AVIATION INVESTIGATION REPORT
A00W0109

LOSS OF CONTROL—STALL

AERIAL RECON SURVEYS
CESSNA 177B CARDINAL C-GPML
CALLING LAKE, ALBERTA
30 MAY 2000

REPORT NUMBER A00W0109

Aviation Investigation Report

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Synopsis

The Cessna 177B Cardinal took off from runway 10 at the Calling Lake, Alberta, aerodrome on a day visual flight rules flight to Lloydminster, Alberta, with one pilot and one passenger on board. At the time of the departure there were visual meteorological conditions, with a gusting and variable cross-wind. After the aircraft became airborne, the stall warning horn activated, the left wing dropped abruptly, and the aircraft crashed into trees approximately 400 feet past the end of the runway. An intense, fuel-fed, post-crash fire ensued, which destroyed the aircraft. The pilot sustained fatal injuries due to the fire, and the passenger sustained fractures and serious burns.

Ce rapport est également disponible en français.

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1.0 Factual Information

1.1 History of the Flight

The aircraft departed Whitecourt, Alberta, at 1410 mountain daylight time[1] on a visual flight rules company flight itinerary to Calgary, Alberta, with intermediate stops at Calling Lake and Lloydminster. The purpose of the second leg of the flight was to pick up and transport a passenger, a company-contracted freelance photographer, from Calling Lake to Lloydminster. The Cardinal arrived at Calling Lake at approximately 1510 and a company Robinson R-44 helicopter delivered the passenger to the airstrip at 1645. The helicopter pilot spoke briefly to the Cardinal pilot, assisted her with loading the passenger's gear into the aircraft, and then departed the airstrip at about 1700.

The Cardinal pilot taxied to the threshold of runway 10, completed a 180-degree left turn, and lined up on the centre of the runway to the right of the centre. An estimated 200 feet of usable runway was behind the aircraft when the take-off was commenced.

There was no discernable change in the sound of the engine after take-off, and the stall warning horn activated before the impact.

There were no witnesses to the crash, which occurred at about 1715. The small forest fire created by the crash was observed and reported from a local forestry fire tower at 1725. Air and ground personnel responding to the fire found the wreckage of the aircraft east of the departure end of runway 10. After the impact, the passenger cut his lap-belt with a knife, kicked his door open, and moved away from the burning aircraft. Realizing that the pilot was still in the aircraft, the passenger returned and attempted to rescue the pilot. The passenger was forced to abandon his rescue efforts because of the rapidly escalating fire. The aircraft was destroyed by the post-crash fire; the pilot sustained fatal injuries and the passenger sustained serious injuries. The injured passenger walked to a nearby secondary road, where he was assisted by passing motorists and forestry personnel.

1.2 Injuries to Persons

	Crew	Passengers	Others	Total
Fatal	1	-	-	1
Serious	-	1	-	1
Minor/None	-	-	-	-
Total	1	1	-	2

Although the post-mortem examination determined that it is highly probable that the pilot sustained non-life-threatening impact injuries, it also determined that she succumbed to the thermal effects of the fuel-fed fire.

[1] All times are mountain daylight time (Coordinated Universal Time minus six hours) unless otherwise noted.

The passenger sustained a fractured collar bone and a fractured shoulder blade at impact. He extricated himself from the wreckage and afterward received serious burns to his hands, arms, back, and legs when he attempted to rescue the pilot from the fire.

1.3 Damage to Aircraft

The aircraft was destroyed by the fire.

1.4 Other Damage

The crash initiated a forest fire that burned several hectares of non-merchantable, immature timber, much of it in the clearway zone of the aerodrome.

1.5 Personnel

	Pilot
Age	29
Pilot Licence	Commercial
Medical Expiry Date	01 September 2000
Total Flying Hours	343
Hours on Type	140
Hours Last 90 Days	121.5
Hours on Type Last 90 Days	121.5
Hours on Duty Prior to Occurrence	5
Hours Off Duty Prior to Work Period	15

The pilot was certified and qualified for the flight in accordance with existing regulations. She had begun *ab initio* flying training in April 1998 and had earned her private pilot licence in April 1999. She had received her commercial pilot licence, valid for all single-pilot non-high-performance, single-engine land aeroplanes in November 1999, and had begun employment with the operator in February 2000. At the time of the accident she had accumulated approximately 343 hours of flight time, all on single-engine aircraft. Approximately 140 hours of her flight experience had been acquired on Cessna model 177B aircraft. Since beginning employment with the operator, most of her flight experience had been gained on gas pipeline patrols, at cruise airspeeds. She had limited experience on grass runways and had not used the Calling Lake aerodrome in the past. She had received all of the required company basic flight training and approximately 109 flight hours of additional pipeline route and flight training with another company pilot occupying the right seat of the aircraft. Since she had just recently obtained her commercial pilot licence, and since this was her first flying job, the company was closely monitoring her flying skills and progress.

1.6 Aircraft

Manufacturer	Cessna Aircraft
Type and Model	177B Cardinal
Year of Manufacture	1975
Serial Number	177-02250
Certificate of Airworthiness	05 January 1982
Total Airframe Time	2166.7 hours
Engine Type (number of)	Lycoming O-360-A1F6 (1)
Propeller Type (number of)	McCauley B2D34C208B (1)
Maximum Allowable Take-off Weight	2500 pounds
Recommended Fuel Type(s)	100/130 or 100 LL
Fuel Type Used	100 LL

1.6.1 General

Maintenance records indicated that the aircraft was maintained and certified in accordance with existing regulations. The aircraft had been manufactured in 1975, and had accumulated 2166.7 airframe hours at the time of the accident.

1.6.2 Weight and Balance

Weight calculations determined that the aircraft was at or near the approved gross weight of 2500 pounds at take-off. The aircraft operational empty weight was 1659 pounds, the actual occupants' weight was 370 pounds, the estimated weight of the passenger's gear was 190 pounds, and the estimated fuel weight was 285 pounds. It was determined that the aircraft was within normal C of G for the flight.

1.6.3 Cessna Model 177 Cardinal Performance

Performance data in the 1975 *Cessna 177 and Cardinal Owner's Manual* indicates that at 2500 feet above sea level and 50 degrees Fahrenheit (10 degrees Celsius [°C]), a maximum-weight take-off from a hard-surface runway with flaps selected at 15° requires a distance of 1675 feet to clear 50-foot obstacles. Allowances for higher temperature, longitudinal runway slope, grass surface, and flaps up would increase this distance by about 32 percent, to approximately 2211 feet. The *Owner's Manual* states that take-offs may be accomplished with the wing flaps set anywhere from 0° to 15°; however, the preferred setting for normal take-off is 10°. The flap actuator found in the wreckage indicated that the flaps were in the up (0°) position at impact. It was not determined with certainty if the pilot completed the take-off without flap, or if she raised the flap immediately after becoming airborne. Either technique would have resulted in an increase in the distance required to climb to 50 feet.

The *Owner's Manual* states that a maximum performance take-off is to be done with the wing flaps set at 15°, and the throttle opened fully prior to brake release. A climb speed of 69 miles per hour is to be maintained until all obstacles are cleared, and the wing flaps are to be retracted slowly after the obstacles are cleared. The manual states that take-offs into strong cross-winds are normally performed with the minimum flap setting necessary for the field length. In addition, the aircraft should be accelerated to a speed slightly higher than normal and then pulled off abruptly to prevent possible settling back to the runway while drifting sideways in the cross-wind. The *Owner's Manual* does not provide take-off distance data for a 0° flap take-off.

The Transport Canada *Flight Training Manual* states that "it is a certification requirement that an aircraft be capable of safe operation in a 90° cross-wind, provided the speed of the wind does not exceed 20 percent of the stalling speed of the aircraft". The power-off, flaps 0° stall speed of the Cessna 177B is 63 miles per hour or 55 knots. Applying this, the calculated permissible 90° wind speed is 11 knots. The stalling speed for power-on, flaps 15° is not provided in the *Owner's Manual*, but the manual states that, for cross-wind landings, and with average pilot technique, direct cross-winds of 15 knots can be handled with safety. The *Owner's Manual* does not provide a maximum cross-wind speed for take-off.

1.7 Weather

The helicopter pilot who delivered the passenger to the airstrip reported the winds to be north to northwest at 10 to 15 knots. He climbed out above runway 10 after take-off, and described his departure as having a tailwind. Personnel responding to the fire reported the sky condition as clear with unlimited visibility and estimated the winds to be variable from the northwest to the northeast at 12 to 15 knots with gusts to 20 knots. The temperature was estimated to have been 15°C. In the existing wind conditions, a departure on runway 10 would have subjected the aircraft to, at minimum, a strong cross-wind from the left and, in all probability, an occasional tailwind.

1.8 Aids to Navigation

There are no radio navigation aids at the Calling Lake aerodrome.

1.9 Communications

Not applicable.

1.10 Aerodrome

The grass-surfaced runway is 2950 feet long.[2] The surface was in good condition, with a grass length of three to four inches at the time of the occurrence. The longitudinal up-slope on runway 10 is 1.5 percent for approximately 2700 feet and 0.40 percent for the remainder. The elevation at the threshold end of runway 10 is 2054 feet, and at the departure end it is 2092 feet.

[2] Units are consistent with official manuals, documents, and instructions used by or issued to the crew.

The aerodrome is operated by Municipal District of Opportunity No. 17 and is categorized as a registered aerodrome in the *Canada Flight Supplement.* Tree clearing for the aerodrome had occurred in 1983; construction of the aerodrome was completed in 1985. An extensive clearway had originally been provided at the departure end of runway 10.[3] The clearway for runway 10 had not been maintained since the aerodrome was originally constructed, and it contained second-growth trees that were estimated to be up to 30 feet tall. Transport Canada regulations do not require clearways to be provided, or to be maintained devoid of vegetation, at a registered aerodrome.

1.11 Flight Recorders

The aircraft was fitted with neither a flight data recorder nor a cockpit voice recorder; neither was required by regulation.

1.12 Impact and Wreckage

The aircraft struck approximately 30-foot-tall, second-growth aspen trees in what was originally the clearway zone of the aerodrome. Wreckage trail examination determined that the aircraft descended through the trees in an extreme left-wing-low attitude, bounced at initial ground contact, and cartwheeled to an upright position. The wreckage trail was 151 feet long.

No significant pre-impact discrepancies were identified, either during a visual examination of the aircraft flight control cables or during a teardown examination of the engine. No reliable information was obtained from the aircraft instrumentation due to the extent of the fire damage. The limb and trunk sections of several aspen trees had been chopped into short lengths by the propeller, in a manner that indicated that the engine was producing power at impact. The throttle, propeller, mixture, and carburettor heat controls were recovered fully forward, which is the normal position for take-off. Due to the almost complete destruction of the aircraft by the crash and fire, it could not be conclusively determined whether any pre-impact failure or system malfunction contributed to this accident; however, none were identified.

The right wing fuel tank survived the impact and fire intact and was found to contain approximately 16 gallons of 100 LL aviation fuel. The fuel was free of visible solid contamination. The fuel selector was recovered in the right tank position, and the fuel shutoff valve was found in the open position.

1.13 Medical Information

It was concluded by the provincial medical examiner that the pilot was alive but probably unconscious as a result of the crash. She died from inhalation of fire-produced gases.

1.14 Fire

The cabin, fuselage, and left wing were destroyed in the fire. Because of the scope of the fire damage to the cabin and forward fuselage, the ignition source and fire origin were not determined. The fire appeared to

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3 A clearway is a rectangular area on the ground, under the control of the appropriate authority, that is prepared as a suitable area over which an aeroplane may make a portion of its initial climb to a specified height.

emanate from the floor area of the aircraft, below and aft of the front seats. Several fuel system components, including fuel lines and a small fuel reservoir tank or surge tank, installed to ensure that the engine is supplied with fuel during manoeuvring flight, are located under the cabin floor. The extent of the impact damage to these components could not be determined due to destruction by fire. It was noted that the carburettor and lower firewall-mounted fuel gascolator had sustained impact damage that would have resulted in post-impact fuel spillage.

1.15 Survival Aspects

Both occupants were wearing the available lap-belt and single-point, diagonal shoulder harnesses. The passenger did not attempt to undo his lap-belt buckle after the crash. Instead he cut the lap-belt with a pocket knife and kicked open the right front door to extricate himself from the wreckage. Both front seat lap-belt buckles were recovered in the buckled position.

1.16 Tests and Research

Considerable research and accident investigation data exist with regard to methods of reducing the incidence of post-crash fires in aviation accidents. In many light aircraft, critical fuel system components—including fuel lines, fuel strainers and filters, reservoir and surge tanks, and carburettors—are frequently located in areas that are vulnerable to impact damage. As well, the Cessna Cardinal, like many aircraft, is fitted with “wet wing” fuel tanks, which are not fitted with any sort of high-strength tear or puncture-resistant liner, and are vulnerable to leaking large quantities of fuel if torn open during an impact. The integral tanks in the Cessna Cardinal are mounted forward of the main spar and, therefore, are not afforded any protection by the main spar on impact.

A search of the Federal Aviation Administration (FAA) aircraft accident/incident database, which lists occurrences as of 1973, identified 4092 records with “fire after crash” as a contributing factor. Further research is required to determine the number of those 4092 accidents that were survivable and that were associated with serious injuries and/or fatalities. Notwithstanding, post-impact fire is a relatively common occurrence.

For the period January 1976 to January 2001, the TSB database contains data on 469 accidents involving aircraft weighing less than 5700 kilograms (kg) where a post-crash fire occurred; 667 fatalities resulted from these accidents. The cause of death in at least 195 fatalities (29%) was fire or smoke inhalation, either partly or solely; 374 fatalities (56%) were due to impact; and the cause of death in 98 fatalities (15%) was undetermined. At least 73 accident survivors sustained fire injuries. Most of the aircraft involved in these occurrences were certified to American and European standards that contain minimal or no provisions for crashworthy fuel system design.

Many of the concerns related to post-crash fires were addressed in a US National Transportation Safety Board (NTSB) Special Study Report entitled *General Aviation Accidents: Postcrash Fires and How to Prevent or Control Them* (NTSB-AAS-80-2, 1980). The report clearly identified, that the injury and fatality rate in accidents where the aircraft burned was significantly higher than that in accidents where the aircraft did not burn, and that the certification requirements at that time did not address fuel containment in crash conditions. Based on the Special Study, the NTSB made six recommendations to the US FAA, three of which contained proposals to revise FAA airworthiness regulations to enhance fuel system crashworthiness. The FAA established projects to study the recommendations, issued Notices of Proposed Rulemaking, and worked with the General Aviation Safety Panel from 1980 until 1996 without, according to the NTSB, any tangible action to improve fuel containment in crash conditions. In 1996 the NTSB, noting the lack of action on the part of the FAA, classified the six recommendations as “Closed – Unacceptable Action”.

For normal, utility, and aerobatic category aeroplanes with a maximum certified take-off weight of at most 5700 kg, Canadian design standards are based on the *Airworthiness Manual*, Chapter 523, which is based on part of the FARs. While there are numerous fuel system design requirements to eliminate the potential for in-flight fire, and a requirement for fuel tanks to retain fuel during a wheels-up landing, Chapter 523 does not address additional requirements to enhance fuel system crashworthiness.

1.17 Organizational and Management Information

The company was operating a charter fleet of 7 fixed-wing aircraft and 40 helicopters in accordance with *Canadian Aviation Regulations*, Parts 702 and 703, at the time of the occurrence. A large portion of the flying was associated with oilfield exploration, survey, and support. The annual fleet utilization exceeded 30 000 hours. The company organizational and management structure met Transport Canada requirements, and the applicable company *Air Operator Certificate* was approved and in effect.

1.18 Additional Information

If a pilot attempts to climb an aircraft in the slow flight range, at an airspeed that is below the best-angle-of-climb airspeed, the aircraft can enter a condition known as “flying on the back side of the power curve”. In this circumstance the aircraft is flying at low speed, at an extreme angle of attack, with the engine at a high power setting. This configuration places the aircraft in a condition of high aerodynamic drag, and if the pilot attempts to clear approaching obstacles by increasing pitch attitude, the airspeed will decrease further, until a stall occurs. Wind gusts can exacerbate this situation by causing momentary fluctuations in airspeed, and if the aircraft encounters a downwind gust, airspeed and lift may briefly decrease without any change in aircraft attitude. This is particularly hazardous at low altitude during an initial climb, as the pilot must lower the nose and relinquish altitude in order to re-establish the proper climb speed.

The aircraft was fitted with Cessna model S2070H-16 front lap belt and shoulder harness assemblies. Although not considered a factor in the occurrence, two design discrepancies were identified that could have impeded rapid release of the harness assembly and hamper occupant escape from the aircraft. On this belt assembly it is possible to mistake the latch handle frame for the latch handle itself, and for occupants to insert their fingers under the frame and pull on the frame rather than the latch handle when attempting to release the buckle. This could confuse occupants in an emergency and delay the release of the buckle.

In addition, the lap belt length adjustment is on the latch side of the buckle and the short, fixed strap is on the tongue side of the buckle. The shoulder strap engages in a slot in the tongue and the short, fixed lap strap holds the shoulder strap in the diagonal position across the front of the occupant. Because the belt is mounted with the tongue of the latch on the opposite side of the occupant relative to the shoulder strap, releasing the lap belt loosens but does not release the shoulder strap. The occupant must then either disengage the shoulder strap separately from the lap belt or crawl out from under the shoulder strap to get out of the seat.

The design of the lap belt and shoulder harness assemblies was changed in 1975 with the introduction of the S2275 style assembly. On the new assembly the latch tongue and the shoulder strap are connected and oriented on the same side of the occupant, and releasing the latch releases the lap belt and the shoulder strap in one motion. As well the latch part of the buckle is attached to the lap belt in a manner that precludes occupants from placing their fingers under the latch handle when releasing the buckle. Between 21 July 2000 and 7

December 2000, the operator removed the old S2070H-16 style seat belt and shoulder harness assemblies from the other three Cessna 177B Cardinals in the fleet and installed the S2275 harness assemblies.

2.0 Analysis

2.1 General

The investigation identified no aircraft discrepancies that would have contributed to the accident. Therefore, the analysis will focus on the cross-wind and runway conditions, the pilot's take-off technique, and post-crash survival factors.

2.2 Take-off Management

The pilot had many variables to consider in this departure. A combination of variables—a strong, gusting cross-wind, an uphill runway slope, a grass runway surface, and an aircraft weight at or near maximum—required that the take-off be well managed in order for it to be completed successfully.

It is probable that the pilot elected to accomplish the take-off without flaps because of the strong cross-wind. Although this configuration would have enabled better cross-wind handling, it would have extended the ground run and increased the distance required to clear the obstacles in the clearway zone of the runway. The pilot may not have recognized that the take-off would require careful management in the existing conditions, as evidenced by her leaving an estimated 200 feet of usable runway behind the aircraft before beginning the take-off run.

The take-off performance figures in the *Aircraft Flight Manual* indicate that with proper pilot technique, the aircraft was capable of departing from the runway and clearing the existing obstacles in the available distance, with several hundred feet to spare. It is probable, therefore, that the pilot attempted to climb the aircraft at less than the best-angle-of-climb speed as she approached the trees and brush in the clearway zone of runway 10, and that the aircraft remained at low airspeed, on the back side of the power curve, until the stall occurred. There was little or no headwind component to reduce the take-off distance, and the aircraft may have actually encountered a downwind gust after liftoff; however, this could not be determined. The aircraft stall occurred at an altitude that precluded successful recovery.

2.3 Post-Crash Fire Survival

It is highly probable that the pilot would have survived the accident if the post-crash fire had not occurred. Several factors—the location of the fuel reservoir tank and the fuel lines below the cabin floor, the unprotected positions of the fuel gascolator and carburettor, and the wet wing design of the fuel tanks, etc.—may have contributed to the initiation, intensity, and rapid spread of the post-crash fire. Since the aircraft came to rest upright, and the fuel shut-off valve remained in the open position with the fuel selector on the right tank position, gravity would have caused fuel to continue to flow from the right wing tank and spill from the damaged gascolator and carburettor. Fuel would have also continued to flow from the left wing tank if the associated fuel lines upstream of the fuel selector had sustained impact damage.

Several manufacturers have voluntarily improved fuel system designs in their newest aircraft models. Examples of these improvements include routing fuel system components away from occupied areas, increasing the distance between fuel tanks and the passenger cabin, reinforcing fuel tanks internally to prevent rupture due to fluid inertia forces during a crash, and isolating potential ignition sources from areas of probable fluid leakage.

3.0 Conclusions

3.1 Findings as to Causes and Contributing Factors

1. The aircraft stalled after take-off at an altitude where recovery was not possible, and it crashed.

2. It is probable that the pilot did not achieve the required best-angle-of-climb speed after lift-off and that the aircraft remained at low airspeed, on the back side of the power curve, until the stall occurred.

3. It is highly probable that the pilot sustained non-life-threatening impact injuries; however, she succumbed to the thermal effects of the fuel-fed, post-crash fire.

3.2 Findings as to Risk

1. The aircraft was not fitted with a crashworthy fuel system design that might have prevented or reduced the intensity of the post-crash fire, nor is it required on new or existing aircraft models by existing regulation.

2. There is no requirement for the clearways at a registered aerodrome to be maintained clear of vegetation; the original clearway zone at the departure end of runway 10 was overgrown with brush and trees up to approximately 30 feet in height.

3.3 Other Findings

1. The aircraft was certified and equipped in accordance with existing regulations, and there was no indication of any engine or system malfunction.

2. In the existing conditions, the aircraft was capable of departing from the runway and clearing the obstacles in the available distance.

3. The aircraft was fitted with front seat belt and shoulder harness assemblies that could have impeded rapid escape from the aircraft; however, it was determined that these assemblies were not a factor in this occurrence.

4.0 Safety Action

4.1 Action Taken

Following this occurrence, the aerodrome operator removed the trees on the clearway at the departure end of runway 10 at the Calling Lake aerodrome.

Transport Canada is developing a new commercial pilot training program, Integrated Commercial Pilot Training Program, to reduce the incidence of accidents of this type. The goal of this program is to prepare student pilots more effectively for employment in a commercial air service. It is anticipated that pilots in an integrated program will be exposed, under controlled conditions with the guidance of an instructor, to the conditions they are likely to encounter operationally, including the kind of conditions described in this report.

Upon identification of seat belt and shoulder harness design deficiencies that could impede rapid escape from the aircraft, the operator removed the S2070 style seat belt and shoulder harness assemblies and installed S2275 style assemblies in the other three Cessna 177 Cardinal aircraft in the fleet.

4.2 Safety Concern

In this accident it is highly probable that the pilot sustained non-life-threatening impact injuries but died due to the effects of the post-impact fire; the passenger sustained serious burns. As indicated by a review of the FAA and TSB databases, the problem of post-crash fire is not unique to any single model of aircraft, nor is it a particularly infrequent event. Furthermore, the TSB study on post-impact fire accidents involving aircraft under 5700 kg indicates that fire or smoke inhalation was identified as either partly or solely the cause of death for almost 30 percent of the 677 fatalities over the 25-year period.

While the design principles for crashworthy fuel systems are well known, a review of the CARs and the FARs indicates that there are, at present, no airworthiness standards that require enhanced technical countermeasures to be fitted to light aircraft to reduce the incidence of post-crash fire in circumstances other than gear-up landings.

The Board is concerned that, in general, the fuel systems in small aircraft do not provide adequate protection against crash-induced fires. A fire, in an otherwise survivable accident, puts the aircraft occupants at unnecessary risk. The Board will continue its investigation into this safety issue, including an assessment of the adequacy of current regulations.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 27 November 2001.

Appendix A – Supporting Report

US National Transportation Safety Board Special Study NTSB-AAS-80-2:

General Aviation Accidents: Postcrash Fires and How to Prevent or Control Them

Appendix B – Calling Lake Aerodrome

Appendix C – Glossary

C	Celsius
CARs	*Canadian Aviation Regulations*
FAA	Federal Aviation Administration
FARs	*Federal Aviation Regulations*
kg	kilogram
LL	low lead
NTSB	National Transportation Safety Board
TSB	Transportation Safety Board of Canada
US	United States
°	degree(s)