P90091E
Sept. 30, 1979

Transport Canada Transports Canada

Air Air

Report No. P90091
Aircraft Accident
West Coast Air Services Limited
de Havilland, DHC6-200 (floats)
Registration C-FWAF
Sechelt, British Columbia
13:00 PDT, September 30, 1979

AVIATION SAFETY BUREAU

BUREAU DE LA SÉCURITÉ AERONAUTIQUE

AVIATION SAFETY INVESTIGATION

ENQUÊTE SUR LA SÉCURITÉ DE L'AVIATION

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SYNOPSIS

At an altitude of approximately 200 ft on final approach to Sechelt water aerodrome, the aircraft suddenly turned to the right and descended in a right wing-down, nose-low attitude. It crossed the shoreline, struck the ground right wing first and then cartwheeled into a tree-covered area.

Investigation revealed that a component of the aileron control system had failed in flight.

Honourable the Minister of Transport

This Accident Investigation and this Report have been audited by the Aircraft Accident Review Board. The Board has considered all information available including that from involved parties. The Board agrees with the contents of this Report for release as public information.

Aircraft Accident Review Board

Approved 21 January 1981

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Section

1. Factual Information

1.1 History of the Flight

Twin Otter C-FWAF, operating as flight 106, was on a scheduled VFR flight. It departed Vancouver Harbour, B.C. at 12:35 PDT*, September 30, 1979, enroute to Powell River via Sechelt. On board were two crew members and 14 passengers.

Take-off and departure from Vancouver Harbour was normal. At 12:42 the aircraft crew contacted their dispatch on company frequency and reported off Vancouver Harbour at 12:35, estimating Sechelt (Porpoise Bay) at 12:50 and Powell River at 13:10. This was the last known communication from the aircraft.

The flight was uneventful until it neared Sechelt. Witnesses and passengers described a normal approach to land on the water at Porpoise Bay. As the aircraft passed over the southern shoreline of the bay at about 200 ft. it began to roll to the right. The angle of bank increased "to about 90°", with the nose dropping. The aircraft descended and struck the ground in a right wing-down nose-low attitude on the eastern shore of the bay 165 ft from the water.

* All times in this report are Pacific Daylight (GMT-7)

Initial impact was with the right wing, followed by the right float and the nose of the aircraft. It then cartwheeled and came to rest against trees facing about 110° to the right of the final direction of flight. The aircraft captain was killed on impact and one passenger died later as a result of injuries sustained. The first officer received serious injuries and has been unable to recall details of the accident.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Others
Fatal	1	1	-
Serious	1	3	-
Minor/none	-	10	-

1.3 Damage to Aircraft

The aircraft was substantially damaged on impact with the ground and trees and the wreckage was confined to a small area.

1.4 Other Damage

None

1.5 Personnel Information

(a) The pilot-in-command (captain) was 35 years old and held an Airline Transport Pilot Licence valid for aeroplanes single and multi-engine, land and sea, with a Class I instrument rating. His total flying experience was in excess of 10,000 hours, of which 210 hours were on the Twin Otter. He was employed by the company in July 1978 and received initial training on the Twin Otter in October 1978 consisting of 21 hours ground instruction and 9.6 hours flight instruction. He satisfactorily completed the initial pilot proficiency check on May 3, 1979 and following additional training in the Twin Otter on floats, he was assigned to duty as a Twin Otter Captain - wheels and floats - although he occasionally flew other company aircraft. In the 90 days preceding the accident he accumulated a total of 206 hours of which 86 hours were on the Twin Otter on wheels and 75 hours on floats. His last medical, September 27, 1979 was assessed as Category I, with no restrictions.

(b) The First Officer/Cabin Attendant was 24 years old and held a Commercial Pilot Licence valid for aeroplanes single and multi-engine land and sea, with a Class II instrument rating. His total flying experience was in excess of 700 hours, of which 325 hours were as First Officer on the Twin Otter. He was employed by the company in May 1979 and received initial training on the Twin Otter consisting of 21 hours ground instruction and 4.7 hours flight instruction in the right seat. He had also received training and passed an examination concerning the duties of a cabin attendant and was assigned to duty as a Twin Otter First Officer/Cabin Attendant. In the 90 days preceding the accident he accumulated a total of 193 hours as a First Officer. His last medical, May 1, 1979 was assessed as Category I, with no restrictions.

(c) In the 3 days preceding the accident, both the captain and the first officer had been on days off. They reported for duty at 08:30 on September 30, half an hour before their first scheduled flight. At 09:37 they departed Vancouver Harbour on a flight to Victoria Harbour with an enroute stop-over at Bedwell Harbour, returning to Vancouver Harbour at 11:02. Flight time for the return trip was one hour. At 12:35 they departed Vancouver Harbour for the flight to Powell River via Sechelt.

1.6 Company/Aircraft Information

The aircraft, Serial No. 122, was manufactured in 1968 by de Havilland Aircraft of Canada Ltd. and powered by two Pratt and Whitney PT6A-20 engines. The maximum authorized take-off weight was 11,600 lbs. The weight and centre of gravity at the time of the accident were within limits.

The airline took delivery of this aircraft on May 2, 1979. It had previously operated in the Arctic for an extended period of time. On receipt floats were installed and the aircraft was treated for salt water operation. At this time also the aircraft was repainted. Total airframe hours at the time of ownership transfer was 13,378.3. Total airframe time when the accident occurred was 13,815.4 hours.

The operator's maintenance facilities, records and practices were examined and no deficiences were found. The company employed the EMMA (Equalized Maintenance Maximum Availability) inspection system developed by the manufacturer. EMMA check No. 17, carried out on May 1, 1979 prior to ownership transfer, included examination of the right wing flight controls. Other EMMA checks were carried out in sequence. The next requiring inspection of the right wing flight controls was EMMA check No. 25, which was not yet due.

In addition, special inspections applicable to aircraft operating in areas of high salt content had been carried out. These inspections, done every 50 flying hours, were in accordance with the airframe manufacturer's bulletin TAB 626/1. Section 3.5(b) of that bulletin reads as follows:

> "Push Rods C6CW1019-1 and C6CW1018-1. These should be examined particularly at the magneformed ends for breaks or blisters in the paint indicating corrosion beneath the surface; or for signs of corrosion at any area of anodic treatment breakdown. Any attack in this area, which is highly stressed, could cause stress corrosion with the additional danger of cracking and loosening of the magneformed ends."

This meant that the aileron control rods had been visually inspected at least eight times during the period from May 1, 1979 and September 30, 1979.

1.7 Meteorological Information

The weather at the time of the accident was VMC (visual meteorological conditions). There is no observing station at Sechelt but at the time Vancouver (30 nautical miles S.E.) reported 2500 feet scattered, estimated ceiling 14,000 broken 25,000 broken, visibility 12 miles, barometric pressure 1027.1 millibars; temperature 16°C, dew point 13°C, wind 260 at 6, altimeter setting 30.33" Hg. Vancouver Harbour (the point of departure) reported 3000 scattered, 12,000 scattered, 26,000 thin scattered, visibility 15 miles, barometric pressure 1026.6 millibars, temperature 18°C, dew point 13°C wind calm, altimeter setting 30.32" Hg. According to witnesses, the weather was similar at Sechelt. Pilots flying in the area did not report any turbulence.

1.8 Aids to Navigation

There were no aids to navigation serving the Sechelt water-aerodrome.

1.9 Communications

Communications with Air Traffic Services for departure and company dispatch enroute were normal and routine.

1.10 Aerodrome

The Sechelt water aerodrome is situated at 49° 29'N, 123°46'W on Porpoise Bay at the southern end of Sechelt Inlet. It is sheltered salt water with a tidal range of 12 feet. The alighting area is 3 miles by 3/4 of a mile, aligned northwest/southeast.

1.11 Recorders

There was neither a voice nor a flight data recorder on board, nor were they required by regulations.

1.12 Wreckage and Impact Information

Power Plants

1.12.1 Left Engine PT6A-20, Serial Number PCE 21680

The engine was still attached to the wing which had separated from the fuselage at the wing root fittings. There was evidence of fuel and oil at the engine and fuel and oil filters were clean. No abnormality was found which would have prevented the engine from operating normally and it was evident from the torsional wrinkling of the exhaust duct that the engine was delivering power at the time of impact.

1.12.2 Right Engine PT6A-20, Serial Number PCE 21465

The engine had separated from the wing in an outboard direction at the firewall area. Engine controls had failed in tension at the firewall and cambox area. Also, the propeller reversing interconnect linkage had separated between the push-pull control wire rope terminal and the rod-end clevis. From the position of the lock nut on the terminal, it appeared that only 1-1½ threads of the terminal had been engaged in the clevis when separation occurred[1]. Nevertheless, it was concluded on close examination that this amount of engagement would tolerate normal operational loads and that the failure was a result of ground impact (Engineering Facility Report LP 263/79 refers).

The engine showed slight torsional wrinkling of the exhaust duct, similar to the left engine. There was evidence of fuel and oil at the engine and fuel and oil filters were clean. No abnormalities were found which would have prevented the engine from operating normally and it was evident that the engine was running at low power at the time of impact (Engineering Facility Report 262/79 refers).

1.12.3 Left Propeller, Hartzell Model HC-B3TN-3 Serial No. BU1886

The blades were found in the latched (zero thrust) position. The latches were released and the spring moved the blades to the feathered position. Examination showed it was capable of normal operation prior to impact. Because of hub condition and absence of impact marks within the piston, blade angle at impact could not be established. Blade damage was consistent with blade strikes in the forward fuselage structure. Positive bending of the blades indicated forward thrusting (positive pitch) when they contacted the fuselage.

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1 Airworthiness authorities were immediately notified of this unsafe condition. An Airworthiness Directive (CF-79-20) was issued to all operators of DHC-6-100 and -200 series aircraft.

1.12.4 Right Propeller, Hartzell Model HC-B3TN-3BY, Serial No. BU2580

When the right engine and propeller were lifted off the ground at the scene, two blades moved to the feathered position. The other blade pitch link arm had separated from the blade clamp due to shearing of the clamp pin and the counterweight of this blade had impacted the outside aft portion of the piston. Realignment of these components showed that this gouge was made following separation of the blade pitch link. The blade angle at the time the counterweight struck the piston was estimated to be 22 to 24 degrees. As with the left propeller, a blade pitch angle at impact could not be determined. Examination of the propeller showed it was capable of normal operation prior to impact. Chordwise scratching and abrasive removal of paint from the front (cambered) side of the blades suggests that the propeller disc was tilted downwards, contacting the ground in a near horizontal position. This is consistent with propeller slash marks found in the ground along the impact trail during breakup.

1.12.5 Engine Control (overhead) Console

The control console was badly damaged. Actual positions of the levers at impact could not be determined due to destruction of the plastic levers and pulley components. The power lever operated beta system disarm switch was tested and found to function normally.

1.12.6 Fuel System

The fuel cells were ruptured on impact and a substantial quantity of fuel was spilled on the ground. Fuel on board at impact was calculated to be 700 pounds. No evidence of failure or malfunction was found in the fuel system.

1.12.7 Structures

The wreckage and witness marks in the ground showed that the aircraft had struck right wing tip first. A gouge in the soft earth made by the right outboard flap aileron hinge bracket indicated a bank angle of 45 ± 5 degrees. This is further confirmed by the upward and rearward failure of the outer wing sections, the mode of failure of the front and rear spar attachments, and the damage to the wing trailing edge, adjacent fuselage and the right float. As the right wing separated at the root attachments it rotated the leading edge down, by the moment arm of the engine, to a position where the propeller disc was nearly horizontal when it slashed the ground.

When the nose impacted the ground, the right forward fuselage (front cabin area) was arrested by a tree stump. Inertia forces acting on the left wing caused it to fail forward, permitting a propeller blade to enter the cockpit area cutting through the circuit breaker panel and fuselage skin, adjacent to the pilot's seat. A second blade slashed through the door frame and into the pilot's seat. A third strike was evident on the right rear side of the elevator/aileron control yoke. As the left wing failed forward, the spanwise flap tubes were loaded in tension, pulling the left hand flaps to the full down position and causing the bellcrank to over travel into the wing structure. This overtravel caused a bending overload failure (inboard end) of the spanwise outboard flap rod. Subequent impact of the wing/flaps with a tree drove the outboard flap sections to the full up position failing the outboard chordwise flap rod in compression.

As the fuselage continued to cartwheel, first the left float and then the tail section separated, and the cabin came to rest about 110° from the original direction of flight. Although the cockpit and right front corner of the cabin were badly damaged, the remainder of it was relatively intact.

Impact marks of the right hand control wheel confirm that full left wing down was being demanded at impact. Severe crushing damage had jammed the rudder pedals in a near neutral position; elevator trim was nearly neutral. The flaps were 20-22° down. No useful information could be obtained from the aircraft instruments (Engineering Facility Report LP 257/79 refers).

Flight control linkages were found to be intact with the exception of the right bellcrank to aileron push-rod P/N C6CW 1019-1. The clevis end fitting had separated from the rod at the bellcrank end. The failed end of the rod was found to have a longitudinal split of approximately two inches in length, extending across the magneformed swage to the rod end and it was suspected that the separation had occurred before the ground impact (see Fig 3).

No other discrepancies were found in the control systems or structure.

1.13 Medical and Pathological Information

Captain

Autopsy showed that this pilot died instantly when struck by the left propeller during the crash sequence. On his right upper extremity were abrasions and lacerations of the hand and forearm, but none in the left upper extremity. There were lacerations over both knees, the

right foot and left foreleg, anteriorly. This injury pattern suggests that at impact the captain was manipulating the overhead power controls but not the control column; injuries in the legs suggest that he was not pushing on one rudder more than the other. No condition was found which might have acutely impaired his performance during the final approach.
Biochemical determinations did not reveal the presence of alcohol. Post mortem tissue lactate would indicate that the captain had an acute stress reaction of approximately 7 seconds.

First Officer
This pilot survived with fractures of his right leg and amputation of fingers of the left hand. These injuries suggest that he was manipulating the control column at impact.

1.14 Fire
There was no fire.

1.15 Survival Aspects
The accident was survivable.

The impact forces were not severe enough to produce failure of the cabin seat attachments to the floor and wall, which are designed to withstand an acceleration of 9G forward. The two right hand front cabin seats had failed, due to floor and cabin wall damage in that area. The passenger in the front row right hand seat subsequently died from injuries received. The passenger in the second row right hand seat received serious injuries but survived.

Passenger statements confirmed that the co-pilot had given a pre-take-off briefing on emergency exits and life jackets. The overhead emergency exit was not used but operated normally. The lefthand airstair entrance/exit door operated normally as did the right hand emergency exit door.

1.16 Tests and Research

1.16.1 Aileron Control Rod Failure
Field examination of the control systems had identified one possible deficiency; the separation of the right aileron push-rod at the bell-crank end (See 1.12.7). Laboratory examination revealed a 1 15/16 inch longitudinal crack across the swaged portion of the rod end. The failure mechanism was identified as stress corrosion except for a small (.01 by .03 in.) overload shear lip at the end of the rod. It was concluded that

the crack had progressed sufficiently to allow separation of the rod and end fitting under normal operational loads for the approach configuration (Engineering Facility Report LP 254/79 refers - see also section 1.16.3).

1.16.2 Stress Corrosion Failures-General

The three essential ingredients for stress corrosion: a susceptible material; the presence of residual stress; and a corrosive environment were all present. Operational loads do not have a significant effect on stress corrosion crack growth rate. Thus, in this case, the crack may have existed at the time of the last relevant EMMA check, but was undetected because visual inspection is inadequate for this purpose and no other type of inspection was required. Previous experience has demonstrated that removal of paint and application of dye penetrant is essential for the detection of this type of failure mechanism (see Fig 4).

1.16.3 Aileron Rod Tests

Flight test data supplied by the manufacturer reveal that the operational loads on the rod in the final approach configuration with 20° flap would be in the range of 90 to 170 lbs.

Laboratory tests were conducted to determine what tensile loads were required to separate rods and end fittings. One intact rod required a pull of 4650 lbs. Other rods removed from service were cut to simulate the stress corrosion crack.
The pull required in 17 tests ranged from 69 to 330 pounds, with eight of them failing below the 170 lb upper limit of operational loads (Engineering Facility Report LP254/79 refers).

1.16.4 Aileron Configuration at Impact

Impact witness marks showed that the right aileron was in the full UP or higher position, possibly as high as 32°. The aileron controls, with the exception of the right aileron and aileron control rod C6CW1019-1, corresponded to a full left control wheel input. Physical evidence also disclosed that the left aileron was in an UP positon, near its control limit.

High speed taxi tests conducted by the manufacturer demonstrated that a free aileron will float progressively upward as the speed increases, reaching fully UP at 40 knots with flaps set at 20° down.

The left aileron would also have a tendency to move up, and the pilot would no doubt have made that control input; because its linkage was still intact, the aileron would have been limited to about 21° UP (Engineering Facility reports LP 26/80 and LP 55/80 refer).

1.16.5 Aircraft Controllability

The effect of a right aileron control rod failure in the landing configuration would be that the right aileron would float upward, beyond its control limit, reducing the lift on the right side and causing the right wing to drop and the aircraft to roll to the right. This would immediately create an unstable flight condition. Freed of the counterbalancing effect of its linkage the left aileron would tend to move upward, and with pilot input would travel to its control limit, 21°. This would be insufficient to correct the right rolling tendency, and there would also be further loss of total lift.

Information provided by the manufacturer indicates that a roll rate of 8.2° per second would develop with a failed aileron rod.

With maximum asymmetric power (idle power LH engine, takeoff power RH engine), theoretical calculations and measured flight test data show that the rolling moment derived from the power asymmetry is very slightly in excess of the rolling moment resulting from the asymmetric aileron. It is therefore theoretically possible to offset the aileron induced roll, providing the problem is immediately diagnosed and asymmetric power promptly applied. Reaction time would be an important factor since the situation would deteriorate rapidly. The right roll could not be arrested by the remaining aileron and rudder effect because they would not supply sufficient roll power in the opposite sense. In any event, there was very little time or altitude remaining and in the actual case of C-FWAF the pilot was not able to regain control of the aircraft prior to striking the ground (Engineering Facility Report LP 55/80 refers).

1.17 Additional Information - Witnesses

A number of persons on the ground saw the accident and were able to provide useful observations. In addition, surviving passengers described their experience.

1.17.1 Eyewitnesses

Many witnesses agreed that the aircraft rolled to the right as it crossed the shoreline of Porpoise Bay. Height estimates ranged from 50 to 300 feet. All these witnesses described a gradual roll that progressed "to about 90°" of bank when the aircraft struck the ground or disappeared from view. All except one of those who heard engine sounds described what would normally be expected from a DHC6 on approach with reduced power. The exception described a variation in sound after the aircraft had banked "to about 80°" and disappeared behind trees.

1.17.2 Passengers

Of the thirteen surviving passengers the majority reported that the flight had been uneventful until final approach. One spoke of hearing a buzzing noise from the cockpit at about the time the problem developed. (Other than possibly the stall warning, this could not be related to usual sounds from the cockpit.) Those who were looking forward saw both pilots with their hands on the overhead controls. One passenger was quite positive about the pitch levers being pushed fully forward just before the roll to the right began. A number stated that the pilot had pushed the power levers ahead and these persons were anticipating an overshoot when the roll to the right occurred. One passenger had the impression that the pilot was trying to turn left but he could not explain why he had that impression. One other made reference to shouting from the cockpit by the crew members but he could not distinguish what was being said. Only one passenger made reference to abnormal engine noises.

The surviving crew member was not able to provide any information concerning the accident. He had sustained serious injuries and reported he could not recall events surrounding the accident.

1.18 Special Investigation Techniques

Video cameras were used to record examination and reconstruction of the damaged aircraft, and to study the operation of the control systems. These recordings greatly assisted field and laboratory specialists.

2.0 ANALYSIS

2.1 From witness information it is apparent the flight was routine until crossing the shoreline of Porpoise Bay. The engines were operating normally, and the aircraft while on final landing approach suddenly rolled and turned to the right until the wings were "nearly vertical" before it struck the ground. Whether the angle of bank was as steep as it appeared to the witnesses (nearly 90°) could be in question but physical evidence at the site confirmed that the right wingtip struck the ground at an angle of $45 \pm 5°$.

The evidence makes it clear that the right aileron rod failed in flight, creating a situation which rendered the aircraft uncontrollable in the particular circumstances.

The laboratory studies determined that there existed a stress corrosion crack near an end of the rod which weakened it so that complete failure and separation occurred under normal flight loads.

Stress corrosion cracking is difficult to detect during inspections, both because a crack may be obscured by paint and because special procedures, such as the use of a dye penetrant, are necessary to reveal the crack.

Dye penetrant inspections were not mandatory in routine inspections of the aileron rods. Nevertheless they were mandatory in relation to flap rods of this aircraft type which had been the subject of a number of Airworthiness Directives prior to this accident (AD #CF-79-03 Feb 28/79 and #CF-79-04 March 20/79).

The flap rods and aileron rods are of similar design and construction.

Records have shown that the flight crew was properly qualified and competent. The emergency, when it developed, was of an unexpected nature and completely outside what might have been anticipated in flight training. When the right aileron control rod failed, it allowed the right aileron to move to a full UP position causing an immediate strong right roll tendency. In addition, the left aileron would have tended to move UP, to near its control limit and the control wheels in the cockpit , as a consequence, would also have moved to a left position. As the technical examinations and studies determined, the left aileron was limited to about 21° UP whereas the disconnected right aileron would go to 31.5° UP. In addition to a resultant strong right roll tendency there would have also been significant loss of lift.

In such a situation a natural pilot reaction would be to apply immediate left input at the control wheel and also to pull back on it.

At the same time, the pilots would also be concerned with the engine and propeller controls.

The seven second period of severe stress as determined by postmortem biochemical tests is compatible with the time between failure of the aileron rod and the final impact.

3.0 FINDINGS

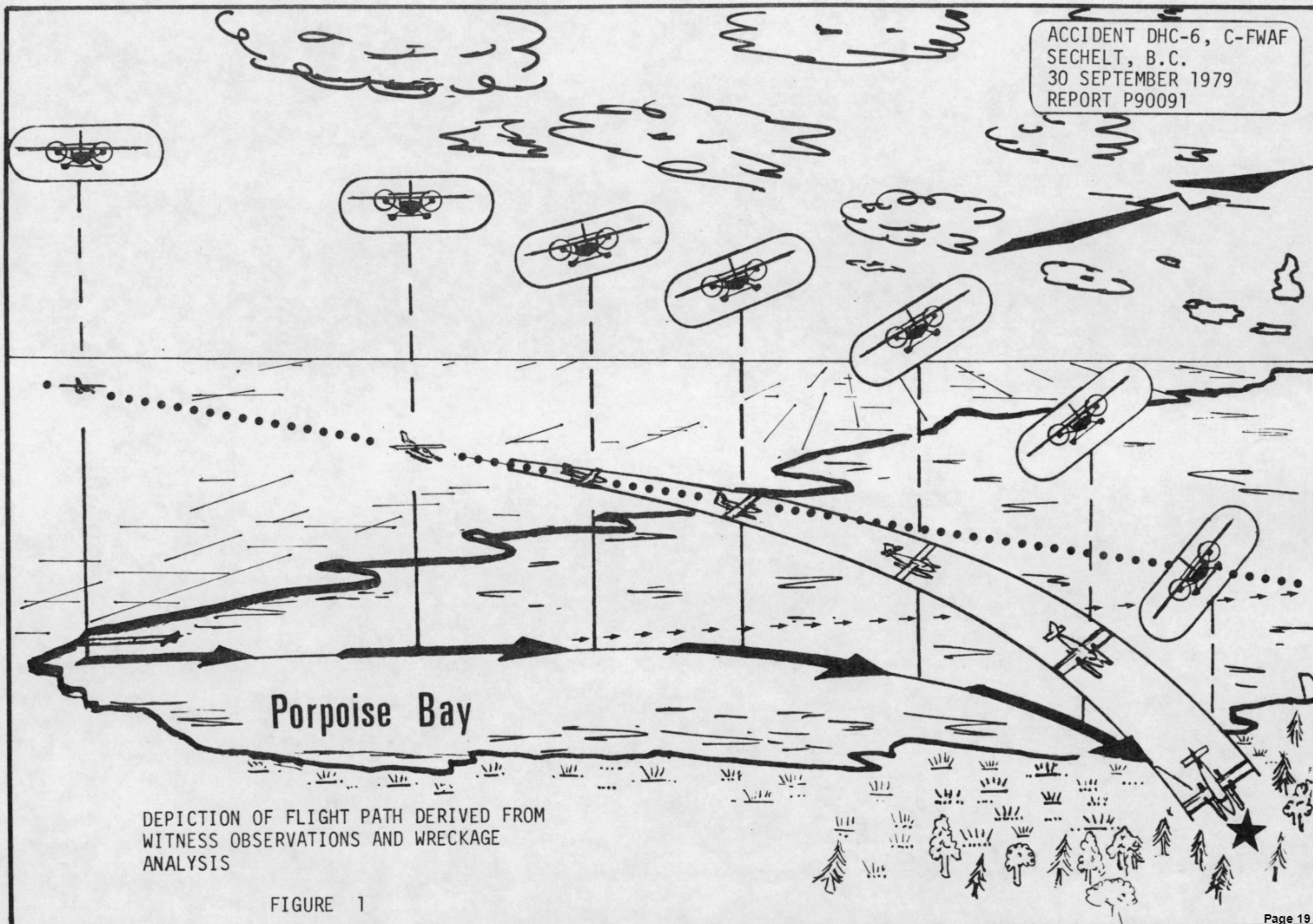
1. Under normal flight loads the right hand aileron control rod of the aircraft (bellcrank to aileron push-pull rod PT # C6CW 1019-1) separated from the bellcrank end fitting due to an extensive stress corrosion crack.

2. The failure of the right hand aileron control rod allowed the right aileron to float to an UP position, causing an asymmetric lift condition and consequent loss of control.

3. At an altitude of about 200 feet on final approach the aircraft began a roll to the right which under the circumstances was uncontrollable, it descended and struck the ground with the right wing down 45±5 degrees.

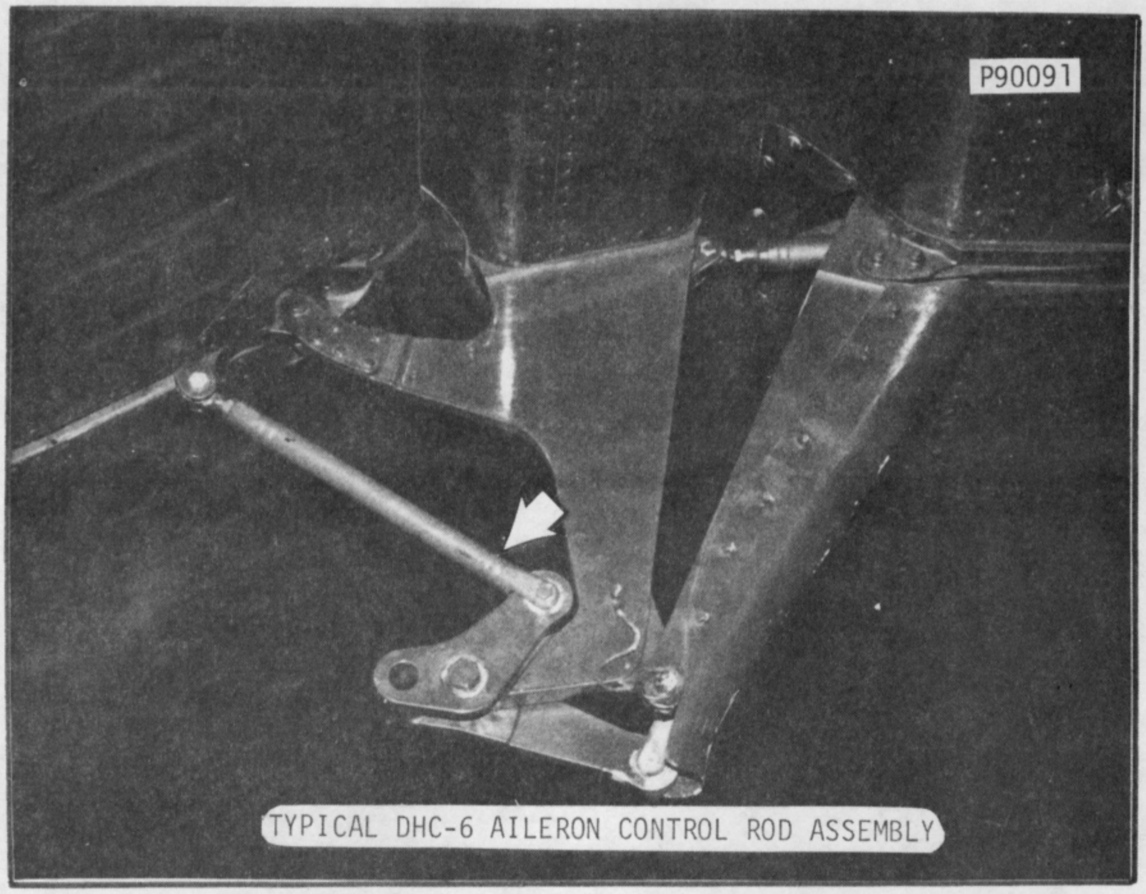
4. The specified visual inspection of aileron control rods was inadequate to detect stress corrosion cracking.

5. Previous stress corrosion failures of flap control rods on aircraft of this type had led to corrective airworthiness action by the Department of Transport and the manufacturer. These measures however had not been applied to the aileron rods which are of similar construction.



DEPICTION OF FLIGHT PATH DERIVED FROM WITNESS OBSERVATIONS AND WRECKAGE ANALYSIS

FIGURE 1



TYPICAL DHC-6 AILERON CONTROL ROD ASSEMBLY

FIGURE 2

C-FWAF FAILED CONTROL ROD AND ASSOCIATED PARTS

FIGURE 3

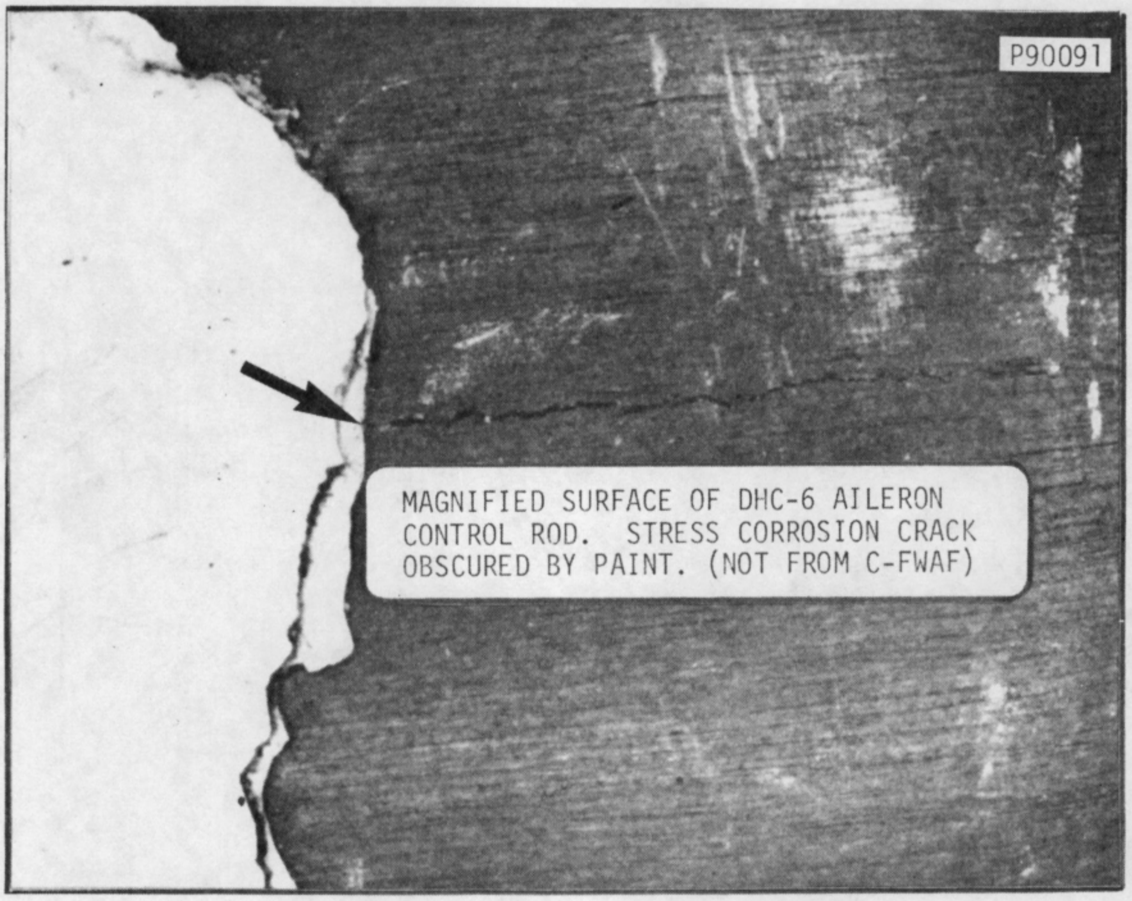


FIGURE 4

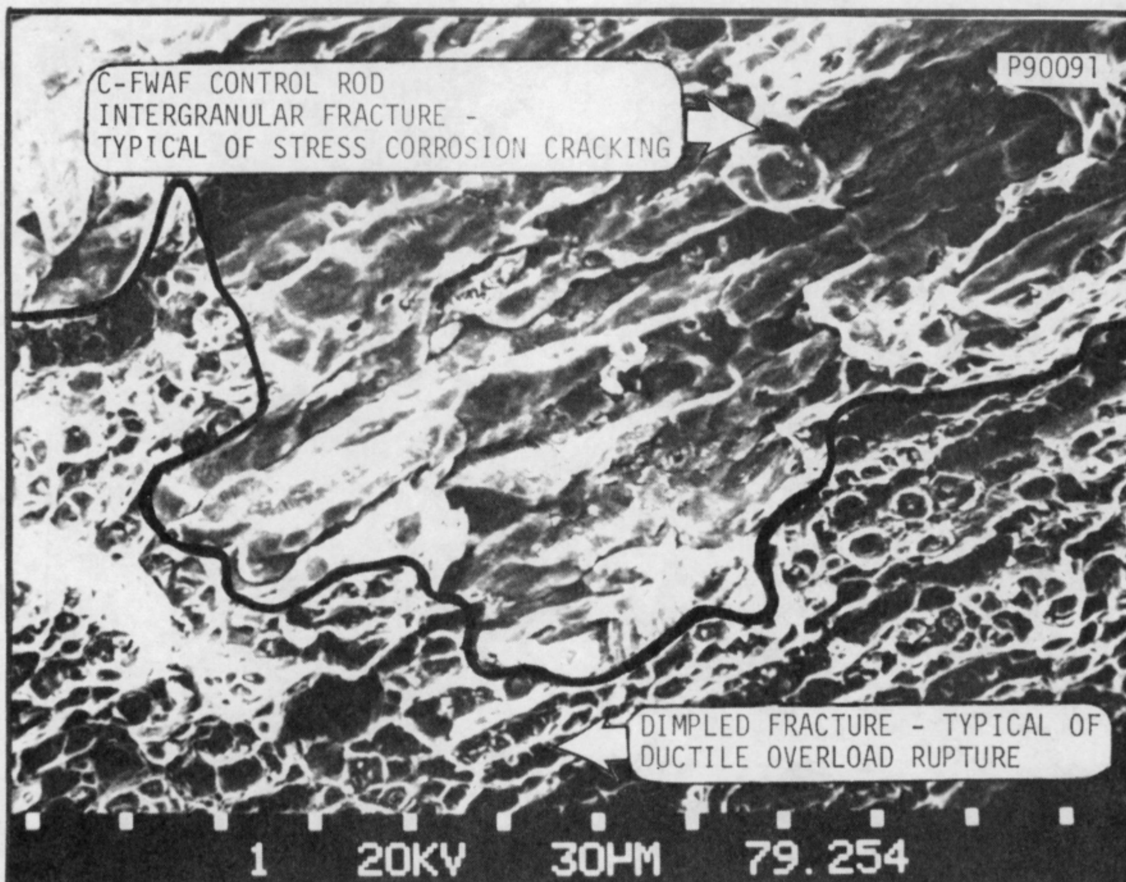


FIGURE 5