No. 6

DeHavilland DHC-6-200 (floats), CF-AIV, accident at Vancouver Harbour, B.C., Canada on 3 September 1978. Report No. H80003 released by Transport Canada, Canada.

SYNOPSIS

A visual approach was being made to Vancouver Harbour, when at 175 ft above the surface and approximately 2 500 ft from the intended landing area, the aircraft suddenly rolled left and plunged into the water.

1. FACTUAL INFORMATION

1.1 History of the Flight

Twin Otter CF-AIV, operating as a scheduled VFR flight, departed Victoria Harbour, B.C. at 0018 hours*, 3 September 1978, with Vancouver Harbour water-aerodrome as destination. The estimated time en route was 20 minutes.

The flight proceeded normally and reported by Active Pass at 2 000 ft. This altitude was maintained in order to cross the Vancouver Control Zone in accordance with standard procedure; once out of the control zone, a slow descent was begun towards Vancouver Harbour.

Normal radio procedures were followed as the flight reported by standard visual reporting points. Just before joining final approach, the transmission, "AIV, Third Beach", was made and landing clearance was given to the flight by the Harbour Tower. The approach continued, and when the aircraft reached approximately 175 feet above the surface, nine ground witnesses heard a loud noise from the aircraft. Two surviving witnesses also heard a noise. Power was subsequently applied and CF-AIV yawed left, rolled in the same direction and plunged into the harbour in a left-wing and nose-down attitude, 2 500 feet from the intended landing area.

An ELT (Emergency Locator Transmitter) tone was heard by the tower controller 54 seconds after the radio call at Third Beach. The controller called the aircraft several times but there was no response.

The flight had been of 24 minutes duration.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Others
Fatal	2	9	0
Serious	0	2**	0
Minor/None	0	0	

* All times in this report are GMT, which is Pacific Daylight Time + 7 hours.

**One, a pilot with 300 hours experience, employed as 2nd officer on 747 aircraft. One, a tour-guide.

1.3 Damage to Aircraft

The aircraft was destroyed on impact with water and the wreckage was confined to a small area.

1.4 Other Damage

None.

1.5 Personnel Information

(a) The pilot-in-command was 27 years old and held a valid Airline Transport rating. He had been working for the Company since 1974 and had accumulated in excess of 6 000 hours flight time of which 3 600 were on the Twin Otter. His last medical, 27 June 1978, was assessed as Category I, with no restrictions. Transport Canada medical records indicate that his first examination for a pilot's licence was in 1967 when it was noted that he had previously experienced back pains for two years, diagnosed by an orthopaedist as epiphysitis. The records show no indication of physical problems thereafter except for a torn ligament in his left ankle in 1968.

Because of the previous diagnoses, enquiries were made of Company personnel and of various physicians who had examined him. It was found that his disabilities during previous employment had prevented him from doing any heavy work such as lifting, and he would not load aircraft. Information was also obtained that on one occasion while employed by another company, he was in so much pain following a flight, that he had to be lifted from the cockpit and out of the aircraft. Enquiries did not reveal a firm diagnosis but evidently he had been complaining of pains in the back and swelling and pain in the left and/or right foot, periodically since 1964. A diagnosis of gout had been considered at one time.

On the day of the accident he had flown 3.5 hours, which consisted of two flights to Nanaimo and three flights to Victoria Harbour. The first (to Nanaimo) commenced at 1503 hours, the accident occurring on the return leg of the third flight to Victoria Harbour. His activity during the day appeared to have been normal although he was observed to have rested supine on a counter top in the Vancouver office before his last flight to Victoria.

(b) The cabin attendant was 23 years old and held a valid Commercial Pilot's licence. He began flying in 1974 and had acquired over 450 hours of flying time. Normally he sat in the right hand pilot seat but was not authorized by the Company or Transport Canada to handle the controls of the aircraft on revenue flights. Discussions with other Company pilots, however, indicated that this captain allowed him to fly the aircraft on occasion and a survivor stated that he did so during the cruise segment of the accident flight. His last medical examination was in 1 March 1978 and he was granted a medical Category I with no restrictions. He was employed by the Company in April 1977 as a ticket agent but later transferred to the position of cabin attendant on Twin Otters.

1.6 Company/Aircraft Information

The aircraft was operated as a Class II service. The Vancouver Harbour to Victoria Harbour segment of the company's operation is classed as Scheduled VFR (floats). For this type of operation the company uses a crew complement of a captain and one cabin attendant; the latter was permitted by Transport Canada to occupy the first officer's station.

The aircraft, Serial No. 215, was manufactured in 1969 by DeHavilland 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 of CF-AIV, at the time of the accident, were within limits.

The maintenance facilities, records and practices were examined and no deficiencies were found. However, the maintenance procedures in effect at the time precluded adequate inspection of the installed flap control rods.

1.7 Meteorological Information

The weather at the time of the accident was VMC (Visual Meteorological Conditions). The post weather sequence, recorded at 0052 hours, showed 1 500 feet scattered, 4 000 ft scattered, estimated 7 500 feet broken, 9 000 ft overcast. The visibility was 12 miles, temperature 16°C, dew point 14°C, wind 050° at 3 knots.

Pilots flying in the area at the time of the accident reported no significant turbulence.

1.8 Aids to Navigation

There are no aids to navigation serving the Vancouver Harbour water aerodrome.

1.9 Communications

The aircraft's communication equipment was selected to appropriate local frequencies and operated correctly. Communications with Air Traffic services and company dispatch were normal and routine.

Because of the location of the Vancouver Harbour tower it was impossible for controllers to view continuously aircraft landing from the west until on short final; because of this, the first indication of a crash was the transmission of the ELT tone. Confirmation of the accident was obtained by communication with the pilot of another aircraft who observed the impact. The controller immediately notified the Vancouver Marine Traffic Centre in accordance with Vancouver Harbour emergency procedures.

1.10 Aerodrome

The water aerodrome is situated 49°18'N 123°07'W, is generally well sheltered and has a tidal range of 14 feet. The alighting area is 4 miles long in an east/west direction and one mile long, north/south. A note of caution on the chart which depicts the water drome states "Aircraft arriving Vancouver from the west are to approach over Beaver Lake in Stanley Park."

1.11 Recorders

There was neither a voice nor a flight data recorder on board, nor was there a requirement for either.

1.12 Wreckage and Impact Information

1.12.1 Power Plants

Left Engine - PT6A-20, Serial Number PCE 20786

The engine had separated from the wing at the firewall area. The tower area of the cowl and nacelle had received impact forces in an outboard direction. The inboard side of the engine support structure had been in tension while the outboard side was in compression. Engine control cables had failed in tension. A section of the propeller control linkage (from firewall to cambox) was found in the nose of the left float. The propeller and engine were recovered as a unit.

1.12.2 Right Engine - PT6A-20, Serial Number PCB 21873

This engine separated from the wing at approximately the same location as the left. Examination of the support structure showed failure from torsional forces opposite to the direction of rotation. This was probably a reaction from the propeller striking the heavier fuselage structure of the cockpit. Engine control cables had failed in tension. The propeller and engine were recovered as a unit.

1.12.3 Left Propeller - Hartzell HC-B3TN-3*, Serial BU577

Two blades were bent aft at mid-span and the third had a slight forward bend near mid-span, then an aft bend near its tip; there were no nicks or gouges. The latch pins of two blades were corroded in the recessed position; the pin of the third blade held the piston and the other two blades at the zero thrust angle; when the latch was depressed the propeller piston and blades travelled to the "feather" position. The spinner, which had impacted into the piston and counterweight assemblies, was ruptured, and provided no valid information.

Externally there was visible damage to the propeller hub/spider assembly. The blade links, attaching the blade/clamps to the piston, appeared compressed; the guide collar had been impacted by all three of the blade-link pins and/or zero thrust latch cams; also some damage to the guide rod bushing circlips was evident. It was therefore apparent that the piston at some time during impact had moved to the full reverse position.

1.12.4 Right Propeller - Hartzell HC-B3TN-3, Serial BU1492

All three blades had been bent in a forward direction, the centre of the bends being about mid-span. Two blades had sustained severe tip damage resulting in loss of metal; the third blade was intact. The piston was in the feathered position. The spinner had impacted into the piston and counterweights but no useful information was gained from the spinner damage.

1.12.5 Engine Control (Overhead) Console

The engine control console was virtually destroyed by impact forces. Power levers, the right propeller lever, fuel levers and their respective pulleys were shattered or broken out of the console; the left propeller lever was not recovered. The right propeller mechanical stop appeared to have been out of rig by comparison with other adjacent stops. Mod. 6/1223 (Prop/Power lever interlock) had been fitted. The power-lever microswitch was removed, tested and found to be serviceable. No pre-impact lever positions could be determined because of extensive damage.

1.12.6 Fuel System

The fuel cells were ruptured on impact, which precluded determination of the quantity or quality of the fuel. It was reported that a substantial amount of fuel was present on the water after the accident. Weight and balance calculation showed that there should have been approximately 310 pounds of fuel remaining. The fuel ejectors and motive line check-valve (with finger strainer) from the aft tank (left engine) were checked and found to be clean and serviceable.

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*See Appendix A (Description of propeller function).

1.12.7 Structures

During recovery attempts to lift the aircraft from the water and to remove the passengers, the fuselage suffered further damage. A cable had been attached to the empennage and the wreckage had been dragged over the harbour floor, tearing away pieces of significant value.

The fuselage was lifted from the water, taken by barge to a dock and transported by flatbed to Vancouver International Airport. It was then placed in a storage area and impact damage was analysed to determine the breakup sequence. Initially safety investigators considered that both right and left flaps were down at impact. Some months later, a swaged portion of a flap actuating rod, the fracture-face of which mated with the fracture-face of a portion that was recovered with the aircraft, was retrieved from the harbour. The wreckage was moved to a warehouse and re-assembled on jigs to determine the direction of initial impact forces and to re-assess the sequence of breakup.

Damage to the aircraft, supported by the injury pattern of the passengers, indicated that the left wing tip impacted the water prior to any other part of the aircraft. Damage examination further indicated that the flaps were up on the left and down on the right at the time.

(See Analysis of Sequence of Break-up, Appendix D.)

1.13 Autopsy and Biochemical Information

1.13.1 Captain

The autopsy showed no evidence of disease which might have impaired his flying performance, and death was due to asphyxia from drowning. The injury pattern suggested that at impact the pilot was thrown towards his left side and that his head contacted the instrument panel. Also it would appear he either held the control column neutral or slightly forward with his left hand, while his right hand was above his head in the area of the overhead controls. The former conclusion was supported by contact marks on the yoke assembly which indicated a near neutral position.

Injuries to his feet and an imprint on the sole of his right shoe suggested that he was applying moderate pressure on the right rudder with his right foot placed at an angle on the pedal with his toes outward. This finding is compatible with foot movement limited by pain and led to enquiries into his medical history.

Biochemical tests on the blood, liver and urine did not show the presence of any alcohol or drugs. A carbon monoxide saturation level of less than 10% was present in the blood and was considered insignificant.

1.13.2 Cabin Attendant

Autopsy of this crew member showed no evidence of disease which might have affected his duties. From his injuries it was apparent that he had been struck by the right propeller during the crash sequence and died instantly. At the time he was leaning forward and to the left. The injury pattern does not suggest that this person was handling any flight controls at the time of impact.

Biochemical analysis of blood did not show any presence of alcohol or drugs, and less than 10% of carbon monoxide was found.

1.13.3 Passengers

The position of the eleven passengers in the aircraft was determined from information provided by survivors. Of the nine passengers who died in the accident one was killed by impact forces. This passenger was seated in the first row, left hand side. Two other passengers probably lost consciousness and died of aspiration of water. One of these two was seated in the third row on the right hand window seat and suffered a fracture of the skull and contusion of the brain. The other, sitting in the first row right window, was found to have a small fracture at the floor of the skull and some fractured ribs. The injuries to the remaining passengers did not appear sufficient to cause any unconsciousness and their deaths were due to drowning. Of the two survivors, one was in the front row centre seat and the other occupied the rear seat. Both sustained serious injuries.

The skin on some bodies showed the effects of exposure to fuel.

1.14 Fire

There was no fire.

1.15 Survival Aspects

The accident was survivable.

All passengers sat at window seats except for the front row survivor who sat in the middle seat; seat belts were used by all on board.

The impact forces were not severe enough to produce failure of seat attachments to the floor and wall, which are required to withstand an ultimate acceleration of 9G forward.

There appeared to be a progression to the injury patterns, being more severe to the forward passengers and diminishing toward the rear. Also most of the injuries were more severe on each person's left side.

A survivor seated on the middle seat of the front row suffered multiple injuries but, because of a break in the fuselage, was able to swim free. The survivor occupying the rear window seat injured his back but managed to escape with difficulty through the rear baggage door which had opened at impact.

The survivors' statements indicate that the standard pre-take-off briefing described in Air West's Operations Manual was not given in full. The actual briefing was given in Japanese, the native tongue of all the passengers, by the tour guide accompanying them, and included only the use of seatbelts and smoking restrictions. Thus the emergency exists were not pointed out nor was reference made to the safety information cards which show the location of the emergency exits.

A survivor stated that there were several people standing when he left the aircraft. Those passengers who may have been conscious after impact but drowned, possibly did not escape because they were unaware of the position of the emergency exits. Although the main door was jammed because of distortion, the main emergency exit on the right side and one on top of the fuselage were available for use and functioned properly.

1.16 Tests and Research

Voice Identification

The voice transmissions from the aircraft to the tower were positively identified as those of the cabin attendant; they were consistent with a routine approach to the Vancouver Harbour, with no indication of concern or alarm.

The interval between the last transmissions and the ELT signal was determined to be 54 seconds. The ELT transmitted for 57 seconds. Analysis of the tape revealed no other significant information.

1.16.1 Airspeed Indicator Analysis

The pilot's airspeed indicator was severely damaged by direct impact. The instrument case and face-glass were missing. The dial, pointer and aneroid were all deformed and corroded by sea-water. The pointer was indicating 195 knots but no corresponding impact imprints were found on the dial. However, when the deformations of the dial and pointer were matched, the pointer indicated 75 knots. Examination of the mechanism also showed that it was jammed in the 75 knot position; the sector gear and pointer pinion did not reveal any marks which would indicate their disengagement during the impact sequence.

1.16.2 Emergency Locator Transmitter (ELT)

The ELT was undamaged by impact forces but there was evidence of the effects of having been immersed in sea-water. This damage was limited to corrosion deposits on most terminal posts and some staining of the circuit board and a number of components.

The inertia switch had been triggered. Functional testing of the switch to establish its trigger threshold was not considered practical. As received, the switch was unserviceable because of the sea-water deposits and although removal of these deposits and re-furbishing the switch would have allowed functional testing, it would probably have altered the switch characteristics. It would be equally reasonable to assume that the inertia switch was within required tolerances at the time of impact. With this assumption, the deceleration experienced by the ELT along the aircraft's longitudinal axis would have been greater than 5 G.

1.16.3 Systems Examination

Left Propeller

The propeller dome (piston) on examination showed a light impact mark at $+5^{\circ}$ (the blades latch at $+2^{\circ}$), and a heavier and more obvious mark at -9°. As discussed previously, the propeller was found to have been in the full reverse position so that it must have struck the water at some angle above $+5^{\circ}$ blade angle, and then the blades were progressively driven back to the reverse position. When the turbine stopped rotating the internal propeller spring drove the blades toward feather; they were, however, trapped in the zero thrust position by the engagement of the serviceable latch.

1.16.4 Right Propeller

On examination it was determined that the blades were in positive pitch ($+23^{\circ}$ at time of impact). (See Appendix C.)

1.16.5 Propeller Operating Oil Pressures

To determine the propeller-oil operating pressures during a wide range of power/propeller selections, tests were conducted using a series 300 DHC6 powered by PT6A-27 engines fitted with an oil line routed from an oil pressure source between the propeller governor and the overspeed governor. The oil line terminated in a 0-1 000 psi (pounds per square inch) pressure gauge with 10 psi graduations.

Oil pressure indications were noted during start, taxi, reverse, take-off, climb and descent. The results showed very rapid response in all modes, with maximum pressures being reached during take-off, and minimum at coarse-pitch constant speeding.

Although these tests were carried out on a -27 engine, the results obtained are considered to apply also to the -20 engine.

1.16.6 Flap Control Tube

Failure analysis of the recovered portion of the rod was conducted to determine possible pre-impact, impact and post-impact conditions and a probable sequence of failure for the separation of the rod end (ASE Report LP 65/79, refers). Later scanning electron microscope confirmation of aspects crucial to the determined failure sequence is covered in ASE Report LP 23/80 (Appendix E).

From these analyses, it was concluded that prior to impact, the flap control rod contained one major and other secondary stress corrosion cracks. The main fracture was 2-3/4 inches in length and extended longitudinally from the open end of the tube. This crack alone was shown to have reached a sufficiently advanced stage of growth to bring about separation of the tube from the end cap fitting at less than applied loads from the full flap setting in the approach configuration. In the case of the accident aircraft, the flaps were set at the full down position during the approach.

Note: Stress corrosion cracking (SCC) is a mechanism of brittle fracture in a nominally ductile material involving a combination of electrochemical action and sustained tensile load. Failure occurs over a period of time which is determined by the severity of the conditions which are prerequisites for SCC, namely:

(i) a particular metallurgical requirement, or susceptibility in terms of the composition and structure of the alloy;

(ii) a sustained tensile stress, either applied or residual in excess of some minimum threshold level below which SCC does not occur;

(iii) a specific corrosive environment.

For CF-AIV all three conditions for SCC were present:

(i) The 2024-T3 alloy of the flap control rod is known to be highly susceptible to SCC and not recommended for applications where high sustained tensile stresses are likely to act in either the long or short transverse grain directions;

(ii) The magneforming of the tube to the end fitting leaves residual tensile (hoop) stresses in the area of the swaging of sufficient magnitude to exceed the threshold stress level for SCC to occur in the long transverse grain structure of the tube;

(iii) CF-AIV's normal working environment of sea air, coupled with sulphur-bearing gases in the ever-present exhaust fumes, is a more than adequate corrosive environment to support SCC.

It should be noted that operationally induced loads generally have a negligible effect on the stress corrosion cracks. Accordingly, cracking is a function of calendar, not flying, time, through the sustained residual stresses in the swaged rod end.

Aircraft maintenance records show that inspections had been done in accordance with approved inspection procedures. However, detection of a crack at the swaged end of a control rod would have been quite unlikely under the inspection requirements as detailed in EMMA (Equalized Maintenance Maximum Availability) checks, as they existed prior to the accident. Proper inspection would require both physical and visual access to the rod ends and this would entail removal of the paint for proper penetrant checks.

1.16.7 Flap Rod Tensile Tests

Tests were performed on sample flap push-rods to simulate the effect of a longitudinal crack in the magneform tube end on the load-carrying capability of the rod. It was found that there is considerable variation in tensile separation load versus pre-crack length from sample to sample, i.e.:

1-1/2" crack	- 2 400 lb
2-1/4" crack	- 510 lb
2-1/2" crack	- 610 lb
2-3/4" crack	- 1 680 lb

Manufacturer's tests showed that when two rods were cracked in a manner similar to the accident case, one (2.5 inches long), failed at 825 lb and the other (2.75 inches long), at 500 lb. It is considered that the difference in separation loads is because of the variation in original clamping action (i.e. variation in material strength, fit, residual stresses). The manufacturer stated that the working loads on the rod during a normal approach with flaps-down condition vary from -330 to +650 lb, whereas the design breaking load is 8 000 lb and the nominal breaking load is 11 000 lb. The tests therefore clearly showed that cracks greater than two inches (as found on the CF-AIV rod), and which have progressed to the free end, could lower the load-carrying capacity of the rod into the range of the actual loads with flaps down.

(See Appendix F,Metallurgical Analysis.)

(See attached pictorial of Swaged-connection, Figure 3.)

1.17 Additional Information

1.17.1 Cine-Film Analysis

An 8 mm motion picture camera containing a cassette with an exposed roll of colour film was recovered from the wreckage; both were damaged by immersion in the sea-water. Development of the film showed that the camera had been operated by a passenger from a right rear seat to within 30 seconds of impact.

The results of the analysis are tabulated on the attached Appendix G and G (1) and established:

- the position of the aircraft at 9 (nine) stations in metres in the Universal Transverse Mercator Projection, Zone 10;
- the height of the aircraft at the same 9 stations;
- the wing flap angles at the first, centre and last frame stations;
- the pitch attitude of the aircraft to the true horizon at the above 9 stations;
- the rate of descent; and
- the ground speed in knots and metres per second.

1.17.2 35 mm Photograph - Analysis

Approximately 10 seconds prior to impact the aircraft was photographed by a person who was standing in Stanley Park, Vancouver. After taking the photograph the cameraman lowered the camera and closed the front flap (about 2-3 seconds). He then heard a loud "bang", looked towards the aircraft and saw it rolling to the left.

The related photographic slide was analysed and the left flap angle, altitude of the aircraft and its distance from the camera were determined. (See Appendix H.)

An Azimuth (the yaw of the fuselage to the camera negative) of 39^{o} and Tilt (the elevation of the lens longitudinal axis) of 27^{o} were established.

From this information further calculations indicated that the horizontal range from the camera position to the nose of the aircraft was approximately 388 feet. The aircraft nose was between 197.87 (minus 5.5%) feet above the camera. The slant range from the camera to the nose of the aircraft was approximately 433 feet. The camera angle of view (in the horizontal) was 39.8 degrees. The left main flap was extended to the equivalent of 33^{o} cockpit-indicator setting.

1.17.3 Witnesses

Witness information is incorporated in this report.

Persons interviewed included eye-witnesses, survivors, peers of the accident pilot and company operations personnel.

There was an abundance of witness information available from persons who were in or near a wooded park adjacent to the impact area and there was general agreement in their descriptions of the flight trajectory. Six witnesses stated that the approach was normal; five stated it was low; none said it was high.

Although not all saw the aircraft strike the water because of boathouses and other obstructions, 21 witnesses gave evidence that they had viewed the aircraft in left-wing-low and nose-down attitude to within approximately 50 feet of the surface.

Those that reported they heard a noise described it in different ways such as, "heard a crack", - "sounded like a cable breaking", - "sounded like a metal drum being struck by a hammer", - "sounded like the load shifted from one side to the other", - "a metallic noise", - "like a compressor stall on a 747 engine". Two stated they heard engines sputtering. Witnesses standing laterally to the aircraft were within 500 feet of the estimated position of where the noise originated. One witness who heard the noise was standing about 300 feet away.

There was conflicting evidence introduced by the survivors, as each placed the geographical area over which they had heard the noise approximately 12 seconds prior to the point where ground witnesses asserted the noise had occurred. Although the analysis of the 35 mm slide showed that the flaps were almost down and the engines running 10 to 12 seconds before impact, the survivors indicated that there was a time-frame of 15 to 30 seconds from the noise to the start of the left roll.

Following analysis of the witness evidence it was found that if a flap had failed at the position stated by the two surviving witnesses, then the aircraft would have been unable to continue to the impact area; or if a left propeller problem occurred in the same area, the pitching, wobbling and yaw described by the survivors would have been obvious on the cine film. Neither was the case. It was therefore, concluded that the time-frame of 15-30 seconds to the critical phase of the accident sequence was unreliable evidence.

1.17.4 Twin Otter Flap Rods

In 1973, flap control tubes fabricated from a 2024 alloy in a T-81 temper were released for service by the manufacturer. This material is less susceptible to stress corrosion cracking than the 2024 T-3 tempered alloy specified previously. This type of rod was fitted to all aircraft subsequent to Serial No. 420. At the time of the accident the manufacturer had neither required nor recommended to retro-fitting of the new tube to existing aircraft. The flap system installed in CF-AIV at the time of the accident was manufactured to the old specification.

Comments from the manufacturer stated that the modification to 2024-T3 control rods followed upon a study of stress corrosion problems during the period 1968-70 and that operators were advised of the problem by Technical Advisory Bulletin 6/626 in November 1970. This was followed by Modification 6-1487, December 1973, which covered the change of control rods. The modification applicability was quoted as Aircraft No. 1 and subsequent, and "production cut in" as Aircraft No. 421 and subsequent. Transport Canada's Airworthiness Division approval was not mandatory.

2. RESUME OF EVENTS DURING THE APPROACH

Following flight from Victoria Harbour the aircraft commenced descent towards Vancouver Harbour shortly after the crew had reported by Third Beach.

From the cine-camera data it was calculated that 29 seconds later the aircraft was over position "1", (as indicated on Figure 1) and that the flap at that time had been extended to 20°.

The descent toward the harbour aerodrome continued for another 8 seconds at which time the film data showed that the flap had reached a position of 28^{o} and that the average approach speed for the 8 seconds had been approximately 76 knots.

Following the termination of the cine-film a witness took a photograph of the aircraft. It was calculated that the flaps had reached a setting of 33^{o}* and that the aircraft was approximately 200 feet above the water surface, about 2 500 feet from the intended landing area.

Approximately three seconds later a loud "noise" was heard from the aircraft. According to ground witness testimony the aircraft subsequently yawed, rolled to the left and continued an uncontrolled descent into the water. These witnesses variously state that the time from noise to impact was between 6 and 10 seconds.

2.1 Analysis

On the third day following the accident a helicopter, equipped with a video camera, was used to simulate the flight path of the accident aircraft prior to impact. Witness statements were used to trace the flight path and the resulting video film indicated that the aircraft had entered an unusually violent left roll followed by a high rate of descent to impact.

After examining the initial statements of the witnesses, the following possibilities as a plausible lead event in the accident sequence were considered:

1. The aircraft had stalled aerodynamically at a height too low to effect recovery.

2. An unusual amount of drag on the left side had caused a left yaw and uncontrollable roll in the same direction.

3. Loss of lift on the left side caused a roll moment that made the aircraft uncontrollable.

2.1.1 Aerodynamic Stall

This hypothesis was discarded for the following reasons:

1. The DHC6, with full flap and at a power setting of 10 to 12 pounds torque, required a significant amount of nose-up attitude (4^{o} to 5^{o}) before a stall can be induced. Only two witnesses, about three-quarters of a mile away, stated that the aircraft was in a climb attitude.

(An investigator who watched several aircraft approach the harbour from the position of these witnesses [in a high-rise apartment], noticed that all aircraft appeared to be in a nose-up attitude. This illusion was attributed to the slope of the terrain toward the water's edge.)

2. It is improbable that an aerodynamic stall would generate an unusual noise.

3. The airspeed indicator was impacted at 75 kt, approximately 20 kt above the stall speed of this type of aircraft when in full flap configuration.

*All flap positions are indicator settings.

2.1.2 Unusual Drag - Left Propeller

The latched left propeller and other physical evidence indicated that at some time the blade angle had been in full-reverse position.

The evidence of the two on-board witnesses indicated that the pilot had both hands on the control column at the time of the unusual noise. This would be incompatible with an intentionally induced "reverse beta" to increase the rate of descent. Additionally, from the cine and 35 mm photo-analyses, it was concluded that the approach was normal.

Experts from the propeller manufacturer stated that when this type of propeller is impacted while at low power, the tendency would be for the blades to be driven toward reverse mode. However, there is inconsistency in this hypothesis, since in other accidents where both propellers had struck, physical evidence showed that only one of the propellers displayed reverse blade angles. In the CF-AIV accident, the right propeller dome showed that the blades were at a +23° angle, the mark presumably made when the propeller struck the right side of the fuselage, right door sill and the first officer's seat.

The left propeller dome showed an initial mark of +5° and subsequent chatter marks, including -9°, as the blades were driven toward full-reverse. If the left propeller had errantly travelled into reverse mode prior to impact, the 5° mark could not have been made on the dome. It follows that the left propeller was not in the latched condition at impact.

The variance of blade angles between each propeller (left +5° and right +23°), can be explained by the physical evidence of the impact. When the left wing struck, and was folded back, the left power and propeller control cables were stretched in a manner that would disrupt the pre-set pitch position.

It is considered that as each blade travelled deeper into the water, the propeller progressed toward the full reverse position; because the aircraft cartwheeled at impact the propeller disc may have struck the water in an unusual attitude.

Flight tests in a -300 and a -200 Twin Otter showed that when "reverse beta" was induced, followed by application of 10 or 12 lb of torque, airframe "buffeting" was very significant. It was considered by the safety investigation team that if a propeller travelled uncontrolled into the reverse regime and full power was then applied, the vibration or buffeting would be severe (manufacturers' flight tests proved this to be so). The witnesses who survived the accident did not speak of vibration during the aircraft's left roll and dive into the water.

There was no evidence to indicate that the left propeller control system had not been functioning properly prior to the accident.

2.1.3 Loss of Lift - Left Side

The possibility that a collapse of the complete left flap system would contribute to the pre-impact trajectory of the aircraft, was considered.

Manufacturer's flight tests, with one flap secured in the up position and the other operating normally, demonstrated that the aircraft would initially yaw towards the retracted flap. This was consistent with what witnesses reported.

These flight tests conclusively proved that with more than 25^{o} asymmetric flap the aircraft would be uncontrollable at "flight idle", and that at "full thrust", control would be lost with asymmetric flap in excess of 20^{o}.

To account for the collapse of the left flap system, an extensive investigation of the flap control tube and of the sequence of structural failure, with the results given in paras 1.12.7, 1.16.6, 1.16.7 and Appendix D, was derived from ASE reports LP65/79 and FI194/78. The preponderance of evidence supports the conviction that the separation of the flap rod from its end fitting occurred in flight and that the subsequent separation of the end of the flap push-pull rod occurred during impact with the water.

It was therefore deduced that the loss of control was in-flight collapse of the complete left flap system.

2.2 Flight Path - Computer Simulations

Despite the fact that the weight of evidence supported the conclusion that the accident resulted from the collapse of the left wing flap system, further efforts were made to examine the effects on the flight path in the event of a latched propeller arising from the deliberate or unintentional selection of the "reverse beta" mode. To this end, trajectory simulations were made by the manufacturer using a computer model designated as program EN 821; and advantage was taken of the model also to simulate trajectories arising from a collapse of the left wing flap system.

The results of these simulations cannot be definitive, in that there was convincing evidence from the results of the simulations that either of the two causes of asymmetry was compatible with the known facts relating to the terminal phase of the flight. On the other hand, the simulation evidence did tend to confirm that a condition of "reverse beta" propeller latch could produce a terminal trajectory somewhat similar to that produced by a condition of asymmetric flap.

The results of these simulations therefore provided no adequate grounds to reject the deduction that the left flap system failed in flight, but did induce concern with the safety of the "reverse beta" system in operational terms.

3. FINDINGS

1. The final approach to land was normal until an unusual noise occurred followed by loss of control.

2. The aircraft dived into the water with left wing down, nose down and with some sideslip. Value of roll, pitch and yaw, at impact could not be estimated with useful accuracy.

3. At impact, the complete left flap system was in the retracted position.

4. The inboard span-wise push-pull flap control rod (inboard bell-crank to inboard rod, PT # C6CW-1029-1), was severely stress-corroded and had at least three longitudinal cracks; the rod had separated from its inboard fitting.

5. It was deduced that the in-flight failure of the left-hand inboard flap control rod led to sudden retraction of the complete left-hand flap system and sudden loss of control.

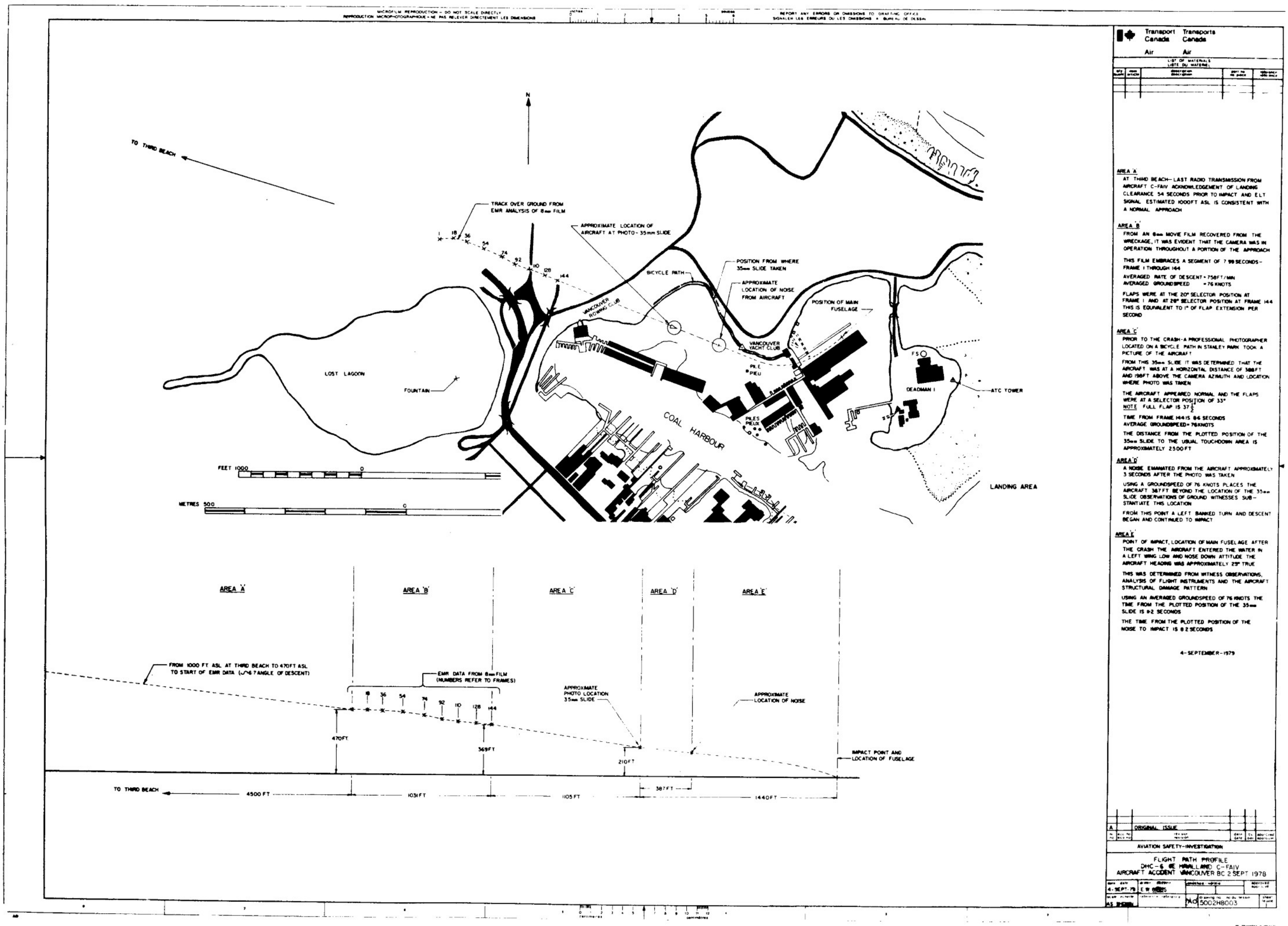
6. The passengers had not been briefed in evacuation procedures.

7. The crew was qualified for the type of operation in accordance with Transport Canada regulations. After the failure of the left flap control rod, no action by the pilot could have averted the accident.

ICAO Note 1: Appendices are not reproduced.

ICAO Note 2: This accident has been included because of its contribution to accident prevention, although the format used does not include the cause(s) and safety recommendations.

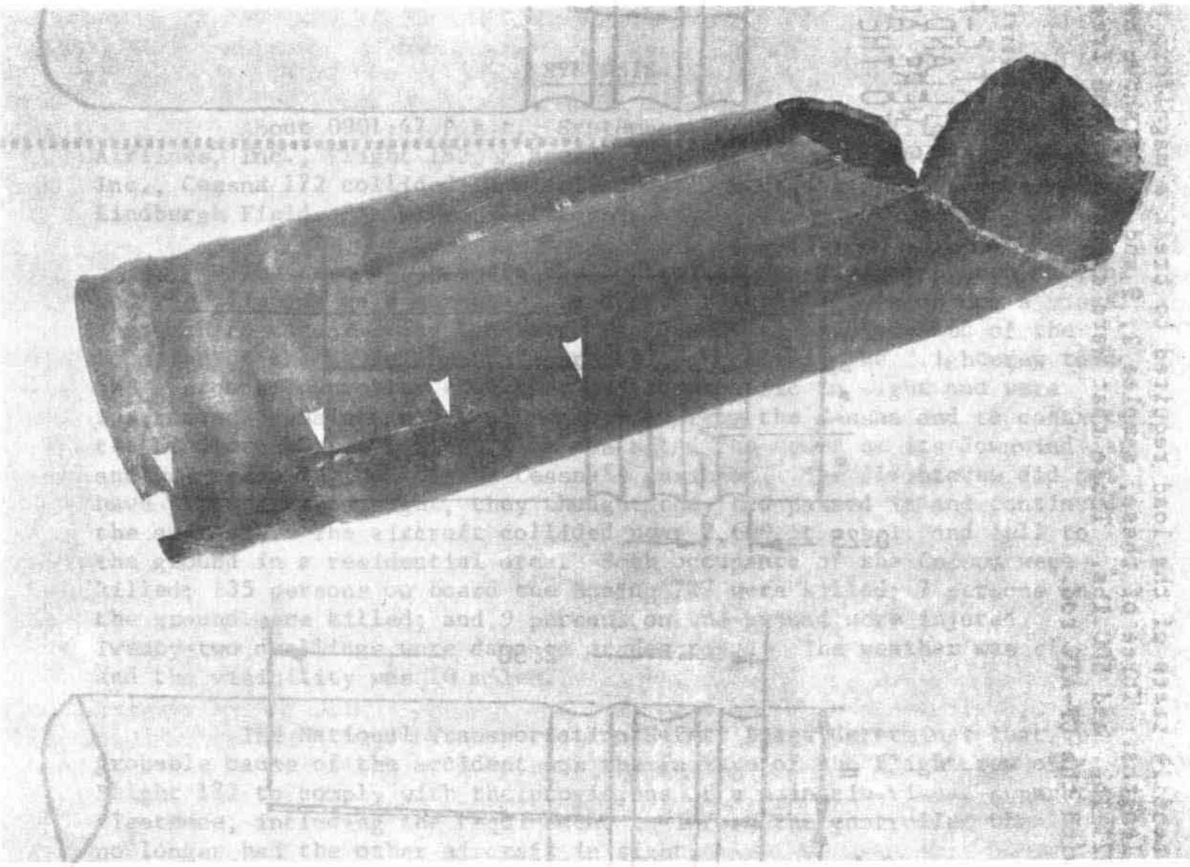
ICAO Ref.: AIG/301/78



Transport Canada Air
Transports Canada Air
N
TO THIRD BEACH
TRACK OVER GROUND FROM EMR ANALYSIS OF 8mm FILM
APPROXIMATE LOCATION OF AIRCRAFT AT PHOTO - 35mm SLIDE
POSITION FROM WHERE 35mm SLIDE TAKEN
APPROXIMATE LOCATION OF NOISE FROM AIRCRAFT
BICYCLE PATH
POSITION OF MAIN FUSELAGE
VANCOUVER ROWING CLUB
VANCOUVER YACHT CLUB
LOST LAGOON
FOUNTAIN
PILE PIEU
PILES PIEUX
COAL HARBOUR
DEADMAN I.
ATC TOWER
LANDING AREA
FEET 1000 0
METRES 500 0
AREA 'A'
AREA 'B'
AREA 'C'
AREA 'D'
AREA 'E'
FROM 1000 FT ASL AT THIRD BEACH TO 470FT ASL TO START OF EMR DATA (√°6.7 ANGLE OF DESCENT)
EMR DATA FROM 8mm FILM (NUMBERS REFER TO FRAMES)
APPROXIMATE PHOTO LOCATION 35mm SLIDE
APPROXIMATE LOCATION OF NOISE
IMPACT POINT AND LOCATION OF FUSELAGE
470FT
369FT
210FT
TO THIRD BEACH
4500 FT
1031 FT
1105 FT
387FT
1440FT
AREA 'A'
AT THIRD BEACH— LAST RADIO TRANSMISSION FROM AIRCRAFT C-FAIV ACKNOWLEDGEMENT OF LANDING CLEARANCE 54 SECONDS PRIOR TO IMPACT AND ELT SIGNAL. ESTIMATED 1000FT ASL IS CONSISTENT WITH A NORMAL APPROACH
AREA 'B'
FROM AN 8mm MOVIE FILM RECOVERED FROM THE WRECKAGE, IT WAS EVIDENT THAT THE CAMERA WAS IN OPERATION THROUGHOUT A PORTION OF THE APPROACH
THIS FILM EMBRACES A SEGMENT OF 7.99 SECONDS - FRAME 1 THROUGH 144
AVERAGED RATE OF DESCENT = 758FT/MIN
AVERAGED GROUNDSPEED = 76 KNOTS
FLAPS WERE AT THE 20° SELECTOR POSITION AT FRAME 1 AND AT 28° SELECTOR POSITION AT FRAME 144 THIS IS EQUIVALENT TO 1° OF FLAP EXTENSION PER SECOND
AREA 'C'
PRIOR TO THE CRASH - A PROFESSIONAL PHOTOGRAPHER LOCATED ON A BICYCLE PATH IN STANLEY PARK TOOK A PICTURE OF THE AIRCRAFT
FROM THIS 35mm SLIDE IT WAS DETERMINED THAT THE AIRCRAFT WAS AT A HORIZONTAL DISTANCE OF 388FT AND 198FT ABOVE THE CAMERA AZIMUTH AND LOCATION WHERE PHOTO WAS TAKEN
THE AIRCRAFT APPEARED NORMAL AND THE FLAPS WERE AT A SELECTOR POSITION OF 33°
NOTE FULL FLAP IS 37½°
TIME FROM FRAME 144 IS 8.6 SECONDS
AVERAGE GROUNDSPEED = 76KNOTS
THE DISTANCE FROM THE PLOTTED POSITION OF THE 35mm SLIDE TO THE USUAL TOUCHDOWN AREA IS APPROXIMATELY 2500FT
AREA 'D'
A NOISE EMANATED FROM THE AIRCRAFT APPROXIMATELY 3 SECONDS AFTER THE PHOTO WAS TAKEN
USING A GROUNDSPEED OF 76 KNOTS PLACES THE AIRCRAFT 387FT BEYOND THE LOCATION OF THE 35mm SLIDE OBSERVATIONS OF GROUND WITNESSES SUBSTANTIATE THIS LOCATION
FROM THIS POINT A LEFT BANKED TURN AND DESCENT BEGAN AND CONTINUED TO IMPACT
AREA 'E'
POINT OF IMPACT, LOCATION OF MAIN FUSELAGE AFTER THE CRASH THE AIRCRAFT ENTERED THE WATER IN A LEFT WING LOW AND NOSE DOWN ATTITUDE THE AIRCRAFT HEADING WAS APPROXIMATELY 25° TRUE
THIS WAS DETERMINED FROM WITNESS OBSERVATIONS, ANALYSIS OF FLIGHT INSTRUMENTS AND THE AIRCRAFT STRUCTURAL DAMAGE PATTERN
USING AN AVERAGED GROUNDSPEED OF 76 KNOTS THE TIME FROM THE PLOTTED POSITION OF THE 35mm SLIDE IS 11.2 SECONDS
THE TIME FROM THE PLOTTED POSITION OF THE NOISE TO IMPACT IS 8.2 SECONDS
4-SEPTEMBER-1979
ORIGINAL ISSUE
AVIATION SAFETY-INVESTIGATION
FLIGHT PATH PROFILE
DHC-6 DE HAVILLAND C-FAIV
AIRCRAFT ACCIDENT VANCOUVER BC 2 SEPT 1978
5002H8003

Figure 1

DHC 6 FLAP ROD - P/N C6CW 1029-1



CLOSE-UP PHOTOGRAPH OF THE INBOARD TUBE END OF THE BELL CRANK TO INBOARD ROD, FLAP ROD ASSEMBLY. SHOWN BY ARROWS IS THE 2-3/4 INCH STRESS CORROSION CRACK.

Figure 2

DHC 6 Flap Rod - Magniform Connection - Tensile Tests

The manufacturer carried out a series of tensile tests of the load required to break a magniform connection with cracks artificially cut to specific lengths. Three of these, samples 2, 9 and 5 are shown below with tensile-strength values of 12150 lbs., 1221 lbs. and 500 lbs. Those that were cracked to the free end, failed at low values; such was the case with the CF-AIV rod.

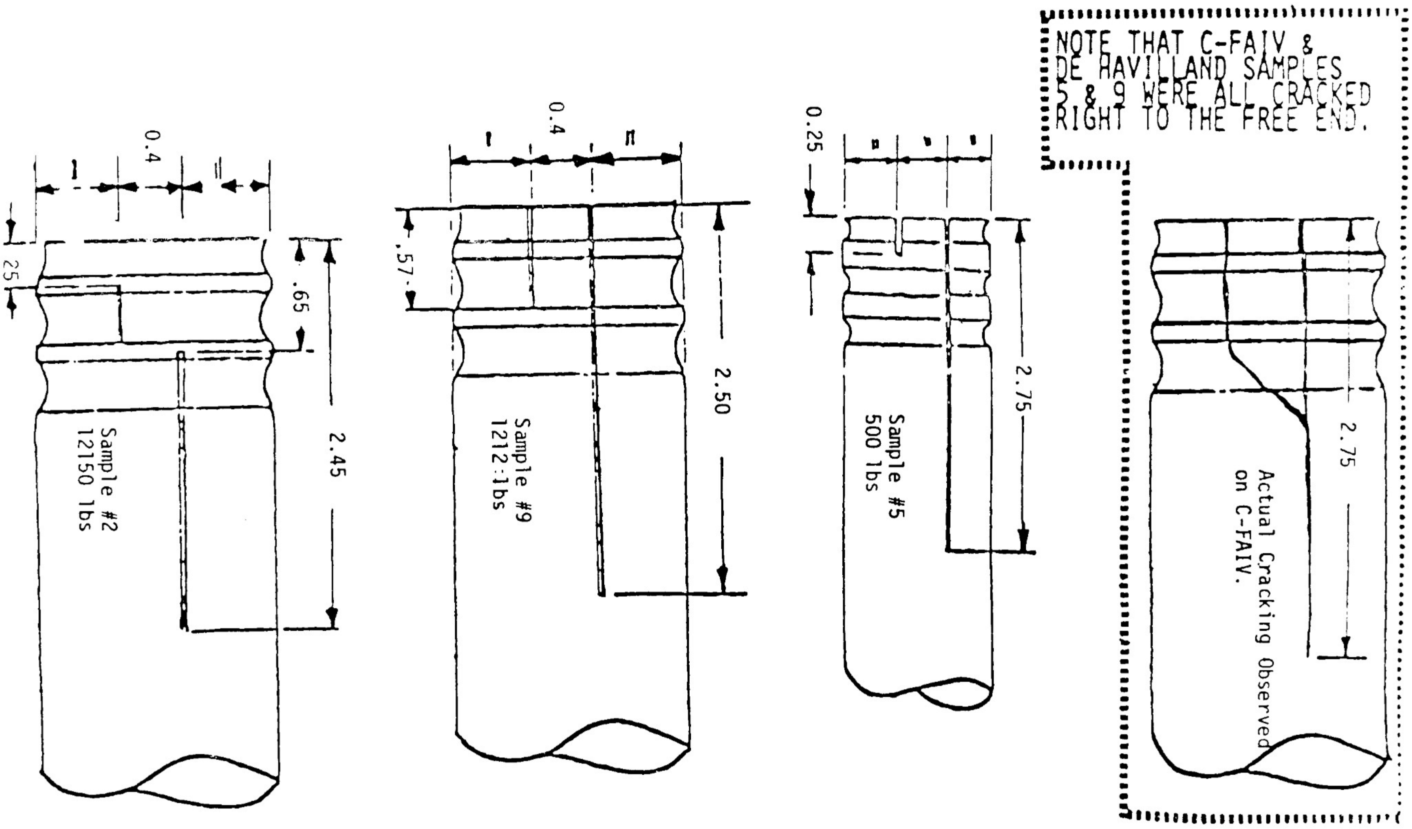


Figure 3