AIR TRANSPORTATION SAFETY INVESTIGATION REPORT A92C0154

COLLISION WITH TERRAIN

Newcal Aviation Inc.
Modified de Havilland DHC-4A (prototype conversion) N400NC
Gimli Industrial Park, Manitoba
27 August 1992

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.

Summary

The aircraft had just taken off on an experimental test flight when it entered a gradually steepening climb. During the climb, the aircraft rolled slowly to the right and, at approximately 200 feet above ground level (agl), it entered a steep nose-down, right-wing-low attitude and crashed. Upon impact, the on-board fuel ignited and the majority of the aircraft wreckage was destroyed by fire. The three crew members aboard the aircraft were fatally injured.

The Transportation Safety Board of Canada determined that the gust lock system was not fully disengaged prior to flight and one or more of the gust locking pins became re-engaged for undetermined reasons after lift-off. It is unlikely that a control check had been completed prior to take-off and, once airborne, the crew were unable to disengage the gust lock mechanism before losing control of the aircraft.

Table 1. Investigation information

Information source:	Field investigation
Local time:	1020 CDT
Type of operator:	Other
Type of operation:	Experimental
Damage:	Destroyed
Pilot licence:	Airline transport

Table 2. Injuries

	Fatal	Serious	Minor/None
Crew	3	0	0
Passengers	n/a	n/a	n/a

Table 3. Personnel information

	Pilot-in-command	Co-pilot
Pilot hours, all types	8812	1542
Pilot hours on type	4700	240
Pilot hours in the last 90 days, all types	138	71
Pilot hours in the last 90 days on type	96	6

1.0 FACTUAL INFORMATION

1.1 History of the flight

The aircraft had just taken off on an experimental flight when it entered a gradually steepening climb. During the climb the aircraft rolled slowly to the right and, at approximately 200 feet above ground level (agl), it entered a steep nose-down, right-wing-low attitude and crashed. Upon impact, the on-board fuel ignited and the majority of the aircraft wreckage was destroyed by fire. The three crew members aboard the aircraft were fatally injured.

1.2 Aircraft history

The aircraft was manufactured on 18 November 1965 and was sold to the Kenyan Air Force, with whom it spent the next 21 years. On 05 June 1986, the aircraft was purchased from the Kenyan Air Force by NewCal Aviation Incorporated, of Little Ferry, New Jersey; the aircraft was assigned U.S. registration markings N400NC and was issued a Certificate of Airworthiness for operation as a Transport Category aircraft.

1.2.1 Turbine engine conversion program

In August 1988, NewCal Aviation Inc. applied for a Supplemental Type Certificate (STC) to change the powerplant installation on the aircraft from reciprocating to turboprop engines. NewCal Aviation of Canada was formed to undertake the turbine engine conversion program and, for the purpose of this program, DHC 4 (Caribou) serial number 240 was granted approval to operate under the EXPERIMENTAL category of CAR 4b. The original manufacturer, de Havilland Inc, was not involved in the flight test program.

The modification project involved the removal of the original Pratt & Whitney R-2000-7M2 piston engines and the installation of Pratt & Whitney PT6A-67R turbo-prop engines and associated equipment. This new configuration included the addition of a five-bladed Hartzell propeller system, along with new engine mounts and cowlings. Other systems affected by the modification included the fuel system, powerplant controls, powerplant instruments, hydraulic system, fire protection system, electrical system, and the engine oil system. This conversion significantly modified the aircraft from the original DHC-4 Caribou as type certificated.

The turbine conversion was accomplished at the Gimli Industrial Park and the first flight tests of the modified aircraft began on 16 November 1991. A total of 12 test flights were carried out between 16 and 28 November 1991, with an accumulated flight time of 22.9 hours; the aircraft was then hangared over the winter.

Results of the evaluation flight test program conducted in late 1991 indicated that minor design changes were required to several of the aircraft systems. These changes included the replacement of the aircraft's mechanical vacuum pumps with a Bendix suction system, the addition of in-line fuel boost-pumps, and the installation of a newly designed hydraulic pump.

Data acquired during earlier taxi tests indicated that, with the new in-line fuel boost pumps installed, the fuel flow corresponding to a normal take-off power setting of 100 per cent torque was 740 pounds per hour (pph).

1.3 Purpose of the occurrence flight

The occurrence flight was intended to be the first of several trips designed to flight-check the fuel and hydraulic systems. On the morning of the accident, the crew attended a pre-flight briefing, which included a thorough review of the flight test plan. The aircraft was lightly loaded at a mid centre of gravity (C of G) position. In-flight checks were scheduled to include simulated failures of both the wing fuel pumps and the in-line pumps; records were to be maintained regarding the resulting fuel pressures.

A company engineer who had been involved in the design of the fuel and hydraulic modifications was included on this flight to record flight test results and to evaluate in-flight performance of the two systems.

1.3.1 Flight profile

The crew completed a pre-flight inspection of the aircraft, started the engines, and spent approximately 45 minutes doing a ground run and systems check before proceeding to the button of runway 14.

The aircraft was taxied onto the runway surface and brought to a full stop. Approximately 20 seconds later, the engine power was advanced and the brakes were released. Directional control of the aircraft was maintained throughout the ground run and the aircraft became airborne in approximately 900 feet.

The entire flight was recorded on amateur eight millimetre (mm) videotape and in a series of 35 mm still photographs. This photographic information confirmed that elevator authority existed at rotation and that the aircraft's pitch attitude increased to a position significantly higher than had been observed on previous take-offs under similar environmental conditions. With the exception of a higher-than-normal nose attitude at lift-off, the aircraft's initial climb appeared normal. At about 35 feet agl, the aircraft made a noticeable pitch-up movement; from that point onwards, the elevator control surfaces were observed to remain in their neutral position.

The aircraft completed a gradually steepening wing-over manoeuvre, then it entered a steep dive and struck the ground. Airspeed remained above the stall speed throughout the manoeuvre. Careful examination of the photographic evidence revealed that there were no discernable control surface deflections throughout the entire manoeuvre, from the point where the in-flight pitch-up movement occurred through to the point where the aircraft struck the ground. Enhancement of the photographic images made it possible to identify an upward deflection of the elevator spring tabs with no corresponding movement of the control surfaces.

1.4 Wreckage examination

The aircraft struck the ground in a near vertical, right-wing-low attitude. Primary wreckage was distributed within a 50-foot radius of the aircraft and, except for the detached outboard portion of the right wing, the entire aircraft had been engulfed in an intense post-crash fire. The landing gear was confirmed to be down and locked; the aircraft's tail section and front fuselage section were located forward of the left engine area and were completely destroyed. Both wings outboard of the engine nacelle area were torn open and severely burnt. The outboard wing sections contained an internal, eight-cell, wet-wing-design fuel tank arrangement, which burst open upon ground impact.

1.4.1 Flight control system examination

An examination of the flight control system revealed no pre-impact faults; continuity of the entire flight control system was confirmed. The flaps were determined to be at a seven-degree setting at impact, and the aileron and elevator trim tabs were near their neutral positions. The rudder trim tab was located half-way between the neutral and full-nose-left position.

1.4.2 Propeller examination

Both the left and right propeller systems were examined following the accident. Damage to these systems indicates that the blades contained significant rotational energy at the time of the crash. Blade angles had been captured at approximately 26 degrees; that blade angle is in the normal in-flight governing range, and is consistent with values that would be expected when the engines are producing high power.

1.4.3 Engine examination

Teardown and examination of the engines revealed high internal rotational damage, consistent with a high power setting at impact. Neither engine displayed any pre-impact anomaly or distress that would have prevented normal operation prior to impact.

1.4.4 Instrument examination

The TSB Engineering Laboratory determined that both of the fuel flow indicators were captured at 740 lb/hour. No useful data was derived from the remaining instruments.

1.4.5 Aircraft gust lock system

The aircraft is equipped with an internal gust lock system for locking the control surfaces in neutral when the aircraft is parked or is being taxied. The system is controlled by a gust lock handle which is located on the overhead console, forward of the throttles. The handle has two positions, marked LOCKED and UNLOCKED. When the handle is moved aft to the LOCKED position and the control surfaces are moved to their neutral position, the gust locks will engage and secure the ailerons, elevator, and rudder from further movement. However, if the control surfaces are out of position when the gust lock handle is moved to the LOCKED position, any subsequent deflection of the control surfaces through their neutral position will cause them to automatically lock.

1.4.6 Gust lock lever/Power lever relationship

The aircraft controls are designed such that, when the gust lock handle is moved aft to the LOCKED position, it prevents the throttles from being advanced to their full power position. This relationship between the throttles and the gust lock handle provides a safety feature which is designed to ensure that a take-off cannot be attempted while the control locks are engaged.

The throttle quadrant of the accident aircraft had been re-designed as part of the engine modification project. The resultant changes to the throttle system did not adversely affect the positional relationship between the gust lock handle and the throttle levers; in the newly designed system, the throttle levers still could not be advanced to achieve take-off power when the gust lock lever was in its LOCKED position.

1.4.7 Elevator gust lock system

The elevator gust lock mechanism is mounted to a channel on the bottom surface of the horizontal stabilizer, located to the right of the aircraft centre-line. This mechanism is operated by the gust lock system's chain and cable circuit. When the gust lock is actuated to its LOCKED position, the elevator lock pivots and, provided that the elevators are in their neutral position, a slot in the gust lock engages with the spring-loaded plunger of the lock arm to prevent the control surface from moving. If the elevators are not in neutral when the gust lock system is actuated, the spring-loaded plunger will be depressed against the face of the elevator lock, and will engage with the slot only when the elevators are later moved to their neutral position.

The elevator gust lock assembly was recovered intact from the tail section of the aircraft wreckage and was found in the spring-loaded DISENGAGED position. The mechanism was exercised and found to operate normally through its full travel range. This assembly was confirmed to have been rigged in accordance with the manufacturer's rigging instructions, although the gust lock tension spring appeared weak and exhibited evidence of fire damage.

1.4.8 Rudder gust lock system

The rudder gust lock mechanism is mounted at the aft end of the rear fuselage, and is operated by the rear sprocket of the gust lock system's chain and cable circuit. Operation of the rudder gust lock mechanism is similar to that of the elevator gust lock system described above.

The rudder gust lock assembly was recovered from the wreckage and the gust lock's mechanical actuating lever-arm was captured in the ENGAGED position. In addition, the spring-loaded plunger was jammed in its fully extended position, and had been rotated approximately seven degrees in its guide boss. The rotational damage to the plunger is consistent with torsional loading damage that would be expected if the plunger had been engaged, and had subsequently rotated during ground impact.

A sprocket assembly that interconnects the rudder and elevator control lock actuation mechanisms was also recovered from the wreckage. A number of the sprocket's gear teeth had been bent in overload at impact, causing the assembly's chains to jam. By measurement, and comparison with a serviceable control lock mechanism, it was determined that the sprocket was oriented midway between the gust lock ENGAGED and DISENGAGED positions.

1.4.9 Aileron gust lock system

The aileron gust lock mechanism was recovered in its spring-loaded DISENGAGED position. However, further examination of the aileron system revealed that the heads of all eight (AN470-3) rivets used to secure the aileron control quadrant's centre pivot-bearing structure had failed in tensile overload. This damage is believed to have occurred when the aileron cables were stretched beyond their normal loading limits while the control quadrant was locked and unable to rotate. The two devices in the system that could prevent free rotation of the control quadrant are the quadrant stops and the spring- loaded plunger when it is in the ENGAGED position. Both of these devices were examined and no unusual damage was apparent.

1.4.10 Gust lock handle

Portions of the gust-lock handle assembly were recovered from the cockpit wreckage. These components exhibited severe impact deformation and overload failure. Examination of the relationship between several of the moveable components of this control system indicated that the gust lock lever was in a fully DISENGAGED position when recovered.

The aircraft captain had been seated in the left crew-seat position. A knob from the gust lock control handle was found embedded in his right wrist.

1.5 Gust lock operation

Following the accident, a number of tests were conducted on a serviceable Caribou aircraft to determine how the gust lock mechanism would operate under circumstances in which one of the locking pins was jammed and unable to be released. During these tests, the rudder locking pin was held in place, and the gust lock handle in the cockpit was released. The consistent result was that the gust lock handle moved forward, under spring power, to a position approximately one-half the distance between its LOCKED and UNLOCKED positions. The flight controls were then exercised and it was found that, under these conditions, the flight crew would have aft (nose-up) elevator authority but no forward (nose-down) elevator authority. Although the rudder itself remained securely in place because of the actuation of the locking pin, it was easily possible to deflect the rudder spring tabs by applying pressure to the rudder pedals.

During follow-up testing, the elevator gust lock mechanism was rotated to a mid-range position between its fully LOCKED and UNLOCKED station. It was noted that, at this mid-point, the elevator gust lock pin disengaged sufficiently to allow the elevator to be deflected to command a nose-up pitch attitude. However, because of the system design, when the elevator controls were moved forward to command a nose-down pitch attitude, the control lock would re-engage as the elevator returned to its neutral position. Further forward movement of the elevator control column caused the elevator spring tabs to deflect upward, and out of their neutral position without a corresponding deflection of the elevator control surface.

From these tests, it was also determined that it is not possible to move the gust lock handle fully forward unless the locking pins have been completely released.

1.6 Aircraft performance: General

Aircraft performance figures available from the aircraft flight manual, the servicing manuals, and from previous flight test records were carefully reviewed.

1.6.1 Aircraft performance: Weight and balance

Loading for the accident flight was within the constraints of the weight and balance envelope. All ballast used on previous test flights had been removed. The total take-off weight for the accident flight is estimated to be 22,000 pounds. The maximum gross weight allowable under the conditions of the day was 28,500 pounds.

1.6.2 Aircraft performance: Take-off power

The normal maximum-power permissible for take-off corresponds to 1,281 Static Horse-Power (SHP) at 1,700 rpm and 100 per cent output torque. Either engine is capable of producing 1,424 SHP at 1,700 rpm, which corresponds to 111 per cent torque.

The engine manufacturer estimates that, with the control lock handle in the LOCKED position, the engines may have been capable of producing between 400 and 800 SHP, with the most likely value falling to the low end of that range.

1.6.3 Aircraft performance: Take-off distance

Aircraft performance charts indicate that the expected take-off distance for the conditions of the day should have been 700 feet. The ground run of the accident flight was measured to be approximately 900 feet and was therefore more than 20 per cent longer than the performance charts predict.

1.6.4 Aircraft performance: Take-off speed

Actual lift-off speeds are not available; however, take-off performance charts in the draft Aircraft Flight Manual, which was developed and compiled by Newcal Aviation during the flight test program, indicate that both the engine failure speed and the take-off safety speed for the conditions of the day would have been approximately 87 miles per hour (mph).

The aircraft did not stall throughout the entire in-flight manoeuvre. The Aircraft Flight Manual indicates that the normal 1-g stall speed for take-off configuration is 71 mph when at zero thrust. The power-on stall speed, in take-off configuration, is not published but would be lower than the published value of 71 mph.

1.7 Pre-flight checks

Standard procedures for the operation of the Caribou aircraft include the execution of a six-point control check prior to take-off. This check is essential to assure the crew that it has full and unimpeded operation of the primary control surfaces. This check is especially important on any aircraft that has the capability of locking the flight controls while manoeuvring on the ground.

No control check was seen by witnesses on the ground, nor was one captured on videotape or 35 mm film.

1.8 Weather

The Area Forecast for the time of the accident predicted that the Gimli region would be under the influence of an unstable air mass, a light to moderate southwesterly flow, and patchy, moist mid-level clouds. An automated weather observation system (Auto5) is located at the Gimli Industrial Park. That system indicated that the surface winds at the time of the accident were from 200 degrees (True) at 15 knots.

1.9 Flight crew

Both flight crew members were licensed and qualified to conduct this flight. Experience of either crew member on the turbo-conversion aircraft was limited in that it was a newly modified, "one-of-a-kind" aircraft. Neither pilot was an experienced flight test crew.

Autopsy and toxicology examinations did not reveal any physiological, toxicological, or pathological factors that would have had a bearing on this accident.

2.0 ANALYSIS

2.1 Pre-flight preparation

This flight was pre-briefed in detail and was intended to form part of an on-going flight test program that was being conducted as part of the aircraft modification.

2.2 Elevator authority

The aircraft rotated at lift-off to a pitch attitude that was slightly higher than that used on previous take-offs. The smooth nose-rotation seen on the videotape indicates that the crew did have up-elevator authority at lift-off. However, in subsequent video frames, the elevator is seen to remain in its neutral position with the spring tab deflected upwards; this situation is known to occur when the elevator movement has been impeded while pressure is being applied to the control column.

During its initial climb, the aircraft's pitch attitude continually increased. It would be logical to expect the crew to counter this continuous upward movement of the aircraft's nose by applying forward control column pressure. Photographic evidence of this occurrence does show an upward deflection of the spring tab but does not show any corresponding control surface movement. Such a situation can be duplicated on the ground, with the gust locks

ENGAGED, by applying a forward control column pressure against the locked elevator system. In the air, the resultant spring tab deflection would cause an aerodynamic effect that is the reverse of the commanded control input. The photographic information, coupled with the dynamics of the aircraft's flight profile, corroborates physical evidence which indicates that the elevator system was being restricted from moving toward a commanded nose-down position. It is therefore concluded that the crew was likely attempting to lower the nose by applying forward control column pressure, but that the elevator system was either locked or otherwise restricted from movement. The crew's continuing effort to apply forward control column pressure deflected the spring tabs, and caused a further increase to the aircraft's pitch attitude.

2.3 Rudder gust locks

Damage to the rudder gust lock mechanism indicates that it was ENGAGED at the time of the impact. With the rudder locks ENGAGED in flight, any attempt by the crew to counter an uncommanded right roll by using left rudder inputs would have deflected the rudder spring tab towards the right and increased the right-hand roll rate; this movement would be consistent with the roll profile observed on the videotape.

2.4 Aileron gust locks

Damage to the aileron control quadrant suggests that the aileron gust lock may have been engaged at impact. If the ailerons had been available for use throughout this flight, it would be logical to have expected some attempt by the crew to control the aircraft's roll rate throughout the wing-over manoeuvre; no change in roll rate was observed. It is therefore unlikely that aileron control was available to the crew during the in-flight portion of this trip.

2.5 Gust lock handle release

The aircraft gust lock handle is designed to restrict forward throttle movement when the lock is ENGAGED. Estimates by the engine manufacturer indicate that the maximum throttle setting that would be possible with the gust lock handle ENGAGED would have provided approximately 30 per cent to 40 per cent of the available engine power - an amount considered insufficient to complete a take-off even under light weight conditions.

In this occurrence, the aircraft became airborne in approximately 900 feet and flew the entire flight profile above its stall speed. The stalling speed for this aircraft under take-off power is not published, but would be less than 71 mph. The aircraft's acceleration to speeds above the stall, along with its subsequent lift-off and climb performance as observed on the videotape, would not be expected if the aircraft throttles were restricted to allow the engines to produce less than 40 per cent of their maximum power. It is therefore concluded that the gust lock handle had been released from its LOCKED position prior to, or during, the take-off roll.

2.6 Crew activity

During this flight, the aircraft entered a gradually steepening, nose-high, attitude which eventually progressed to become a very steep dive. It would be reasonable to expect that, if either pilot had been holding the throttle levers throughout this manoeuvre, some attempt would have been made to adjust the throttle position to compensate for the steep pitch attitudes.

An examination of the aircraft flight instruments provided indications that both engine fuel flow readings were 740 pph at the time of the crash. This figure is significant, in that it represents the precise fuel flow value that corresponds to normal take-off power; the engine is capable of producing power at levels either above or below this particular setting. Because the fuel flow readings at the time of the impact relate precisely to take-off power, it can be concluded that no throttle adjustments were attempted after take-off power was set. It is therefore unlikely that either crew member had his hand on the throttle levers throughout the flight phase of this occurrence.

During the autopsy, a knob from the gust lock handle was found embedded in the captain's right wrist. It follows, then, that the captain's right hand was elevated and positioned in the region of the gust lock handle at the time of the crash. Based on this information, it is likely the captain was attempting to operate the gust lock handle at the time that the aircraft hit the ground.

2.7 Six-point control check

Standard procedures for the Caribou aircraft allow for locking the flight controls during ground operation. The aircraft flight manual indicates that a six-point control check is required prior to take-off to ensure free and proper movement of the flight control system. No control check was seen by witnesses on the ground, nor was one captured on videotape or 35 mm film. It is likely that if the controls were locked prior to take-off because of some unknown component failure or system jamming, a full control check would have identified the restriction. It is therefore concluded that the control check was likely omitted for undetermined reasons.

3.0 CONCLUSIONS

3.1 Findings

1. The occurrence aircraft was operating under an EXPERIMENTAL category of CAR 4b; the aircraft had acquired an accumulated flight time of 23 hours in its modified configuration.

2. The aircraft was loaded within the weight and balance constraints published in the Aircraft Flight Manual.

3. The aileron and elevator trim tabs were near their neutral positions.

4. No flight control check was observed prior to commencement of the take-off roll.

5. The take-off ground run was 20 per cent longer than the performance charts predict.

6. Aft elevator authority existed at rotation.

7. The aircraft's initial climb attitude was significantly higher than on previous take-offs under similar environmental conditions.

8. At approximately 35 feet agl, the aircraft made a noticeable pitch-up movement; from that point onwards, the elevator control surfaces remained in their neutral position.

9. Airspeed remained above the stall speed throughout the in-flight manoeuvre.

10. The flight control system had not been modified during the conversion process; there was no evidence of pre-impact faults in this system.

11. The propeller blades contained significant rotational energy at the time of the crash; blade angles had been captured at approximately 26 degrees and were consistent with a high engine power setting.

12. Both engines were under high power at impact; neither engine displayed any pre-impact anomaly or distress that would have prevented normal operation prior to impact.

13. While the aircraft was in flight, the elevator spring tabs were deflected upward with no corresponding movement of the elevator; this situation occurs when forward control column pressure is applied and the elevator control lock is engaged.

14. The rudder gust lock's mechanical actuating lever-arm was captured in the ENGAGED position at impact.

15. A sprocket assembly that interconnects the rudder and elevator control lock actuation mechanisms was oriented midway between the gust lock ENGAGED and gust lock DISENGAGED position.

16. Damage to the aileron control quadrant's centre pivot-bearing structure is consistent with the aileron control lock being engaged at impact.

17. Post-accident tests show that, in situations where one or more gust lock pins does not fully disengage, it is possible to have aft (nose-up) elevator authority with no forward (nose-down) elevator control.

3.2 Causes

The gust lock system was not fully disengaged prior to flight and one or more of the gust locking pins became re-engaged for undetermined reasons after lift-off. It is unlikely that a control check had been completed prior to take-off and, once airborne, the crew were unable to disengage the gust lock mechanism before losing control of the aircraft.

4.0 SAFETY ACTION

4.1 Action taken

4.1.1 Aircraft gust locks

Subsequent to this occurrence, the Transportation Safety Board forwarded an Aviation Safety Advisory to Transport Canada concerning the adequacy of pre-take-off checklists and procedures pertaining to the removal of aircraft control gust locks.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson, John W. Stants, and members Gerald E. Bennett, Zita Brunet, the Hon. Wilfred R. DuPont and Hugh MacNeil, has authorized the release of this report.