AVIATION OCCURRENCE REPORT

IN-FLIGHT FIRE

WILDCOUNTRY AIRWAYS LTD.
DE HAVILLAND DHC-3 OTTER C-FMEL
COCHENOUR, ONTARIO 5 NM E
16 JUNE 1996

REPORT NUMBER A96C0091

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Wildcountry Airways Ltd.
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Summary

The float-equipped DHC-3 (Otter), carrying the pilot and six passengers, departed the company's water base at Cochenour, Ontario, on a charter flight to Sandy Beach Lodge, located on Trout Lake approximately 25 miles to the east. The pilot levelled the aircraft and configured it for cruise flight at approximately 2,500 feet above sea level (asl). Shortly after level-off, the pilot heard a popping sound and noted a slight loss of engine power, and wisps of whitish-grey smoke entered the cabin. The aircraft instruments indicated normal engine operation, and the fire warning system did not activate.

The pilot suspected that the engine had suffered a cylinder failure and turned to return to Cochenour. A passenger seated in the right front crew seat reported flames near the floor at the front, right corner of the cockpit. The pilot radioed the Thunder Bay Flight Service Station to advise of the emergency, had the passenger vacate the crew seat, and attempted to suppress the fire with a hand-held extinguisher. Thick, black smoke billowed into the cabin, restricting visibility and causing respiratory distress for all of the occupants. The pilot opened the left crew door in order to see ahead and landed the aircraft, still on fire, on McNeely Bay, the first available landing site. The aircraft landed hard but remained upright on the floats. The occupants left by the main door, with their life jackets, and were picked up almost immediately by nearby boats. The aircraft was consumed by fire within minutes after landing. The pilot suffered second degree burns to his face and right forearm, and the passenger in the right crew seat suffered burns to his right leg. The remaining five passengers escaped serious injury.

Ce rapport est également disponible en français.

Other Factual Information

The weather conditions were good and were not a factor in the occurrence.

The aircraft manufacturer considers an engine to have “failed” if it is not capable of producing power demanded by the pilot. Engine-related emergency procedures are provided in the aircraft flight manual under the heading of “ENGINE FAILURE...”. These procedures list the steps for a “dead engine landing” that occurs above 800 feet after take-off, and also lists a ”re-start” procedure if an engine failure occurs during flight. The aircraft manufacturer does not provide procedures to be followed in the event of a partial loss of engine performance, and there are no warnings relating to continued operation of a rough-running engine.

The pilot was certified and qualified for the flight. He had 20,000 hours total flight time with over 8,000 hours on this aircraft type. He was familiar with the local area and with the charter operation. The pilot had experienced a number of engine malfunctions related to cylinder failures during his Otter flying. These malfunctions had been minor in nature, and the pilot had always been able to recover the aircraft safely at a suitable landing site. In this instance, after experiencing a possible cylinder failure and encountering a reduction of engine performance, the pilot monitored his instruments as he continued to operate the engine and turned the aircraft back toward the departure water base.

The DHC-3 (Otter) aeroplane is an all-metal, high-wing monoplane powered by a single Pratt & Whitney R-1340 radial engine. This geared, nine-cylinder engine is supercharged and rated at 600 brake horsepower. Engine exhaust is routed to four exhaust augmentor tubes, two of which are installed on either side of the fuselage, just below the cockpit doors. The flow of the exhaust gases through the augmentor tubes produces suction that is designed to pull cooling air around the engine and engine accessories compartment, while simultaneously producing increased thrust in cruise flight.

The engine compartment is equipped with a fire warning sensor and extinguisher system that is controlled from a panel below the flight instruments. The system provides fire warning and fire protection in the area of the carburettor and engine accessories section of the engine; other areas of the engine and the remainder of the aircraft are not equipped with fire sensors or extinguisher systems. In the event of an engine compartment fire, a red warning light on the extinguisher panel illuminates, and the extinguisher system can be activated after the engine has been shut down. A hand-operated fire extinguisher is stowed in the cockpit within reach of the pilot.

A Janitrol heater, for cabin heat, is normally mounted on the upper right forward face of the engine firewall. When in use, the heater feeds heated air through the firewall to a fibreglass duct that routes the air down the cabin side of the engine firewall, through the cockpit floor, and back to heater discharge tubes in the cabin area. The heat duct turns rearwards beneath the cockpit floor, near the right side of the firewall and close to and above fuselage skin that is shaped to enable installation of the upper right exhaust augmentor on the outside of the aircraft.

The Janitrol heater in this aircraft had been removed prior to this occurrence, and a temporary aluminium blanking plate had been installed in the porting chamber for the heat ducting. The blanking plate was smoke stained on the cabin side and relatively clean on the side facing the engine compartment.

Following the landing, the engine compartment, aircraft tail section, and both wings broke free from their support structures because of the fire damage to the upper fuselage. Fire damage to the right-side firewall and sub-floor area of the aircraft was extensive. Aluminum had melted in this region, and the fibreglass ducting to the heater system had burned to ash. On the left side of the cockpit, the corresponding floor structure and fuselage skin did not display burn patterns, and the floor structure was torn rather than burned away from the firewall.

All interior components of the aircraft had been destroyed by the fire. The aircraft upholstery was not original de Havilland fabric; some 15 years earlier, the interior walls of the cockpit and cabin had been re-covered with a Naugahyde-like material. The same material was applied to the upper portion of the main doors, but the lower portions of the doors were covered with metal plating to limit damage during aircraft loading and unloading. The majority of the upholstery fabric had been reduced to ash. The forward left door panel and associated upholstery had broken free of the fuselage and submerged in the lake, along with the engine section, and remained relatively undamaged. The upholstery on the left rear door panel showed a progression of heat stress ranging from minor shrivelling to total charring. All undamaged interior upholstery was forwarded to the TSB Engineering Branch for testing and evaluation respecting its fire retardant properties. Tests of the fabric material determined that the material met the fire retardant standards identified in the type certificate, and it is probable that the fire in the cabin was fuelled by some other source.

Fuel tanks, located below the cabin flooring, remained intact throughout the landing and post-crash fire. About 300 litres of fuel were removed after the occurrence, and it was evident that the fire had not been fed by fuel from the tanks, with the possible exception of fumes from the tank vents.

The propeller, engine, engine cowlings, and forward face of the engine firewall were relatively clean and undamaged. The No. 2 cylinder head had been split in two and separated from the cylinder barrel, the cylinder induction pipe had been pulled from the engine case, and the oil transfer tube had separated between the intake and exhaust rocker bosses. A section of the upper cowling was scorched and a corresponding section of the inner aft cowling evidenced a narrow path of scorching and panel burn-through. The path was from the No. 2 cylinder, along the outside of the upper right engine mount, across and down toward the upper augmentor tube at the right side of the firewall.

The insides of three of the four exhaust augmentor tubes were covered with considerable carbon and oil by-products, consistent with operation under normal exhaust temperature ranges. However, the interior of the top right exhaust augmentor tube was notably different in that the exhaust by-products had been burned away, leaving the tube clean. This upper right

augmentor tube receives exhaust gases from an exhaust stack shared by No. 2 and No. 3 cylinders.

Aero Recip Canada Ltd. completed an overhaul of this engine (Pratt & Whitney model R1340-61 S1H1G, serial number ZP102072) on 05 April 1993. Within one year and five months of the overhaul, six cylinders had been changed. A cam-follower problem was then identified in the nose case, and the engine was removed, repaired, and re-installed. The aircraft operated uneventfully for an additional one year and seven months until two cylinders were changed because of anomalies noted during a routine inspection. A 500-hour inspection of the aircraft was completed 12 days after the double cylinder change. The failure of the No. 2 cylinder and subsequent fire on this occurrence was four days and 24.9 flight hours after completion of the 500-hour inspection. The pilot indicated that the engine had been running smoothly and was dependable prior to this cylinder failure.

The No. 2 cylinder (Part number CE91ER-W, Serial number AR16418) had been installed at the time of the engine overhaul and, along with the engine, had accumulated 887.9 flight hours. Cylinders do not have a time-life nor are they tracked, and records for the total number of hours of operation for the cylinders and their components are not maintained.

The No. 2 cylinder was forwarded to the TSB Engineering Branch for analysis. A heli-coil insert in the exhaust stud hole indicated that there had been a previous exhaust stud/attachment problem on this cylinder. Fretting and heat discolouration at the exhaust valve port and evidence of exhaust by-products in cracks between cooling fins in the cylinder head indicated that an overheating of the exhaust ear had been occurring for some time prior to the failure of the cylinder. High operating temperatures in the exhaust ear resulted in an interdendritic cracking of the exhaust valve guide and a subsequent failure of the exhaust valve. Continued operation of the engine with failed valve components inside the cylinder resulted in progressive breaching, and eventual overload failure, of the cylinder head.

The TSB Engineering Branch burn-tested a sample piece of fibreglass heat ducting following the occurrence. The test showed that at 300 degrees Celsius, a grey smoke was emitted; at 350 degrees, the edges of the fibreglass began to glow red; at 600 degrees, the samples ignited within 10 seconds; and at 650 degrees, the samples ignited within 5 seconds. A second test was conducted igniting the ducting with a match flame (750-800 degrees Celsius); the duct burned until the resins were consumed, leaving the fibreglass tape. It was further noted that, once the duct erupted into flames, it gave off thick, black smoke.

The passengers had difficulty breathing due to the thick smoke. They opened both rear doors of the aircraft and moved from their seats to the floor of the aircraft where there was less smoke, and where they would be in a better position to evacuate the aircraft at the earliest opportunity.

Analysis

The precipitating event to this accident was a fatigue failure of the exhaust valve in the engine's No. 2 cylinder. This failure allowed combustible fuel-air mixture and exhaust by-products to pass through a damaged and continuously open exhaust port into an exhaust manifold that is shared with the No. 3 cylinder. Flaming gases from the two cylinders combined in the manifold and were ported into the upper right exhaust augmentor tube. The abnormally high temperatures that developed inside the augmentor tube were sufficient to cause carbon and oil deposits, normally found in the tube, to be burned away.

The fretting and heat discolouration at the exhaust valve port and evidence of exhaust by-products found within the cracks between cooling fins in the cylinder head indicate that an overheating condition of the exhaust ear had been occurring for some time prior to the failure of the cylinder. These conditions may have existed and gone undetected at the time of the 500-hour inspection, completed approximately four days and 25 flight hours prior to the occurrence.

Engine cylinders do not have a time-life nor is their usage tracked. Records for total hours of operation are not maintained for cylinders or their components, nor are such records required by regulation.

When the cylinder head failed, the resultant flame/gas path was above and away from the area of the engine that is sensed by the fire warning system; consequently, the fire warning light did not activate. The flame path proceeded to the right side of the firewall and down towards the right augmentor. The in-flight buildup of light grey smoke, flames, then dense black smoke was consistent with the burning characteristics noted during fire testing of duct samples. The flames and smoke observed coming through the floor were at the location of the fibreglass heat duct. It is concluded that the fire was related to the failure of the cylinder; however, fire damage precluded a determination of how the fire travelled from the engine compartment to ignite the fibreglass duct work.

The pilot's response to the fire emergency was consistent with procedures that are published in the aircraft flight manual. However, the hand-held extinguisher was ineffective against the fire.

Once the aircraft was on the water, the fire spread rapidly. Within minutes, the engine and instrument panel of the cockpit, both wings, and the tail of the aircraft had burned away from the fuselage and dropped into the water. The aircraft fuel tanks remained intact throughout the hard landing and post-crash fire. Based on the amount of fuel removed after the occurrence, it is apparent that the fire was not directly fed by the fuel, although it is possible that fumes escaping from the fuel tanks may have fed the post-crash fire.

The following Engineering Branch reports have been completed:

LP 087/96 - Exhaust Valve Failure;
LP 088/96 - Fire Characteristics; and
LP 089/96 - Fire Damage Assessment.

Findings

1. The pilot was certified and qualified for the flight.

2. Records indicate that the aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures.

3. Engine cylinders do not have a time-life nor are they tracked. Records are not maintained for the total number of hours of operation of cylinders and their components, nor are such records required by regulation.

4. Cracks developing between cooling fins in the cylinder head and evidence of exhaust leakage may have gone undetected during the 500-hour inspection completed approximately four days and 25 flight hours prior to the occurrence.

5. Failure of the No. 2 exhaust valve guide and subsequent failure of the exhaust valve likely occurred as a result of the effects of exhaust gases leaking at the exhaust port and heating the exhaust ear of the cylinder.

6. There are no procedures to be followed in the event of a partial loss of engine performance, nor are there warnings relating to continued operation of a rough-running engine.

7. Following the loss of engine performance, the pilot continued to operate the engine as he initiated a recovery to the departure water base.

8. As the engine continued to operate, flaming fuel-air mixture escaped from the cylinder through the continuously open exhaust port and joined with the exhaust from the No. 3 cylinder. These combined exhaust gases produced a high heat that burned away carbon and oil residues normally found in the upper right exhaust augmentor tube.

9. Failure of the valve in the No. 2 cylinder resulted in failure of the cylinder head and development of a gas/fire path across the top of the engine to the firewall and down towards the upper right augmentor.

10. The fire started following the failure of the cylinder; however, fire damage precluded a determination of how the fire travelled from the engine compartment to ignite the fibreglass duct work.

11. The pilot was unable to extinguish the fire using the on-board hand-held fire extinguisher. The aircraft was destroyed by fire within minutes after landing.

Causes and Contributing Factors

Continued operation of the engine following an exhaust valve failure on the No. 2 cylinder resulted in a flaming gas path near the right side of the firewall, an exhaust system overheat, and a subsequent cabin fire.

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 29 July 1997.