot, who was at the aerodrome maintenance area and saw most of the take-off, said that he thought the aircraft sounded and looked normal during the take-off roll. He said the right wing then lifted, and another wing lift occurred about 70 m further down the runway. He said the aircraft appeared to be airborne but not climbing, before it abruptly pitched up and rolled to the right before going out of view.

1.1.20 The controller said the aircraft appeared to get to a height of about 3-4 m agl before it began a shallow right turn, and then sank onto the runway. The take-off concerned him enough that he alerted the other control tower staff. ZK-WWH lifted off again, got a little higher and banked more sharply than before, but touched down again. When it lifted off a third time to about 10 m agl, but appeared very "waffly", the controller activated the crash alarm. The trainee controller gave a similar description of the take-off, but thought ZK-WWH did not get above about 5 m. The trainee controller made a 111 telephone call to the New Zealand Fire Service, at about the same time as the first aerodrome rescue fire service (RFS) vehicle responded to the crash alarm.

1.1.21 The first RFS vehicle arrived at the scene of the accident within 2 minutes of the alarm, and a second vehicle arrived about a minute later. The pilot provided the Commission with a photograph that he took of the aircraft at about that time. One of the RFS crew said that, when he arrived, he saw frost on the wing upper surfaces. Fuel was running from the wing tank vents, so the RFS crew deployed a low-pressure hose to lay foam over the engine cowl and the ground beneath the vents. The foam mixer initially malfunctioned and delivered water only. A further short segment of the passenger video recording showed water being directed in a broad spray over the engine cowling and grass. Foam was eventually applied around the aircraft. The Chief Fire Rescue Officer later said that the wing surfaces themselves were not directly sprayed.

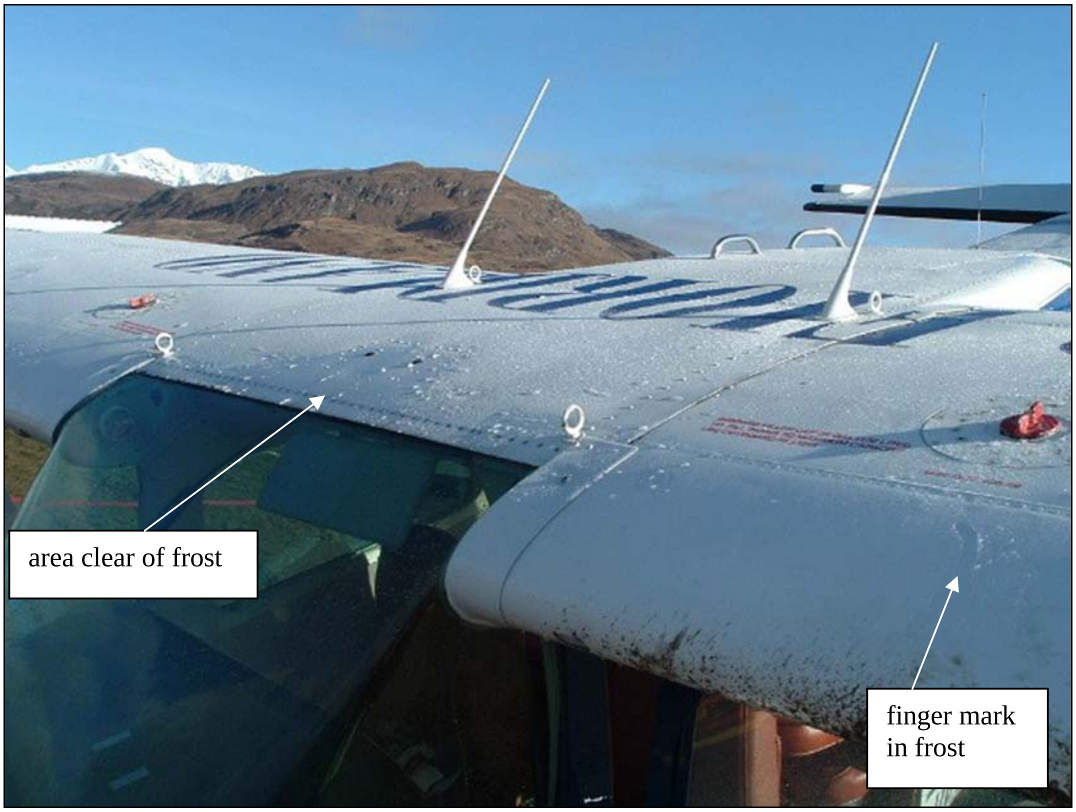

Figure 2
ZK-WWH, about 30 minutes after the accident
(photograph courtesy of Milford Flightseeing Limited)

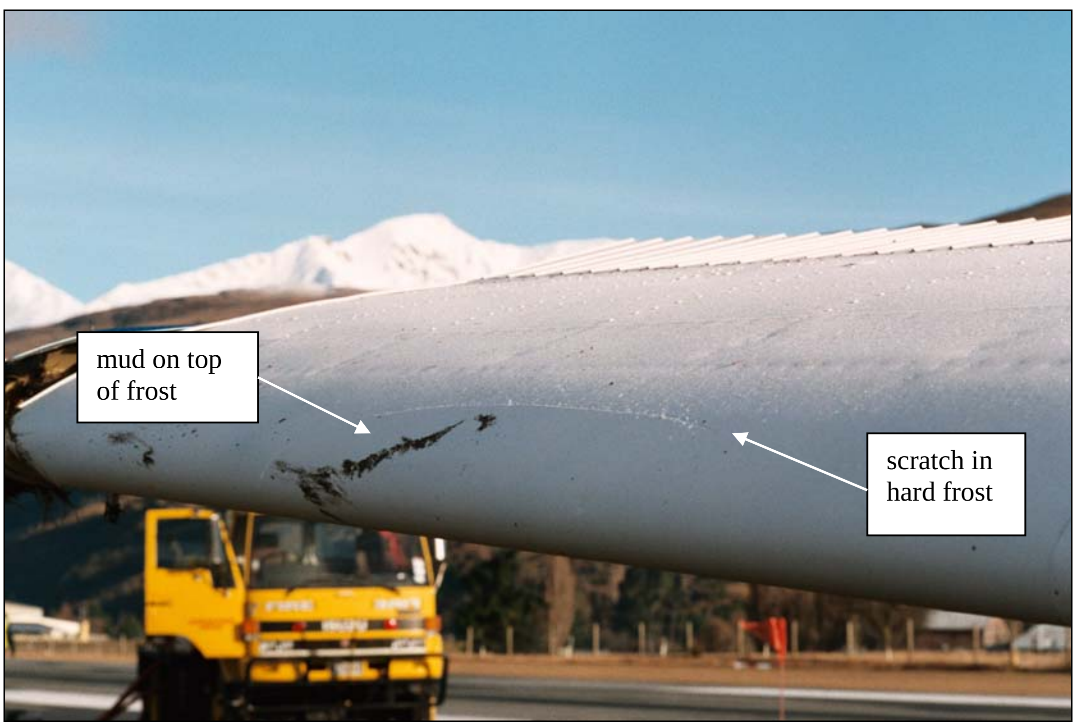

Figure 3
ZK-WWH right wing
(photograph courtesy of New Zealand Police)

1.1.22 A volunteer fireman, who was a licensed aircraft maintenance engineer, said that he saw frost on the wings of ZK-WWH when he arrived on the scene at about 0856. At about the same time, the first police officers, one of whom was a licensed pilot, arrived and later took digital photographs and video recordings of the aircraft. The police officers said the upper surfaces of the wings were coated in frost "approximately one millimetre thick" that was "extremely hard and difficult to remove". They said that there appeared to be a similar covering on the tail plane, but they did not take close-up pictures because the tail was high off the ground.

1.1.23 The photographs in Figures 2 and 3 were taken between about 0915 and 0945. The police took another photograph in the same time period of the underside of the left wing, which appeared to show water drops and foam residue.

1.1.24 The operator was insistent that the frost seen in the photographs came from RFS action when only water had been sprayed, and from natural frost that formed in the 30-60 minutes that elapsed between the accident occurring and the photographs being taken.

1.1.25 There was no fire. No injuries were reported, but at some stage a ski boot had hit one of the passengers on his head. After a medical clearance, the passengers continued with the planned trip in another of the operator's aircraft.

1.2 Damage to aircraft

1.2.1 The left wing, landing gear, propeller and nose section were substantially damaged.

1.3 Other damage

1.3.1 There was minor turf disruption alongside the runway, and approximately 150 litres of fuel were drained onto the grass.

1.4 Personnel information

Pilot's age	43
Licence and ratings	Commercial Pilot Licence (Aeroplane)
Aircraft type ratings	Partenavia P68B, Piper PA23, PA28R, Cessna C172, C177, C206, C207
Medical certificate	Class 1, valid to 2 November 2005
Last competency check	2 August 2005
Last biennial flight review	2 August 2005
Flying experience	1858 hours total, 570 hours on type
Duty time	1.3 hours
Time since end of last duty	39 hours
Flying last 7 days	9.1 hours
Flying last 90 days	56.4 hours (27.8 on type)

1.4.1 The pilot completed his initial flight training in the United States in 1988, and obtained a New Zealand Commercial Pilot Licence in February 1990. He had intermittent flying training and aviation employment until August 2002, when he commenced full-time employment with the operator. He had completed a mountain flying course, and had flying experience over 5 winters in the Queenstown area.

1.4.2 On 2 August 2005, an independent examiner conducted the pilot's annual flight crew competency check, annual area and mountain competency check, and biennial flight review. The examiner said that he assessed the pilot to be very competent and well motivated, and that he had not exhibited any non-standard handling techniques. The pilot's knowledge and performance of daily inspections and the cleaning of aircraft were also checked on the same day.

1.4.3 The pilot held a Class 1 medical certificate with no restrictions, endorsements or conditions, valid until 2 November 2005. He said that he enjoyed good health and a high level of physical fitness, and was very happy in his employment.

1.4.4 During July 2005, the pilot recorded 85 hour's duty and 17.5 hour's flight time. He had the period from 30 July to 1 August free of duty, and then worked 7 consecutive days. In that time, he accrued 55 hours of duty and 10.75 flight hours, mostly in the Cessna 206 type. The pilot had 9 August free of duty and reported that, having had about 10 hour's sleep that night, he felt well rested when he reported for duty on 10 August.

1.5 Aircraft information

1.5.1 ZK-WWH was a 1976 model Cessna U206G, imported into New Zealand in December 1976, and registered with the operator in January 2003.

1.5.2 The Cessna 206 was a high-wing light aircraft with conventional flight controls, powered by one Teledyne Continental IO-520F engine. The pilot occupied the front left seat and a second pilot or passenger could occupy the front right seat. Behind the front seats were 2 rows of 2 seats each. The fore-and-aft position of all seats could be adjusted for comfort and to assist in keeping the centre of gravity (CG) within the allowable range. The space behind the last row of seats was a designated baggage and cargo compartment.

1.5.3 Entry to, and exit from, the cabin was through a door by the pilot's seat, or through a double cargo door next to the right rear seat. The Pilot's Operating Handbook (POH) noted that, if the flaps were not extended, the forward half of the cargo door could be used as an emergency exit. If the flaps were extended, as they normally were for take-off and landing, both sections of the door had to be opened according to instructions placarded, in English only, on the forward section. The rear section latch could not be accessed until the forward section was opened.

1.5.4 ZK-WWH had a Non-terminating Certificate of Airworthiness and was approved for air transport operations. According to its logbooks, the aircraft had been maintained in accordance with the operator's approved maintenance programme. The last 50-hour inspection was carried out on 7 May 2005, and the last Annual Review of Airworthiness on 15 March 2005. On 10 August, the airframe total flight hours were 8927.2, leaving 12 hours until the next inspection.

1.5.5 On 10 August 2005, the engine had accumulated 8114.05 hours since new, and 494.1 hours since the last overhaul. The next engine overhaul was due in about 1200 hours. On the same date, the propeller had accumulated 3403.3 hours since new, and 1336.05 hours since overhaul. The propeller was due for an overhaul after a further 1064 hours, or by February 2007.

1.5.6 The last non-scheduled maintenance action on ZK-WWH was carried out on 5 July 2005, when the nose oleo assembly was removed and the seals replaced because the oleo had deflated. There were no deferred defects prior to the flight on 10 August.

1.5.7 The aircraft CG range at MCTOW was 42.5 inches to 49.7 inches aft of the datum. The rear limit was the same for all weights.

1.5.8 The operator had a computer program that permitted calculation of the take-off weight and CG position for any aircraft in the fleet. Pilots had been encouraged to use the program to calculate "worst case" load scenarios for each aircraft, in order to develop an awareness of aircraft load capability, especially when operating from remote areas.

1.5.9 The pilot's estimate of the weight of the boots and skis was accurate, when compared with the weight of similar items. As he believed the load was not more than any of his worst case scenarios, the pilot did not actually check the CG position. The CG for the accident flight, using the load sheet details, was calculated with the computer program and found to be 50.5 inches aft of datum, or 0.8 inches aft of the rear limit.

1.5.10 Although the actual seat positions at take-off could not be confirmed, the CG position was calculated to be aft of the rear limit when using either the total standard passenger weight of 415 kg or their declared total weight of 331 kg (plus a regulated allowance of 4 kg per passenger).

1.5.11 The manufacturer advised that an aft CG on a Cessna 206 increased the aircraft response to small pitch inputs, and could increase the possibility of a pitch excursion, particularly close to the ground where a pilot's flight control inputs tended to be larger.

1.5.12 Apart from a heated pitot tube, the aircraft was not equipped with any anti-icing or de-icing equipment. The POH had a brief reference to possible use of isopropyl alcohol for ice removal before flight, but included the following requirement as part of the pre-flight inspection[3]:

> Remove even small accumulations of frost, ice or snow from wing, tail and control surfaces. Also, make sure that control surfaces contain no internal accumulation of ice or debris.

1.5.13 The manufacturer advised that limited studies on the effect of frost or ice on the wing surfaces of similar aircraft had shown the potential for reduced roll authority at high angles of attack, for example at rotation, due to the roughened wing surface ahead of the ailerons.

1.5.14 A B-category flight instructor and the operator's Chief Executive Officer said industry experience was that a light frost on the wings would not, of itself, lead to loss of control of a Cessna 206 during take-off, if the aircraft was not at slow speed. They said other factors, such as wake turbulence, were probably present in this accident, either alone or in combination.

1.5.15 A vane-type stall warning unit was installed in the leading edge of the left wing, and electrically connected to a cockpit warning horn. The unit was designed to sound the horn at an air speed 5-10 kt above the stall in all configurations. The pilot said he had checked that the vane was serviceable before the flight. According to the POH, at the MCTOW and with the CG on the aft limit, 10^{o} of flap and wings level, the power-off stall speed was about 52 KIAS.

1.5.16 The POH normal take-off procedure was to rotate at 50 kt, and to climb at 70 -80 kt.

1.5.17 The aircraft was fitted with an electronic engine tachometer that recorded the highest revolutions per minute (RPM) achieved. The tachometer recorded a maximum 2810 RPM during the take-off. The maximum permitted RPM was 2850.

1.6 Meteorological information

1.6.1 An aftercast prepared by MetService stated, in part:

> Total rainfall in the period between 36 and 24 hours before [1000 on 10 August] was 18.2 millimetres. Skies cleared in the evening … and the air temperature fell to –2°C. However broken stratocumulus cloud developed around [0400] and didn't clear until [1000]. This prevented the temperature from significantly rising after sunrise. There would have been frost on the ground and it is likely that any surface water remaining from the previous day's rain would have frozen overnight and remained frozen until late morning.

[3] Cessna 1977 Stationair model U206G POH, page 8-13 and Figure 4-1.

1.6.2 The routine aerodrome meteorological reports for 10 August included the following data:

Time	Wind direction (^{o}True) and speed (kt)	Air temperature (^{o}C)	Dew point temperature (^{o}C)
0700	040 /4	-1	-2
0800	030 /5	-2	-2
0900	030 /6	0	-1
1000	040 /6	+2	-1

1.6.3 Hoar frost forms when water vapour transitions from a gaseous state to a solid state and is deposited as ice on a surface that is below freezing temperature. The ideal conditions for frost formation are nights with generally clear skies and light winds.

1.6.4 For the purposes of the investigation, the Commission engaged a meteorologist. He examined some photographs of ZK-WWH taken after the accident, including those shown in Figures 2 and 3. He said that the photographs clearly showed a naturally formed hoar frost with a depth and uniformity of coverage that he expected would have taken some hours to form under the conditions that prevailed. He noticed that close examination of Figure 3 showed some mud on top of the frost layer.

1.6.5 The meteorologist considered that conditions remained favourable for frost deposition in the time between when the pilot said he cleaned ZK-WWH and when the photographs were taken, but unless the aircraft had been completely cleaned of all prior frost and also dried, he would have expected to see evidence of that cleaning, such as broom streaks and a less uniform frost coverage.

1.6.6 Hoar frost usually did not form on the undersides of wings in the same way that it was deposited on the topside, as the lower wing surface was warmed from heat radiated from the cooling ground. A police photograph of the underside of the wing appeared to show liquid water that was probably from RFS action. The meteorologist said that frost was not formed directly from a liquid water state, such as hose spray. He said that hose spray would have caused streaking and run-off in previously formed frost, but neither effect was apparent in the photographs.

1.6.7 The meteorologist found some of the “lumps” seen in Figure 2 on the cabin roof difficult to explain. He thought they could be frozen raindrops from 2 nights earlier, which were too big to evaporate during 9 August when the aircraft did not fly, or water from melted frost that had coalesced and run forward while the aircraft nose was tipped down. He thought that the frost clearance above the windshield was possibly caused by the relatively warm propeller wash.

1.6.8 For the purposes of the investigation, the Commission engaged an experienced pilot who had been involved in the preparation of an Aircraft Icing Handbook for the Civil Aviation Authority (CAA). He independently reviewed the available photographs and witness statements and reached a similar conclusion to the meteorologist: that frost would probably have formed on the cold-soaked aircraft in the time since the pilot said that he had swept the aircraft, but not to the extent found by those first on the scene after the accident. He also considered that the frost seen in the photographs around the fuel filler caps was not a product of RFS action.

1.6.9 The instructor referred to in paragraph 1.5.14 stated that, in his experience, the formation and characteristics of frost and ice depended, among other things, on the water content of the air and the rate and amount of temperature change. Frost sometimes overlaid hard ice, which could not be removed with a broom. He believed that Queenstown-based pilots had a reasonably high awareness of the ice risk and the requirement to clear all ice from an aircraft before flight.

1.6.10 The independent reviewer provided further information from an experienced agricultural and airline pilot that corroborated the possibility of a hard layer of ice forming below hoar frost on a cold-soaked aircraft. That pilot had also commented that a broom would remove frost but not an underlying ice layer under such circumstances, and that if residual ice was suspected, a pilot might use increased rotation and climb speeds to provide an improved stall margin until the aircraft was operating in warmer air.

1.6.11 On 10 August 2005, the sun rose at Queenstown Aerodrome at about 0749 and sunlight first reached the aerodrome apron at about 0815.

1.7 Aerodrome information

1.7.1 Queenstown Aerodrome had a sealed runway 05, which was 1891 m long and 30 m wide. The distance between taxiways A and C was about 650 m.

1.7.2 Airways Corporation of New Zealand provided an aerodrome ATC service. When 2 aircraft with an MCTOW of 2300 kg or less were taking off from a single runway in daylight, the controller was permitted to clear the following aircraft for take-off when the preceding aircraft was airborne and at least 600 m ahead of the following aircraft[4].

1.7.3 Aerodrome controllers at Queenstown Aerodrome used the distance between taxiways A and C as a guide for the application of that standard, and the pilot of ZK-WWH was familiar with its use.

1.7.4 The minimum 600 m separation was introduced in 1995 following consultation with operators, flight trials and comparison with other countries' procedures. The International Civil Aviation Organisation (ICAO) standard[5] for 600 m separation permitted the lead aircraft MCTOW to be up to 7000 kg.

1.8 Wreckage and impact information

1.8.1 In order to facilitate the re-opening of the runway, the Commission approved the removal of the wreckage to a hangar on the aerodrome before its investigators arrived on site.

1.8.2 A blue paint scrape, about 3 m long, was found near the right edge of runway 05, by the intersection with taxiway C. Abeam the end of the paint scrape were tyre marks across about 7 m of taxiway C, and almost parallel to the runway direction. The spacing of the tyre marks indicated that, at the time they were made, ZK-WWH was yawed to the left (see Figure 4).

1.8.3 Other signs of the impact were gouges, tyre tracks and propeller slashes that began about 30 m beyond the taxiway and were contained within the grass to the right of runway 05. The aircraft had stopped about 10 m off the side of the runway.

1.8.4 The emergency locator transmitter (ELT) was found selected to the automatic position, but it had not been activated by the impact.

1.8.5 A fuel sample, taken from ZK-WWH at about 0900, was clean, bright and free of water. The sample was the correct colour for the fuel grade.

1.8.6 The left wing was bent upwards approximately 15^{o} along a line through the aileron inboard edge, and the underside of the tip fairing was abraded. The propeller blades were bent rearwards. The right landing gear leaf-spring strut was deformed inwards, and the nose gear strut was completely detached. The engine was retained in its mounts, but some accessories had penetrated the firewall. Distortion in this area had caused the elevator cross-shaft beneath the instrument panel to be dislocated. Minor scraping was evident on the right wing tip and the left elevator outboard trailing edge. The cabin space was not distorted or penetrated.

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[4] Aeronautical Information Publication New Zealand AD1.5-14, effective 2 September 2004.
[5] ICAO Doc 4444, Procedures for Air Navigation-Air Traffic Management, 24 November 2005.

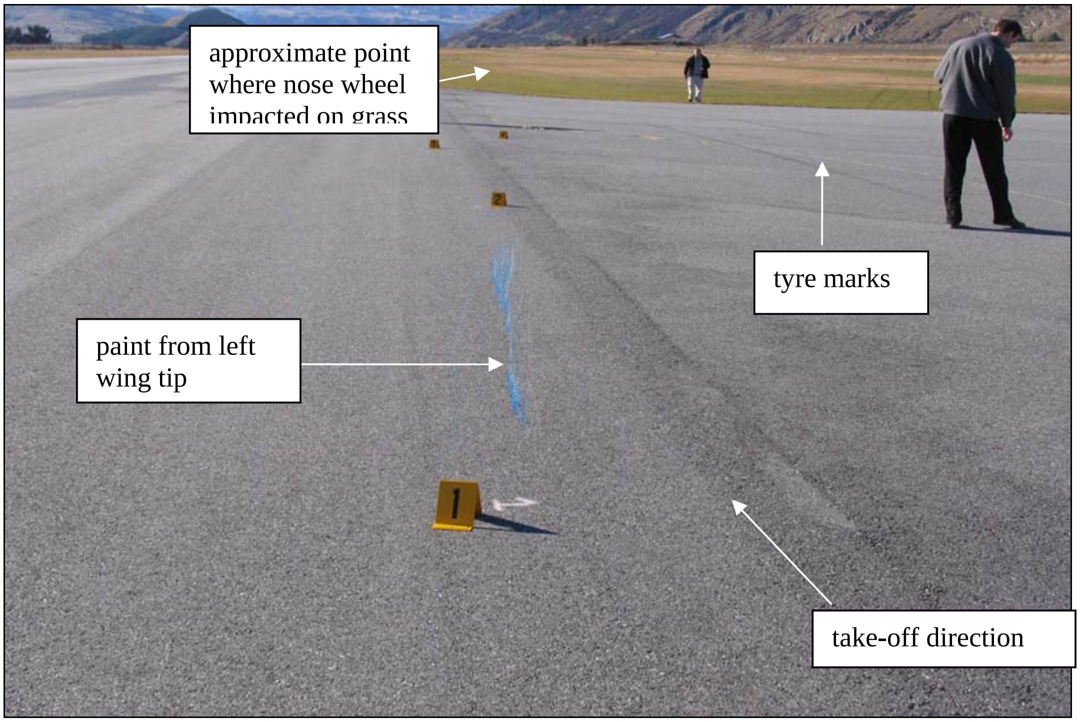

Figure 4
Impact marks on runway 05 and taxiway C
(photograph courtesy of New Zealand Police)

1.8.7 The throttle lever was found closed, the propeller lever at maximum RPM and the mixture lever pulled to the lean position. The master electrics switch and the fuel were found selected off. The rudder trim control was found set to the normal position for take-off, and the elevator trim wheel was set just on the nose-up side of the position marked "take-off". The flap lever was found set at 10^{o} and the flaps were extended to about that angle. The right seat rudder pedals were found properly stowed. The pilot confirmed that he had not selected the pitot heat on.

1.9 Medical information

1.9.1 The pilot's medical certificate had no conditions, restrictions or endorsements. The pilot said he had not consumed any alcohol or taken any medication within the 24 hours prior to the accident.

1.10 Survival aspects

1.10.1 The passengers in the rear seats said that the cargo door had seemed to be obstructed when they went to exit, but the pilot had assisted them from the outside.

1.10.2 Civil Aviation Rule (CAR) 91.211, Passenger briefing, stated in part:

> (a) A person operating an aircraft carrying passengers must ensure that each passenger has been briefed on—…
>
> (3) the location and means for opening the passenger entry doors and emergency exits; and…
>
> (5) procedures in the case of an emergency landing; and…
>
> (b) The briefing required under paragraph (a)—…
>
> (5) may be supplemented by printed cards for the use of each passenger containing—
>
> (i) diagrams of, and methods of operating the emergency exits; and…

1.10.3 The pilot had supplemented his safety briefing with multi-lingual passenger briefing cards. The location and operation of the cargo door handles were not accurately depicted on the cards.

1.11 Tests and research

1.11.1 The flight control systems were checked at an approved maintenance facility. The damaged left aileron had to be removed, and the elevator cross-shaft reconnected, before full, free and correct movement of all flight controls was demonstrated.

1.11.2 The pitot-static system was tested by an approved person and found to be accurate over the examined range of 50-90 KIAS.

1.11.3 The ELT was bench tested by an approved person and found to be serviceable.

1.12 Organisational and management information

1.12.1 The operator held an Air Operator's Certificate issued under CAR Part 135. The operator's head office was in Te Anau, and although some operations were conducted from Te Anau Aerodrome, the main operational base was Queenstown Aerodrome. A senior pilot was appointed to oversee operations at the Queenstown base.

1.12.2 The operator's procedures allowed the total weight of passengers, including their carry-on baggage, to be determined using any one of the following methods:

- the sum of actual weights
- the sum of passenger-declared weights, plus 4 kg for each passenger
- a standard weight of 83 kg for each adult.

In practice, the standard adult weight of 83 kg was used.

1.12.3 In late 2003, the CAA raised the standard passenger weights. Prior to that, in anticipation that the weight would change to 85 kg, the operator examined the load capability of each of its aircraft. In September 2003, the operator advised staff that Cessna 206 aircraft could be loaded with a pilot and 5 adults at 85 kg each, and the CG would remain within limits.

1.12.4 The operator's Operations Manual (OM) contained an example Cessna 206 "Load Plan" that placed the first passenger in the front seat next to the pilot, and thereafter filled the successive rows. A note stated that if the middle row was full, all seats had to be on their forward-most stops. The OM stated that a standard load plan kept the CG within limits, but the standard plans did not specify any baggage or cargo condition or where in the cabin baggage should be placed.

1.12.5 The cover of the operator's book of Load Manifest forms noted:

> On signing the Load Sheet, the Pilot in Command is certifying that the Centre of Gravity is within limits as per examples in the Company Operations Manual and in accordance with the POH for this particular aircraft.

1.12.6 The terms ”load manifest”, ”load sheet” and ”passenger manifest” referred to the same document.

1.12.7 CAR 135.305 obligated both the operator and the pilot of an aircraft to ensure that the aircraft weight and balance remained within approved limits for the duration of every flight. Operators had to provide their pilots with the necessary information for compliance to be determined.

1.12.8 CAA records showed that in April 2004, following an incident in which one of the operator's aircraft was damaged by loose baggage during turbulence, the operator issued a Pilot Safety Notice to remind its pilots of their responsibility to secure bags.

1.12.9 The OM paraphrased CAR 91.315, Operating in snow and ice conditions, and stated in part:

> **5.24 Icing Conditions**
> …4. No pilot shall take off under VFR in an aircraft that has snow, ice or frost adhering to the wings, stabilisers or control surfaces.

1.12.10 The operator did not hangar its aircraft at Queenstown, but did have wing covers for use when a frost was forecast. De-icing fluid was not used, but some operators at Queenstown had access to de-icing fluid. The operator's scheduled morning flights from Queenstown usually departed after any frost had thawed.

1.13 Additional information

Weight and balance

1.13.1 Within its Good Aviation Practice (GAP) information series, the CAA published a booklet on aircraft weight and balance. The GAP series was advertised in the CAA's Vector magazine[6], and booklets were available from the CAA and most flight training organisations.

1.13.2 The Weight and Balance GAP provided the following general description of the effect of an aft CG on aircraft handling, for an assumed uncontaminated wing, as follows:

> The more aft the [CG], the more unstable the aircraft. Violent stall characteristics are frequently associated with this condition. Forward pressure on the control column and full nose-down trim may be necessary to keep the aircraft from pitching up and stalling. The need for increased forward pressure on the control column, and a tendency for the aircraft to take off in a dangerously nose-high attitude, are symptoms of an aft [CG]. It is often characterised by light rearward control column forces, making the aircraft susceptible in flight to inadvertent overstressing by the pilot.

Wake turbulence

1.13.3 Wake turbulence is the term used to describe the effect of the rotating air masses, or vortices, which form behind the wing tips of aircraft in flight. The vortices are only present when a wing is producing lift and first become significant when the aircraft is rotated for take-off. All aircraft produce wake turbulence during flight, with the most severe turbulence generated by heavy wide-bodied aircraft. However, any aircraft's wake can be a hazard for a lighter aircraft.

1.13.4 ICAO categorised each aircraft type as heavy, medium or light, according to its weight and wake turbulence potential. The Cessna 206 was in the light category, those with a MCTOW less than 7000 kg. The manufacturer's opinion was that the Cessna 206 did not generate significant wake turbulence, but some local pilots and the operator disagreed with that view.

1.13.5 The vortices from the left and right wingtips of an aircraft rotated in opposite directions and expanded and moved downwards. The strength of any vortices diminished with time and increasing distance from the generating aircraft, but could persist in still atmospheric conditions. On reaching the ground, they drifted with the surface wind.

1.13.6 To reduce the potential for wake turbulence control problems, ATC applied a minimum separation between departing aircraft, except when both were in the light category, in which case the usual runway separation rules applied. If a pilot considered that the offered separation was inadequate, a specific increased separation could be requested. For many years at Queenstown Aerodrome, ATC had routinely applied the minimum 600 m separation between departing light aircraft, when both had a MCTOW less than 2300 kg, and had received no reports of related wake turbulence. The pilot of ZK-WWH said that he had no experience of severe wake turbulence.

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[6] A flight safety magazine published 6 times a year by the CAA and sent to all current pilots and licensed aircraft maintenance engineers.

1.13.7 The CAA published a GAP booklet entitled Wake Turbulence that gave 3 basic warnings concerning wake turbulence:

> Do not get too close to the leading aircraft.
> Do not get below the leading aircraft's flight path.
> Be particularly wary when light wind conditions exist.

1.13.8 The booklet's emphasis was on light aircraft pilots avoiding wake turbulence behind a heavy or medium category aircraft, although it noted that a light aircraft can generate significant wake turbulence for a closely following light aircraft. The booklet primarily referred to operations where an ATC service was provided.

1.13.9 In the period 1995-2005, there were 2 accidents reported in New Zealand involving light aircraft that encountered wake turbulence behind aircraft that were in the medium or heavy wake category. The CAA database had no reports of wake turbulence incidents involving only light aircraft.

1.13.10 Over the same period, the Australian Transport Safety Bureau (ATSB) received one report that involved light aircraft wake turbulence. A student pilot in a Victa Airtourer encountered the wake of a preceding PA28 Cherokee during the landing and then lost control during an attempted go-around. The Victa was substantially damaged but the ATSB did not investigate the accident.

1.13.11 The operator claimed that wake turbulence events involving light aircraft only had occurred at Queenstown and elsewhere, but he said these events had not been reported because operators and ATC did not want to increase the departure separation and thereby restrict operational capacity.

1.13.12 On 28 March 2006, the operator notified the CAA of 2 wake turbulence incidents involving his organisation that had occurred earlier that month at Queenstown. Both events involved the one pilot in a Cessna 185 taking off behind another light aircraft, a Cessna 207. It was reported that the Cessna 185 experienced substantial roll, yaw and some sink, and the pilot involved in these 2 events later said that complete loss of control was narrowly averted.

1.13.13 The Commission reviewed the circumstances of these 2 events, which occurred during stream take-offs where ATC was applying the minimum 600 m departure separation. In the first, the Cessna 185 was cleared to take off 47 sec after one of the operator's Cessna 207 aircraft. Over the next 8 minutes, 7 light aircraft departed with intervals between ATC issuing take-off clearances ranging from 36 to 59 sec. In 2 of those departure pairs, the MCTOW of the following aircraft was less than that of the lead aircraft. In the second occurrence, the C185 pilot accepted a take-off clearance 45 sec after the preceding aircraft had been cleared for take-off. On both occasions the wind was within 10^{o} of the runway heading and between 5 and 7 kt.

1.13.14 No ATC staff observed either of these 2 events, and no other wake turbulence report was received. The operator did not advise ATC of either event. None of the ATC staff spoken to had ever seen or heard of a light aircraft anywhere being seriously affected by the wake turbulence of another light aircraft. Only one other light aircraft operator at Queenstown could recall a wake turbulence event: a Cessna 172 getting "a bit of a knock" behind an Islander after take-off. The operators said that the subject of wake turbulence had been raised at Queenstown Airport User Group meetings only in connection with light aircraft following medium or heavy aircraft.

1.13.15 The Commission, accepting that there was probably a degree of under-reporting of aviation incidents, conducted a short survey of the wake turbulence experiences of members of the Aviation Industry Association (AIA) who operated 3 or more light aircraft. Replies were received from 9 of the 24 members surveyed, including the operator, and a senior manager in the CAA who had relevant experience. Copies of the covering letter and questionnaire used are at Appendix A.

1.13.16 Three of the survey respondents had no experience of wake turbulence from another light aircraft. Of the 7 who had experienced wake turbulence, 2 noted severe events during take-off from an uncontrolled airport and the remainder noted events of moderate or lesser intensity during various phases of flight. The general view was that wake turbulence from a light aircraft had rarely been troublesome.

1.13.17 Apart from the operator, who described the 2 recent take-off wake turbulence events at Queenstown as being of moderate intensity, none of the respondents had notified their events to ATC, the CAA or their own organisations. The reasons given for not notifying even what was judged to be a severe encounter, were "wake turbulence is an everyday event", "there was no requirement to report a wake encounter", the turbulence "was no more problematic than wind shear", or the cause for the upset was evident at the time.

Aircraft icing

1.13.18 The imperative to ensure that wings and critical surfaces are clear of ice and similar contaminants prior to take-off has been well established and publicised. As new operators and new aircraft models continually enter the aviation system, the information is constantly reviewed and given further emphasis.

1.13.19 The United States-based Aircraft Owners and Pilots Association (AOPA), which represents two thirds of all pilots in the United States, advised that[7]:

> Wind tunnel and flight tests have shown that frost, snow and ice accumulations (on the leading edge or upper surface of the wing) no thicker or rougher than a piece of coarse sandpaper can reduce lift by 30% and increase drag up to 40%.

1.13.20 AOPA also noted that [clear, or glaze] ice can form on aircraft surfaces at 0^oC, or colder, whenever liquid water is present. The quoted article emphasised "a perfectly clean wing is the only safe wing".

1.13.21 A wing stall because of icing will usually occur at a lower angle of attack and a higher speed than normal. Thus, for an aircraft taking off with ice or frost contamination on the wings, the usual take-off speed could be near, or even below, the actual stall speed for the conditions.

1.13.22 In 2000, the CAA published a comprehensive Aircraft Icing Handbook, applicable to all aircraft types, which, in the chapter on pre-flight preparation, emphasised the need to clean an aircraft of ice and snow prior to flight. The Handbook noted that icing destroyed the smooth flow of air over a wing, increased drag, degraded control authority and decreased the ability of an airfoil to produce lift. At the stall, an aircraft could pitch or roll uncontrollably and recovery could be impossible.

1.13.23 Operators of large aircraft often used de-icing fluids to remove ice from critical surfaces prior to flight. In sub-zero temperatures, melted contaminant can re-freeze before an aircraft departs, so there is a defined period of effectiveness for de-icing fluids, known as the "holdover time". If a de-iced aircraft cannot depart within the holdover time, further de-icing is required.

1.13.24 The United States National Transportation Safety Board (NTSB) has promoted the importance of a tactile, or touch, check before flight to ensure that all frost and ice has been removed. The NTSB Safety Alert, shown at Appendix B, makes reference to higher-performance jet aircraft, but the general comments are valid for all aeroplanes.

1.13.25 The CAA had also published a GAP booklet on Winter Flying that repeated the AOPA advice, and the NTSB recommendation that critical surfaces should be touched to ensure they were completely clean. The booklet noted that "hand brushing will clear what is not stuck to the surface" and gave guidance on how to remove underlying ice. The CAA booklet commented

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[7] AOPA Safety Advisor, Weather No.1. (www.aopa.org/asf/publications/sa11.pdf) accessed 5 September 2005.

that the degrading effect of frost on aircraft performance was subtler than that of snow or hard ice, and warned that a wing stall would probably occur at a lower angle of attack than the aircraft stall warning system was set for.

1.13.26 Between July 2000 and December 2004, the CAA published in Vector magazine, distributed to all current pilots, 5 articles over 14 pages on airframe icing. While most articles were oriented towards operations under instrument flight rules (IFR), one had the following advice:

> Even a light layer of ice or frost on the wings will result in higher stall speeds and lower stall angles of attack… The aircraft may get airborne in ground-effect, but when the nose is raised to climb away an incipient stall may result at an angle of attack considerably less than normal.

1.13.27 In the period 1995-2005, there were 2 accidents reported in New Zealand that involved light aircraft failing to get airborne, in which airframe icing was confirmed or suspected.

2 Analysis

2.1 This accident occurred on the first flight of the day, during generally favourable weather conditions. The preceding Cessna 206, which had been parked uncovered overnight, like ZK-WWH, departed safely with a similar load.

2.2 The ATC witnesses described ZK-WWH making a number of attempts to get airborne. The passenger video recording showed the aircraft apparently getting airborne, touching down, and then drifting across the runway before the left wing tip hit the runway near taxiway C.

2.3 For the left wing tip to hit the runway, ZK-WWH would have had to be banked about 25°, or at a greater angle if the left wheel was off the ground at the time. The relative positions of the long blue paint scrape and the tyre marks across the entrance to taxiway C indicated that the aircraft then rolled rapidly right but was yawed about 45° to the left when it touched down again. That was probably the point where the right landing gear leaf spring was deformed.

2.4 A pitch-up was not apparent on the passenger video before the wing tip hit the runway, and after that the camera was pointed to the cabin floor. Therefore, any pitch-up must have occurred between taxiway C and the next impact evidence, in the grass about 30 m past the taxiway. The nose leg probably detached at that point. The video recording confirmed that the engine was running until the first major impact, about 7 sec after the wing tip hit the runway.

2.5 The first persons on the scene immediately after the accident said that there was frost on the wings, and probably the tail plane, when they arrived. The copy of the digital photograph that the pilot took before RFS action had commenced was too indistinct to enable any reliable conclusion to be drawn about the condition of the wings. However, another photograph showed mud on top of the frost, which confirmed that frost was present at the time of the accident. The short police video supported the police report of a hard layer of frost on the outer wings.

2.6 The mud overlaying the frost was contrary to the operator's suggestion that RFS action had caused the frost seen in the photographs. In addition, the meteorologist said that RFS water spray would not have formed hoar frost. The observed frost was of fairly uniform density across the wingspan, and probably the tail plane, surfaces that had not been sprayed by RFS.

2.7 Expert meteorological and operational opinion was that, even though frost could have been formed up until an hour after the accident, the amount of frost seen in the photographs could not have formed in the time available between when the pilot said he cleaned the aircraft and when the photographs were taken. Therefore, the pilot's brushing had not removed all of the frost and ice, and additional frost was probably deposited before the flight commenced.

2.8 Although much of the available educational material on aircraft icing applied to IFR operations, and drew on data related to aircraft with higher performance than the Cessna 206, the general conclusions applied to all types. The information published by the CAA was current, relevant and generally adequate. An exception was the comment in the Winter Flying GAP that "hand brushing will clear what is not stuck to the surface". Brooms and brushes were commonly used to clean frost from light aircraft but were known to be ineffective against harder frost. The GAP text might be better expressed as "hand brushing alone will not clear what is stuck to the surface". A safety recommendation was made to the Director of Civil Aviation regarding this issue.

2.9 The pilot did not check the upper wings with his bare hand and presumably did not see harder frost underneath. A tactile check, as suggested by the CAA and the NTSB, is essential to ensure the surfaces are clean. Although it can be difficult to access wings and control surfaces on larger aircraft in order to perform a tactile check, light aircraft should not present such a problem.

2.10 Even if the pilot had managed to clean the wings and control surfaces of ZK-WWH completely, the prevailing conditions could have led to an unacceptable amount of frost forming on the cold aircraft in the time between frost removal and take-off. In the same way that a de-icing fluid holdover time limitation must be observed, operators and pilots of light aircraft should minimise any delay between removal of frost and taking off and, if delayed, check critical surfaces again before take-off.

2.11 There was ample research data that confirmed that wings contaminated with frost or ice suffered major performance degradation. The Cessna 206, like most light aircraft, was not certified for flight into known icing conditions, so the manufacturer had no flight test data to support flight operations in such conditions. The manufacturer included a categorical statement in the POH that "even small accumulations of frost, ice or snow from wing, tail and control surfaces" had to be removed before flight. A pilot's assessment of the degree of frost on the airframe would be entirely subjective, and they could not know at any point in the flight by how much the lift was reduced or the drag increased, nor the stall margin.

2.12 The take-off behaviour of an aircraft with contaminated wings was unpredictable. Many reports on take-off accidents, where contaminated wings or flight controls were a factor, have described uncommanded roll and difficulty in controlling the aircraft. The manufacturer advised that there was potential for reduced roll authority if there was a roughened wing surface ahead of the ailerons, and photographs and reliable witnesses confirmed that there had been a frost layer ahead of the ailerons on ZK-WWH. The pilot described taking corrective action for the initial uncommanded roll, and the aircraft then rolling the other way. He said the aileron and rudder responses were "sluggish".

2.13 The pilot positioned ZK-WWH on the upwind side of the runway, the appropriate side to avoid possible wake from the preceding Cessna 206, but it was possible that an initial uncommanded roll was caused by ZK-WWH encountering wake turbulence from ZK-TFW. During the take-off, ZK-WWH drifted to the right side of the runway, as would have the vortices from ZK-TFW. The separation between the 2 aircraft exceeded the minimum 600 m, but the cold, light wind conditions could have caused any wake to persist.

2.14 The take-off points of the 2 aircraft could not be determined, so ZK-WWH might have been above or below the wake from ZK-TFW. The pilot should have been able to counter a minor wake upset and make a safe take-off, but the aircraft's performance was severely compromised by the frost on the wings. Even if there had been no possibility of wake turbulence, the pilot of ZK-WWH would still probably have had control difficulties at take-off because of the frost.

2.15 The global aviation view, that the wake or propeller wash from a light aircraft did not create a significant hazard for a following light aircraft if the minimum separation distance was observed, was strongly supported by the dearth of accident reports and an ICAO air traffic management standard that permitted the lead aircraft to have an MCTOW up to 7000 kg.

2.16 The response to the short survey of AIA members suggested that light aircraft wake turbulence was not a major concern of operators, nor the serious hazard suggested by the operator. The majority of the respondents said either that they had never encountered wake turbulence from another light aircraft, or that what they had experienced was of little consequence and had been easily controlled.

2.17 The operator's further comment, that severe wake turbulence events involving only light aircraft were not reported, received some support in the survey. The decision of some very experienced flight instructors and pilots to not report severe wake turbulence encounters, which are clearly not "an everyday event", was of concern. Safety authorities cannot address hazards that have not been reported. However, both of the severe wake turbulence encounters that were noted in the survey had occurred at uncontrolled aerodromes, and it might be reasonably supposed that the pilots involved realised, after the event, that they had not allowed sufficient spacing from the aircraft ahead. Separation should not be an issue at a controlled aerodrome like Queenstown.

2.18 The information on wake turbulence available to ATC, operators and pilots was generally adequate and this accident was not a reason to increase the minimum departure separation criteria for light aircraft.

2.19 However, a safety recommendation was made to the Director of Civil Aviation that he revise the CAA educational material on wake turbulence to include guidance for operations at uncontrolled aerodromes, and to emphasise that light aircraft pilots should observe the ICAO recommended minimum separation distance between light aircraft and report any severe wake turbulence incidents.

2.20 The main cause of the loss of control of ZK-WWH was considered to have been the frost on the wings. The aircraft was vulnerable to stalling shortly after take-off because the contaminated wings would have had a seriously degraded performance and a higher stalling speed and a lower stalling angle of attack than a clean wing. The pilot's action in holding the aircraft on the runway until reaching a higher take-off speed could have restored some of the stall margin. The stall warning system probably did not activate because the stall angle of the contaminated wing was less than that of a clean wing.

2.21 Take-off conditions for ZK-WWH were very similar to those for ZK-TFW, which departed successfully at the front of the stream. It was not possible to conclude that the absence or not of wake turbulence was the sole reason for the different outcomes, as it could not be determined whether all the frost and ice had been removed from the wings of ZK-TFW.

2.22 The take-off CG position was probably aft of the rear limit. Had the pilot checked the computer, he would have been alerted to the anomaly and he probably would have re-evaluated the load and its distribution.

2.23 The pilot's decision not to calculate the actual CG was not unreasonable. The loading appeared standard and the OM gave an assurance that standard load plans kept the CG within limits. However, that assurance was dependent upon adherence to the associated conditions, for example the seat positions and minimum fuel load. No baggage compartment restrictions were specified on the operator's standard plans but baggage could put the CG aft of the rear limit. In particular, hand baggage that was put in the baggage compartment might not be properly accounted for in the weight and balance calculation.

2.24 On the accident flight, there were 25 kg loaded into the baggage area. The actual positions of the seats during take-off could not be determined, but calculation showed that the baggage weight and location probably put the CG aft of the rear limit for take-off. An aft CG could have exacerbated the control difficulty and could have been a factor in the aircraft behaviour during the take-off.

2.25 The operator later amended the OM to require pilots, or a delegated staff member, to calculate the CG any time that the load conditions varied from the applicable standard plan, but baggage compartment limitations were not specified. A recommendation was made to the operator that he specify any baggage or cargo conditions that must be met if pilots are to rely on the plans to keep the CG within limits.

2.26 The pilot was responsible for securing the passengers' boots and skis before flight. Although each of the operator's Cessna 185 aircraft had a net as part of the aircraft equipment, the other aircraft types used nets from the operator's stock at Queenstown Aerodrome. A safety recommendation was made to the operator that he equip each aircraft in his fleet with adequate means of securing baggage and cargo.

2.27 The procedure for fully opening the cargo door was not obvious, and passengers using that door as an emergency exit would not expect an obstruction from the lowered flaps. As the placarded instructions were in English only, the passenger briefing or the supplementary cards were required to provide exit information. The supplementary cards were generally clear, but they did not show accurately the location or operation of the rear cargo door latch. A safety recommendation was made to the operator concerning this issue.

3 Findings

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

3.1 The pilot was qualified, authorised for, and fit to conduct the flight.

3.2 The aircraft records showed that it had been maintained in accordance with the operator's approved maintenance programme and was suitable for the type of operation.

3.3 The weather conditions were suitable for the flight, but frost had formed on the aircraft overnight.

3.4 The frost and ice was not completely removed before flight, and the pilot was probably not aware that a harder layer of ice could be beneath the frost.

3.5 The frost and ice degraded the wing performance and the roll authority available to the pilot.

3.6 Wake turbulence from a preceding Cessna 206 might have caused an initial roll, but any such upset was unlikely to have been severe enough, on its own, to lead to the loss of control.

3.7 Control was lost primarily because the wing was contaminated with frost and ice, and the aircraft stalled at low level.

3.8 The standard load plans did not specify any baggage limitations, yet baggage compartment loading had a major effect on the CG position.

3.9 The take-off weight of ZK-WWH was below MCTOW, but the CG was probably aft of the rear limit, which could have exacerbated the control difficulty.

3.10 The baggage was not properly secured.

3.11 The operator's supplementary passenger briefing cards for the Cessna 206 did not accurately show the location or operation of the rear cargo door latch, or that extended flaps could obstruct door opening.

4 Safety Actions

4.1 On 28 October 2005, the operator amended the OM to clarify the weight and balance procedures. The amendment stated in part:

> If any variation from the above [standard weights and plans], a weight and balance calculation must be carried out by the [pilot in command] or delegate.

4.2 On 6 December 2005, the operator advised, in part:

> [I have] checked and confirmed the arms for the [weight and balance] of all our [aircraft] against the data in the respective [aircraft] POH and these are in the computer system that the Pilots must use for calculations when they may be uncertain about the CG position or they may be operating outside [a standard plan].

5 Safety Recommendations

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

5.1 On 4 January 2006 the Commission recommended to the Director of Civil Aviation that he:

5.1.1 Revise the GAP booklet Winter Flying to emphasise that hard ice will not be removed by brushing. (023/06)

5.2 On 25 January 2006 the Director of Civil Aviation replied, in part, that he:

> will accept this recommendation and the Manager of Communication and Education will amend the CAA GAP booklet Winter Flying to include an emphasis that hard ice will not be removed by brushing. This amendment will take place at the next booklet reprint.

5.3 On 12 May 2006 the Commission recommended to the Director of Civil Aviation that he:

5.3.1 Revise the educational material on wake turbulence to include guidance for operations at uncontrolled aerodromes, and to emphasise that pilots should observe the ICAO recommended minimum separation distance between light aircraft and report any severe wake turbulence incidents. (029/06)

5.4 On 12 May 2006 the Director of Civil Aviation replied, in part, that he:

> accepts this recommendation and will revise the educational material on wake turbulence to include guidance for operations at uncontrolled aerodromes, and to emphasise that pilots should observe the ICAO recommended minimum separation distance between light aircraft and notify any severe wake turbulence incidents to the CAA. This will be completed by October this year. In addition an article highlighting the dangers of wake turbulence will be published in the next edition of the CAA "Vector Magazine".

5.5 On 12 May 2006 the Commission recommended to the Chief Executive Officer of Fiordland Experience Group Limited that he:

5.5.1 Instruct his pilots to perform a tactile check before take-off, when conditions dictate, to ensure that critical surfaces are free of contaminants such as frost and ice. (024/06)

5.5.2 Equip each of his aircraft with adequate means of securing baggage and cargo. (025/06)

5.5.3 Amend his standard load plans to specify the baggage or cargo conditions that must be met if pilots are to rely on the plans to keep the centre of gravity within limits. (026/06)

5.5.4 Amend the Cessna 206 passenger safety information cards to show accurately how to operate the cargo doors and exit the aircraft, including when the flaps are extended. (027/06)

Approved on 18 May 2006 for publication

Hon W P Jeffries
Chief Commissioner

Appendix A

10 April 2006

Dear AIA Member,

Short survey of light aircraft wake turbulence hazard

A person has suggested to the Transport Accident Investigation Commission (TAIC) that there have been unreported severe wake turbulence incidents in New Zealand that involved only light aircraft. However, no official reports have been found in New Zealand of a light aircraft being upset by the wake turbulence or prop wash of another light aircraft.

The hazard posed to light aircraft by the wake of medium and heavy wake turbulence category aircraft is well known and ATC and pilots apply appropriate separation standards, but light aircraft have not been considered to create a hazardous wake. Consequently, there is no national or international wake turbulence separation specified between 2 light aircraft.

TAIC wishes to confirm whether or not there is an unrecognised hazard to light aircraft caused by the wake turbulence and prop wash of another light aircraft and has decided to survey Aviation Industry Association (AIA) members who operate 3 or more light aircraft (i.e. MCTOW less than 7000 kg). You are invited to complete the attached short survey and to return it by email to me by the 17th April 2006. The TAIC Act restricts disclosure of any information supplied to the TAIC, so completed questionnaires sent to TAIC will be treated in-confidence.

The TAIC Act also permits a person who made a statement or submission to the TAIC to disclose to any other person the information contained in their own statement or submission. As the AIA has a general interest in operating matters such as wake turbulence, you are also invited to copy your completed questionnaire to the AIA, but replies copied to the AIA may not be protected.

We look forward to your participation in this short survey and thank you in advance for your cooperation. If you have any queries about the survey, please contact me.

Transport Accident Investigation Commission

Light Aircraft Wake Turbulence Survey, April 2006

The AIP New Zealand definitions for reporting en-route turbulence are a guide for describing turbulence intensity.

Light – less than moderate.
Moderate – Moderate changes to aircraft attitude and/or altitude may occur but aircraft remains under positive control. Usually small changes in air speed.
Severe – Abrupt changes to aircraft attitude and/or altitude may occur; aircraft may be out of control for short periods. Usually large changes of air speed.

Instructions:
Save this document to your desktop, complete the questionnaire, then send the completed page back to TAIC from your desktop. Please email your completed questionnaire to TAIC by the 17th April 2006, and copy it to the AIA if you wish.

1. What aircraft type(s) do you operate?

2. While operating a light aircraft, have you ever experienced wake turbulence or prop wash from a preceding light aircraft (Y/N)?   If no, go to line 11.

3. If yes, in what phase of flight did it occur? (X your choice):
take-off (to 50 ft AGL)___ climb____cruise___descent____circuit___
final approach____landing_____

4. What intensity was the event? (X one):
severe___ moderate___light____ or insignificant___

5. Briefly describe what happened.

6. If a severe or moderate encounter, was the event reported to ATC (Y/N), CAA (Y/N) or recorded by the operator (Y/N)?

7. If severe or moderate and not reported, why not?

8. What was your aircraft type _____________and the type of aircraft ahead _______________?

[Copy and Paste Q3 - Q8 after this line for any other light aircraft only wake turbulence events.]

9. Do you routinely take-off with ATC applying the minimum reduced runway separation of 600 m between light aircraft departures (Y/N)?

10. If yes, at which airport(s) does this occur?

11. Any other comments?

12. Name, organisation, contact phone number or email address.

Thank you for helping TAIC with this survey.

Appendix B

National Transportation Safety Board Safety Alert
March 2005

Aircraft Icing
Pilots urged to beware of aircraft upper wing surface ice accumulation before takeoff

The problem:

• Fine particles of frost or ice, the size of a grain of table salt and distributed as sparsely as one per square centimeter over an airplane wing's upper surface, can destroy enough lift to prevent a plane from taking off.
• Almost visually imperceptible amounts of ice on an airplane's wing upper surface during takeoff can result in significant performance degradation.
• Small, almost visually imperceptible amounts of ice distributed on an airplane’s wing upper surface cause the same aerodynamic penalties as much larger (and more visible) ice accumulations.
• Small patches of ice or frost can result in localized, asymmetrical stalls on the wing, which can result in roll control problems during lift off.
• It is nearly impossible to determine by observation whether a wing is wet or has a thin film of ice. A very thin film of ice or frost will degrade the aerodynamic performance of any airplane.
• Ice accumulation on the wing upper surface may be very difficult to detect from the cockpit, cabin, or front and back of the wing because it is clear/white.
• Accident history shows that nonslatted, turbojet, transport-category airplanes have been involved in a disproportionate number of takeoff accidents where undetected upper wing ice contamination has been cited as the probable cause or sole contributing factor.
• Most pilots understand that visible ice contamination on a wing can cause severe aerodynamic and control penalties, but it is apparent that many pilots do not recognize that minute amounts of ice adhering to a wing can result in similar penalties.
• Despite evidence to the contrary, these beliefs may still exist because many pilots have seen their aircraft operate with large amounts of ice adhering to the leading edges (including the dramatic double horn accretion) and consider a thin layer of ice or frost on the wing upper surface to be more benign.

What should pilots know and do to fly safely in icing conditions?

• Pilots should be aware that no amount of snow, ice or frost accumulation on the wing upper surface should be considered safe for takeoff. It is critically important to ensure, by any means necessary, that the upper wing surface is clear of contamination before takeoff.
• The NTSB believes strongly that the only way to ensure that the wing is free from critical contamination is to touch it.
• With a careful and thorough preflight inspection, including tactile inspections and proper and liberal use of deicing processes and techniques, airplanes can be operated safely in spite of the adversities encountered during winter months.
National Transportation Safety Board
• Pilots should be aware that even with the wing inspection light, the observation of a wing from a 30- to 40-foot distance, through a window that was probably wet from precipitation, does not constitute a careful examination.
• Pilots may observe what they perceive to be an insignificant amount of ice on the airplane's surface and be unaware that they may still be at risk because of reduced stall margins resulting from icing-related degraded airplane performance.
• Depending on the airplane's design (size, high wing, low wing, etc.) and the environmental and lighting conditions (wet wings, dark night, dim lights, etc.) it may be difficult for a pilot to see frost, snow, and rime ice on the upper wing surface from the ground or through the cockpit or other windows.

• Frost, snow, and rime ice can be very difficult to detect on a white upper wing surface and clear ice can be difficult to detect on an upper wing surface of any color.
• Many pilots may believe that if they have sufficient engine power available, they can simply "power through" any performance degradation that might result from almost imperceptible amounts of upper wing surface ice accumulation. However, engine power will not prevent a stall and loss of control at lift off, where the highest angles of attack are normally achieved.
• Some pilots believe that if they cannot see ice or frost on the wing from a distance, or maybe through a cockpit or cabin window, it must not be there - or if it is there and they cannot see it under those circumstances, then the accumulation must be too minute to be of any consequence.

Need more information?

• Visit the NTSB's website: http://www.ntsb.gov.
• For additional information, see http://www.ntsb.gov/recs/letters/2004/A04_64_67.pdf.
• Refer to the Safety Board's final and factual reports:

- Takeoff Stall in Icing Conditions, USAir flight 405, Fokker F-28, N485US, LaGuardia Airport, Flushing, New York, March 22, 1992. Aircraft Accident Report NTSB/AAR-93/02. Washington, D.C.
- Ryan International Airlines, DC-9-15, N565PC, Loss of Control on Takeoff, Cleveland-Hopkins International Airport, Cleveland, Ohio, February 17, 1991. Aircraft Accident Report NTSB/AAR-91/09. Washington, D.C.
- In-flight Icing Encounter and Uncontrolled Collision with Terrain, Comair flight 3272, Embraer EMB-120RT, N265CA, Monroe, Michigan, January 9, 1997. Aircraft Accident Report NTSB/AAR- 98/04. Washington, D.C.
- Refer to the Air Accidents Investigation Branch (AAIB), Department for Transport, Great Britain final report. Additional information on this accident can be found at http://www.aaib.gov.uk/cms_resources/dft_avsafety_pdf_030576.pdf
- The NTSB has also investigated other types of icing issues, some of which may be found on the Board's Most Wanted List, at http://www.ntsb.gov/Recs/mostwanted/air_ice.htm.

End

Recent Aviation Occurrence Reports published by the Transport Accident Investigation Commission (most recent at top of list)

05-008	Cessna U206G, ZK-WWH, loss of control on take-off, Queenstown Aerodrome, 10 August 2005
01-005R	Bell UH-1H Iroquois ZK-HJH, in-flight break-up, Taumarunui, 4 June 2001
05-010	Aerospatiale-Alenia ATR 72-500, ZK-MCJ, runway excursion, Queenstown Aerodrome, 5 October 2005
05-003	Piper PA34-200T Seneca II, ZK-FMW, controlled flight into terrain, 8 km north-east of Taupo Aerodrome, 2 February 2005
05-002	Cessna 172, ZK-LLB, collision with terrain while low flying, 7 km south of Gibbston, 29 January 2005
05-009	Eurocopter AS350 BA Squirrel, ZK-HGI, roll over on landing, Franz Josef Glacier, 17 August 2005
05-007	Piper PA-34-200T Seneca II, ZK-MSL, Wheels-up landing, Napier Aerodrome, 7 July 2005
05-001	Gulfstream G-IV ZK-KFB and Piper PA 28 ZK-FTR , loss of separation, near Taupo 7 January 2005
04-009	Hughes 360D, ZK-HHT, heavy landing, Wanganui River, South Westland, 21 December 2004
04-007	PA-34-200T Sceneca 11, ZK-JAN, collision with terrain, Mount Taranaki, 20 November 2004
04-008	Cessna 172, ZK-JES, ditching Cable Bay, Northland, 15 December 2004
04-003	Bell/Garlick UH1B Iroquois helicopter, ZK-HSF, in-flight break-up, near Mokoreta, Southland, 23 April 2004
04-006	Boeing 777, HL 7497, landed short of displaced threshold, Auckland International Airport, 16 November 2004
04-001	Piper PA23-250E Axtec, ZK-DGS, landing gear collapse during taxi, Paraparaumu Aerodrome, 9 January 2004
03-007	Hughes 369HS, ZK-HCC, in-flight power loss and emergency landing, Fox Glacier, 30 November 2003

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