Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT
A00P0210

LOSS OF POWER AND COLLISION WITH WATER

WEST COAST AIR
de HAVILLAND DHC-6 (TWIN OTTER) C-GGAW
VANCOUVER HARBOUR, BRITISH COLUMBIA
01 NOVEMBER 2000

Canada

Aviation Investigation Report

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Summary

A de Havilland DHC-6-100 float-equipped Twin Otter (serial number 086), operated by West Coast Air Ltd., was on a regularly scheduled flight as Coast 608 from Vancouver Harbour water aerodrome, British Columbia, to Victoria Harbour water aerodrome. The flight departed at about 1510 Pacific standard time with two crew members and 15 passengers on board. Shortly after lift-off, there was a loud bang and a noise similar to gravel hitting the aircraft. Simultaneously, a flame emanated from the forward section of the No. 2 (right-hand) engine, and this engine completely lost propulsion. The aircraft altitude was estimated to be between 50 and 100 feet at the time. The aircraft struck the water about 25 seconds later in a nose-down, right wing-low attitude. The right-hand float and wing both detached from the fuselage at impact. The aircraft remained upright and partially submerged while the occupants evacuated the cabin through the main entrance door and the two pilot doors. They then congregated on top of the left wing and fuselage. Within minutes, several vessels, including a public transit SeaBus, arrived at the scene. The SeaBus deployed an inflatable raft for the occupants, and they were taken ashore by several vessels and transported to hospital for observation. There were no serious injuries. The aircraft subsequently sank. All of the wreckage was recovered within five days.

Ce rapport est également disponible en français.

Other Factual Information

The accident flight was the fifth take-off of the day for the crew in this aircraft. Before the engines were started, passengers received a safety briefing. Normal pre-flight checks and pilot briefings were completed in accordance with the operator's standard operating procedures (SOPs)[1].

Take-off proceeded normally as the aircraft lifted off and began to climb. As the aircraft approached 70 knots indicated airspeed (KIAS), loss of propulsion occurred causing a sudden yaw to the right. The pilot flying immediately applied full left rudder. Both crew members acknowledged a loss of engine power and agreed to land straight ahead. The pilots selected full flaps, confirmed that the No. 2 engine (Pratt & Whitney PT6A-20, serial number 21867) was the affected engine, pulled the fire extinguisher T-handle, and activated the fuel emergency shut-off valve. Take-off power was maintained on the No. 1 engine until power was intentionally reduced immediately before impact. The aircraft was not equipped with an optional auto-feather system, and the crew did not attempt to manually feather the right-hand propeller. At impact, the right wing separated from the fuselage at the wing root, but cables or other miscellaneous materials kept the two sections together as the wreckage sank. The right float also separated at impact and was recovered before it sank. All of the recovered wreckage was found at a single site.

The aircraft was departing under visual meteorological conditions on a northeasterly heading with an easterly wind of 5 to 10 knots. General area weather recorded at 1500 Pacific standard time[2] for the Vancouver International Airport, seven nautical miles south of Vancouver Harbour, was as follows: wind 150° true (130° magnetic) at 4 knots, a few clouds at 4000 feet, and higher, broken cloud layers. Weather did not contribute to this occurrence.

The calculated take-off weight and centre of gravity of the aircraft, 10 736 pounds and 28% MAC respectively, were within the take-off limits of 11 600 pounds and 25 to 32% MAC. The aircraft was equipped with conventional floats and configured for a commuter operation with 18 passenger seats. The aircraft's Universal 30A cockpit voice recorder was recovered and provided meaningful information. No flight data recorder was installed, nor was it required by regulation.

The aircraft was equipped with an engine-fire detection and extinguisher system. The engine fire warning system did not activate in response to the internal engine fire, nor should it have by design. The flight crew discharged the engine fire extinguisher when they saw the reflection of flames emanating from the area of the No. 2 engine. The crew would not have known that the fire extinguisher would not be effective. The internal engine fire would likely have been short-lived once the engine stopped running. The fire was extinguished completely by water immersion at impact. The balance of the aircraft was unaffected by fire.

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1 SOPs enable flight crew members to operate the aircraft within the limitations specified in the aircraft flight manual and forms a document accepted by Transport Canada.

2 All times are PST (Coordinated Universal Time minus eight hours) unless otherwise noted.

Post-accident inspection of the No. 2 engine revealed that the power turbine had disconnected from the propeller because a first-stage planetary gear in the propeller reduction gear box (RGB) had fractured and disintegrated, causing extensive internal damage. Once the disconnect occurred, the power turbine disk oversped and shed all of its blades, as designed. Metallurgical analysis showed that fracturing of the planetary gear resulted from damage on the surface of the gear bore. This damage was caused by the bearing sleeve rotating within the gear bore. The most probable scenario is that the bearing sleeve bound to the associated planetary gear shaft (axle) because small pieces of wire from the individual planetary gear oil strainer screen contaminated the lubrication oil and entered the bearing sleeve / planetary gear shaft (axle) interface. The binding of these two surfaces caused the bearing sleeve to rotate within the gear bore. The engine and RGB were manufactured by Pratt & Whitney Canada Corp. (P&WC). Representatives of the manufacturer participated in a TSB supervised tear-down and analysis. Pratt & Whitney report number TL-1626 concluded the following:

> The planet gear oil strainer screen exhibited a deformed Teflon insert, pinched “O” ring, bent “neck” and fretting of the strainer housing suggesting an improper installation of the strainer within the pin. The screen beneath the outer screen exhibited fractures in the braze and wires. The wires fractured by fatigue. Some wire fracture surfaces were smeared and corroded suggesting the fractures were not recent, and as a result, the fracture of the strainer is believed to be a consequence of the installation. The release of wire fragments and debris may have subsequently initiated or contributed to the distress of the bearing sleeve.

Each engine on the aircraft was equipped with a magnetic engine oil chip detector installed in the RGB casing. The detector will attract any magnetic metal particles in the engine oil (the same oil lubricates the RGB). A collection of metal particles will make a contact between two terminals in the detector, thereby establishing continuity, which can be tested by maintenance personnel. This aircraft was not manufactured with flight instrument panel-mounted annunciators connected to the chip detectors, nor was it required by regulations. The annunciator system is available as a retro-fit package; however, without this package, detection is limited to visual inspection.

Each engine on the aircraft was also equipped with a fully feathering, reversible pitch propeller. An optional auto-feather system was not installed, nor was it required by regulation. An auto-feather system is armed when prescribed criteria are met; if the system detects a difference in torque between the two propulsion systems, it automatically feathers the propeller blades on the side with reduced power, thereby reducing the aerodynamic drag of the windmilling propeller. This function can significantly reduce the pilot workload required to maintain control of an aircraft in an asymetric thrust condition.

West Coast Air maintenance records indicated that the No. 2 engine was last overhauled by P&WC Aircraft Services Inc. of Bridgeport, West Virginia in 1993. During overhaul by an approved facility is the only time a RGB is disassembled. At that time, the planetary gear oil strainers were replaced. (See Appendix A.) Since then, the engine had operated about 3235 hours. Regular RGB maintenance consists of prescribed inspections and was performed by West Coast Air as part of the de Havilland Equalized Maintenance Maximum Availability (EMMA) program. The EMMA program required a continuity check of each magnetic chip detector at 100-hour intervals and removal of the chip detectors for visual inspection at 600 hour intervals. West Coast Air records showed that a regularly scheduled 100-hour inspection had been completed about 46 hours before the accident flight. Information provided by West Coast Air indicates that their 100-hour inspections exceed requirements by including removal of each chip detector for visual as well as continuity checks and submission of an oil sample to a separate agency for analysis. Analysis of the last oil sample did not indicate any change in wear-metal readings from previous samples. Post-accident metallurgical analysis resulted in the assessment that wire fractures in the affected planet gear oil strainer were not recent, and therefore, this unsafe condition had developed over a longer period. However, there was no detectable evidence of a pending problem at the last inspection and the result of this unsafe condition occurred in less than 46 hours of operating time.

The DHC-6 becomes airborne at 55 to 65 KIAS, varying with the aircraft weight. The velocity of minimum control (V_{mc}) for single-engine operation is 66 KIAS with 20° of flaps set, which is the only approved flap setting for take-off on floats. The Transport Canada-approved aircraft flight manual (AFM) recommends lifting off at about 60 KIAS and accelerating to a target speed of 76 KIAS at 50 feet above ground level when taking off at gross take-off weight.

The West Coast Air SOPs indicate that normal take-off procedure is to lift off at 55 to 65 KIAS and accelerate to 70 KIAS, at which time a speed call is made by the pilot not flying. At a confirmed positive rate of climb, flaps will be retracted from 20° to 10°. During flap retraction, acceleration will continue to a target speed of 76 KIAS at 50 feet. At 76 KIAS, the focus changes from acceleration to altitude gain. Another call is made at 400 feet, at which time flaps are fully retracted and speed is increased to 83 KIAS. The first power reduction and after take-off checks commence at this time.

The pilot’s SOP emergency procedures briefing prescribed that if a safety-related problem occurred before lift-off, or after lift-off with sufficient water (distance) remaining, the pilot flying would reject the take-off. Neither the AFM (which is incorporated into the operator’s SOPs), nor other sections of the operator’s SOPs describe a procedure for rejecting a take-off in a float operation when indicated airspeed is above V_{mc}. The AFM-recommended emergency procedure for rejecting a take-off due to a power loss while airborne and at a speed below V_{mc} is to reduce power on the operating engine sufficiently to assure control of the airplane and land straight ahead.[3] The AFM emergency operating procedures section prescribes the following actions if a power loss occurs when airborne but at a speed below V_{mc}:[4]

> 1) Power levers - IDLE
> 2) Land straight ahead . . .
> Note: If time permits, fuel levers OFF,
> DC master switch OFF.

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[3] Supplementary Operating Data, Part 5, Section II, Paragraph 5.2.2.b.

[4] Section III, Paragraph 3.1.1.b.

The *Canadian Aviation Regulations* (CARs) do not require pilot proficiency training to be completed in a flight simulator for non-pressurized, turboprop-powered aircraft. The only full flight simulator for the DHC-6 is located in Toronto and is configured for a wheel equipped aircraft; neither pilot had received DHC-6 emergency training in a simulator. The operator's Transport Canada-approved pilot training syllabus incorporates training in the aircraft and includes emergency scenarios and procedures during and after take-off. However, the scope of exercises that can be carried out in the aircraft is inherently limited because of safety concerns.

The pilot-in-command held a valid Canadian airline transport pilot licence—aeroplane (ATPL–A) and had a current pilot proficiency check for the DHC-6. He had logged about 4000 hours' total flight time, with about 2500 hours logged on the DHC-6. He had been employed by the operator since April 2000.

The first officer held a valid Canadian commercial pilot licence—aeroplane (CPL–A) and had a current pilot proficiency check for the DHC-6. He had logged about 2000 hours' total flight time, with about 1650 hours logged on the DHC-6. He had been employed by the operator for about three years and as a pilot since January 1999.

Each pilot was wearing a seat lap belt with two shoulder straps. Neither pilot was injured, and both were able to help passengers evacuate. All passengers were able to exit the aircraft through the main entrance door and the two pilot doors. Although no serious injuries occurred, the two passengers seated in the first row hit their heads on the forward bulkhead behind the pilot seats during impact. About half of the passengers donned their life vests. Several passengers found the life vests hard to reach under the seat cushion. Each seat on board was equipped with a life vest; regulations require a life vest for each person on board.

Analysis

The fact that the aircraft remained upright and floating in daylight conditions contributed to the successful evacuation of the cabin without injury and enabled about half of the passengers to locate and don their life vests.

Power loss of the No. 2 engine was a consequence of the installation of the planetary gear oil strainer at overhaul. This is believed to have been a sporadic occurrence, however, P&WC has recognized possible installation problems of the strainer. As such, the applicable Overhaul Manual was revised in 1998 to clarify the installation procedure of the strainer screen. The subject engine was overhauled in 1993 prior to the change in the manuals. Even though fractures in the planet gear oil strainer screen are not believed to have been a recent or sudden event, an unsafe condition existed. The West Coast Air maintenance procedure in effect prior to the accident exceeded the requirements of the de Havilland EMMA program. In spite of additional precautions, an unsafe condition developed during the unmonitored period between inspections.

Regulations require the installation of engine oil chip detectors, but do not require the associated annunciator system on the DHC-6. Without an annunciator system, monitoring of engine oil contamination is limited to the frequency and thoroughness of maintenance inspections. An annunciator system would have provided a method of continuous monitoring and may have warned the crew of the impending problem.

Take-off is the most critical time for a power loss, and the response procedure can vary from simple to complex. The flight crew must take immediate action to maintain control of the aircraft and decide, based on a number of critical factors, whether to force land or to climb away from the point of the power loss. Considerable handling skills are required to overcome an unexpected loss of power in a twin-engine aircraft shortly after take-off, while at low altitude. However, the first and highest priority is to maintain control of the aircraft.

With the aircraft just reaching 70 KIAS when the power loss occurred, an immediate and aggressive control input to lower the nose would be required to prevent deceleration to V_{MC} or below. Below V_{MC}, maintaining control of the aircraft (with the remaining engine at take-off power) becomes impossible due to the inability of the rudder to overcome the asymmetric thrust condition. The selection of full flaps decreased the stall speed from 60 to 55 KIAS, but it also significantly increased the aerodynamic drag. The drag from the flaps and the windmilling propeller resulted in a continuing loss of airspeed and a progressive loss of rudder authority due to asymmetric thrust.

The AFM-recommended emergency procedure for rejecting a take-off due to a power loss while airborne and below V_{MC} is to reduce power on the operating engine, sufficiently to assure control of the airplane, and land straight ahead. The airspeed was above V_{MC} at the time of the power loss and the crew agreed to reject the take-off and land straight ahead. The airspeed was subsequently allowed to fall below V_{MC}, possibly due to the increasing drag of the extending flaps and the crew’s distraction with fire fighting rather than focusing upon maintaining control and landing. When the airspeed fell below V_{MC}, any incremental reduction in power on the operating engine would have contributed to increased control as long as the airspeed did not decrease further. The power on the remaining engine was not reduced until impact was imminent.

Findings as to Causes and Contributing Factors

1. A planetary gear disintegrated in the propeller reduction gearbox of the No. 2 engine and caused the engine drive shaft to disconnect from the propeller, resulting in a loss of propulsion from this engine.

2. The planetary gear oil strainer screen wires fractured by fatigue as a consequence of the installation at the last overhaul. This created an unsafe condition and it is most probable that the release of wire fragments and debris from this strainer screen subsequently initiated or contributed to distress of the planetary gear bearing sleeve and resulted in the disintegration of the planetary gear.

3. Although airspeed was above V_{mc} at the time of the power loss, the aircraft became progressively uncontrollable due to power on the remaining engine not being reduced to relieve the asymmetric thrust condition until impact was imminent.

Findings as to Risk

1. The propeller reduction gearboxes were inspected in accordance with the West Coast Air maintenance control manual. These inspections exceeded requirements of the de Havilland Equalized Maintenance Maximum Availability program. Since the last inspection, 46 hours of flight time before the accident, did not reveal any anomaly, a risk remains of adverse developments with resulting consequences occurring during the unmonitored period between inspections.

2. Regulations require the installation of engine oil chip detectors, but not the associated annunciator system on the DHC-6. Without an annunciator system, monitoring of engine oil contamination is limited to the frequency and thoroughness of maintenance inspections. An annunciator system would have provided a method of continuous monitoring and may have warned the crew of the impending problem.

3. Although regulations do not require the aircraft to be equipped with an auto-feather system, its presence may have assisted the flight crew in handling the sudden loss of power by reducing the drag created by a windmilling propeller.

4. Since most air taxi and commuter operators use their own aircraft rather than a simulator for pilot proficiency training, higher-risk emergency scenarios can only be practiced at altitude and discussed in the classroom. As a result, pilots do not gain the benefit of a realistic experience during training.

Other Findings

1. The fact that the aircraft remained upright and floating in daylight conditions contributed to the successful evacuation of the cabin without injury and enabled about half of the passengers to locate and don their life vests.

2. The aircraft was at low altitude and low airspeed at the time of power loss. The selection of full flaps may have contributed to a single-engine, high-drag situation, making a successful landing difficult.

Safety Action Taken

Since this accident, the operator has revised its pilot emergency training syllabus. The revised syllabus, approved by Transport Canada, places increased emphasis on aircraft handling and emergency procedures in response to loss of power at low altitude and low airspeed. The operator's revision goes beyond the minimum standards required by Transport Canada.

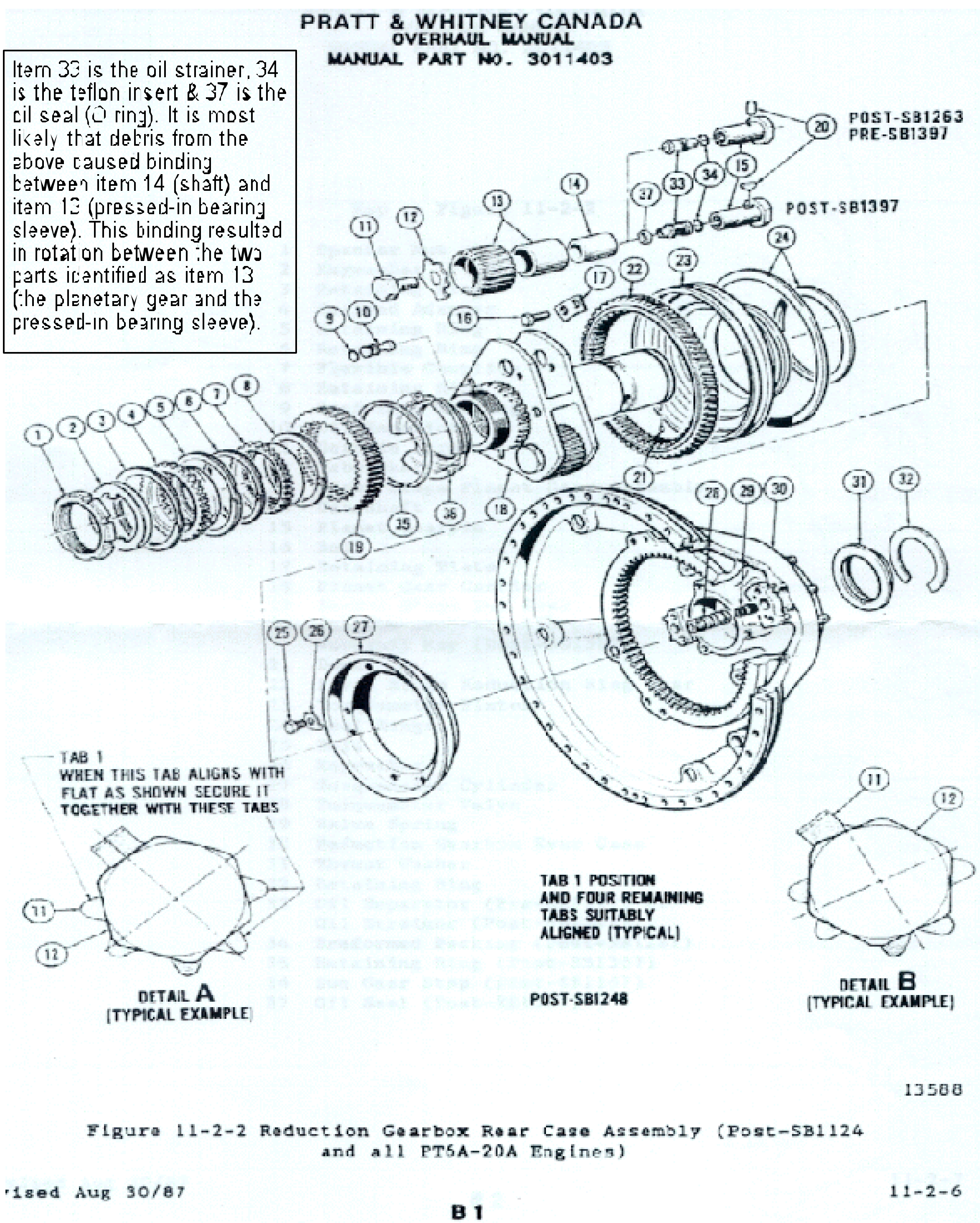
The operator has also revised its maintenance inspection program. The weekly airframe and engine inspection (A&E) now incorporates an electrical continuity test of the engine oil chip detector on the propeller reduction gearbox casing.

Pratt & Whitney Canada has confirmed that the Overhaul Manual applicable to the P&WC PT6-20 series engine RGB was revised in 1998 to clarify the installation procedure of the planetary gear oil strainer screens.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 22 August 2002.

Appendix A1—Reduction Gearbox Rear Case Assembly

Ce document n'existe pas en français.



Appendix A2—Parts Key for Appendix A1

Ce document n'existe pas en français.

Key to Figure 11-2-2

1 Spanner Nut
2 Keywasher
3 Retaining Ring
4 Splined Adapter
5 Retaining Ring
6 Retaining Ring
7 Flexible Coupling
8 Retaining Ring
9 Preformed Packing
10 Oil Restrictor
11 Gearpin Screw
12 Tabwasher
13 First Stage Planet Gear Assembly
14 Gearshaft
15 Planet Gearpin
16 Bolt
17 Retaining Plate
18 Planet Gear Carrier
19 Second Stage Sun Gear
20 Lockpin (Pre-SB1397) or
Woodruff Key (Post-SB1397)
21 Dowel
22 First Stage Reduction Ring Gear
23 Torquemeter Piston
24 Seal Rings
25 Bolt
26 Keywasher
27 Torquemeter Cylinder
28 Torquemeter Valve
29 Valve Spring
30 Reduction Gearbox Rear Case
31 Thrust Washer
32 Retaining Ring
33 Oil Separator (Pre-SB1397) or
Oil Strainer (Post-SB1397)
34 Preformed Packing (Post-SB1261)
35 Retaining Ring (Post-SB1367)
36 Sun Gear Stop (Post-SB1367)
37 Oil Seal (Post-SB1397)