Inquiry 11-001: Bell Helicopter Textron 206L-3, ZK-ISF
Ditching after engine power decrease, Bream Bay, Northland
20 January 2011

Final Report

Aviation inquiry 11-001

Bell Helicopter Textron 206L-3, ZK-ISF

Ditching after engine power decrease

Bream Bay, Northland

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Approved for publication: February 2013

Transport Accident Investigation Commission

About the Transport Accident Investigation Commission

The Transport Accident Investigation Commission (Commission) is an independent Crown entity responsible for inquiring into maritime, aviation and rail accidents and incidents for New Zealand, and co-ordinating and co-operating with other accident investigation organisations overseas. The principal purpose of its inquiries is to determine the circumstances and causes of occurrences with a view to avoiding similar occurrences in the future. Its purpose is not to ascribe blame to any person or agency or to pursue (or to assist an agency to pursue) criminal, civil or regulatory action against a person or agency. The Commission carries out its purpose by informing members of the transport sector, both domestically and internationally, of the lessons that can be learnt from transport accidents and incidents.

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Important notes

Nature of the final report

This final report has not been prepared for the purpose of supporting any criminal, civil or regulatory action against any person or agency. The Transport Accident Investigation Commission Act 1990 makes this final report inadmissible as evidence in any proceedings with the exception of a Coroner's inquest.

Ownership of report

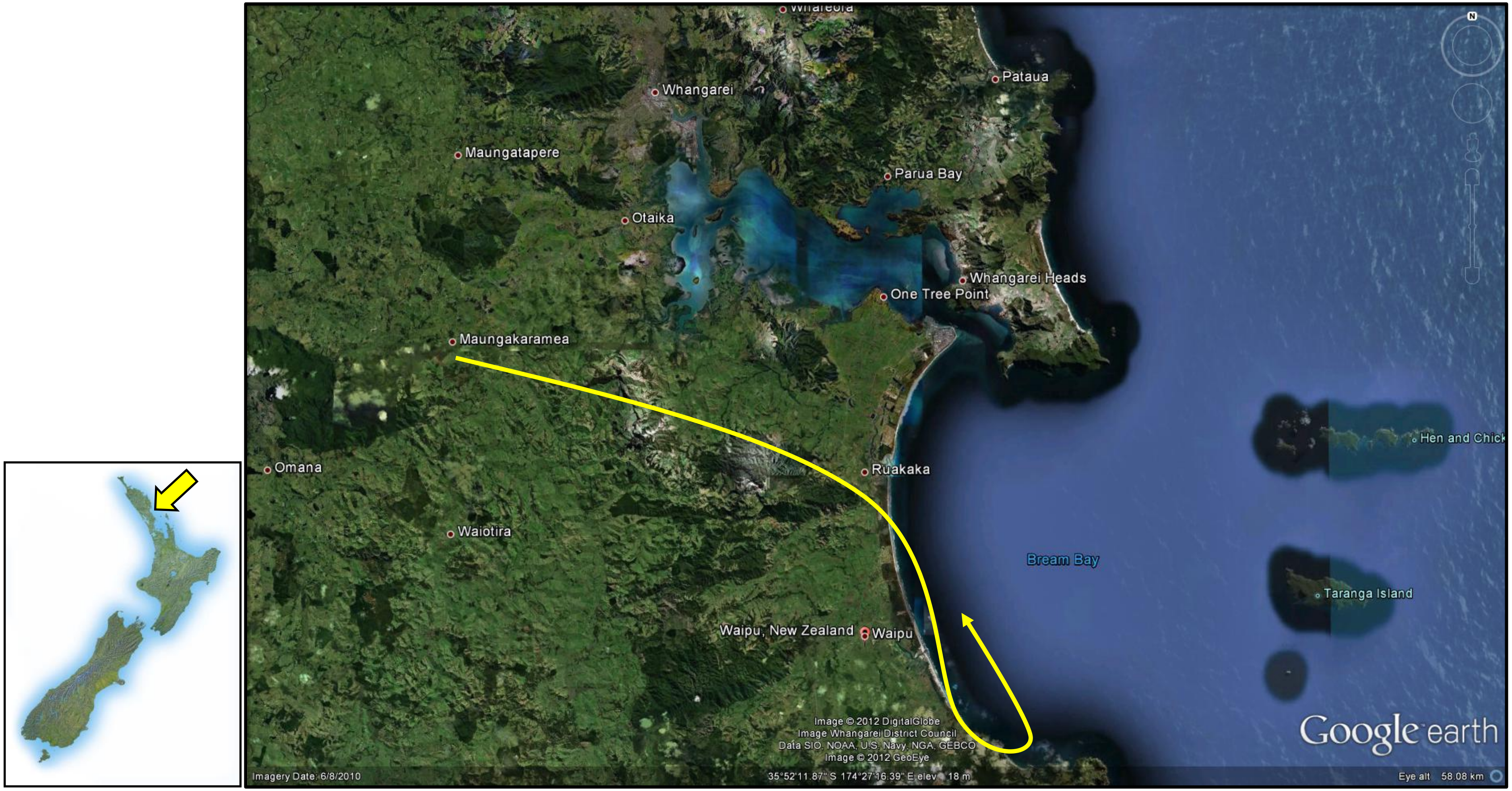
Citations and referencing

Information derived from interviews during the Commission's inquiry into the occurrence is not cited in this final report. Documents that would normally be accessible to industry participants only and not discoverable under the Official Information Act 1980 have been referenced as footnotes only. Other documents referred to during the Commission's inquiry that are publicly available are cited.

Photographs, diagrams, pictures

Unless otherwise specified, photographs, diagrams and pictures included in this final report are provided by, and owned by, the Commission.

Bell 206L-3, ZK-ISF



Bream Bay, and approximate flight path

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Abbreviations

Commission	Transport Accident Investigation Commission
GPS	global positioning system
kg	kilogram(s)
lb	pound(s)
m	metre(s)
N1	the RPM of the engine gas producer turbine (100% = 51 000 RPM)
N2	the RPM of the engine power turbine (100% = 30 650 RPM)
N_R	main rotor RPM
RPM	revolution(s) per minute
UTC	co-ordinated universal time

Glossary

autorotation	the condition of flight during which a helicopter's main rotor is driven only by aerodynamic forces, with no power from the engine
B-nut	a nut that connects a piece of flared tubing to a threaded fitting
beep switch	a thumb-operated switch used to make small adjustments to the engine power turbine governor setting
compressor stall	an abnormal airflow within the compressor section, resulting from a stall of the aerofoils within the compressor
ditching	the forced landing of an aircraft into water
flight-following	the process of reporting one's progress or the termination of a flight to a responsible person who will initiate a search if an expected call is not received after a certain time
mandatory broadcast zone	a zone established to provide increased protection to aircraft in areas where high traffic density or special operations may occur. Pilots are required to broadcast their positions and intentions at certain locations and at specified intervals
torque	a measure of the power output of the engine
torque paint	a paint stripe marked across a pipe and nut after tightening, which will show if the nut has since turned
yaw	the movement of an aircraft about its vertical axis

Data summary

Aircraft particulars

Aircraft registration:	ZK-ISF
Type and serial number:	Bell Helicopter Textron 206L-3 LongRanger, 51145
Number and type of engines:	one Rolls-Royce 250-C30P turbo-shaft
Year of manufacture:	1985
Operator:	the pilot
Type of flight:	private
Persons on board:	one
Pilot's licence:	commercial pilot licence (helicopter)
Pilot's age:	43
Pilot's total flying experience:	4435 hours, with 445 hours on type

Date and time	20 January 2011, 1210[1]
Location	Bream Bay, Northland latitude: 35°57.423´ south longitude: 174°29.98´ east
Injuries	minor
Damage	helicopter destroyed

[1] Times in this report are in New Zealand Daylight Time (UTC+13 hours) and expressed in the 24-hour format.

1. Executive summary

1.1. On 20 January 2011, the pilot of a Bell 206L-3 LongRanger helicopter ditched the helicopter after experiencing a significant engine power reduction while in the cruise. The pilot did not have time to make an emergency radio call, but the accident was witnessed by people on shore. The pilot was not wearing a life jacket and spent more than 2 hours in the water before he was rescued. He suffered minor injuries only. The helicopter was not able to be recovered from the sea for about one week.

1.2. The cause of the reported engine power reduction was not determined.

1.3. The pilot did not take appropriate survival precautions for a flight that was intended to be operated over water. His rescue was greatly assisted by the accident being witnessed and by a favourable on-shore wind.

1.4. The Commission made no safety recommendations.

1.5. The following key lessons were noted:

- pilots should have a flight-following arrangement or submit a flight plan for every flight to ensure that a search is started without delay should the flight become overdue
- the occupants of single-engine aircraft operating at low level over water should wear, not just carry, life jackets when they plan to fly beyond gliding range of a suitable landing place
- when a forced landing appears likely, pilots should activate the emergency locator transmitter as soon as possible and make an emergency radio call
- helicopter pilots who frequently operate over water should undertake helicopter underwater escape training.

2. Conduct of the inquiry

2.1. On 20 January 2011 the Civil Aviation Authority notified the Transport Accident Investigation Commission (Commission) that a search and rescue operation was underway in Bream Bay, Northland, following a report that a helicopter had crashed. The helicopter's pilot was rescued after spending more than 2 hours in the water, but the helicopter had sunk.

2.2. On 21 January 2011 the Commission opened an inquiry into the accident and obtained brief details of the event from the pilot by telephone. He was interviewed in person on 25 January.

2.3. The helicopter tail boom and 2 short sections of a main rotor blade were washed ashore on 24 January. However, the weather had deteriorated since the time of the pilot's rescue and remained unsuitable for a Navy dive team, which assisted the Commission, to begin a search for the main wreckage until 25 January.

2.4. The main wreckage was found late on 26 January and recovered onto a barge the next day. The engine was immediately flushed with fresh water to delay the inevitable corrosion, and a preliminary inspection made by an investigator from Rolls-Royce Corporation, the manufacturer of the engine. The wreckage was then taken, via Auckland, to Ardmore Aerodrome for further examination at the premises of a helicopter maintenance organisation.

2.5. From information provided by the pilot, the investigation focused on the engine, which was disassembled on 28 January by the Rolls-Royce investigator, in the presence of the Commission's investigator in charge. Some engine accessories were removed for specialist examination in the United States. A Bell Helicopter customer support representative was also present at the initial airframe inspection.

2.6. At the completion of the engine examination and initial airframe inspection, the wreckage was returned to the insurer on 3 February 2011.

2.7. On 25 January 2011 the Transportation Safety Board of Canada, the State of Manufacture for the helicopter, appointed an Accredited Representative in accordance with section 5.18 of Annex 13 to the International Convention on Civil Aviation.

2.8. On 2 February 2011 the National Transportation Safety Board of the United States, the State of Manufacture for the engine, appointed an Accredited Representative. A specialist from the Federal Aviation Administration was appointed by the National Transportation Safety Board to supervise the examination of the engine accessories that were sent to their manufacturer.

2.9. The following processes also took place during the inquiry:

- interviews of the pilot, other Bell 206L-3 pilots, and helicopter maintenance engineers
- reviews of the accident databases in New Zealand, Australia, Canada and the United States, as well as that of Rolls-Royce Corporation, for relevant occurrences.

2.10. The Commission acknowledges the assistance of the New Zealand Defence Force, Rolls-Royce Corporation, the National Transportation Safety Board and the Transportation Safety Board of Canada.

2.11. On 24 October 2012 the Commission approved the draft report for circulation to Interested Persons for their comment. Submissions were received from the National Transportation Safety Board, Rolls-Royce, Bell Helicopters and the Civil Aviation Authority.

2.12. On 13 February 2013, having considered the submissions, the Commission approved the final report for publication.

3. Factual information

3.1 History of the flight

3.1.1. Shortly before noon on Thursday 20 January 2011, the pilot departed from his home base near Maungakaramea in a Bell 206L-3 helicopter, registered ZK-ISF (the helicopter). The private flight was being made so that he could check the suitability of conditions in Bream Bay for fishing later that day. The pilot had told a friend of his plan, but he had not arranged any form of flight-following.[2] The flight was conducted outside controlled airspace, within or adjacent to the Whangarei mandatory broadcast zone.[3]

3.1.2. The flight proceeded normally from the home base directly to Ruakaka and then south along the coast to Langs Beach, about 40 kilometres from the departure point, where the pilot turned to retrace his track (see Figure 2). He said he was cruising at about 1000 feet above the sea, at 110 knots. He noted the indicated engine torque was approximately 70%.[4,] The engine then "surged", and the indicated power turbine revolutions per minute (RPM) decreased.[5] Power turbine RPM is often referred to as N2. The pilot said that he used N2 as his primary reference for engine power.[6]

3.1.3. The N2 and the main rotor RPM (N_R) are displayed on a large dual tachometer directly in front of the pilot (see Figure 3). In normal flight, N2 and N_R have the same RPM limits, expressed as a percentage, and the pointers overlap. As the engine fuel control system attempts to maintain the N2 at the selected value, normally 100%, a reduction in output power will usually be obvious by seeing the dual tachometer needles "split". The pilot will also likely hear the engine running down.

3.1.4. For turbine-powered helicopters, the primary power indicators are generally considered to be the torque and the gas producer turbine RPM, often referred to as N1. These are shown on separate small indicators on the instrument panel (see Figure 3).

3.1.5. The pilot said that both fuel boost pumps had been ON and there were about 600 pounds (lb) (272 kilograms [kg]) of fuel remaining when the event occurred. There had been no indication of an impending malfunction. When describing the event, the pilot made no mention of the helicopter yawing.[7] When asked whether there had been yaw, he hesitated before saying there "would have been a left yaw".

3.1.6. The pilot immediately entered autorotation to preserve main rotor RPM. He checked that the twist-grip throttle was fully open and attempted to increase the N2 using the governor "beep" switch[8], but that seemed unresponsive. The N2 continued to vary between 60% and 70% and the main rotor RPM decreased slightly, but it did not go below the low N_R warning horn setting.

3.1.7. Descending through 300 feet the pilot saw that the N2 was "surging" between 60% and 70% and that the main rotor RPM was steady at about 95%. He said there were no warning annunciators and he did not recall any other instrument indications. Realising that a ditching was inevitable, he turned the helicopter into wind. At about 100 feet above the sea, the pilot selected the emergency locator transmitter beacon remote switch to ON, but did not have time to make an emergency radio call.

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[2] Flight-following involves reporting one's progress or the termination of the flight to a responsible person who will initiate a search if an expected call is not received after a certain time. It is less formal than a flight plan.

[3] A zone established to provide increased protection to aircraft in areas where high traffic density or special operations may occur. Pilots are required to broadcast their positions and intentions at certain locations and at specified intervals.

[4] Torque is a measure of the power output of the engine.

[5] The chief engineer of the maintenance provider said that the pilot told him on the day after the accident that the engine had surged or might have had a compressor stall.

[6] The Appendix has a description of the turbine engine and relevant components.

[7] Yaw is rotation about the vertical axis of the helicopter. [8] A thumb-operated switch used to make small adjustments to the engine power turbine governor setting.

[8] A thumb-operated switch used to make small adjustments to the engine power turbine governor setting.

Figure 1
Instrument panel in ZK-ISF

3.1.8. The pilot said that he flared normally to reduce the rate of descent before applying full collective pitch to cushion the water entry. He said the landing was "firm". The pilot then rolled the helicopter to the right to allow the main rotor blades to strike the water and stop turning. He said the rotor striking the water had a harder impact. The forward windscreens and chin windows then broke and the cabin filled with water as the helicopter rolled inverted.

3.1.9. The helicopter was not equipped with emergency flotation gear, but initially floated just below the sea surface. The pilot had had no training in escaping from a submerged helicopter and he experienced some disorientation before he managed to escape from the cabin. He clung to the landing skids for less than 15 minutes before the helicopter began to sink. The pilot said that the tail boom was still attached at that stage and he saw that a tail rotor blade had hit the tail boom. He was not wearing a life jacket and had none on board. He began to swim towards the shore, using his helmet and pieces of main rotor blade for flotation, and was aware of swimming through floating fuel.

3.1.10. A number of witnesses on or near Waipu Beach saw the crash and reported this to Police at about 1217. A large arrow pointing towards the impact point was drawn in the sand to guide search aircraft, but the reported distance offshore was overestimated. An Air Force Orion maritime patrol aeroplane that was operating in the Hauraki Gulf was diverted to the search. The witnesses passed advice through Police to guide the Orion towards the accident site.

3.1.11. Witnesses and search personnel said there was an on-shore easterly wind with white caps on the sea. In spite of the sea condition, the pilot was found by the Orion crew at 1422, approximately 1500 metres (m) offshore, and a rescue helicopter from Whangarei rescued him soon afterwards. He suffered mild hypothermia and minor bruising, as well as fuel burns to exposed skin.

3.1.12. The accident happened on 20 January 2011 at, according to the pilot, about 1210. On 26 January a Navy dive team found the main wreckage at a depth of 19.5 m in position 35 degrees 57.42 minutes south, 174 degrees 29.98 minutes east. This position is almost 3 kilometres offshore and approximately 1600 m east of where the pilot was rescued (see Figure 4).

Figure 2
Locations of accident and pilot's rescue

3.2 Pilot information

3.2.1 The pilot had obtained a private pilot licence (helicopter) in 1998 and a commercial pilot licence (helicopter) in March 1999. In December 2007 he had obtained a Basic Gas Turbine rating, a prerequisite for obtaining a type rating on an aircraft powered by a gas turbine ("jet") engine. He had obtained a type rating for the Bell 206 in January 2008 and for the Bell 206L in November 2008. He also held type ratings for the larger Bell 407, the Hughes 269 and the Robinson R22 and R44 helicopters; and a grade 1 agricultural rating. His class 1 medical certificate had no restrictions or endorsements and was valid until September 2011. His previous competency check and biennial flight review had been conducted on 31 May 2010.

3.2.2 The pilot had not flown for 6 days before 20 January 2011 and had considered himself well rested and fit for the flight that day. In the previous 30 days he had flown 76 hours, but only 2.3 hours had been in ZK-ISF. In the previous 90 days he had flown 148 hours, of which nearly all had been on an overseas contract while ZK-ISF was undergoing maintenance. He had a total of 4435 flight hours, of which 445 hours were on the Bell 206L-3 helicopter.

3.3 Organisation information

3.3.1 The pilot had initially been employed as an agricultural pilot for North Shore Helicopters Limited at its Dargaville base, flying a Robinson R44 helicopter. In 2005 that operation and the helicopter had been sold to the pilot, who established Finlayson Helicopters (the company). Finlayson Helicopters was certificated under Civil Aviation Rules Part 137 to provide agricultural and aerial work services. The company purchased ZK-ISF in the United States in 2008 to replace the R44, although the latter was retained until late 2009.

3.3.2 The pilot had bought the helicopter without the help of an independent aircraft surveyor/assessor. It was subsequently discovered in New Zealand that some main transmission components that should have been replaced during an overhaul in the United

Sates appeared to have been reinstalled. Those parts were replaced. A further major expense was incurred when the main rotor head was found to be in an unsatisfactory condition.

3.3.3 The most recent audit of the company by the Civil Aviation Authority had been a routine re-certification audit conducted on 27 April 2010. No finding had been made and a low "risk profile" was assigned. At the prior audit, when its risk profile was slightly higher, the company had been considered to be "steady and compliant".

3.3.4 In 2009 the Civil Aviation Authority had approved the helicopter for use on air transport operations, but the pilot had lacked the prescribed experience to be the chief pilot of an air transport operator. Therefore, in July 2010 the helicopter had been added to the Operations Specifications of North Shore Helicopters to allow air transport operations under its supervision. In the event, no air transport operations were flown.

3.3.5 The Civil Aviation Authority records showed that the registered owner of the helicopter had changed from Finlayson Helicopters to North Shore Helicopters on 10 August 2010, at about the time when the helicopter was added to North Shore Helicopters' Operations Specifications.[9]

3.4 Aircraft information

General

3.4.1 The Bell 206L-3 is a variant of the 7-place LongRanger helicopter, which is a stretched and higher-powered version of the 5-place Bell 206 JetRanger. The accident helicopter was manufactured in 1985 at the Bell Helicopter Textron factory in Canada. Transport Canada was the certificating authority for the assembled helicopter.

3.4.2 The helicopter was fitted with a Rolls-Royce 250-C30P turbo-shaft engine, part number 23004545 and serial number CAE895199, which had been manufactured in the United States in 1985.[10] The Federal Aviation Administration of the United States was the certificating authority for the engine. The engine was mounted on a deck that formed the cabin roof, and drove a 2-bladed main rotor and a 2-bladed tail rotor through the main transmission. A fuller description of the engine is given in the Appendix.

3.4.3 The helicopter was controlled with the cyclic stick, collective lever and yaw pedals. The collective lever, which was operated with the pilot's left hand, incorporated a twist-grip throttle that was set fully open for normal operation. At the end of the lever was the beep switch and the engine start switch. The beep switch sent a signal to an actuator that adjusted the setting of the power turbine governor and hence the N2. The adjustable range was plus or minus 3%.

3.4.4 The allowable range of N1 for continuous operation was between 63% and 105%.[11] The lower figure was the approximate idle RPM. The N2 range for continuous operation was between 97% and 100%. The main rotor RPM limits with power on were also 97% to 100%, and were 90% to 107% with power off (autorotation).

3.4.5 The caution and warning system included the warning light panel located along the top of the instrument panel, and the engine failure and low N_R warning systems. The system was protected by the CAUTION circuit breaker. A red ENGINE OUT warning light would illuminate and an intermittent horn would sound when the N1 decreased below 55%. Optional engine auto-relight equipment was not fitted to the helicopter.[12] An amber ROTOR LOW RPM caution light would illuminate and a continuous horn sound if the main rotor RPM decreased below 90%.

[9] The owner for the purposes of the Civil Aviation Act 1990 and the associated Rules includes any person lawfully entitled to the possession of the aircraft for 28 days or longer, and is not necessarily the financial owner.
[10] The engine was manufactured by the Allison Engine Company, which was bought by Rolls-Royce Corporation in 1995.
[11] The helicopter specifications and limitations are from the approved flight manual, Civil Aviation Authority "AIR 2450".
[12] In the event of a "flame out", an auto-relight system automatically operates to re-ignite the fuel-air mixture in the combustion section.

3.4.6 The helicopter fuel tank consisted of 3 interconnected, crash-resistant cells, with a total capacity of 753 lb (342 kg). Fuel was supplied to the engine by 2 electric boost pumps in the rear cell, passing through a shut-off valve and an airframe fuel filter before reaching the engine fuel pump and the fuel control unit. When the throttle twist-grip was opened, fuel flowed to the fuel nozzle and into the combustion chamber of the engine.

3.4.7 The power turbine governor and fuel control unit had been manufactured by Honeywell in the United States.

Maintenance - general

3.4.8 When imported into New Zealand in July 2008 the helicopter airframe had accrued 12 184.2 hours and 22 638 cycles, and the engine had accrued 11 984.7 hours and 17 135 cycles. Emergency flotation equipment had then been removed and the landing skids replaced. An airworthiness certificate had been first issued in the Restricted category in August 2008, and reissued in April 2009 in the dual categories of Standard, for use in air transport operations, and Restricted for when it was used in agricultural operations.

3.4.9 In the 2½ years that the helicopter had been in New Zealand, it had flown just 290 hours. Maintenance of the helicopter had been performed by 4 different organisations since it was imported. Since November 2009, major maintenance had been performed by an organisation in the Taranaki province.

3.4.10 According to the logbooks, the helicopter and its engine had been maintained in accordance with the relevant Bell and Rolls-Royce manuals. Before the accident, the previous 300-hour inspection had been completed at 12 076.1 airframe hours. The previous 100-hour airframe inspection and 150-hour engine inspection, and inspections of various other components, had been carried out during a prolonged downtime in late 2010 at 12 469.9 airframe hours. The engine compressor had been washed during this period and no agricultural flights had been flown since.[13]

3.4.11 The helicopter had not been flown between 4 September 2010 and 11 January 2011 while the tail boom was sent to Canada for repairs to the tail rotor gearbox mounting holes. At the completion of that work, an annual review of airworthiness was completed.

3.4.12 The pilot had conducted a post-maintenance test flight on 11 January 2011 and flown the helicopter to Whangarei Aerodrome, where he refuelled it before flying it to his home base. The accident flight had been the only flight since then. At the time of the accident, the airframe had accrued approximately 12 474 flight hours, and the engine 12 275 hours and 17 404 cycles.

3.4.13 The pilot said that he had never had any fuel-related problems with the helicopter. He said that he had topped up the tanks from a fuel trailer at his home base just before the accident flight. However, he said he had not kept a record of refuels from the trailer. He said he had performed the specified flight manual water check before departing on the accident flight.

Engine accessories maintenance

3.4.14 In March 2009 a reported defect with the power turbine governor had been traced to a loose wire in the beep switch. The current maintenance engineer advised that such a defect would most likely have caused the N2 to stabilise at about 97%, not the much lower value reported by the pilot during the accident sequence.

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[13] The engine compressor was washed regularly to prolong the life of the blades and to ensure a smooth airflow through the compressor. Agricultural operations are harsh on compressors because chemical aerosols are inevitably ingested by the engine.

3.4.15 The previously fitted power turbine governor had been replaced on 29 December 2009, just short of the 2000 hours' overhaul life. The replacement power turbine governor had operated satisfactorily for approximately 96 hours prior to the accident.[14]

3.4.16 The fuel control unit had been installed on 21 October 2005 and had operated satisfactorily for 371 hours since then.[15]

3.4.17 The previously fitted engine-driven fuel pump had been replaced on 3 August 2010, about 10 hours before the end of the 3000 hours' overhaul life. The details of the change were not shown in the Engine Component Record section of the engine logbook, but had been recorded on a computer spreadsheet. The replacement pump had operated satisfactorily for approximately 18 flight hours prior to the accident.

3.4.18 Two other discrepancies were noted in the engine component records. The accessory gearbox data plate gave the part number as 23035178, but the logbook recorded it as 23005655; and the installed compressor part number was 23033193, although the logbook showed it as 23005250. All of those part numbers were acceptable for installation in the engine. The differences related to whether a particular service bulletin had been incorporated on a component. The latest logbook entries had been made in 2004 and were annotated "new config[uration]", but the component serial numbers were unchanged.

3.4.19 The fuel nozzle had operated for 847 hours since it was installed and the compressor bleed valve for 868 hours.

Flight manual emergency procedures

3.4.20 The flight manual emergency/malfunction procedures pertinent to this flight were as follows:

ENGINE FAILURE – IN-FLIGHT

INDICATIONS:

1. Left yaw
2. ENG OUT light illuminated
3. Engine instruments indicate power loss
4. Engine out audio (if installed) activated when N1 drops below 55%
5. N_R decreasing with ROTOR LOW RPM light and audio on when N_R drops below 90%.

PROCEDURE:

1. Enter autorotation
2. Attempt engine restart if ample altitude remains

If engine restart not attempted;

3. Throttle closed
4. FUEL VALVE switch OFF
5. Accomplish autorotative descent and landing
6. Complete helicopter shutdown.

ENGINE UNDERSPEED

INDICATIONS:

1. Decrease in N1
2. Subsequent decrease in N2
3. Possible decrease in N_R

[14] PTG model AL-AD1, part number 2524692-11.
[15] FCU model DP-V1, part number 2549092-6.

4. Decrease in TORQUE.

PROCEDURE:

1. Collective – adjust as required to maintain 90 to 107% N_R
2. Throttle – confirm full open
3. If unable to maintain N_R, establish autorotative glide
4. Prepare for power-off landing.

NOTE

If engine underspeeds, but continues to operate, do not shut down engine. This will help maintain tail rotor effectiveness and assist to cushion landing.

ENGINE COMPRESSOR STALL/SURGE

INDICATIONS:

1. Engine pops
2. High or erratic turbine outlet temperature
3. Decreasing or erratic N1 or N2
4. TORQUE oscillations.

3.4.21 The chief pilot of North Shore Helicopters said that if the compressor discharge pressure line to the power turbine governor failed, the N1 would decrease towards idle, but the N2 would stay at 100% initially and while in autorotation. The pilot would hear the engine speed decrease and definitely feel the helicopter yaw before they noticed any engine indicator movement. He said the first instinct of a pilot should be to enter autorotation. After checking the engine instruments, they would see that the N1 had reduced below the beep switch effective range. He said this scenario was covered during training for a LongRanger type rating.

3.4.22 The rate of descent when in autorotation at the estimated accident weight of approximately 3350 lb (1520 kg) would likely have been between 1500 and 1800 feet per minute, depending on the forward airspeed. The flight manual did not include a procedure or any guidance for ditching the helicopter.

Weight and balance

3.4.23 The helicopter had been last physically weighed on 5 July 2005 in the United States, but the logbook did not list the fixed equipment installed at that time. The weight and balance had been recalculated before the New Zealand airworthiness certificate was issued.[16] Further recalculations had been made when avionics equipment was installed, most recently on 14 July 2009.

3.4.24 The recorded empty weight was 2753 lb (1249 kg).[17] The pilot said there had been about 600 lb (272 kg) of fuel on board shortly before the accident. Therefore, at his stated average fuel consumption of 130 litres (228 lb or 104 kg) per hour, the take-off weight for the flight of less than 30 minutes would have been approximately 3467 lb (1573 kg).[18,19] The maximum certificated take-off weight was 4150 lb (1882 kg). Using these figures, the helicopter weight and centre of gravity were calculated to have been within limits throughout the flight.

[16] Civil Aviation Rule 91.605(e)(10) required the helicopter to be physically re-weighed at intervals not exceeding 10 years.

[17] Weight and Balance form number CAA2173.

[18] Based on Jet A1 fuel density of 1.76 lb (0.8 kg) per litre.

[19] The stated fuel consumption was close to the flight manual data for cruise at 100 knots at sea level.

3.5 Wreckage and impact information

3.5.1 The helicopter was substantially damaged as a result of the main rotor striking the sea. The engine was substantially damaged from having been in the sea for 7 days.

3.5.2 The tail boom and 2 short sections of a main rotor blade were washed ashore near Waipu Beach on 24 January. The boom had separated from the fuselage, approximately half a metre aft of the mounting frame. There was no evidence that a main rotor blade had struck the boom, but one tail rotor blade had struck the boom and was missing.

3.5.3 The main wreckage was found inverted on the sea bed at a depth of 19.5 m. The engine and the main transmission, and the rotor mast and blades, had been torn from the engine deck. Bell Helicopters advised that "transmission and roof departure from the airframe is rather typical of a roll-over accident in a LongRanger on land or water where one blade solidly contacts the surface".

3.5.4 The fuselage was brought to the surface with the help of air bags and lifted onto a barge with strops that were passed through the cabin doors. Air bags were also used to assist in bringing the engine, main transmission and main rotor blades to the surface as a single load. No new damage was incurred during the recovery onto the barge, which took 2 hours.

3.5.5 The lower fuselage and cabin sides were remarkably undamaged (see Figure 5), which indicated that the helicopter had entered the water with a low rate of descent. However, the disruption to the flight and engine controls caused when the engine and transmission broke free prevented a full determination of their continuity, proper functioning and positions before impact.

Figure 3
Fuselage underside, after recovery

3.5.6 The input driveshaft was separated from the main transmission and showed extensive rotational scoring. The drive gear teeth were chipped. The lack of torsional damage to the tail rotor drive shaft suggested that it had separated while it was not rotating or rotating at a very low RPM.

3.5.7 During the on-site investigation, no engine anomalies were noted that would have precluded normal operation. The fuel cells had been breached and fuel and water drained out. The airframe fuel filter was also full of sea water, but with no visible particulate contamination. The fuel valve shut-off switch on the instrument panel was in the guarded ON position.

3.5.8 No useful information was obtained from the flight and engine instruments. The CAUTION circuit breaker was one of 5 circuit breakers for unrelated systems that were found in the open position.

3.5.9 The wreckage was taken to a helicopter maintenance facility, where the engine was inspected and disassembled by a Rolls-Royce accident investigator, with assistance from technicians qualified to overhaul 250-series engines.

3.5.10 An initial inspection found that the compressor (N1) and power turbine (N2) wheels would not rotate, but they did once separated from the accessory gearbox. All pneumatic, fuel and oil lines associated with the engine function and control were visually inspected for integrity and no abnormalities were detected.[20] Impact damage precluded pressure testing of the pneumatic lines. There was no reliable evidence that the B-nuts[21] had been marked with torque paint.[22] There was no external damage to the compressor air discharge tubes or the outer combustion case. The upper and lower magnetic chip detectors were clean.

3.5.11 When the engine was recovered from the sea, the throttle lever on the power turbine governor indicated about 45 degrees on the adjacent protractor plate (scale). The fuel control unit throttle input was at the MAX position and the lever end was broken; damage that had almost certainly been caused by the impact. The throttle input lever of each component could be moved through its full range.

3.5.12 Fuel was present at the fuel nozzle, and the nozzle filter screen was clean, intact and of the correct shape. As there was evidence that the engine had continued to operate until the landing, the nozzle spray pattern was not tested.

3.5.13 The compressor shroud assembly showed rub from impeller contact over 360 degrees, which corroborated the pilot's evidence that the engine was rotating at impact. The gas producer turbine and power turbine were not disassembled, but they and their nozzles appeared normal and they rotated freely.

3.5.14 A disassembly of the engine did not reveal any pre-existing faults or failures of any of the components.

3.5.15 There were no on-board recorders that recorded engine parameters.

3.6 Survival aspects

3.6.1 The pilot made the required broadcasts during the flight, but did not make an emergency radio call. He was not aware of other aircraft in the area, although witnesses had seen at least one other in the area at around the same time.

3.6.2 Most helicopter types, when ditched, will sink quickly unless they are fitted with flotation equipment. Without flotation equipment, it is usual for the pilot to roll the helicopter after landing on the water, so that the main rotor blades strike the water. This will stop the blades and allow the occupants to exit. However, rolling the helicopter usually results in it sinking inverted, making disorientation a major impediment to escape. Helicopter underwater escape training is available in New Zealand, but is not prescribed. Operators of helicopters that regularly operate over-water flights, for example to offshore oil platforms, usually mandate such training for their pilots and passengers.

3.6.3 The pilot was wearing a helmet but not a life jacket, and he did not have one on board. Civil Aviation Rules required that one life jacket be carried for each person on board when "an aircraft is a single-engine aircraft and the flight distance to shore is more than [the] gliding distance for the aircraft".[23]

3.6.4 The seat cushions were fixed to their frames and were not potential flotation aids. Although cushions can be used on many passenger aeroplanes, there is a risk with helicopters that a loose cushion will be blown out an open door and strike the tail rotor.

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[20] However, the possibility of an undetected crack in the flared end of a line could not be excluded.
[21] A B-nut is a nut that connects a piece of flared line or tubing to a threaded fitting.
[22] A paint stripe marked across the line and nut after tightening, which will show if the nut has since turned.
[23] Civil Aviation Rule 91.525(a). The Rule terminology is "life preserver", to cater for other means of flotation.

3.6.5 The pilot said that he was a determined, but not a strong, swimmer. By using pieces of main rotor blade to help flotation, he had drifted and/or swum about half the distance from the impact site to the shore.

3.6.6 Emergency flotation equipment was not required to be fitted to the helicopter, even if it was used for air transport operations. In many foreign accident reports, helicopters that had been equipped with flotation equipment and successfully ditched had subsequently rolled over due to wind and wave action. However, as long as the helicopters floated the occupants had had more time to escape and the search and rescues had been aided by the wreckage being visible.

3.6.7 An ARTEX 406 emergency locator transmitter was fitted behind the cabin, with its aerial on the roof. The mode switch on the unit was found in the ARMED position, which allowed the transmitter to activate if there was a sufficiently strong impact or if the remote control switch on the lower left instrument panel was switched to ON. The remote control switch was found ON, as the pilot had reported. The signal would identify the transmitter as belonging to ZK-ISF.

3.6.8 The emergency locator transmitter had to be activated for 60 seconds before it made its first transmission burst. When the signal was received by the geostationary satellite and passed to the nearest rescue co-ordination centre, the identification of the vehicle or person in distress would be known very quickly. However, in this case the transmitter was turned on less than a minute before the ditching and the helicopter inverted after landing, leaving the aerial pointing down. No signal was detected.

3.6.9 An optional feature available with modern emergency location transmitters is for the last global positioning system (GPS) position to be transmitted with the identification signal. If that additional information is received, the location of the incident is immediately known.[24] Without the transmitted location, the Rescue Coordination Centre New Zealand receives an "unlocated" alert, which will not be resolved until 2 orbiting satellites have detected the basic signal.

3.7 Tests and research

3.7.1 At the request of the Commission the power turbine governor and the engine-driven fuel pump with attached fuel control unit were inspected by Honeywell under the supervision of a Federal Aviation Administration inspector acting for the National Transportation Safety Board.

3.7.2 Honeywell's inspection reports stated that neither unit could be functionally tested due to sea-water immersion. The throttle lever arms on both had, by then, seized due to corrosion. The reports for both components stated that, discounting corrosion and contamination from sea water, "disassembly found no condition that would cause a sudden loss of function".

3.7.3 The pilot had last put fuel from the fuel trailer into the helicopter on the morning of the accident flight. A sample taken from the fuel trailer 5 days after the accident was clear and bright in appearance, and was later analysed by the Defence Technology Agency. The analysis found that the sample, although less than the recommended volume, did not appear to have any gross contamination with organic compounds and it conformed with the composition, density and flash point expected for Jet A1 aviation fuel.

3.8 Additional information

3.8.1 In addition to reviewing the Commission's investigation files, the inquiry searched the safety databases of the Civil Aviation Authority, the Australian Transport Safety Bureau, the Transportation Safety Board of Canada and the National Transportation Safety Board (United States) for occurrences with circumstances that were broadly similar to this accident. Many of the similar occurrences had involved 250-C20 engines. Although that model has a different compressor from, and lower power output than, the 250-C30 engine fitted to ZK-ISF, the engine control systems have very similar hydro-mechanical systems, so the reports were a useful guide to the causes of power loss and informed the Analysis section in this report.

[24] Apart from any additional distance travelled since the last GPS input.

3.8.2 Rolls-Royce identified one occurrence between 2007 and 2012 of a 250-C30P engine run-down where no technical explanation had been found. It involved a Bell 206L-3 helicopter that had lost power when departing an offshore oil rig, but been successfully landed on the sea.[25]

3.8.3 A Technical Briefing given to operators and maintainers by Rolls-Royce in 2011 included a review of helicopter accidents involving the 250 engine in the period 1996-2008.[26] The review noted that 20% of the accidents had involved the engine. In the period 2003-2008, the causes of 11% of the engine-related events were unknown.

3.8.4 The Rolls-Royce review listed the following examples of general maintenance-related causes of engine events:

- fuel contamination
- foreign object damage or engine air inlet blockage
- compressor corrosion and erosion
- fatigue cracks in air or fuel tubes, due to fitting errors
- loose B-nuts
- oil starvation
- fuel nozzle screen contamination
- over-temperature or turbine damage, and turbine sulfidation.

[25] National Transportation Safety Board reference CEN10IA438.
[26] Rolls-Royce M250 Technical Briefing, Amsterdam, October 2011.

4. Analysis

4.1 General

4.1.1 The pilot reported a sudden, large decrease in engine power while the helicopter was in the cruise. His subsequent inability to restore sufficient power to recover to the shore forced him to ditch the helicopter. The pilot's recollection of the engine parameters at the time of the ditching was the only information that might have been useful for diagnosing the problem. Unfortunately, his recollection of the engine performance was vague and he did not recall parameters such as the N1, which would have indicated how much power the engine was developing.

4.1.2 The one recollection the pilot did have was an observed decrease in the N2. There are 3 broad factors that could cause such a reduction: pilot action, a technical defect and an environmental (weather) factor. The weather was acceptable for the nature of the flight, with mild temperatures and no precipitation, and is not considered further. The other potential factors are examined further, and some survival issues are also examined.

4.2 Possible causes for the power loss

Pilot action

4.2.1 The pilot said that he was in the cruise when he heard a noise and saw the N2 decrease. The noise was likely the change in engine note with the N2 reduction, rather than a sound of mechanical failure for which no evidence was found. Also, the engine continued to run. A compressor stall was unlikely to occur in the cruise when the power demand was steady, and the reported symptoms were unlike those of a compressor stall.

4.2.2 In any event, he took the appropriate immediate action of putting the helicopter into an autorotative descent and he also ensured that the throttle was wide open. He said the N2 settled at about 60-70%, which would have been well outside the beep switch range.

4.2.3 The autorotative descent probably took less than 35 seconds. In this time the pilot would have assessed the situation before turning more than 90 degrees to be more into wind for the potential water landing. The concentration required to perform this manoeuvre might explain why he was unable to recall other engine indications during the descent.

4.2.4 The pilot's immediate reaction of lowering the collective lever conserved the N_R, which was critical for his continued control of the helicopter, and was also the appropriate action had the N2 decrease been caused by a catastrophic engine failure. In spite of his describing the landing as firm, the lack of significant damage to the fuselage belly suggested that he made a well executed ditching. The harder impact that followed could have been the result of his not reducing the N_R sufficiently before he tilted the rotor blades towards the water.

4.2.5 The pilot had no unprompted recollection that the helicopter yawed, which was surprising given the size and abruptness of the power reduction. Helicopter pilots are generally very aware of yaw and the direction of yaw, as it can distinguish engine and tail rotor malfunctions that usually require an immediate reaction. The absence of continued yaw and his retaining full directional control until the water entry indicated that the aircraft had not suffered a tail rotor problem. In any event, a tail rotor malfunction would not have decreased the N2.

4.2.6 The pilot said that the ENG OUT and ROTOR LOW RPM warning lights did not illuminate, nor were there any aural warnings. The CAUTION circuit breaker, which protects these 2 systems, was found open after the accident, which could explain that. However, it is also common to find that circuit breakers have opened after an aircraft has sustained a substantial impact, and the main rotor striking the sea might have been of sufficient force to open circuit breakers. Although the pilot did not recall the N1, he did say that the engine had kept operating. If the N1 had remained above 55% the ENG OUT warning would not have been triggered. Similarly, the pilot had likely kept the N_R within the autorotation range, which would have avoided a ROTOR LOW RPM warning.

> **Finding**
>
> There was no evidence that any act or omission of the pilot contributed to the loss of engine performance.

Technical causes

4.2.7 The Rolls-Royce Technical Review in 2011 listed the general causes for maintenance-related engine events. While that list did not include all possible causes, most of those given were eliminated as potential causes of this event.

4.2.8 The fuel control unit and power turbine governor work together to deliver the fuel flow required to meet the power demand. The N2 speed is a function of the N1 speed, which is a direct result of the amount of fuel being sent to the combustor. The reported large reduction in N2 could have resulted from an issue with the power turbine governor or the fuel control unit and/or their respective external lines.

4.2.9 The pneumatic lines could not be pressure checked because of impact damage. The B-nuts in the lines were only checked to be finger tight, rather than having their break-away torque measured. Although some evidence of torque paint was seen, it could not be confirmed whether it had been applied at the time that the engine, fuel control unit or power turbine governor had last been serviced. Even if the nuts had been tightened to the correct torque, the flared end of a line could have been cracked.

4.2.10 No significant defect was found during the inspections of the fuel control unit and the power turbine governor, the key fuel system components. Neither component could be functionally tested, so there was a remote possibility that one or other had a transient defect. However, it would have been very unlikely for a transient defect to cause the prolonged N2 reduction.

4.2.11 When the engine was disassembled, no evidence was found of a pre-existing mechanical defect or of foreign object damage in the compressor or turbine sections. Bearings showed evidence of normal oil supply. The accessory gearbox was disintegrating by the time the engine was disassembled due to the effects of salt-water corrosion on the gearbox case. As a result, although all the gears and bearings appeared to be present, comment on their pre-impact integrity was limited to noting that the output shaft to the main rotor had been turning at impact.

4.2.12 The pilot said that the helicopter fuel tank had been filled 9 days before the accident at Whangarei Aerodrome. There had been no incidents reported around that time to suggest that there might have been a problem with the aerodrome supply. He had topped up the fuel tank before the flight from his fuel trailer, and a sample of that fuel was later tested and found to be of acceptable quality. Having a near-full tank when the helicopter was parked for a week would have minimised the condensation of water. The pilot said that he had performed the required water check before the flight. With full tanks, the flight duration was well within the fuel endurance. The pilot's skin was burned by contact with floating fuel, and when the wreckage was recovered considerable fuel drained from the fuselage. All of this evidence confirmed that the event had not been a case of fuel exhaustion (running out of fuel).

4.2.13 Clean fuel was found in the nozzle when it was removed from the combustion liner, and the screen was clean and not malformed. The helicopter engine functioned normally until the reduction in N2, but the engine continued to run until the ditching. Therefore fuel continued to reach the engine and this was not a case of fuel starvation (interruption of supply).

4.2.14 The logbook discrepancies regarding the accessories gearbox and compressor section part numbers were not resolved, but were very unlikely to be related to the occurrence. However, the discrepancies and some inconsistencies in details recorded in the logbooks and spreadsheets indicated that some past maintenance control procedures had not met the standards required by Civil Aviation Rules.

Finding

No technical reason was found for the reported engine speed decrease.

4.3 Survival factors

4.3.1 The flight was made without the pilot having arranged flight-following. Part of the flight was conducted well outside autorotation range of the shore when the helicopter was not equipped with an emergency flotation system and the pilot was not wearing a life jacket. This was a relatively high-risk scenario.

4.3.2 The pilot had told a friend that he would be making the flight, but there was no legal requirement for him to submit a flight plan or to arrange flight-following. Therefore it was not certain whether anyone would have reported him to be missing if the accident had not been witnessed. The pilot did not make an emergency radio call because he had too little time and spare capacity to do that while controlling the helicopter during the descent to the sea.

4.3.3 Although it was summer and the water temperature was not cold, his survival very much depended on the fortuitous sighting of the accident by people on shore and by the Orion aeroplane being nearby. The pilot was not wearing a life jacket and, contrary to the Civil Aviation Rule applicable to the offshore flight, none was on board. Deciding whether to swim for what appears to be a nearby shore can be a difficult choice for someone in the pilot's position, but in this case the helicopter had sunk so there was nothing to cling to other than debris. He would not have known whether his accident had been witnessed and the emergency locator transmitter was of no help when it was on the sea bed. As a rule, a rescue will be more assured if the survivor actually wears a life jacket, especially if it is fitted with a personal locator beacon and a flare. Another point to consider is that any oil or fuel slick and floating debris will be more easily spotted from the air. If a survivor remains in the vicinity they will have more chance of being spotted.

4.3.4 Even if the helicopter emergency location transmitter had been activated immediately after the autorotation had been commenced, there was too little time before the landing for the signal to be detected. Had the helicopter remained afloat and upright, it was highly probable that the signal would have been detected. However, emergency flotation equipment was incompatible with this helicopter's usual agricultural role.

4.3.5 Nonetheless, if a forced landing appears likely, pilots should do as this one did and activate the emergency locator transmitter as soon as possible and, if time and circumstances permit, make an emergency radio call. Both distress alerts can be easily cancelled if the situation is resolved without needing further help.

4.3.6 The pilot experienced some disorientation before escaping from the inverted and submerged helicopter, which might have been lessened had he undertaken a course in helicopter underwater escape training. Although not a legal requirement, the potential benefit of such training – even for pilots of single-engine aeroplanes who frequently operate over water – is apparent.

Findings

The pilot operated over water without having a life jacket on board, contrary to Civil Aviation Rules. Not wearing a life jacket reduced his chances of survival.

The pilot's rescue was due to the fortuitous presence of witnesses on shore. Had he arranged flight-following and made a timely emergency radio call, his rescue might have been more assured even without witnesses.

4.4 Summary

4.4.1 The cause of the reported engine N2 reduction was not determined.

4.4.2 The fact that this and other accidents and incidents in New Zealand and overseas have resulted from apparent technical failures, of which some remain unresolved, highlights the need for robust systems to be in place to enhance the survivability of such events.

4.4.3 The pilot did not follow some required and recommended steps that would have increased his chances of survival in the event of an accident when operating over water. His rescue was greatly assisted by the accident being witnessed and by a favourable on-shore wind.

5. Findings

5.1. There was no evidence that any act or omission of the pilot contributed to the loss of engine performance.

5.2. No technical reason was found for the reported engine speed decrease.

5.3. The pilot operated over water without having a life jacket on board, contrary to Civil Aviation Rules. Not wearing a life jacket reduced his chances of survival.

5.4. The pilot's rescue was due to the fortuitous presence of witnesses on shore. Had he arranged flight-following and made a timely emergency radio call, his rescue might have been more assured even without witnesses.

6. Safety actions

General

6.1. The Commission classifies safety actions by 2 types:

(a) safety actions taken by the regulator or an operator to address safety issues identified by the Commission that would otherwise have resulted in the Commission issuing a recommendation; and

(b) safety actions taken by the regulator or an operator to address other safety issues that would not normally have resulted in the Commission issuing a safety recommendation.

6.2. No safety actions of either type were noted.

7. Recommendations

General

7.1. The Commission may issue, or give notice of, recommendations to any person or organisation that it considers the most appropriate to address the identified safety issues, depending on whether these safety issues are applicable to a single operator only or to the wider transport sector. In this case, no recommendations were made.

7.2. No safety recommendations have been identified due to this inquiry.

8. Key lessons

8.1. Pilots should have a flight-following arrangement or submit a flight plan for every flight to ensure that a search is started without delay should the flight become overdue.

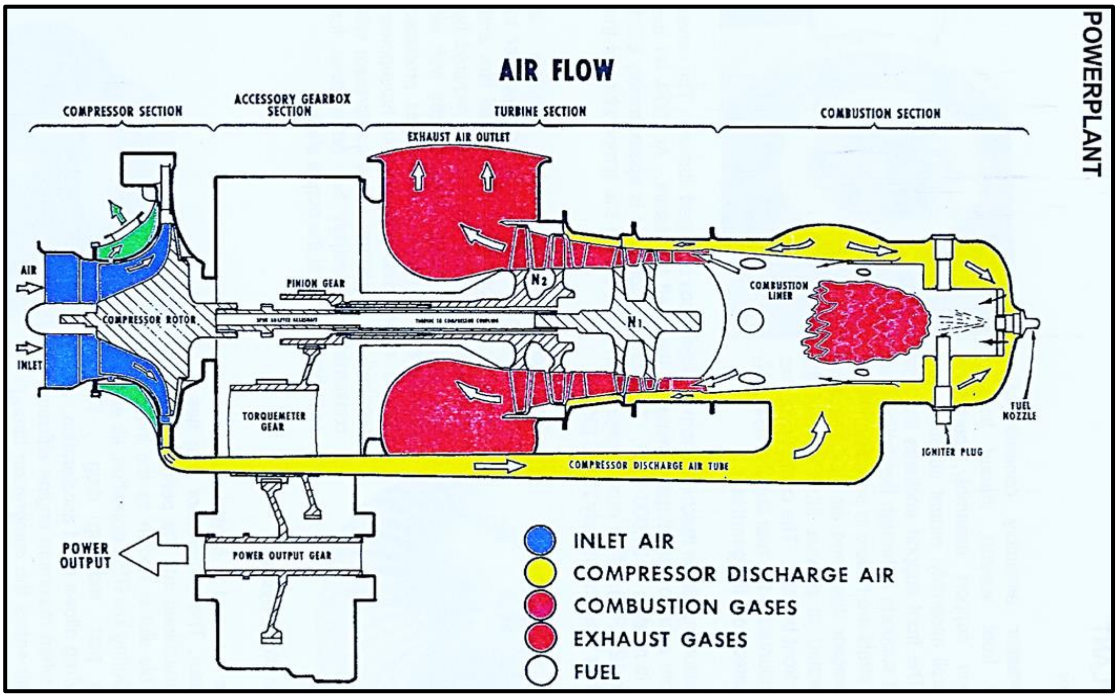
8.2. The occupants of single-engine aircraft operating at low level over water should wear, not just carry, life jackets when they plan to fly beyond gliding range of a suitable landing place.

8.3. When a forced landing appears likely, pilots should activate the emergency locator transmitter as soon as possible and make an emergency radio call.

8.4. Helicopter pilots who frequently operate over water should undertake helicopter underwater escape training.

Appendix: Rolls-Royce 250-C30P turbo-shaft engine description

The Rolls-Royce model 250-C30P engine used on the Bell 206L-3 helicopter is a turbo-shaft engine with an output of 650 shaft horsepower. The engine consists of the usual turbine engine sections of compressor, combustion, turbine and accessory gearbox and the associated engine accessories.



The compressor section consists of a single-stage centrifugal flow impeller, a diffuser scroll and a bleed valve. The bleed valve improves the engine acceleration during the start cycle and minimises the likelihood of a compressor stall. The bleed valve operation is automatically controlled by the compressor discharge pressure.

The centrifugal impeller provides compressed air to the diffuser scroll, which then directs the air into the compressor discharge air tubes that take it to the back of the engine. The compressed air is turned 180 degrees by the combustion outer case and enters the combustion liner. The fuel nozzle atomises the fuel and injects it into the combustion liner at the proper angle and spray pattern. The nozzle has an integral filter to further minimise the possibility of contamination.

The fuel spray is ignited and the hot combustion gases drive the turbine wheels. The turbine section consists of 2 "gas producer" turbine wheels (usually referred to by their rotational speed, N1) and 2 "power turbine" wheels (N2). The nominal 100% values of N1 and N2 are 51 000 RPM and 30 650 RPM respectively. This turbine design, with no mechanical connection between the N1 and N2 wheels, is known as a "free turbine". After the turbines have extracted the energy from the hot gas, it is discharged through an exhaust at the top of the engine.

There are 2 gear trains inside the accessory gearbox, driven independently by the N1 and the N2 wheels. The N1 drives the starter-generator, N1 tachometer-generator, oil pump, fuel pump and fuel control unit The N2 drives the power turbine governor, N2 tachometer-generator, torquemeter and output shaft to the main transmission that drives the main and tail rotors.

The principal engine fuel system controls are the fuel control unit and the power turbine governor. The fuel control unit and the power turbine governor between them sense N1, N2, throttle position and compressor discharge pressure to regulate the fuel flow to the engine according to the power demanded.

The fuel control unit is a pneumatic-mechanical device driven at a speed proportional to the N1. It has 3 positions: OFF, IDLE and MAX. After the engine has been started and the throttle is fully opened, the fuel control unit will be at the MAX setting. The amount of fuel then going to the engine is determined by the air pressure signal received by the fuel control unit from the power turbine governor. An abnormality in any of the pneumatic control lines can cause un-commanded increases or decreases in the fuel delivered to the combustor.

The engine power output is the N2, which is selected by the pilot using the power turbine governor increase/decrease switch, or "beep" switch, on the collective lever. The power required to sustain the selected N2 is maintained by the power turbine governor sending pneumatic signals to the fuel control unit to vary the fuel flow and hence the N1.

The engine controls also include the twist-grip throttle and the "droop compensator" in the collective lever system. These are mechanically linked to the fuel control unit and power turbine governor respectively. The beep switch controls a linear actuator that adjusts the linkage between the collective and the power turbine governor.

A defect with the power turbine governor in flight could affect the correct operation of the fuel control unit. For example, a power turbine governor underspeed failure would cause the N2 and main rotor RPM to decrease. In that case, the initial recovery action would be to lower the collective lever to maintain main rotor RPM and to attempt to fly level at the minimum power speed, which was approximately 60 knots for the Bell 206.

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