Transportation Safety Board of Canada
Bureau de la sécurité des transports du Canada

# AMENDED REPORT

# AVIATION OCCURRENCE REPORT

## FLIGHT CONTROL FAILURE

## PACIFIC COASTAL AIRLINES
## DE HAVILLAND DHC-6-100 TWIN OTTER C-FDMR
## PORT HARDY, BRITISH COLUMBIA 56 nm N
## 17 SEPTEMBER 1994

## REPORT NUMBER A94P0215

Canada

# MANDATE OF THE TSB

The Canadian Transportation Accident Investigation and Safety Board Act provides the legal framework governing the TSB's activities. Basically, the TSB has a mandate to advance safety in the marine, pipeline, rail, and aviation modes of transportation by:

- conducting independent investigations and, if necessary, public inquiries into transportation occurrences in order to make findings as to their causes and contributing factors;
- reporting publicly on its investigations and public inquiries and on the related findings;
- identifying safety deficiencies as evidenced by transportation occurrences;
- making recommendations designed to eliminate or reduce any such safety deficiencies; and
- conducting special studies and special investigations on transportation safety matters.

It is not the function of the Board to assign fault or determine civil or criminal liability. However, the Board must not refrain from fully reporting on the causes and contributing factors merely because fault or liability might be inferred from the Board's findings.

## INDEPENDENCE

To enable the public to have confidence in the transportation accident investigation process, it is essential that the investigating agency be, and be seen to be, independent and free from any conflicts of interest when it investigates accidents, identifies safety deficiencies, and makes safety recommendations. Independence is a key feature of the TSB. The Board reports to Parliament through the President of the Queen's Privy Council for Canada and is separate from other government agencies and departments. Its independence enables it to be fully objective in arriving at its conclusions and recommendations.

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# Amended Report

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## *Synopsis*

Two pilots and two passengers departed from a logging camp on Fish Egg Inlet, British Columbia, in the float-equipped de Havilland DHC-6-100 aircraft for a 16 nautical mile charter flight to Pruth Bay. As the aircraft was climbing through 100 feet above ground level, an elevator control cable broke. The aircraft pitched to a nose-up attitude, stalled, and descended to the surface of the water. The captain, who was seriously injured, escaped from the sinking wreckage; the first officer and the two passengers drowned. The aircraft was destroyed by impact forces and sank.

The Board determined that the down elevator control cable failed at station 376 due to corrosion, and, as a result, the pilot lost control of the aircraft. The corrosion was not detected by the maintenance personnel during the aircraft's last cable inspection.

Ce rapport est également disponible en français.

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# 1.0 Factual Information

## 1.1 History of the Flight

The captain, first officer, and two passengers departed from the Fish Egg Inlet logging camp, located 56 nautical miles (nm)[1] north of Port Hardy, British Columbia, for a 16 nm visual flight rules (VFR) flight to Pruth Bay. This was the second leg of a flight which had originated at Port Hardy.

The first officer, who occupied the left pilot seat and was handling the controls, taxied the aircraft a short distance away from the dock and took off. The captain occupied the right pilot seat.

As the aircraft climbed through 100 feet, and just as the flaps were retracting, the aircraft pitched up violently and stalled. The pilots were unable to regain control of the aircraft, and it crashed into the water about 100 feet from the shore and sank immediately.

The captain, who sustained serious injuries from the crash, escaped from the wreckage and swam to shore. The first officer and the two passengers remained in the aircraft and drowned.

When the aircraft failed to arrive at Pruth Bay, personnel from Pacific Coastal Airlines (the company) notified the Rescue Coordination Centre and started their own search. A search pilot spotted debris in the water near the logging camp at about 1430 Pacific daylight saving time (PDT)[2] that day. He landed to investigate, found the captain on the shore nearby, and transported him to the Port Hardy hospital.

The accident occurred during daylight hours at approximately 1148 PDT, at latitude 51°36'N and longitude 127°41'W. There were no witnesses, other than the aircraft captain, to this accident.

1 See Glossary for all abbreviations and acronyms.

2 All times are Pacific daylight saving time (Coordinated Universal Time [UTC] minus 7 hours) unless otherwise stated.

## 1.2 *Injuries to Persons*

| | Crew | Passengers | Others | Total |
|---|---|---|---|---|
| Fatal | 1 | 2 | - | 3 |
| Serious | 1 | - | - | 1 |
| Minor/None | - | - | - | - |
| Total | 2 | 2 | - | 4 |

## 1.3 *Damage to Aircraft*

The aircraft was destroyed by the impact and was submerged in salt water for more than 24 hours.

## 1.4 *Other Damage*

There was no other damage.

## 1.5 Personnel Information

### 1.5.1 Captain and First Officer

| | Captain | First Officer |
|---|---|---|
| Age | 42 | 29 |
| Pilot Licence | CPL | CPL |
| Medical Expiry Date | 01 March 1995 | 01 October 1995 |
| Total Flying Hours | 11,725 | 2,500 |
| Hours on Type | 4,000 | 150 |
| Hours Last 90 Days | 125 | 120 |
| Hours on Type Last 90 Days | 115 | 90 |
| Hours on Duty Prior to Occurrence | 4 | 4 |
| Hours Off Duty Prior to Work Period | 15 | 15 |

The captain and the first officer were certified and qualified for the flight in accordance with existing regulations.

### 1.5.2 Quality Manager

The company's Port Hardy maintenance base Quality Manager had been employed by the company as such since 1992. He began his career as an aircraft maintenance engineer (AME) in 1975 and he had worked for a number of employers on a wide range of aircraft types, including the DHC-6 in 1980.

The company's Maintenance Control Manual (MCM) states the following:

> The Quality Manager is responsible to the President for the quality and regulatory compliance of all aircraft maintenance work performed at the Quality Manager's base and to the Director of Maintenance for day to day maintenance tasks. Duties of the Quality Manager include ensuring that all the work done in the shops or on the aircraft is carried out in accordance with applicable standards, practices, and specifications, and ensuring this manual and all technical publications are amended in a timely manner as required.

At the time of the occurrence, the Quality Manager at the Port Hardy base was responsible for supervising four licensed AMEs and one apprentice AME.

### 1.5.3 Aircraft Maintenance Engineer

The AME who completed the most recent inspection of the station 376 cable group on the accident aircraft was employed as a senior AME at the company. He had been with the company for about eight years at the time of the accident. He was certified and qualified to conduct the Equal Maintenance for Maximum Availability (EMMA) number 18 inspection in accordance with existing regulations.

The AME had about 15 years of experience working on the DHC-6 aircraft, including the EMMA number 18 inspection. He had read the de Havilland bulletins relating to corrosion, and TAB (Technical Advisory Bulletin) 680/1 relating to previous elevator control cable failures, when they first arrived. However, he did not have a clear recollection of their contents.

## *1.6 Aircraft Information*

| | |
|---|---|
| Manufacturer | de Havilland Aircraft of Canada |
| Type | DHC-6 - 100 |
| Year of Manufacture | 1967 |
| Serial Number | 36 |
| Certificate of Airworthiness | Valid |
| Engine Type (number of) | PT6(A)-20 (2) |
| Maximum Certified Take-off Weight | 11,600 pounds |
| Recommended Fuel Type | Jet A / A-1 / B |
| Fuel Type Used | Jet A-1 |

The weight and centre of gravity were estimated to have been within the prescribed limits.

Documentation indicates that the aircraft was certified and equipped.

## 1.7 Meteorological Information

At the time of the aircraft's departure from Fish Egg Inlet, the cloud base was 3,000 to 4,000 feet above ground level (agl) and the visibility was about 10 to 12 miles in light rain-showers; the wind was light. Weather was not a factor in this accident.

## 1.8 Wreckage and Impact Information

All parts of the aircraft were recovered or accounted for, and were visually inspected for pre-accident defects. Except for the failed elevator cable, no defects were found. However, during the wreckage recovery, the emergency locator transmitter (ELT) was found loose in the aft baggage compartment. There was no sign of impact damage to the ELT case, and no indication of any marks on the ELT case which might have been caused by release from its securing bracket. The antenna connector was undamaged and found not connected to the ELT. No damage was noted to either the connection between the antenna connector and the antenna cable, or to the antenna cable itself. The ribbon antenna on the ELT had extended and the external ELT switch was found in the armed position. The ELT's internal g-switch was examined and found in the untripped position.

## 1.9 Medical Information

There was no evidence that incapacitation, or physiological or psychological factors affected the crew's performance.

## 1.10 Survival Aspects

The captain sustained serious back and other injuries from the crash. He was barely able to swim to shore. The first officer and the passengers also sustained serious and disabling injuries at impact, and they did not escape from the sinking aircraft.

The occupants were not wearing the available flotation devices, nor were they required to by regulation. It was not determined whether their use would have prevented the occupants' drowning.

All aircraft crew and passenger seats were equipped with seat-belts, which were used by the occupants. Although the aircraft crew seats were equipped with shoulder harnesses, neither the captain nor the first officer was wearing one.

## 1.11 Aircraft Maintenance

### 1.11.1 Inspection Program

Section 4 of the company MCM states in part that all aircraft are maintained to the inspection program for that type. An Inspection Program Approval (IPA) for this aircraft type was approved by Transport Canada (TC) on 06 June 1994. The program is described as follows:

> The DHC-6 Twin Otter is maintained as per the manufacturer's developed maintenance program, P.S.M. 1-6-7.

> The program consists of 48 checks of 100 flight hours each, for a complete cycle of 4800 hours.
>
> Each numbered check, from 1 to 48, lists the required inspection to be carried out, on form P.S.M. 1-6-7 (F1)
>
> This aircraft is being maintained in accordance with the provisions of the Airworthiness Manual. Periodic inspections are performed in accordance with the standards of Chapter 571 and this approved inspection program. All work is performed in accordance with the manufacturer's maintenance manuals or other data that is acceptable or approved by Transport Canada (TC).

The manufacturer's developed maintenance program is the TC-approved de Havilland Equal Maintenance for Maximum Availability (EMMA) inspection system. In this system, a number of individual work cards are specified for every 100-hour inspection, each addressing a separate area of inspection on the aircraft.

EMMA work card 18 addresses the aft fuselage and empennage area of the aircraft. This is the location of the cable group at station 376. Under "Inspection," item 6 states:

> ... [inspect] control cables for fraying, broken strands, flattening, corrosion and security of turnbuckles and cable ends; plastic sheathing, where applicable, for cracking and deterioration.
>
> NOTE: It is important to operate controls through full range so that cables move away from pulleys and all portions of cables are exposed for inspection.

Inspection of aircraft control cables is common to almost all aircraft inspections, and, to a large degree, falls into the category known as standard practices. The inspection of control cables is routine, and all licensed AMEs would be very familiar with the task. In addition, de Havilland maintenance manual PSM 1-6-2 contains a section that provides brief, general instructions on the inspection of control cables.

In the Twin Otter, only the most aft portion of the pulley group is visible from the aft fuselage. The control column must be moved in a fore and aft direction by another person at the front of the aircraft when the cables are being inspected so that a length of cable on both sides of the pulley can be viewed.

It is necessary to remove the baggage compartment floor adjacent to station 376 to view both forward and aft sides of the pulley group. In the "Preparation" section, EMMA work card number 18 does not specify the removal of the baggage compartment floor panel that allows access to the forward side of the station 376 pulley cluster. In accordance with EMMA procedures, the cable inspection is required every 800 hours for aircraft in normal service, and every 400 hours whenever a cargo of livestock or corrosive material is regularly transported. The cables had no fixed service life.

### *1.11.2 Aircraft Maintenance History*

The company took possession of this aircraft, in accordance with existing regulations on 28 May 1994 at Red Lake, Ontario, and ferried it to Port Hardy. It arrived with 20,667.4 hours total time since new (TTSN). The maintenance records received from the previous owners and operators were not complete. Consequently, the installation date(s) of the control cables could not be determined.

Maintenance records kept by the company subsequent to the purchase of the aircraft were complete.

The company completed an acceptance inspection on 06 June 1994, in Port Hardy. The aft baggage area floor was removed and the area was pressure washed; the control cables were lubricated and the floor was reinstalled. Other maintenance included painting the aircraft exterior, replacing the cabin interior, and replacing a cracked rudder pedal. Additionally, the area under the baggage compartment floor was cleaned and treated with a corrosion-preventive substance, and corroded screws were replaced with stainless steel screws.

On 28 June 1994, at aircraft time 20,708 hours TTSN, the maintenance required by EMMA work card number 17 was completed. This was the first EMMA inspection completed after the aircraft was purchased by Pacific Coastal Airlines.

The maintenance required by EMMA card number 18 was completed by three company AMEs on 15 August 1994, at aircraft time 20,802 TTSN, while the aircraft was floating at the company's Port Hardy floatplane base.

The AME who inspected the aft fuselage could not recall details of his inspection of the control cables located at aircraft station 376. He did recall, however, that another engineer had moved the controls for him while he examined the cables, and that he had lubricated the cables with a common corrosion-preventive lubricant. He also recalled inspecting the de-ice boot ejectors and recording the ELT number; these items are located at the rear of the aft fuselage.

The aircraft had 20,870 hours TTSN at the time of the accident. This was about 68 hours since the last cable inspection, and 202.6 hours since arriving at Pacific Coastal's base in Port Hardy.

## *1.12 Elevator Cable Failure*

The broken cable was the down elevator cable (part number C6CF1146-1) which runs from station 426.75 to the elevator quadrant. The break occurred at the station 376 pulley cluster, and the frayed ends of the broken cable had chafed the paint from the pulley bracket before the cable broke.

A microscopic examination of the broken cable revealed that individual strands had been significantly reduced in cross-section, and that most of the strands appeared to have been broken for some time. The cables had been immersed in sea water during the period that the aircraft was submerged and all exhibited the effects of salt water corrosion.

The up elevator cable and both rudder cables that passed through the station 376 pulley cluster exhibited evidence of corrosion; broken strands were discovered on two of the cables.

TSB Engineering Branch Report LP 149/94 concluded as follows:

> The elevator cable failed as a result of gradual deterioration due to corrosion in an area which was in contact with the lowermost pulley of a pulley cluster. As the corrosion progressed, individual wires and strands started failing and the wire ends caused paint removal in the surrounding bracket.
>
> Contamination of the physical evidence by exposure to sea water precluded an objective evaluation of the corrosion mechanism. It is believed that moisture collected on the pulley and provided the catalyst for corrosion to take place. Several similar instances of control cable failures were reported with this aircraft [type].
>
> The uncorroded portion of the cable was tested and found to satisfy the manufacturer's specifications [the generic material specification for this cable].

The report did not make an estimate of the time frame over which the corrosion took place.

A corrosion-resistant stainless steel cable was available as an optional alternative to the carbon steel cable. The stainless steel cables are used by some DHC-6 operators and are specified by de Havilland for some applications; however, they are prone to increased wear and require replacement more frequently than the carbon steel cables. Stainless steel cables were not a requirement for this aircraft.

## *1.13 Company Audit History*

Three audits of the company were undertaken by TC between 1989 and the accident date. In addition, at the company's request, TC System Safety Directorate completed a safety review of the company during that time.

During an audit conducted in August 1989, the audit team found some non-conformance items with respect to airworthiness. The company was maintaining sea-planes, based at Port Hardy, by a method that was not described in their Maintenance Control Manual. Additionally, the company's copy of the Air Regulations and Air Navigation Orders did not have current amendments.

During an audit conducted in 1991, the audit team found 42 non-conformance findings in airworthiness areas. In a summary letter regarding the audit, the audit team concluded as follows:

> ... the audit resulted in a number of non-conformance findings which indicate that both flight and airworthiness operations are not being conducted to a satisfactory standard. The company is not in compliance with the approved policies, procedures and control systems which provide guidance to company personnel. The deficiencies in operational control, maintenance management and quality control are below the standard required of an Operating Certificate holder.
>
> ... a program of increased inspection and surveillance will be undertaken by Transport Canada Inspectors to monitor company progress in these areas.

All of the non-conformance findings were subsequently addressed by the company.

The most recent audit of company operation and maintenance facilities, prior to the occurrence, was conducted by TC in October 1992. This audit included the areas of flight operations, flight watch/dispatch, passenger safety, transportation of dangerous goods, flight safety, airworthiness, and security. The audit team concluded as follows:

> Pacific Coastal Airlines is making improvements in many aspects of operations and maintenance, but still requires a dedicated effort to establish administrative documented procedures in the Flight Operations and Maintenance Control Manuals.

The company submitted a corrective action plan to TC, as was required.

## *1.14 Additional Information*

The float supplement in the *DHC-6 Flight Manual* specified a flap setting of 20 degrees for take-off. The company made it a practice to operate with a take-off flap setting of 30 degrees in order to improve take-off performance. De Havilland Inc. and Bombardier Regional Aircraft Division state that the use of 30 degrees of flap for take-off on any Twin Otter aircraft floatplane is not approved and that such a flap setting will reduce that aircraft's single engine climb capability to zero, or a negative number depending upon aircraft gross weight and ambient conditions.

# 2.0 Analysis

## 2.1 Introduction

The laboratory analysis determined that the down elevator cable failed as a result of gradual deterioration due to corrosion; however, contamination of the physical evidence, which occurred when the aircraft sank, precluded an objective evaluation of the corrosion mechanism. It is believed that moisture collected on the pulley and provided the catalyst for corrosion to take place. Attesting to this are several similar instances of control cable failures.

The analysis will focus on the possible reasons why the cable's deterioration progressed to the point of failure without being detected. Two possibilities were considered: first, that the procedures and requirements for inspecting the control cables were inadequate, and second, that the personnel who conducted the inspections did not exercise due diligence in the performance of those inspections.

## 2.2 Cable Inspection

### 2.2.1 Procedures and Requirements

Since the maintenance history of the aircraft was not complete, the original date of installation of the failed cable and the cable's time in service could not be determined. The cable installed in the accident aircraft met the de Havilland specification and, although some operators use corrosion-resistant stainless steel cables on this and other aircraft types, such cables were not required on this aircraft type.

The EMMA 18 maintenance interval for the accident aircraft was in accordance with the parameters of the manufacturer, Transport Canada, and the company. The EMMA number 18 inspection procedure has been proven effective by other aircraft companies in detecting corroded control cables. (See Appendix B.)

### 2.2.2 Personnel Performance

The AME who completed the most recent inspection of the control cables at station 376 was only able to recall lubricating the cables and inspecting non-associated items in the aft fuselage. Following the procedure as laid out in the EMMA number 18 work card, the AME did not remove the aft baggage compartment floor to provide access to both sides of the station 376 pulley group. Nevertheless, when the controls were cycled to the full extent of their travel, it should have been possible for the AME to detect any frayed or discoloured cables. Although he was experienced with the inspection procedure and was aware of control cable failures due to corrosion, it could not be determined with what diligence he performed the inspection.

## 2.3 Company Maintenance Organization

The company Maintenance Control Manual and Inspection Program Approval for the DHC-6 type had been approved by Transport Canada. Airworthiness audits had been conducted, and although some problems had been identified, these had been rectified to the satisfaction of Transport Canada.

## 2.4 Aircraft Operation

It was not possible for the pilots to maintain control of the aircraft after the elevator cable had failed, given the phase of flight and aircraft configuration. It is unlikely that the flap setting of 30 degrees was related to the cable failure.

# 3.0 Conclusions

## 3.1 Findings

1. The aircraft's weight and centre of gravity position were within limits.

2. The captain and first officer were certified and qualified for the flight.

3. The elevator control cable failed as a result of gradual deterioration due to corrosion.

4. Contamination of the physical evidence by exposure to sea water precluded an objective evaluation of the corrosion mechanism.

5. The uncorroded portion of the cable met the manufacturer's specifications.

6. Autopsy, toxicology, and medical records revealed no evidence to indicate that the first officer's performance was degraded by physiological factors.

7. There was no evidence to indicate that the captain's performance was degraded by physiological factors.

8. It was not possible for the pilots to maintain control of the aircraft after the elevator cable had failed.

9. Neither the captain nor the first officer was wearing the available shoulder harnesses.

10. None of the occupants were wearing the available flotation devices.

11. The control cable corrosion was not detected on the accident aircraft during the last cable maintenance inspection.

12. The pilot selected 30 degrees of flap for take-off; the aircraft flight manual specified 20 degrees of flap for take-off.

## 3.2 Causes

The down elevator control cable failed at station 376 due to corrosion, and, as a result, the pilot lost control of the aircraft. The corrosion was not detected by the maintenance personnel during the aircraft's last cable inspection.

# 4.0 Safety Action

## 4.1 Action Taken

### 4.1.1 Bombardier Inc.

On 25 October 1994, Bombardier Regional Aircraft Division (BRAD) issued a service letter to all DHC-6 operators, advising those operators of this occurrence. The service letter advised those operators of existing information regarding cable failures, and noted the following:

> ... operators receiving Twin Otter maintenance publications from BRAD on microfiche are reminded that prior [to] receiving microfiche revisions, hard (paper) copies of revisions and temporary revisions will continue to be issued and forwarded. It is the operator's responsibility to utilize both microfiche and any hard copy revision when maintaining their aircraft, to ensure that they are using the latest information available.
>
> It is also an operator's responsibility when he acquires a new Twin Otter aircraft in his fleet, to fully understand the aircraft's previous maintenance history and the environment in which it was operated. Based upon this understanding, the operator should initiate a detailed inspection of the aircraft prior to entering it into service.
>
> BRAD/DHI is currently in the process of reviewing the DHC-6 Maintenance Manual, Inspection Requirements Manual and the EMMA Program with a view of reinforcing existing maintenance instructions for control cable maintenance and inspection. ...

Bombardier also issued temporary revisions to the *Inspection Requirements Manual*.

Revision 73 pertains to DHC-6 Twin Otter aircraft operating in areas of high salt content or marine environment (floatplane and land plane). It lists increased corrosion inspection requirements for the elevator and rudder control cables. Most significantly, this revision announces the requirement to replace the control cables every 12 months. Previously, control cables were replaced when their condition warranted. There was no fixed service life.

Revision 74 pertains to special inspection requirements for operations with corrosive cargo. In addition, it requires the replacement of the elevator and rudder control cables below the baggage compartment floor if a spill occurs.

Revision 75 pertains to DHC-6 Twin Otter aircraft operating with floats installed. It lists increased corrosion inspection requirements for the elevator and rudder control cables. Like revision 73, this revision announces the requirement to replace the control cables every 12 months.

Revision 79 adds to and revises the inspection requirements for the elevator and rudder control cables in the *Inspection Requirements Manual* for the DHC-6 Twin Otter. In addition, it includes instructions for the amendment of the EMMA work cards.

The changes address the need for complete access to the inspection areas, detailing specific areas for corrosion inspection, and the requirement to apply corrosion preventive compound to the cables. In addition, NOTES are added that require the replacement of all (including aileron) control cables installed in land planes every 60 months; the NOTES also advise that stainless steel control cables are available.

In October 1994, BRAD and DHI issued a DHC-6 SAFETY OF FLIGHT SUPPLEMENT for all aircraft models which states that:

> de Havilland had recently become aware that some DHC-6 operators are using 30 degree flap for take-off. The only approved flap setting for take-off on DHC-6 aircraft operated on floats is 20 degrees and all performance information provided in the AFM is predicated on using flap 20.
>
> Use of 30 degrees flap may degrade aircraft performance in the event of an engine stoppage immediately following liftoff and may adversely affect aircraft handling characteristics during certain centre of gravity and all-up weight conditions.

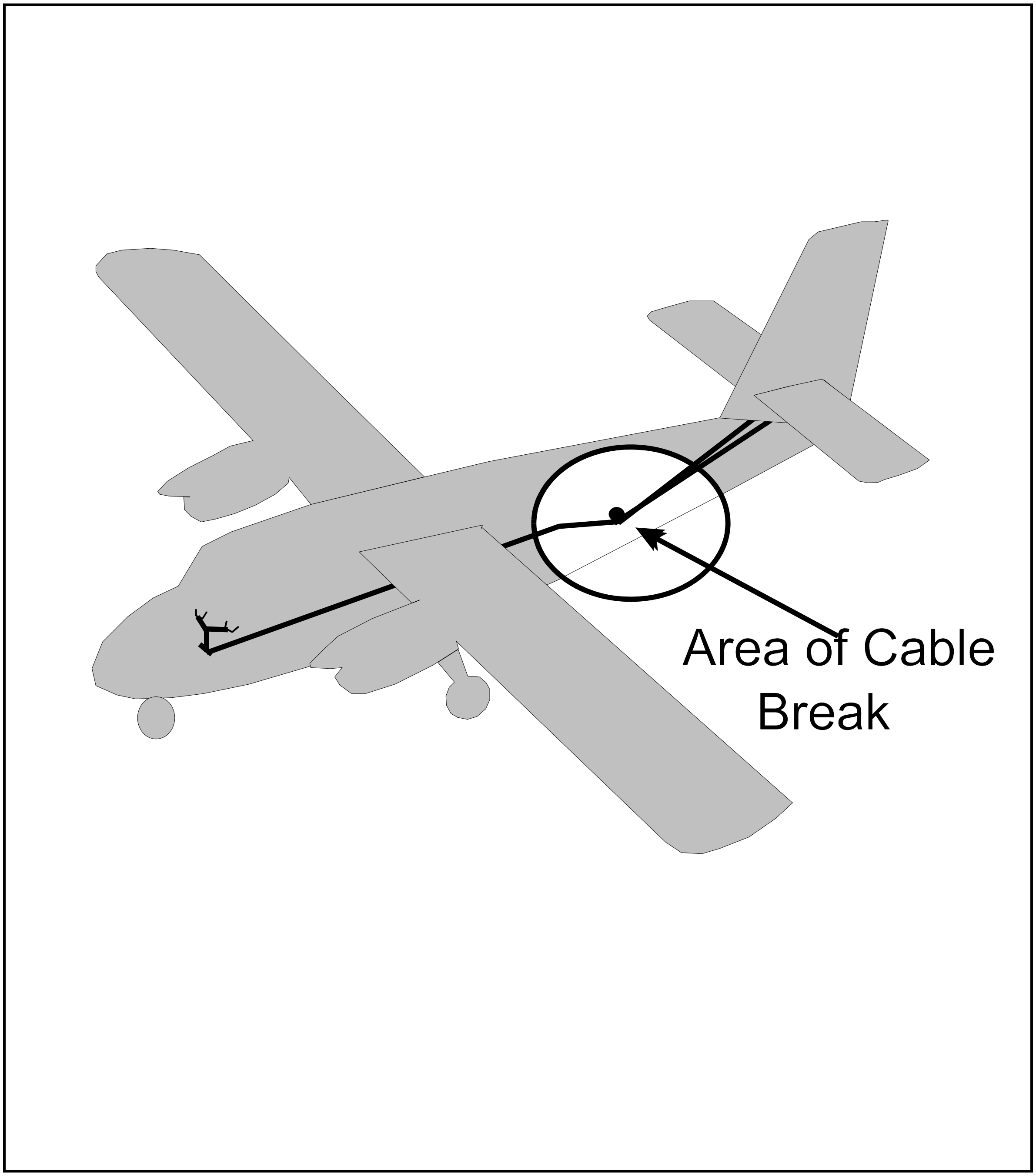
*4.1.2 Transport Canada*

On 27 September 1994, 10 days after the occurrence, Transport Canada issued a Service Difficulty Alert AL-94-05, "de Havilland DHC-6, Down Elevator Cable Failure." The Service Difficulty Alert details de Havilland inspection requirements currently existing, and includes a recommendation that

> ... operators carefully inspect, as soon as practicable, the control cables and related components, paying particular attention to areas where these cables pass over the pulleys, including the pulley cluster area under the baggage compartment at fuselage station 376... The controls should be moved to ensure that no segment of a cable is left uninspected. If suspect, the cable should be removed for a more thorough examination. Furthermore, if the aircraft operates in (or has operated in) a corrosive environment, or carries (or has carried) corrosive cargo, the frequency of inspection should be increased according to the manufacturer's recommendations.

*This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 21 May 1997.*

# *Appendix A - Location of Cable Failure*



# *Appendix B - Previous DHC-6 Cable Failures*

The U.S. Federal Aviation Administration (FAA), General Inspection Aids, (AC NO. 20-7N) January 1977, indicated that pilots in one occurrence had lost control of a DHC-6 due to the failure of an elevator control cable at station 376. The corrosion failure of that cable was believed to be due to drippings, over some time period, from corrosive cargoes placed over the pulley area.

A fatal accident occurred on 21 July 1984, when a DHC-6-300 aircraft operated by South Pacific Island Airways crashed at Tau, Manua Islands, in the South Pacific. In that occurrence, an elevator cable was found to be corroded and broken at Station 376. The broken cable was examined by the National Transportation Safety Board (NTSB) laboratory in Washington, District of Columbia. Its report noted that the cable was "...severely corroded in the area of separation and that rust coloured corrosion products were found within two inches of the separation on both cable pieces. No evidence of fatigue cracking or mechanical wear was found."

At the time of the accident, there were two documented instances in Canada of corrosion-related failure of DHC-6 aircraft control cables. The Aviation Safety Engineering Facility of the Aviation Safety Bureau, Transport Canada, produced LP 278/80 and EP 310/80, reporting their findings. Both aircraft involved in these occurrences had been operating in a salt-water environment. None of the occurrences resulted in aircraft damage or injury. Time in service of the failed cables varied.

Engineering Report LP 278/80, "Rudder Control Cable Failure De Havilland DHC-6-200, C-FGQE," concerned a broken rudder cable that was submitted by an aircraft operator. The cable had failed at the same pulley group location (Station 376) as on the occurrence aircraft. The report made the following conclusions:

4.1 The left hand rudder cable failed prematurely under normal loads at a cross-section which had been severely weakened due to deterioration.

4.2 The deterioration resulted from galvanic corrosion between rogue stainless steel wires and the regular zinc coated plain carbon steel wires in the cable, in the presence of an aqueous marine environment.

4.3 The presence of the stainless steel wires was a serious departure from the applicable specification ...

Engineering Report EP 296/80, "Control Cable Analysis DHC-6 C-FGQE," was concerned with failed rudder and aileron cables from another aircraft from the same operator (from LP 278/80). EP 296/80 was to address whether the corrosion problems constituted a general problem for the Twin Otter control cables of this type and manufacture. Conclusions as to the failure of the rudder cable were similar to those of LP 278/80.

Engineering Report EP 310/80, "Twin Otter Control Cables Corrosion DHC-6 C-GQKN," was conducted on additional cables (including an elevator cable) from the aircraft studied in the first report. In this instance, the rogue strands in the cable were not present, and the report concluded as follows:

4.1 The three control cables examined were found to satisfy all requirements of specification MIL-W-83420 for Type I, Composition A, flexible wire rope [the cable specification].

4.2 None of the cables contained rogue stainless steel wires, yet all showed evidence of accelerated corrosive attack in various stages of development.

4.3 Corrosion products on or adjacent to the corroded regions indicated that the cables had been operating in a moist chloride environment.

4.4 Accelerated corrosive attack in Type I, Composition A Twin Otter control cables would appear to be a factor of the operating environment, and is apparently not dependent on a galvanic reaction resulting from the presence of rogue stainless steel wires in the cable.

4.5 No material deficiencies had contributed to the failure.

Following the completion of the three engineering reports, Transport Canada issued a Notice to Aircraft Maintenance Engineers and Aircraft Owners, N-AME-O 29/80, "Aircraft Control Cables," which reads as follows:

> There have been several cases, reported to the Department of Transport, of carbon steel type control cables which have experienced accelerated corrosion while being operated in a marine environment. An investigation is presently under way to determine the cause.
>
> The purpose of this N-AME-O is to advise aircraft maintenance engineers and aircraft owners of the problem. Corrosion has occurred at or near a pulley at the low point of the cable run. In addition, destructive inspection has shown that in some cases, there have been inclusions of non-standard material within the cable.
>
> Corrosion has been discovered on cables, with as little as 500 hours flight time in service (representing about six months calendar time). Owners operating aircraft in a salt water environment should inspect their aircraft for corrosion of cables at the
>
> earliest opportunity and take into consideration the above information in addition to their inspection and maintenance programmes (ref FAA Advisory Circular AC 43-4, para 20(c)).

The aircraft manufacturer has published numerous references and bulletins referring to the problem of cable failures due to corrosion. The DHC-6 Twin Otter Maintenance Manual (PSM 1-6-2 Series 100 and 200 aircraft / PSM 1-63-2 Series 300 aircraft), Technical Advisory Bulletins (TABs), the Inspection Requirements Manual (PSM 1-6-7), and the EMMA program (PSM 1-6-7E) include specific recommendations to aid in corrosion prevention, its early detection, and subsequent repair. These include the following:

1. PSM 1-63-2, 27-00-00, page 201, Item 2A- "Inspection of Control Cables."

2. PSM 1-6-2, page 2-18, item 2-25- "Inspection of Control Cables."

3. Technical Advisory Bulletin (TAB) 661/9. "Corrosion Rear Fuselage," September 1976.

4. Technical Advisory Bulletin 626/1, "Corrosion Prevention, Rectification and Reprotection," November 1970, including Addenda 1 and 2.

5. Technical Advisory Bulletin 674/1 (E.O. 68922), "Access Panel to Assist in Cable Inspection," December 1980 (Modification 6/1766).

6. PSM 1-6-7, Special Inspection, Page 5, Item #3 - "Operating With Corrosive Cargo," including whenever a cargo of livestock or corrosive materials has been transported, December 1985.

7. PSM 1-6-7, Special Inspection, Pages 5 and 6, Items 3A, General 3B, Structures, and 3C, Controls, "Operating With Corrosive Cargo," December 1985.

8. PSM 1-6-7, Special Inspection, page 4, item #29, "When Operating in Areas of High Humidity," January 1974.

9. PSM 1-6-7, Basic Inspection -27, Temporary Revision #57, Item 11, "Control Cables," December 1993.

10. PSM 1-6-7 Basic Inspection -53, page 2, "Floor Panels," June 1980.

11. Technical Advisory Bulletin 678/3, "Rudder/Elevator Stainless Steel Cables," April 1986.

12. Technical Advisory Bulletin 680/1, Elevator Cable Corrosion," March 1989.

## *Appendix C - List of Supporting Reports*

The following TSB Engineering Branch Reports were completed:

LP 148/94 - Light Bulb Analysis; and
LP 149/94 - Aircraft Control Cables.

These reports are available upon request from the Transportation Safety Board of Canada.

# *Appendix D - Glossary*

| | |
|---|---|
| agl | above ground level |
| AME | aircraft maintenance engineer |
| BRAD | Bombardier Regional Aircraft Division |
| CPL | Commercial Pilot Licence |
| ELT | emergency locator transmitter |
| EMMA | Equal Maintenance for Maximum Availability |
| FAA | Federal Aviation Administration |
| IPA | Inspection Program Approval |
| MCM | Maintenance Control Manual |
| nm | nautical miles |
| NTSB | National Transportation Safety Board |
| PDT | Pacific daylight saving time |
| TAB | Technical Advisory Bulletin |
| TC | Transport Canada |
| TSB | Transportation Safety Board of Canada |
| TTSN | total time since new |
| UTC | Coordinated Universal Time |
| VFR | visual flight rules |
| ' | minute(s) |
| ° | degree(s) |

# TSB OFFICES

## HEAD OFFICE

**HULL, QUEBEC***
Place du Centre
4th Floor
200 Promenade du Portage
Hull, Quebec
K1A 1K8
Phone (819) 994-3741
Facsimile (819) 997-2239

**ENGINEERING**
Engineering Laboratory
1901 Research Road
Gloucester, Ontario
K1A 1K8
Phone (613) 998-8230
24 Hours (613) 998-3425
Facsimile (613) 998-5572

## REGIONAL OFFICES

**GREATER HALIFAX, NOVA SCOTIA***
Marine
Metropolitain Place
11th Floor
99 Wyse Road
Dartmouth, Nova Scotia
B3A 4S5
Phone (902) 426-2348
24 Hours (902) 426-8043
Facsimile (902) 426-5143

**MONCTON, NEW BRUNSWICK**
Pipeline, Rail and Air
310 Baig Boulevard
Moncton, New Brunswick
E1E 1C8
Phone (506) 851-7141
24 Hours (506) 851-7381
Facsimile (506) 851-7467

**GREATER MONTREAL, QUEBEC***
Pipeline, Rail and Air
185 Dorval Avenue
Suite 403
Dorval, Quebec
H9S 5J9
Phone (514) 633-3246
24 Hours (514) 633-3246
Facsimile (514) 633-2944

**GREATER QUÉBEC, QUEBEC***
Marine, Pipeline and Rail
1091 Chemin St. Louis
Room 100
Sillery, Quebec
G1S 1E2
Phone (418) 648-3576
24 Hours (418) 648-3576
Facsimile (418) 648-3656

**GREATER TORONTO, ONTARIO**
Marine, Pipeline, Rail and Air
23 East Wilmot Street
Richmond Hill, Ontario
L4B 1A3
Phone (905) 771-7676
24 Hours (905) 771-7676
Facsimile (905) 771-7709

**PETROLIA, ONTARIO**
Pipeline and Rail
4495 Petrolia Street
P.O. Box 1599
Petrolia, Ontario
N0N 1R0
Phone (519) 882-3703
Facsimile (519) 882-3705

**WINNIPEG, MANITOBA**
Pipeline, Rail and Air
335 - 550 Century Street
Winnipeg, Manitoba
R3H 0Y1
Phone (204) 983-5991
24 Hours (204) 983-5548
Facsimile (204) 983-8026

**EDMONTON, ALBERTA**
Pipeline, Rail and Air
17803 - 106 A Avenue
Edmonton, Alberta
T5S 1V8
Phone (403) 495-3865
24 Hours (403) 495-3999
Facsimile (403) 495-2079

**CALGARY, ALBERTA**
Pipeline and Rail
Sam Livingstone Building
510 - 12th Avenue SW
Room 210, P.O. Box 222
Calgary, Alberta
T2R 0X5
Phone (403) 299-3911
24 Hours (403) 299-3912
Facsimile (403) 299-3913

**GREATER VANCOUVER, BRITISH COLUMBIA**
Marine, Pipeline, Rail and Air
4 - 3071 Number Five Road
Richmond, British Columbia
V6X 2T4
Phone (604) 666-5826
24 Hours (604) 666-5826
Facsimile (604) 666-7230

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