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Failed Hydraulic System Cited in Uncontrolled Descent of AS 350

The Transportation Safety Board of Canada said that, while the pilot was maneuvering the helicopter to land at a remote logging site, he might have encountered control forces 'too extreme to overcome,' which made impossible a return to level flight.

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FSF Editorial Staff

At 1144 local time Jan. 21, 2003, a Eurocopter AS 350B2 helicopter struck the ground as the pilot attempted to land at a logging site after experiencing a hydraulic system failure during a moose-surveying flight about 45 nautical miles (83 kilometers) northeast of Sault Ste. Marie, Ontario, Canada. The helicopter was destroyed by the impact; the pilot and all three passengers were killed. There was no fire.

The Transportation Safety Board (TSB) of Canada said in its final report on the accident, issued March 16, 2005, that the causes and contributing factors were the following:

- "After experiencing a hydraulic system failure, the helicopter departed controlled flight and crashed while maneuvering for landing. The reason for the departure from controlled flight could not be determined;

- "It is likely that the hydraulic pump drive belt failed in flight, precipitating the hydraulic failure; [and,]

- "It is likely that the hydraulic circuit breaker [CB] was in the tripped position in flight, rendering the hydraulic 'CUTOFF' and 'HYD TEST' [hydraulic test] switches inoperative. This would result in hydraulic pressure from the main-rotor servos being depleted asymmetrically."

The day of the accident, the pilot conducted a takeoff at 0910 from the Canadian Ministry of Natural Resources (MNR) ramp at Sault Ste. Marie Airport for a flight to the MNR Provincial Coordination Center, where the three passengers — two resource technicians and one conservation officer — boarded the helicopter. The pilot conducted a takeoff at 0926 from the slipway near the center for a 15-minute flight to the area where the moose survey began.

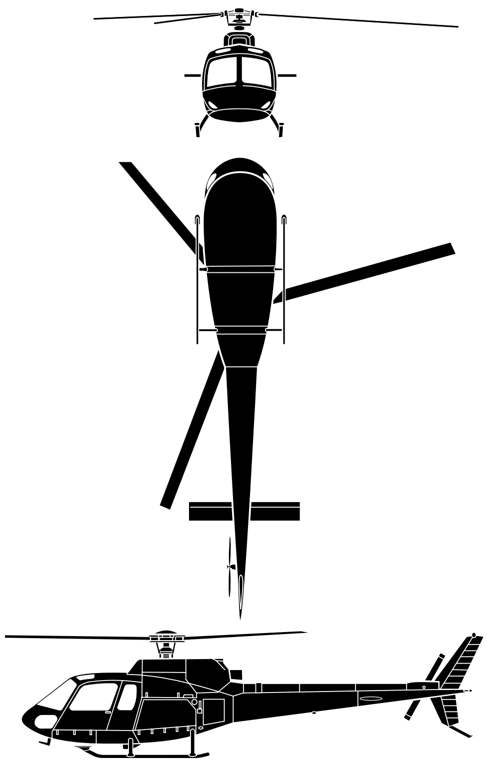
The helicopter's company-monitored aircraft tracking system (ATS) indicated that the hydraulic failure likely occurred at 1141. At 1143, the pilot told a ground-based radio operator in Sault Ste. Marie that the hydraulic system had failed and that he was flying the helicopter to a logging site at Mekatina, Ontario, where he planned to conduct a landing. In his final radio transmission, he said that he expected "a rough spot landing."

He flew the helicopter from the west toward the logging site — a valley with a north-south rail line — and then flew south and then north, first climbing to 2,400 feet above mean sea level (MSL) from 1,800 feet MSL, then descending to about 50 feet above the rising terrain east of the logging site. He flew the helicopter to the northern end of the logging site, where he conducted a left turn and the helicopter descended into rising terrain. At the time of the last ATS position report, the helicopter's airspeed, which previously had been as high as 97 knots, had decreased to 62 knots. The wreckage was found at 1,456 feet MSL.

About the time of the accident, weather conditions in Sault Ste. Marie included wind from 080 degrees at four knots, visibility of 15 statute miles (24 kilometers), broken clouds at 5,400 feet and a temperature of minus 24 degrees Celsius (C; minus 11 degrees Fahrenheit [F]). In Mekatina, the wind was calm, the sky was clear, and the temperature was minus 30 degrees C (minus 22 degrees F).

The pilot had an airline transport pilot license and 9,231 flight hours, including 920 flight hours in type and 31 flight hours in the previous 90 days. He had a medical certificate that was due to expire May 1, 2003; the report did not say what class of medical certificate. The pilot had joined MNR in 2000 as chief pilot–rotary wing. His training included procedures for hydraulic failures during all phases of flight; his most recent training was completed in May 2002. There was no indication that physiological factors affected his performance.

The accident helicopter was manufactured in 1994. Records showed that the helicopter had been certified, equipped and maintained according to regulations and approved procedures. Its weight and center of gravity were within acceptable limits.



Eurocopter AS 350B2

The Eurocopter (formerly Aerospatiale) AS 350B2 is a five-seat or six-seat light utility helicopter with a Turbomeca Arriel 1D1 turboshaft engine and a main rotor of three fiberglass blades that rotate clockwise as viewed from above. A two-blade tail rotor is located on the right side of the tail boom.

Deliveries of the AS 350B began in March 1978; the AS 350B2 was certificated in 1989.

The AS 350B2 has a more powerful 732-shaft-horsepower (546-kilowatt) engine, uprated transmission and wide-chord main-rotor blades and tail-rotor blades that originally were designed for the twin-engine AS 355.

The helicopter's maximum normal takeoff weight is 4,960 pounds (2,250 kilograms). Maximum rate of climb at sea level is 1,750 feet per minute. Maximum cruise speed at sea level is 133 knots, and the service ceiling is 15,750 feet. Hovering ceiling out of ground effect is 8,350 feet. With maximum fuel (143 U.S. gallons [540 liters]) at sea level, the helicopter has a range of 360 nautical miles (666 kilometers).♦

Source: *Jane's All the World's Aircraft*

The helicopter's hydraulic system is designed to lighten control forces during flight and to allow flight at speeds at which manual control loads might be excessive. The hydraulic system comprises a "power-generating section that consists of a hydraulic reservoir, a belt-driven pump and a regulation and filtration unit; a power-absorbing section that consists of four servo controls (servos); and control and monitoring sections provided in the cockpit," the report said.

During emergencies, a hydraulic "CUTOFF" switch on the collective lever is used to depressurize accumulators in the servos by opening the three main electro valves (dump valves) and to facilitate a smooth transition to manual controls. The accumulators store enough pressure to be used for about 20 seconds to 30 seconds — typically long enough for a pilot to reduce speed below 60 knots (a speed below which manual control forces are more manageable). When the pressure in the accumulators is depleted, control forces become significantly higher. Selecting the "CUTOFF" switch also deactivates the warning horn.

The "HYD TEST" switch allows for testing of all four servo accumulators (three associated main servos and a tail-rotor servo). When the switch is placed in the "TEST" position, the hydraulic-test solenoid (regulator solenoid) and the tail-rotor servo solenoid valve open. As a result, the hydraulic pressure decreases, causing the hydraulic warning light to illuminate and the warning horn to sound. During the preflight check, the "HYD TEST" switch is moved to the "TEST" position and the cyclic stick is moved to confirm that the accumulators are functioning.

The "HYD TEST" switch usually is not operated during flight because movement of the switch results in depressurization of the accumulator in the tail-rotor servo, which leads to high yaw-pedal forces. Nevertheless, the flight manual says that, if a tail-rotor control failure occurs, the pilot should move the switch to the "TEST" position, wait five seconds and move the switch to the normal position.

In the event of a hydraulic failure, the pilot places the "CUTOFF" switch in the "CUTOFF" position to provide for "simultaneous depressurization of the accumulators," the report said. "This is designed to dump the hydraulic system pressure to zero and also to ensure the accumulator pressures are rapidly depleted to zero symmetrically. Both these functions are required for safe operation. … Depressurizing the accumulators symmetrically and rapidly is designed to provide consistent behavior of the flight controls when transitioning from powered [flight controls] to unpowered flight controls."

A visual examination of the helicopter's hydraulic system revealed that the hydraulic pump drive belt had fractured at a manufacturing seam. The coated-fabric drive belt had a service life of 600 hours; it had been in service for 390 hours. The report said that failure of the drive belt "would account for the hydraulic failure reported by the pilot."

Examination of the drive belts from several other MNR helicopters revealed "extensive cracking … at the same location as the failure location of the occurrence drive belt," the report said.

Investigators could not determine whether the belt had failed before the accident; nevertheless, "the belt was assessed as being close to failure prior to the crash," the report said.

Before the accident, MNR maintenance personnel conducted daily visual examinations of the drive belt and checked its tension by feel and by trying to turn the belt pulley. Similar examinations and required adjustments were included in 100-hour maintenance inspections. The drive belts were replaced during 500-hour "T" checks, although only a check of drive-belt tension was required.

The investigation found that the three main-rotor servo accumulators had pressures of about six bar (87 pounds per square inch [psi]) and the tail-rotor servo accumulator had pressure of about 22 bar (319 psi). Normal pressure for all servo accumulators was 15 bar (218 psi).

The "CUTOFF" switch was in the forward (normal) position, but because of accident-related damage, investigators could not determine the position of the switch before impact; they also could not test for electrical continuity. Examination of the switch revealed no pre-existing anomalies. The "HYD TEST" switch was in the forward (test) position, and was probably in that position at the time of impact. Examination of the switch revealed no anomalies.

The red "HYD" warning light, which illuminates when hydraulic pressure is below 30 bar, was illuminated at impact, and the hydraulic pressure warning horn probably was functional, although the warning-horn mute switch was in the "AFT" (mute) position.

In addition, the hydraulic CB — which provided power to both the "CUTOFF" switch and the "HYD TEST" switch — was in the tripped position and had been in that position during the accident flight, the report said.

"To determine if the hydraulic CB could have tripped due to an electrical fault, the CB was examined and tested, and a wiring-continuity check was carried out on the related wiring," the report said. "No discrepancies were noted. Another option is that the CB was intentionally tripped by the pilot. This was considered highly unlikely since pulling the CB is not part of the emergency procedure, and it would be difficult for the pilot to readily identify the CB due to its location."

"The hydraulic CB supplies power to both the 'HYD TEST' switch and the hydraulic 'CUTOFF' switch; therefore, activation of the 'HYD TEST' switch or the hydraulic 'CUTOFF' switch would have no effect with the hydraulic CB in the tripped position."

The report said that the pilot, in accordance with training and procedures discussed in the flight manual, would have tried to slow the helicopter to the recommended speed of 40 knots to 60 knots, to conduct a flat approach over a clear landing area and to land the helicopter with slight forward airspeed.

"Since he was confronted with an abnormal situation in which emergency response actions did not result in predictable results, the pilot may have elected to fly the helicopter at higher airspeeds in order to reach the Mekatina landing site sooner," the report said.

"As a result of not slowing the helicopter to the recommended speed, the pilot would have detected higher control forces once the accumulators on the main-rotor servos were depleted. The positions of the hydraulic 'HYD TEST' switch and the hydraulic 'CUTOFF' switch, as found at the occurrence site, indicated that the pilot may have attempted to dump the hydraulic pressure in flight by use of the 'HYD TEST' switch, an inappropriate method that is not in accordance with the [flight manual]. However, given that the pilot was confronted with an abnormal emergency situation due to the tripped hydraulic CB, it is possible that he selected the 'HYD TEST' switch when he recognized that the 'CUTOFF' switch did not function. There is no indication that this action further exacerbated the hydraulic emergency."

The report said that a related incident occurred May 12, 2003, during a preflight check of another Canadian operator's AS 350B2. During this incident, the hydraulic system was shut off with the "HYD TEST" switch and the controls were cycled to deplete all hydraulic pressure provided by the servo accumulators.

"During this preflight check and after the accumulators were depleted, the cyclic control moved uncommanded to an extreme left position," the report said. "Considerable force was required to move the cyclic. The uncommanded movement was repeatable."

An investigation found that the problem was caused by a servo actuator, and the servo actuator was removed for further examination; no anomalies were found.

The report on the MNR accident said that because the hydraulic CB probably was tripped during the flight, the hydraulic pressure from the main-rotor servos would have been depleted asymmetrically, resulting in uneven cyclic loads.

"The experienced pilot would have been flying with a firm grip on the controls in anticipation of increased control loads associated with hydraulic pressure depletion," the report said. "It is unlikely that an … increase in asymmetric cyclic load to a pilot anticipating a load increase could result in the pilot losing control of the helicopter. He may have attempted to dump the hydraulic pressure using the 'HYD TEST' switch, after realizing that the hydraulic 'CUTOFF' switch had no effect. While maneuvering to land at the logging site, the aircraft was seen to enter a left turn from which it did not recover. The forces encountered by the pilot during that turn at low altitude may have been too extreme to overcome, making it impossible for him to recover the aircraft to level flight."

Several safety actions were taken during the investigation, including:

- Transport Canada (TC) issued two airworthiness directives (ADs) that said that AS 350 operators should conduct preflight checks before every flight to ensure that the hydraulic pressure and helicopter controls are functioning properly, that helicopters should be landed as soon as possible in the event of a hydraulic failure and that, except in emergencies, hydraulic systems should not be turned off during flight;

- TSB issued an aviation safety advisory to TC "to address the extensive cracking deficiency on the hydraulic pump drive belt," the report said. "Although the belt manufacturer has produced a modification … there are numerous helicopter operators in Canada that continue to operate their aircraft with the occurrence type hydraulic pump drive belt." TC subsequently issued an AD to require replacement of the type of belt used in the accident helicopter with the modified belt;

- MNR grounded its AS 350B2s after the accident and did not return them to service until after modification of the hydraulic pump drive belt. MNR said that it would replace the modified belts, which have a 1,500-hour service life, every 1,000 flight hours. In addition, MNR inspected the hydraulic system and flight control systems on the helicopters and provided additional training on hydraulic system failures and emergency procedures; and,

- Extreme-cold-weather testing was conducted in Inuvik, Northwest Territories, Canada, to examine AS 350 control forces in the manual mode in very cold temperatures. (After an engineering review, TC received a report of an incident in which another Canadian operator's AS 350 experienced an uncommanded left input after shutting down the hydraulic system in flight because of an apparent problem in flight control forces. The report said that control was regained after the hydraulic system was repressurized.)

As a result of the Inuvik testing, the French Direction Générale de l'Aviation Civile issued ADs to require changes in the rotorcraft flight manual regarding emergency procedures, the hydraulic system description and training procedures; to require modification of the hydraulic bypass system "to reduce residual pressure to an acceptable level"; and to require that hydraulic fluid be replaced after exposure to temperatures below minus 15 degrees C (five degrees F).♦

[FSF editorial note: This article, except where specifically noted, is based on Transportation Safety Board of Canada accident report A03O0012, *Loss of Control — Collision With Terrain, Province of Ontario, Ministry of Natural Resources Eurocopter AS 350 B2 (Helicopter) C-GOGN, Mekatina, Ontario, 21 January 2003*. The 29-page report contains illustrations and appendixes.]

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