Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT
A06P0087

COLLISION WITH TERRAIN

NIAGARA AIR TOURS LTD.
CESSNA T207A C-GGQR
PEMBERTON, BRITISH COLUMBIA, 8 nm NE
18 MAY 2006

Canada

The Transportation Safety Board of Canada (TSB) investigated this occurrence for the purpose of advancing transportation safety. It is not the function of the Board to assign fault or determine civil or criminal liability.

Aviation Investigation Report

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Summary

The Cessna T207A (registration C-GGQR, serial number 20700499) departed from Pemberton Airport, British Columbia, at about 1500 Pacific daylight time on a visual flight rules flight to Edmonton, Alberta. The aircraft initially climbed out to the east and subsequently turned northeast to follow a mountain pass route. The pilot was alone on this aircraft repositioning flight. The pilot had been conducting air quality surveys for Environment Canada's Air Quality Research Section in the Pemberton area. The aircraft was operating on a flight permit and was highly modified to accept various types of probes in equipment pods suspended under the wings, a camera hatch type provision in the centre belly area, and carried internal electronic equipment.

About 30 minutes after the aircraft took off, the Coastal Fire Service responded to a spot fire and discovered the aircraft wreckage in the fire zone. A post-crash fire consumed most of the airframe, and the pilot was fatally injured. The accident occurred at about 1506 Pacific daylight time.

Ce rapport est également disponible en français.

Other Factual Information

Wreckage and Site

The aircraft struck the trees in a left descending turn with an excess of 30 degrees of bank. The wreckage trail was oriented on a heading 180 degrees from the original flight path. Following impact with the ground, the aircraft slipped down the steep mountain slope, was turned around to face the direction of entry into the trees, and came to rest on its right-hand side. During the initial impact with the trees, an outboard section of the right horizontal stabilizer sheared from the empennage. Equipment pods containing lasers separated from the wings and were found about 50 feet back from where the wreckage came to rest. Decals affixed to the exterior of the laser probe pods were marked "DANGER" and warned of laser radiation when opened. The laser devices were electrically disconnected for this particular flight. The engine remained precariously attached to the firewall. Most of the aircraft structure was consumed by a post-crash fire. This destruction limited the analysis of flight controls and instrumentation. Two of the three propeller blades were fractured in overload about four inches from the tips. The three propeller blades exhibited leading edge damage, chordwise scoring, and torsion damage, all indications of applied power. The emergency locator transmitter (ELT) was destroyed by the impact and fire, and no signal was received. Present standards do not require that ELTs resist crash damage.

Weather

The weather at Pemberton on the day and time of the occurrence, recorded by an automatic weather reporting station, was as follows: clear skies; wind 110° true (T) at 4 knots; temperature 28.6°C; dew point 5.3°C; remarks: sea-level pressure 910 hectopascals. The barometric pressure by which the pilot would set the altimeter was 29.80 inches of mercury. The airport elevation is at 670 feet above sea level (asl). The density altitude at this location was equivalent to 2682 feet. Official sunset was at 2136 Pacific daylight time.[1]

Mountain weather is subject to its own systems and particularities. Strong rising air currents form when the hillside slopes are heated up by the sun, and descending currents form when the slopes are subjected to shadows and cooling air. This cooling of air in shadowed areas and the cooling of air above snow-covered surfaces causes downdraughts, also known as katabatic wind in mountainous areas. These phenomena can create heavy turbulence in narrow mountain passes.

A rotor is a large closed eddy that forms in the lee of a mountain range, or any obstacle in the airflow, and is an area of severe turbulence. Rotors are usually found under the crests of mountain waves, often within 3000 feet vertically of the generating ridge. The wind below the rotor will be in the reverse direction to the general flow. Updraughts and downdraughts in a rotor have been measured at over 5000 feet per minute (fpm). The presence of rotors in this occurrence could not be confirmed.

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[1] All times are Pacific daylight time (Coordinated Universal Time minus seven hours).

Flight Planning

The flight was conducted under visual flight rules (VFR). There is no requirement to file a flight plan, and it is unclear if the pilot had formally assigned a person responsible for flight following. Consequently, full details of the flight could not be ascertained. The pilot elected to follow the Duffy Lake road mountain pass route, along Joffre Creek, at the north end of Lillooet Lake. This mountain pass route has a steep, climb section over the first four nautical miles (nm), rising to 4200 feet at ground level in the valley. The altitude or alignment of the aircraft during the climb could not be determined because there was no radar coverage. There were no data available from any navigational aids.

There is a VFR route along the Anderson Lake Valley that provides a much less steep and more graduated climb with a floor elevation limited to about 1400 feet, just north of the airport (see Appendix A).

The TSB Engineering Laboratory performed a terrain shadow analysis (TSB Engineering Laboratory report LP 065/2006). The accident site location corresponds to a narrowing point at the initial climb section, with the valley about one mile wide at this elevation. This site, on the left side of the valley (southeast-facing slope), was in a large shadow region and had been for a couple of hours before the accident. The mountain peaks in the vicinity of the accident site vary in height between 9150 feet and 8550 feet asl, and there was some snow at higher elevations. The wreckage site coordinates, latitude 50°20′ N and longitude 122°34′ W, correspond to an elevation of approximately 3280 feet asl.

Using the standard lapse rate of 2°C per 1000 feet of elevation, the outside air temperature at the accident site at about 3500 feet asl would have been 23.1°C. By extrapolation, the density altitude 1000 feet above terrain elevation, assuming a minimum safe altitude above ground elevation and 21.1°C, would be equivalent to about 6319 feet asl.

The Civil Aviation Authority (CAA) of New Zealand published a *Mountain Flying* booklet about good aviation practices. Flight training schools also offer guidelines for mountain flying. These guidelines suggest procedures to follow when entering a valley. The guidelines are not quoted verbatim.

- The pilot should check with the compass and map to ensure the correct valley is being entered, and know whether the valley climbs and what altitude will be required to clear the pass or ridge at the end.

- It is recommended to fly in smoother, updraughting air.

- If a 180-degree turn becomes necessary, it is made into the wind, requiring less distance over the ground. However, downdraughts may be encountered on the lee side of mountain terrain.

- Always position yourself in a valley so that you will have enough room to turn around if needed. You need 5 to 7.5 seconds to see, evaluate, decide, and execute. If you are sinking and at low level, this time plus any time taken to move over in the valley will be longer than you have.

- Leaving maximum room to turn also means less bank angle is needed, therefore less wing loading and lower stall speeds.

- When executing the turn, control the speed; too much power translates into too much speed, which results in a greater radius.

- A commonly accepted minimum safe altitude in mountainous regions is at least 1000 feet above the valley floor. Furthermore, minimum safe altitude on low-level flights in canyons is at least 2000 feet when downdraughts are expected.

- Wind strength and direction can vary markedly with height. At low level, the wind may be down a valley, while nearer the tops of the ridges, it may be across the valley.

- Pilots are advised to fly on the sunlit side of the valleys to benefit from rising air currents.

Pilot

The pilot held a valid Canadian commercial pilot licence issued by Transport Canada (TC). The licence was endorsed for all non–high-performance, single- and multi-engine land and sea aeroplanes and for an instrument rating. The pilot had accumulated approximately 1500 flying hours on light, single-engine aircraft, including the Cessna T207A, and had flown this particular aircraft at high weights for approximately 75 hours during the five weeks preceding the accident. The occurrence pilot had been provided with a six-page *Pilot's Notes* document describing all of the changes to the aircraft and appropriate operating techniques. The pilot had also received training on the modified aircraft in its least favourable configuration. A description of the pilot's recent work schedule indicated that his schedule was within TC work and rest limits.

Company records indicate that he had recently completed a mountain flying course. In-class topics of study included the following: mountain winds and weather, aircraft performance and manoeuvres, airmanship and pilot decision making, and mountain navigation and flight planning. There was a practical mountain flying component to this training performed in a Cessna 172, but it was very limited in scope because of the risks involved. A similar occurrence (TSB report A03P0199) highlighted some of the risks involved in mountain flying training with aircraft in real conditions.

TC does not issue a rating/endorsement for mountain flying training. There are no standards established to ascertain the proficiency of a pilot in this environment. Pilots who complete a mountain flying course may not acquire the required skill sets.

The pilot showed an interest in photography. He had recently acquired a film camera, which he had used in flight on at least one previous occasion. The camera was found near the pilot's body at the accident site.

An autopsy of the pilot, including a full toxicology examination, did not reveal any condition that could have led or contributed to the accident and revealed that the pilot suffered post-crash–related fatal injuries.

The extent of destruction caused by the impact with the ground and the subsequent fire precluded any valuable analysis in the severity of the pilot's injuries.

Human Factors – Illusions

The most accurate sensory information available to a pilot about aircraft attitude and motion are the visual cues provided by the earth's horizon, the aircraft's flight instruments, or both. The CAA of New Zealand *Mountain Flying* booklet describes common illusions a pilot may experience. The illusion of *Relative Scale* explains that, when you are amongst large mountains, it is very difficult to accurately judge scale and distance. Mountains seem a lot closer than they actually are, simply because they are so much larger than you are. The only way to confirm your distance from the terrain is by picking out features on the surface, such as tussocks, trees, or bush that your mind can accurately judge the size of. This will help you work out how far away you are and give you an indication of your size relative to the mountain. It is important to be able to judge your distance from the terrain and it is a required skill to determine if you have allowed enough room for a reversal turn.

The booklet describes the *False Horizons* illusion that occurs because of the frequent lack of a defined external horizon, which can create aircraft attitude and airspeed problems. When flying amongst the mountains or anywhere the horizon is not visible, the pilot must imagine that horizon. Relying on the aircraft instruments alone will not work. In a confined space with reduced visibility, the eyes must be outside and performance must be interpreted by aircraft nose attitude and then confirmed by instruments (instrument discipline). Inexperienced pilots often fall into the common trap of using a ridgeline as the horizon and unintentionally altering the aircraft attitude, climbing the aircraft with a corresponding decrease in airspeed, and not making a timely decision to reverse course. The horizon goes through the base of the mountains, not the ridges. The *Contrast* illusion may also exacerbate this situation by creating a blending of ridgelines in the distance.

Aircraft

The Cessna T207A, a "normal category airplane,"[2] is certificated under Federal Aviation Administration (FAA) Type Certificate Data Sheet A16CE. Airworthiness standards for the issue of type certificates, and changes to those type certificates, for aircraft in the normal, utility, aerobatic, and commuter categories must be met. An operator may apply and TC may issue a

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2 The normal category is limited to aircraft that have a seating configuration, excluding pilot seats, of nine or less, a maximum certificated take-off weight of 5700 kg (12 566 pounds) or less, and intended for non-aerobatic operation.

limited supplemental type certificate (LSTC) for a specific serial numbered aircraft, provided that compliance is demonstrated with the applicable airworthiness standards. Subsections 511.13(1) and 513.07(1) of the *Canadian Aviation Regulations* (CARs) require that the applicant for a change to a type design meet the latest standards.

A TC-delegated design approval representative (DAR) modified this aircraft and reported that the aircraft met the rate-of-climb requirements. Climb gradient calculations and/or testing were not completed for the modified aircraft, and for this reason, the aircraft could not be approved for an LSTC.

The DAR elected to submit an application to TC for the issue of a "flight permit – specific purpose." A "flight permit – specific purpose" may be issued for an aircraft that does not comply with applicable airworthiness standards, that is, Paragraph 523.65(a),[3] but is deemed capable of safe flight. TC issued a "flight permit – specific purpose" for the occurrence aircraft. This authority was subject to conditions/limitations, and was granted for temporary purposes.[4] It is intended to permit flight testing in order to show compliance with the latest airworthiness standards in the case of a modification to a type design. It was originally issued on 14 July 2005 for the purposes of evaluating the environmental equipment installed and was valid for a period of 60 days from this date. A similar flight authority was reissued on 18 July 2005 and was valid until 18 August 2005. Meanwhile, a concurrent flight authority, a "flight permit – ferry flight" for the purpose of conducting atmospheric research following modification of the T207A, was issued on 10 August 2005 and was valid until 31 October 2005. On 15 November 2005, a "flight permit – ferry flight" granting the flight authority for the purpose of conducting atmospheric research was renewed; it was renewed again on 08 March 2006 and was valid until 31 July 2006.

The aircraft was highly modified to accept four wing-pylon–mounted canisters/laser pods, a roof sample collection probe, and a camera hatch type provision in the centre belly area. It had a Horton STOL-Craft Inc. short take-off and landing (STOL)[5] modification kit installed (supplemental type certificate [STC] SA1328CE), a Hartzell propeller Model PHC-C3YF-1RF installed as per STC A696AL, and it carried electronic computer equipment and apparatus mounted in metal frames, secured as cargo to the aircraft floor. It had been operated at a maximum allowable take-off weight increased to 3955 pounds in accordance with a document proposed by the DAR. To power all this equipment, a 28-volt, 200-amp alternator was adapted

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3 Paragraph 23.65(a) of the *Federal Aviation Regulations* (FARs) and Paragraph 523.65(a) of the CARs—Reciprocating engine-powered aircraft of 6000 pounds or less maximum weight must have a steady climb gradient at sea level of at least 8.3 per cent for land planes, and a climb speed not less than the greater of 1.1 V_{MC} and 1.2 V_{S1} for multi-engine aircraft and not less than 1.2 V_{S1} for single-engine aircraft.

4 A flight permit may only be issued on a temporary basis (12 months or less) where the aircraft in respect of which an application is made does not conform to the conditions of issue for a certificate of airworthiness or a special certificate of airworthiness. A flight permit is issued in an experimental or specific-purpose classification.

5 With the Horton STOL kit installed, the aircraft's stall speed with the flaps extended is approximately 45 knots indicated airspeed (KIAS).

to the engine. An Environment Canada observer would operate this equipment to conduct atmospheric research in flight. The equipment was not operated during this repositioning flight; therefore, there would not have been an additional power requirement from the engine.

A flight test was performed by the DAR to verify that the aircraft could be flown safely in this configuration, and to assure that the engine cooling was adequate while in the climb and producing the required project electrical power (see flight test data at appendices B and C). The occurrence pilot had been instructed to not climb the aircraft too hard. The test flights for certification were to be done at a later date when applying for the LSTC.

There is no requirement to placard such an aircraft as is the case for restricted category or experimental aircraft.

Engine and Fuel System Examination

During examination of the engine (Teledyne Continental TSIO-520-M, serial number 291708R) following the occurrence, a deposit plugging various parts of the fuel system was observed. It was noted that the substance was constricting the flexible fuel supply line and obstructed the inlet fitting to the distributor. Scanning electron microscope (SEM) comparison analysis found no match to the parent material of the flexible fuel hose and fire shield cover. Climb performance would have been degraded further by a fuel system constriction and reduction of power available; therefore, further analysis was commissioned to identify the substance and determine whether the obstruction was a result of the post-crash fire.

The deposit was analyzed by Fourier Transform Infrared Spectroscopy (FTIR) [Powertech file 06025.GRA, Project 12272-43-06]. The infrared spectrum of the deposit resembled that of polyethylene terephthalate (PET), a thermoplastic material that originates from the reinforcing fibres in the fuel line. The material was deposited as a result of the post-crash fire.

There was sufficient fuel on board for the flight. A fuel sample retrieved from the primary refuelling source for this aircraft during the course of the missions was retrieved and analyzed. The sample corresponds to aviation fuel 100 LL and was clear of contamination.

Performance

Weight and balance calculations performed during the investigation indicated that, at take-off, the aircraft weighed approximately 3618 pounds. This was 182 pounds below the aircraft's original maximum gross weight of 3800 pounds, and 337 pounds below the new maximum allowable take-off weight of 3955 pounds. This weight increase was allowed by the DAR as stated in a document referred to as the *Pilot's Notes*, document CN-MSC-011, also referred to as a flight supplement that was to be incorporated to a flight permit authority. A review of TC documentation provided did not reveal the incorporation of this document to any of the flight authorities issued. The centre of gravity (CG) at take-off was calculated to be 42.88 inches aft of the datum. The aircraft had been fuelled to full tanks. Information provided by the manufacturer indicates that this would constitute 36.5 US gallons in each tank. The occurrence flight duration was about six minutes and the fuel burn was five gallons, which included start, taxi, take-off, and climb. The aircraft weight at the time of the accident was calculated to be 3588 pounds and the CG at 42.84 inches aft of the datum, within the allowable range.

Records show that the aircraft was serviced and maintained in accordance with existing directives. The aircraft was manufactured in 1979 and had flown a total of 13 900 hours before the accident flight. A review of the journey, airframe, engine, and propeller logbooks showed nothing remarkable. The engine was operated "on condition," and had accumulated about 2450 hours since overhaul. The maintenance logbooks contained no uncorrected deficiencies.

The Cessna T207A is a fuel-injected turbocharged engine capable of maintaining maximum engine climb power up to 17 000 feet. The pilot operating handbook (POH) indicates that the normal climb—95 KIAS, flaps up, 2500 rpm, 30-inch of manifold pressure (MP), cowl flaps open, and standard temperature—gives 500 fpm at about 6319 feet density altitude. The best or maximum rate of climb for this aircraft is achieved with the following configuration: 87 KIAS, flaps up, 2600 rpm, 35-inch MP, and cowl flaps open. At gross weight, flying at 6319 feet asl, with an outside air temperature of 21.1°C, the rate of climb would be 695 fpm. This best rate-of-climb figure is predicated on the assumption that the aircraft is flying in wings-level flight. In-flight manoeuvring, such as an aggressive turn, will sharply decrease the aircraft's climb performance.

Climb performance figures derived during recent flight testing indicated that the modified Cessna T207A attained a climb rate of 500 fpm under normal climb configuration. The distance the aircraft would have travelled from the airport to the accident site was about 8.3 nm. The climb gradient for the distance travelled is equal to 314.45 feet per nautical mile. Assuming a normal climb configuration, the aircraft would have had to climb steadily at 498 fpm to reach the crash site.

Analysis

There were no reported problems with the aircraft's performance, and no emergency communication was received. This led the investigation and this analysis to focus on operational issues.

A detailed flight plan was not filed and special equipment, such as laser radiation emitting devices and/or hazardous substances were therefore not reported. Decals affixed to the exterior of the laser probe pods were marked "DANGER" and warned of laser radiation when opened. Although the laser devices were electrically disconnected for this particular flight, first responders at the scene would not know this and would be uncertain of the risks involved. The absence of flight plan information regarding these devices could delay search and rescue efforts and also expose first responders to unknown risks.

No mechanical malfunction was recorded or found before the commencement of this flight or during examination that would have resulted in engine power loss or a loss of flight control. The pilot would have checked whether the aircraft was developing full power at take-off. The departure and climb out from Runway 06 was reportedly normal. The damage to the propeller indicates that the engine was developing significant power at impact. Damage to the aircraft, impact marks with natural obstacles, and the direction of the debris trail indicate that the aircraft was configured for normal climb and in controlled flight until impact. It does not appear that the aircraft stalled before striking the ground.

The highest elevation in the valley in this initial climb section was at 4200 feet asl and about 11.8 nm from the airport. If the aircraft entered the mountain pass at 2000 feet, it would have required the aircraft to climb at a rate of 609 fpm to clear this elevation. The modified aircraft was not tested for the required angle of climb/climb gradient for LSTC certification. The pilot had been instructed to not climb the aircraft too hard, and could be presumed to be complying with that expectation until the realization that the aircraft would likely not out-climb the terrain.

The aircraft's climb performance was affected by the relatively high weight, its configuration and modifications, and the high density altitude. It is also probable that downdraughts negatively affected the aircraft's climb performance.

The pilot was familiar with the performance of the occurrence aircraft; however, he had limited mountain flying experience and selected a VFR route that warranted greater altitude clearance. He encountered steeply rising terrain, where false horizon and relative scale illusions in the climb are likely. Realizing that the aircraft would not likely be able to out-climb the approaching terrain elevation, he would have started a turn to reverse his course.

The camera found in close proximity to the pilot's body was burnt. It could not be determined if the pilot was taking photos during this repositioning flight and whether this could have caused a distraction or contributed to perception errors and misjudgement of height above ground.

During the last segment of the flight path, the aircraft was likely centred in the mountain valley, as this would provide the greatest height above ground. Just before the aircraft reversed course at a certain decision altitude, the pilot may have flown the aircraft toward the sunlit right-side hill slope to increase the area for a left turn between the hills. Tightening the turn as the aircraft crossed over the centre of the valley and closed in on the higher terrain would be an intuitive reaction. The aircraft was in a steep, descending left turn (30 degrees plus) facing southwest in down-flowing air currents, and the pilot was unable to arrest its descent before it clipped tree tops and subsequently struck the sloping ground.

The pilot likely misjudged the altitude above ground during his approach to higher terrain, and did not configure the aircraft for slow flight. With the flaps extended, the aircraft was capable of turning in the width of the mountain pass.

During the afternoon, downdraught katabatic winds would have formed in the mountain pass. Given the configuration and weight of the aircraft, the high density altitude, the performance of this modified aircraft, the close proximity to the terrain when the pilot reversed course, and the downdraughts, the aircraft was not able to clear the surrounding terrain.

The following projects were completed:

Powertech file 06025.GRA, Project 12272-43-06

TSB Engineering Laboratory report LP 065/2006 – Terrain Shadow Analysis

Findings as to Causes and Contributing Factors

1. The pilot entered the valley at an altitude above ground that did not provide sufficient terrain clearance given the aircraft's performance.

2. The pilot encountered steeply rising terrain, where false horizon and relative scale illusions in the climb are likely. Realizing that the aircraft would not likely be able to out-climb the approaching terrain, he turned to reverse his course.

3. The aircraft's configuration, relatively high weight, combined with the effects of increased drag from the equipment, density altitude, down-flowing winds, and manoeuvring resulted in the aircraft colliding with terrain during the turn.

Findings as to Risk

1. A detailed flight plan was not filed and special equipment, such as laser radiation emitting devices and/or hazardous substances were not reported. The absence of flight plan information regarding these devices could delay search and rescue efforts and expose first responders to unknown risks.

2. Transport Canada (TC) does not issue a rating/endorsement for mountain flying training. There are no standards established to ascertain the proficiency of a pilot in this environment. Pilots who complete a mountain flying course may not acquire the required skill sets.

3. There was no emergency locator transmitter (ELT) signal received. The ELT was destroyed in the impact and subsequent fire. Present standards do not require that ELTs resist crash damage.

4. "Flight permits – specific purpose" are issued for aircraft that do not perform as per the original type design but are deemed capable of safe flight. Placards are not required; therefore, pilots and observers approved to board may be unaware of the limitations of the aircraft and the associated risks.

5. The TC approval process allowed the continued operation of this modified aircraft for sustained environmental research missions under a flight permit authority. This circumvented the requirement to meet the latest airworthiness standards and removed the risk mitigation built into the approval process for a modification to a type design.

Other Findings

1. The fuel system obstruction found during disassembly was a result of the post-crash fire.

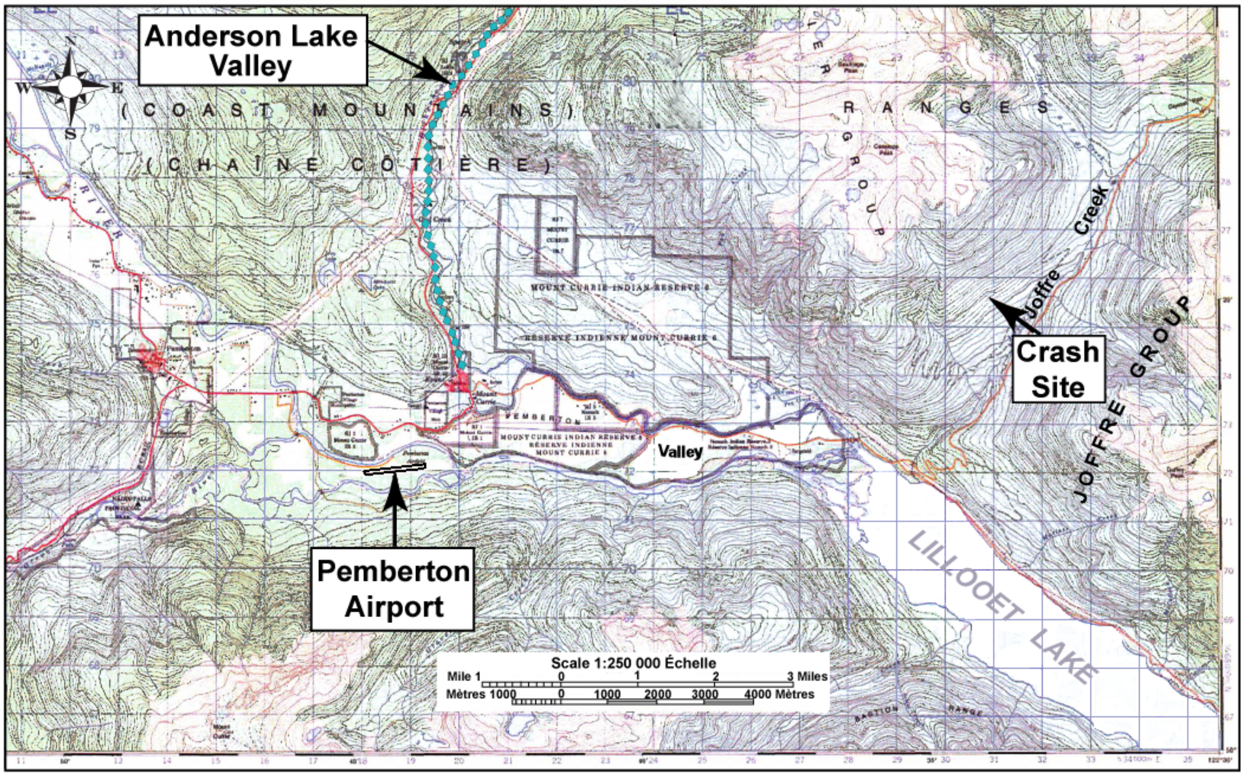
2. The aircraft was operated at an increased weight allowance proposed by the design approval representative (DAR). Such operation was to be approved only in accordance with a suitably worded flight permit and instructions contained in the proposed document CN-MSC-011; however, this increased weight allowance was not incorporated to any flight authority issued by TC.

Safety Action Taken

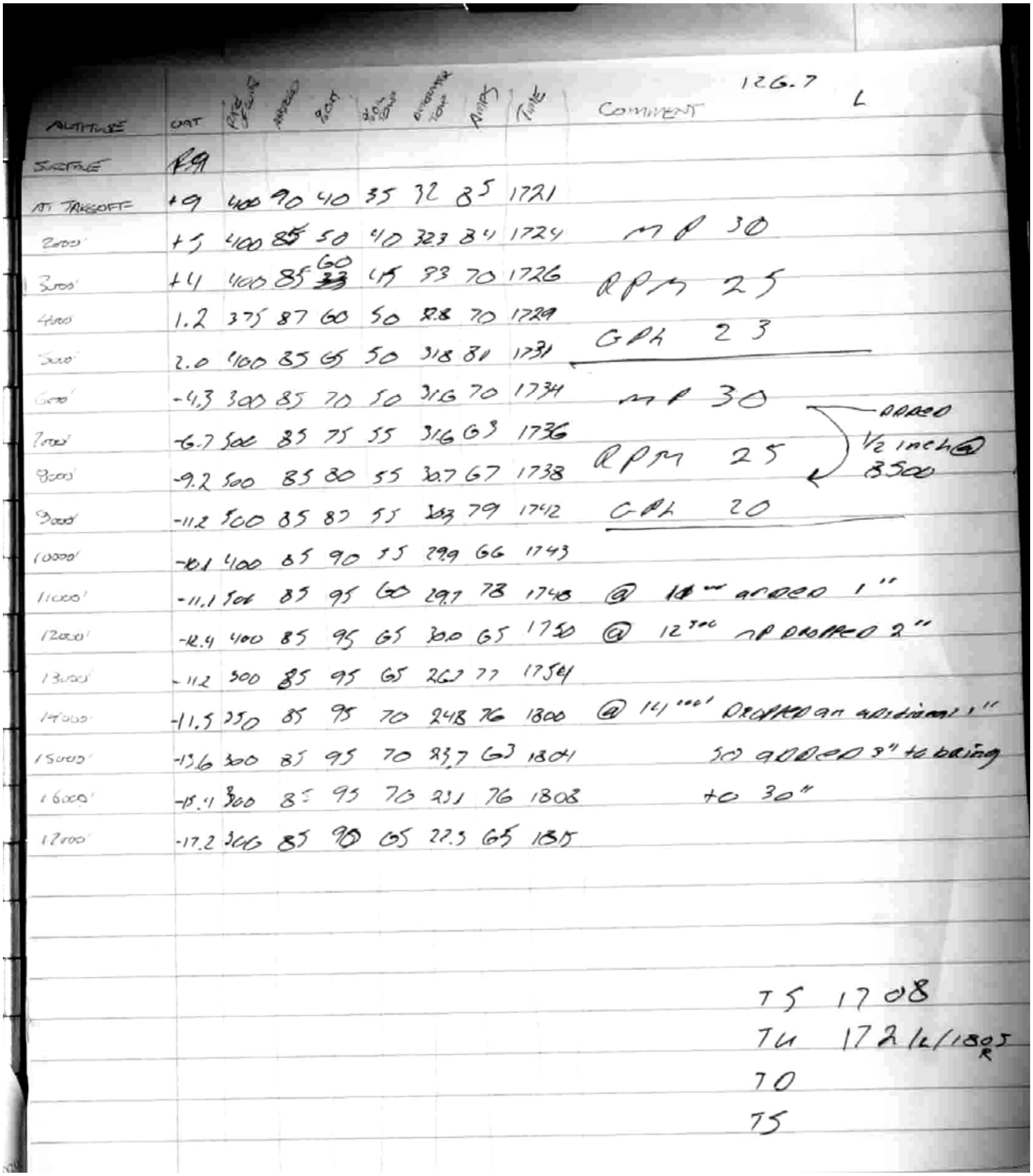
Transport Canada issued Aviation Safety Letter 1/2007 with an attached leaflet entitled *Take Five…for safety - 'Flying VFR in the Mountains'*, to provide some mountain flying guidance to pilots.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 11 December 2007.

Appendix A – Site Location Map



Appendix B – Flight Test



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ALTITUDE	OAT	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	AMPS	TIME	COMMENT
SURFACE	19								
AT TAKEOFF	+9	400	90	40	35	32	85	1721	
2000'	+5	400	85	50	40	32.3	84	1724	MP 30
3000'	+4	400	85	60	45	33	70	1726	RPM 25
4000	1.2	375	87	60	50	32.8	70	1729	GPH 23
5000'	2.0	400	85	65	50	31.8	80	1731	
6000'	-4.3	300	85	70	50	31.6	70	1734	MP 30 — added 1/2 inch @ 8500
7000'	-6.7	500	85	75	55	31.6	63	1736	
8000'	-9.2	500	85	80	55	30.7	67	1738	RPM 25
9000'	-11.2	500	85	87	55	30.3	79	1742	GPH 20
10000'	-10.1	400	85	90	55	29.9	66	1743	
11000'	-11.1	500	85	95	60	29.7	78	1748	@ 10[illegible] added 1"
12000'	-12.4	400	85	95	65	30.0	65	1750	@ 12,000 MP dropped 2"
13000'	-11.2	300	85	95	65	26.2	77	1754	
14000'	-11.5	250	85	95	70	24.8	76	1800	@ 14,000' dropped an additional 1"
15000'	-13.6	300	85	95	70	23.7	63	1804	so added 3" to bring
16000'	-15.1	300	85	95	70	23.1	76	1808	to 30"
17000'	-17.2	300	85	90	65	22.3	65	1815	

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Appendix C – Typed Version of Appendix B

Note 1: Some numbers in Appendix B are difficult to decipher, so this appendix may contain errors.

Note 2: Manifold pressure (MP) drops as the aircraft climbs, so the throttle is increased during the climb to maintain the required 30-inch MP.

Note 3: OAT – outside air temperature, CHT – cylinder head temperature

Altitude	OAT	Rate of Climb	Air Speed	% CHT	% Oil Temp	Alternator Temp (°C)	Amps	Time	Comments
Surface									
At Take-off	9°C	400	90	40	35	32.0	85	1721	↑
2000	5	400	85	50	40	32.3	84	1724	MP 30
3000	4	400	85	60	45	33.0	70	1726	RPM 25
4000	1.2	375	87	60	50	32.8	70	1729	GPH 23
5000	2	400	85	65	50	31.8	81	1731	↓
6000	-4.3	300	85	70	50	31.6	70	1734	↑ MP 30
7000	-6.7	500	85	75	55	31.6	63	1736	RPM 25
8000	-9.2	500	85	80	55	30.7	67	1738	GPH 20 Added ½″ at 8500
9000	-11.2	500	85	87	55	30.3	79	1742	↓
10000	-10.1	400	85	90	55	29.9	66	1743	
11000	-11.1	500	85	95	60	29.7	78	1748	@ 10,000 added 1″ [MP]
12000	-12.4	400	85	95	65	30.0	65	1750	@ 12,000 MP dropped 2″
13000	-11.2	300	85	95	65	26.7	77	1754	
14000	-11.5	350	85	95	70	24.8	76	1800	@ 14,000 [MP] dropped an additional 1″ so added 3″ to bring to 30″
15000	-13.6	300	85	95	70	23.7	63	1804	
16000	-15.4	300	85	95	70	23.1	76	1803	
17000	-17.2	300	85	90	65	22.5	65	1815	