AVIATION INVESTIGATION REPORT
A99P0181

LOSS OF CONTROL

CESSNA 208 CARAVAN AMPHIBIAN   C-FGGG
ABBOTSFORD AIRPORT, BRITISH COLUMBIA
28 DECEMBER 1999

Aviation Investigation Report

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Summary

At 0916 Pacific standard time, the Seair Cessna 208 Caravan amphibious aircraft, serial number 20800310, took off from runway 19 at Abbotsford Airport, British Columbia, on the first leg of a private flight to the Bahamas. One pilot and five passengers were on board. About one minute later, as the aircraft was climbing through an altitude of about 400 feet above ground level and as the pilot retracted flaps from 10 to zero degrees, the aircraft became uncontrollable. The aircraft banked left, descended rapidly, and crashed in a field about one-half mile south of the runway threshold, in a left bank with a near-level pitch attitude. The aircraft was destroyed, and the pilot received serious injuries. Two passengers were also seriously injured, and three passengers received minor injuries. Daylight visual meteorological conditions prevailed at the time of the accident. There was no fire.

Ce rapport est également disponible en français.

Other Factual Information

The southwest region of British Columbia that morning was experiencing a quasi-stationary upper ridge of high pressure. This ridge created extensive areas of low ceilings and low visibilities in stratus cloud and fog. Vancouver International Airport, about 34 miles west of Abbotsford, was experiencing fog and freezing fog throughout the morning. Several aircraft destined for Vancouver had diverted to Abbotsford, where weather conditions were more favourable. The 0900 aviation routine weather report (METAR) for Abbotsford recorded the weather as follows: calm wind, visibility 30 miles, fog in the vicinity, a few clouds at 25 000 feet, temperature minus 3 degrees Celsius (°C), dew point minus 4°C, and an altimeter setting of 30.46 inches of mercury. FROIN[1] was recorded in the remarks section.

The pilot held a Canadian commercial pilot licence and a current medical validation certificate. He had accumulated over 12 000 hours of flying time, with experience on float-equipped aircraft, such as the DHC-2 Beaver and DHC-2T Turbo Beaver. He had a total of about 85 hours of experience on the Cessna 208 Caravan. The pilot had recently completed a five-day initial training syllabus for the aircraft, including simulator flying, at a factory-approved training centre. This training, however, focused on the aircraft's wheel configuration and did not include any flying training. No records indicating that the pilot had received any training on the aircraft in the amphibious configuration could be found.

The pilot and the passengers arrived at the airport at about 0750 Pacific standard time (PST)[2] in preparation for the flight. The pilot received a detailed weather briefing at the Abbotsford Flight Service Station and filed a visual flight rules flight plan from Abbotsford to Billings, Montana. The estimated time en route was filed as four hours, with a fuel endurance of five hours.

The Abbotsford control tower controller issued a take-off clearance to C-FGGG at 0916, and the aircraft departed shortly thereafter. The pilot slowly advanced the throttle during the take-off roll, and he assessed the take-off and initial climb as normal. He retracted the landing gear after establishing a positive rate of climb and made a slight power reduction, while continuing to climb. The pilot used 20 degrees (°) of flap for the take-off. The pilot retracted the flaps in two increments: first, from 20° to 10°, then from 10° to zero. The aircraft departed from controlled flight after the pilot initiated the retraction from 10°.

The aircraft rolled to the left and descended rapidly. The pilot's initial attempt to overcome the uncommanded roll by using aileron control was unsuccessful. He then lowered the aircraft's nose and advanced the throttle. The pilot was able to initially return the wings toward level and reduce the rate of descent; however, there was insufficient height for the aircraft to recover. The flight, from lift-off to collision with the ground, lasted about one minute.

Collision damage markings indicate that when the aircraft contacted the ground, it was on a heading of about 120° magnetic, in a left bank, with a near-level pitch attitude. The left wing tip first struck a fencepost, then the left wing, left float, and right float struck the ground in succession. The floats absorbed much of the impact force and separated from the aircraft during the impact sequence. The aircraft slid along the ground for about

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1 FROIN: abbreviation for "frost on the indicator", meaning that frost had been forming over the last hour.

2 All times are PST (Coordinated Universal Time minus eight hours) unless otherwise noted.

310 feet and came to rest oriented 040° magnetic. Damage to the propeller assembly was consistent with the engine producing power at impact.

Post-crash examination of the aircraft did not reveal any significant abnormalities. To the extent examined, no pre-crash malfunctions were detected that would have caused the aircraft to depart from controlled flight. The flap motor circuit-breaker, however, was found in the open or "popped" position. In addition, the left and right flaps were found in dissimilar positions at the crash site. The left flap was fully retracted, and the right flap was extended about two inches aft on its track. Continuity within the flap system was confirmed by examination, and it was determined that flap extension was not dissimilar during flight. Damage to the flap system was attributed to impact forces, with components breaking in overload. It was determined that the flaps were in transition at impact and that the left flap was forced to the fully retracted position when the wing entered the cabin trailing-edge first, and the flap linkage broke. At about the same time, the flap motor would have stalled and caused the circuit breaker to open.

The main and standby flap motors and the screw jack drive mechanism were sent to the manufacturer for inspection and performance analysis under the supervision of the United States Federal Aviation Administration. The components were bench-checked and performed to approved specification. During the examination, a slight bend was noted in the screw jack. The bend would not have degraded the operation of the flaps or precipitated the loss of control. It was not determined when the bend occurred.

The aircraft engine, a Pratt & Whitney Canada PT6A-114A turbo-prop, serial number PC0684, was examined at an approved maintenance facility under TSB supervision. This examination revealed that the engine was running at impact and that all the engine damage resulted from impact forces and high-speed rotation. It was determined that torsional loads absorbed through the propeller shaft fractured the second-stage sun-gear coupling spline from the first-stage carrier. The fracture unloaded the power turbine shaft and allowed the power turbine to accelerate to an over-speed condition and release its blades into the power turbine shroud and containment ring. The engine displayed no indications of any pre-impact anomalies or distress that would have precluded normal engine operation before impact.

No records exist of the pre-flight calculations for the weight and balance at take-off. The pilot and the passengers were not able to recall the baggage, fuel, or occupant weights used or the final figures so calculated. Furthermore, no information about the two flights before the accident flight was recorded in the aircraft journey log.

The pilot estimated that the weight of the aircraft at take-off on the accident flight was about 8260 pounds, about 100 pounds under the maximum take-off weight (MTOW) of 8360 pounds. Weight calculations performed by the TSB during the investigation revealed that the take-off weight for the aircraft was about 8870 pounds, about 510 pounds over the MTOW. A portion of the difference between the weight estimates by the pilot and the TSB can be attributed to an aircraft modification that was completed two days before the accident flight. The modification included changes to the interior seating configuration and resulted in an increase of about 150 pounds to the aircraft empty weight. No entries reflecting the seating configuration change were made in the aircraft logbooks, although the physical installation of the modified interior was completed. The pilot's calculations did not include this increase in aircraft empty weight, since the required weight and balance revision sheet had not yet been completed. The basic weight of the aircraft used in any weight and balance calculation by the pilot would have been about 150 pounds underweight owing to the undocumented cabin interior and seat modifications. The aircraft owner is responsible for maintenance and aircraft records, and the aircraft empty weight recorded in the aircraft documentation did not reflect the 150-pound increase.

The baggage, seats, and tables were removed from the wreckage. The baggage was weighed by Seair at 244 pounds. The seats and tables weighed 358 pounds using certified aircraft scales. The baggage weight did not include ancillary personal effects in the cabin or first aid and survival equipment. The weight calculations did not include the weight of the carpet kit or the wood panelling additions.

The aircraft wing tanks were filled to capacity the evening preceding the accident. The pilot personally oversaw this fuelling to ensure that there was no contamination and that the tanks were full. The total actual weight of the six occupants, provided by Seair, was 744 pounds. The following table summarizes the weight calculations (in pounds) for the aeroplane at take-off.

Total weight of tables and seats (excluding pilot seats)	358
Subtract 3 life jackets in 3 of the seats	(4)
Original Cessna seats removed	(208)
Weight increase of new seats	**146**
Baggage as weighed by Seair	244
Other cargo	17
Life jackets (6)	8
Total baggage weight	**269**
Fuel (full tanks minus 35 pounds taxi fuel)	2344
Pilot and passengers as weighed by Seair	744
Basic aircraft empty weight (before interior modifications)	5363
Calculated aircraft take-off weight	8866
Maximum certificated take-off weight	8360
AMOUNT AIRCRAFT OVER WEIGHT AT TAKE-OFF	**506**

The aircraft had been parked overnight on the ramp at Abbotsford and had accumulated a layer of frost, which the pilot noted. He used cold tap water to remove frost from the windshield in order to see out of the aircraft. The pilot also checked the top of the wings during his pre-flight check and noted a layer of frost, which he indicated to be about 3/16 inch thick, but he assessed that it was insignificant. He believed that the sun would melt all the frost and that de-icing the wings would not be necessary. The wings were not examined to confirm that the frost had melted before take-off. It is impossible to see the upper surface of the wings from the cockpit.

The leading edge of the wing was painted a dark colour, which increased the solar heating of that part of the wing. The remaining surfaces of the wing, however, were predominantly white. The sun rose at 0810 and was about eight degrees above the horizon by the time the aircraft took off. Ambient temperatures for Abbotsford at 0900 and 0920 were recorded as minus 2.8°C and minus 0.5°C, respectively. The extent to which the early morning sun would have melted frost from these surfaces is negligible.

Witnesses on the ground at Abbotsford who were experienced in aircraft icing/de-icing operations consistently reported that the Caravan was covered in a pronounced layer of frost, about ¼ inch thick. Adjacent aircraft were significantly covered in frost and ice such that scheduled flights were postponed; those aircraft remained frost-covered until late that morning. Furthermore, initial information from the pilot about the thickness of the frost was consistent with observations by other people who saw the aircraft that morning.

The detrimental effects of contaminated wings are well documented.[3] Frost accumulation on the upper surface of an aircraft wing decreases a wing's efficiency and restricts its ability to produce lift. Frost increases stalling speed, decreases the stall angle of attack, and rapidly increases the drag near the stall speed. Stability and control of the aircraft are also adversely affected. These adverse effects on the aerodynamic properties of the aerofoil may result in sudden departure from the commanded flight path and may not be preceded by any indications or aerodynamic warnings to the pilot. Canadian regulations prohibit take-off with ice or frost adhering to the wings. In addition, the aircraft flight manual (AFM) for the Cessna 208 is specific in its warning that a safe take-off and climb-out may not be possible unless the wings and other critical surfaces are free of frost, ice, and snow accumulations.

Cessna's Icing Training Program and the Pilot's Check-list produced for the Caravan state that "It is essential in cold weather to remove even small accumulations of frost, ice, or snow from wing, tail, and control surfaces...." They warn that "If these requirements are not performed, aircraft performance will be degraded to a point where a safe takeoff and climbout may not be possible." Additionally, Cessna warns that "0.1 inch of evenly distributed frost on the aircraft's wing could increase the stalling speed by 35%!! This roughly doubles the required takeoff run."

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[3] TSB Report No. A97H0011; The Honourable Virgil P. Moshansky, Commissioner, *Commission of Inquiry into the Air Ontario Crash at Dryden, Ontario*; Federal Aviation Administration, Advisory Circular AC 20-117; Transport Canada, *When in Doubt...Small and Large Aircraft: Aircraft Critical Surface Contamination Training*, TP10643E; Transport Canada, *A.I.P. Canada*, AIR 2.12.2, TP2300E.

The US National Transportation Safety Board (NTSB) investigated a Cessna 208B Caravan accident in Barrow, Alaska, that had similar characteristics and resulted in multiple fatalities. In that November 1997 accident, the pilot, who held an airline transport pilot license, took off with an accumulation of frost. The focus of the investigation became the aerodynamic characteristics of the NACA 23012 airfoil section, which is used on several production aircraft, such as the Embraer EMB-120 and the (then) McDonnell Douglas DC-9. Several ice contamination studies have been performed on this airfoil section. The results of all these studies showed the same trend of decreased stall angle of attack when contamination is present. They also showed differing reductions in the stall angles of attack for contaminated airfoils with upward and downward deflected ailerons. According to the studies, when the angle of attack on the wing increases beyond the contaminated reduced stall angle of attack, and the ailerons are deflected, the resulting asymmetric stall can impart a rolling moment to the aeroplane. This tendency can be aggravated during increasing angle of attack situations, such as raising the trailing-edge flaps. It was further found that, for a contaminated wing, the onset of stall occurs at lower-than-normal angle of attack. The angle of attack must therefore be increased to produce the required lift at normally scheduled speeds. As well, the increasingly unsteady airflow over the wing results in correspondingly degraded lateral stability, requiring larger and larger control wheel inputs to keep the aeroplane from rolling off. The aeroplane becomes increasingly unstable, eventually stalling without stick shaker activation at speeds normally scheduled for take-off.[4]

The US Federal Aviation Administration (FAA) discusses the importance of de-icing aircraft in several advisory circulars (AC). Contamination can affect numerous flight characteristics, including the following:[5]

- 3.c.(2)(ii) Surface roughness on the afterbody of a wing can have an effect approximately equal to the effect of similar surface roughness on the leading edges of some airfoils;
- 3.c.(2)(v) Stall angle of attack will decrease and in some aircraft stall will occur prior to activation of stall warning devices; and
- 3.c.(2)(vii) Controllability may be reduced requiring more stick deflection for manoeuvres or stall recovery.

Wind tunnel and flight tests indicate that frost, ice, or snow formations, having a thickness and surface roughness similar to medium or coarse sandpaper, on the leading edge and upper surface of a wing can reduce wing lift by as much as 30 per cent and increase drag by as much as 40 per cent. The primary influence of wing contamination is surface roughness on critical portions of the aerodynamic surface.[6] These adverse effects may result in sudden departure from the commanded flight path and may not be preceded by any indications or aerodynamic warning to the pilot. Therefore, it is imperative that take-off not be attempted unless the pilot has ascertained, as required by regulation, that all critical surfaces are free of adhering frost, ice, or snow formations.

The FAA advises that a common winter accident is trying to take-off with frost on the wing surface. It is recommended that all frost, snow, and ice be removed before attempting flight.[7] The Cessna 208B pilot

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[4] Douglas Aircraft Company, *The Effect of Wing Ice Contamination on Essential Flight Characteristics,* 1979.

[5] FAA, 'Appendix 3', "Hazards Following Ground Deicing and Ground Operations in Conditions Conducive to Aircraft Icing" (AC 20-117).

[6] FAA, 'Preface—Clean Aircraft Concept', "Pilot Guide for Large Aircraft Ground Deicing" (AC 120-58).

[7] FAA, "Operation of Aircraft", *Tips on Winter Flying* (FAA 8740-24).

operating handbook has several warnings concerning removal of frost before flight. On pages 4-4, 4-6, and 4-7 under “Pre-flight”, Cessna warns: “WARNING It is essential in cold weather to remove even small accumulations of frost, ice, or snow... .”

In another Cessna 208B Caravan take-off accident in December 1999 from Bethel, Alaska, the NTSB determined that the pilot, who held an airline transport pilot license, had parked the aircraft outside all night and that a noticeable layer of frost had accumulated on the wings, horizontal stabilizer, elevators, and windscreen. The pilot used a broom to remove an accumulation of frost and snow. The pilot recalled that shortly after lift-off, about 100 feet above the runway, he retracted 10° of flap. As the aircraft climbed through 200 feet above ground level, the pilot retracted the remaining flap, and the aircraft descended while rolling left. The pilot had to apply full aileron to keep the aeroplane upright. Despite full engine power, the aeroplane continued to descend to the ground.

Two other fatal Caravan accidents in 1990 (NTSB reference NYC90FA060 and NYC90FA061) have been directly attributed to the pilots not removing the contamination on the wings.

Performance charts for the aircraft indicate that, at MTOW and 0° of flap, the stall speed would be about 64 knots indicated airspeed (KIAS). At MTOW and 10° flap, the stall speed would be 56 KIAS. Performance charts for weights exceeding MTOW are not contained in the AFM; however, stall speeds increase with added weight.

Take-off performance charts for the aircraft indicate that at MTOW the aircraft would require about 1300 feet of ground roll before becoming airborne. Accounts of the take-off, however, reveal that the aircraft consumed about 2200 feet of runway before becoming airborne and that the initial climb profile appeared to be low. The aircraft flew low along the runway initially, as if it were in ground-effect, and then appeared to increase speed before beginning to climb at a shallow angle.

Climb performance charts for the aircraft indicate that the rate of climb would have been about 905 feet per minute (fpm) at MTOW, flaps at 20°, and flying at 87 KIAS. The cruise performance rate of climb would have been about 945 fpm at MTOW, with flaps retracted to 0° and flying at 110 KIAS. In summary, an aircraft loaded to MTOW and flown at AFM-recommended speeds should have achieved a rate of climb exceeding 900 fpm. The pilot estimated that he was climbing at a normal rate and flying about 105 KIAS before initiating flap retraction.

Flaps on the Cessna 208 are large span and of single, slotted type. The flap system is powered by an electric motor and controlled by a selector lever on the control pedestal. The selector lever is moved up and down in a slotted track that provides mechanical stops at 10°, 20°, and 30° (full flap). Extension of the flap surface is a combination of aft and downward travel. When the flaps are moved from 0° to 10°, the flap surface moves about eight inches rearward and about one inch down. This increases the total wing surface area by about 30 square feet, or 5.5 per cent.[8] Accordingly, when flaps are retracted from 10° to 0°, total wing area is reduced, resulting in a reduction to the total amount of lift being produced by the wing.

The Cessna 208 is equipped with a vane-type stall warning unit in the leading edge of the left wing. The unit is electrically connected to a stall warning horn overhead the left pilot’s position. During normal operation, the vane senses the change in airflow over the wing and operates the warning horn at airspeeds between 5 and

[8] Data provided by Cessna.

10 knots above the stall, in all configurations. The pilot and the front seat passenger both heard the horn activate during the later stages of the event, just before impact.

Analysis

The aircraft contacted the ground in a near-level pitch attitude, and the aircraft's floats absorbed much of the impact energy. These conditions likely enhanced the survivability of the accident.
There was frost on the aircraft and wings that was not removed. At 0900, about 15 minutes before take-off, frost was reported on the indicator, the dry temperature was minus 3°C, and the dew point temperature was minus 4°C. Other aircraft on the ramp remained frost-covered until late that morning. The detrimental effects of contaminated wings were present in this occurrence, and the aircraft stalled well above the normal stall speed. Based on these indications, it is concluded that the aircraft was contaminated with frost during the take-off, which would have increased drag and reduced the ability of the wings to produce lift. The aircraft was also overloaded, which adversely affected aircraft performance.

The decreased performance of the aircraft during the take-off and climb is attributable to the combined effects of aircraft overloading and wing and flight control surface contamination. As well, increased weight and surface contamination both increase the stall speed of an aircraft. When the flaps were retracted, further reducing lift, the aircraft experienced an aerodynamic stall and loss of control from which the pilot was unable to recover before the aircraft contacted the ground. Because the wings were contaminated, the classic stall indicators of aircraft buffet and audible stall warning were likely absent, at least initially.

Findings as to Causes and Contributing Factors

1. The pilot took off with frost adhering to the aircraft's lifting surfaces, which increased drag and reduced the ability of the wings to produce lift.

2. At take-off, the aircraft was about 510 pounds in excess of its maximum take-off weight, adversely affecting aircraft performance.

3. The aircraft experienced an aerodynamic stall and loss of control when the flaps were retracted from 10 degrees to zero. Retracting the flaps reduced the amount of lift being produced by the wing, already performing poorly because of contamination.

Other Findings

1. Appropriate entries were not recorded in the aircraft's journey and maintenance logs, and the weight and balance documentation was not amended.

2. The floats absorbed much of the impact energy and likely enhanced survivability of the accident.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 04 April 2001.