FINAL REPORT

AIC 12-1007

PAPUA NEW GUINEA
ACCIDENT INVESTIGATION COMMISSION
AIRCRAFT ACCIDENT REPORT

Hevilift Ltd
P2-HCY
Bell 206L-1/C30P
80 km north east of Kikori, Gulf Province
PAPUA NEW GUINEA
6 July 2012

The Papua New Guinea Accident Investigation Commission (AIC) was informed of the accident by PNG Airservices Ltd on 6 July 2012. Debris from the aircraft was found on 12 July 2012. The aircraft wreckage was located on 13 July 2012. No investigator from the AIC travelled to the accident site. The on-site investigation was conducted by members of the Australian Defence Force and personnel from the operator.

This Report, made publicly available on 19 September 2015 was produced by the AIC, PO Box 1709, Boroko NCD, Port Moresby, Papua New Guinea.

The report is based upon the investigation carried out to date, by the AIC with assistance from the Australian Transport Safety Bureau (ATSB), in accordance with Annex 13 to the Convention on International Civil Aviation, Papua New Guinea (PNG) Act, and Civil Aviation Rules.

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When the AIC makes recommendations as a result of its investigations or research, safety is its primary consideration. The AIC nevertheless recognizes that the implementation of recommendations arising from its investigations will in some cases incur a cost to the industry.

David INAU
CEO
Accident Investigation Commission

19 September 2015

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TERMINOLOGY USED IN THIS REPORT

Occurrence: accident or serious incident.

Safety factor: an event or condition that increases safety risk. It is something that, if it occurred in the future, would increase the likelihood of an occurrence, and/or the severity of the adverse consequences associated with an occurrence. Safety factors include the occurrence events (e.g. engine failure), individual actions (e.g. errors and violations), local conditions, current risk controls, and organisational influences.

Contributing safety factor: a safety factor that, had it not occurred or existed at the time of an occurrence, then either: (a) the occurrence would probably not have occurred; or (b) the adverse consequences associated with the occurrence would probably not have occurred or have been as serious, or (c) another contributing safety factor would probably not have occurred or existed.

Other factor: Other factors refers to safety deficiencies or concerns that are identified during the course of the investigation that while not causal to the accident, nevertheless should be addressed with the aim of accident prevention.

Safety issue: a safety factor that (a) can reasonably be regarded as having the potential to adversely affect the safety of future operations, and (b) is a characteristic of an organisation or a system, rather than a characteristic of a specific individual, or characteristic of an operational environment at a specific point in time.

Safety action: the steps taken or proposed to be taken by a person, organisation, or agency in response to a safety issue.

SYNOPSIS

Following an engine surge just before landing at a remote drill site in Gulf Province, maintenance and troubleshooting was carried out by a company engineer on a Bell B206L-1/C30P helicopter, registered P2-HCY (HCY). To rectify whatever had caused the engine surge, two fuel system components were changed at the same time: the fuel control unit and the power turbine governor. The cause of the engine surge was not isolated to one of the components; instead, after both components had been changed, the helicopter was test-run once and considered to be serviceable. The drill site had run out of Jet A-1 fuel, and it is possible the engineer and pilot did not carry out a test-run after each component was changed to save the fuel on board the helicopter; they may also have wanted to save time in the field and return quickly to the company's base at Mt Hagen, where more thorough checks could be undertaken.

Six minutes after HCY departed on the accident flight, a 'MAYDAY' broadcast was heard from HCY which included the words 'engine failure'. It was reported that the sound of the ENGINE OUT aural warning could be heard in the background of the MAYDAY broadcast. The helicopter's engine had stopped in flight and it crashed approximately 3 km north east of the departure point, fatally injuring all three on board. No signal was detected from the helicopter's emergency locator transmitter (ELT) and the wreckage was found 7 days after the accident following an extensive search.

Damage to the main rotors indicated that the rotor system had been in a very low rotational energy state at impact. Damage to the engine indicated its rotation had been consistent with a spool-down cycle at the time of impact. Detailed testing of the engine and fuel system found no pre-existing defects that would have prevented the engine and fuel system from operating as intended.

Three possible explanations for why the engine stopped in flight are considered in this report; they relate to fuel exhaustion and mechanical issues. The AIC was unable to discount any of them on the evidence available, and all three are regarded as possible explanations for the occurrence. However, evidence from the engine driven fuel pump gear set and carbon seals that rely on fuel for lubrication (showing them to be in good condition with no evidence of deficiencies) and reports of a strong smell of fuel downstream of the wreckage several days after the accident together shed doubt on the likelihood of fuel exhaustion being a contributing factor.

Remoteness from the operator's main base at Mt Hagen is probably, at least in part, why the reason for the engine surge was not established before the helicopter was returned to service. The fuel control unit and power turbine governor were both changed together, the helicopter appeared to be functioning properly, and the accident flight began – but it was still not known why the engine had surged the day before. This highlights a procedural deficiency: the helicopter was returned to service without a clear understanding of the malfunction that led to it being grounded. The Bell 206L-4 helicopter Flight Manual stated that a 'Helicopter should not be operated following any emergency/malfunction procedure or precautionary landing until cause of malfunction has been determined and corrective maintenance action taken.' While HCY was a Bell 206L-1/C30P, the AIC considers that this is prudent advice for any helicopter or aircraft. If this instruction had been followed it is possible the accident would not have occurred.

The AIC recognises the difficulties that remoteness poses for operators, engineers, and pilots when malfunctions occur far from well-equipped maintenance centres; nevertheless, the AIC recommends that operators should implement procedures to ensure that, wherever they are, aircraft are not returned to service unless corrective maintenance action has been taken on the basis of a full diagnosis of the cause of any malfunction.

1 FACTUAL INFORMATION

1.1 HISTORY OF THE FLIGHT

On 5 July 2012, a Bell Helicopter 206L-1/C30P, operated by Hevilift and registered P2-HCY (HCY), was operating from a remote drill site called 'Triceratops 2' (Figures 1 to 4) approximately 80 km north east of Kikori, Gulf Province and 135 km south east of Mt Hagen, Central Highlands Province. Triceratops 2 is approximately 2,000 ft above mean sea level (AMSL). After experiencing an engine surge within about 1 km of Triceratops 2, the pilot landed at the drill site.

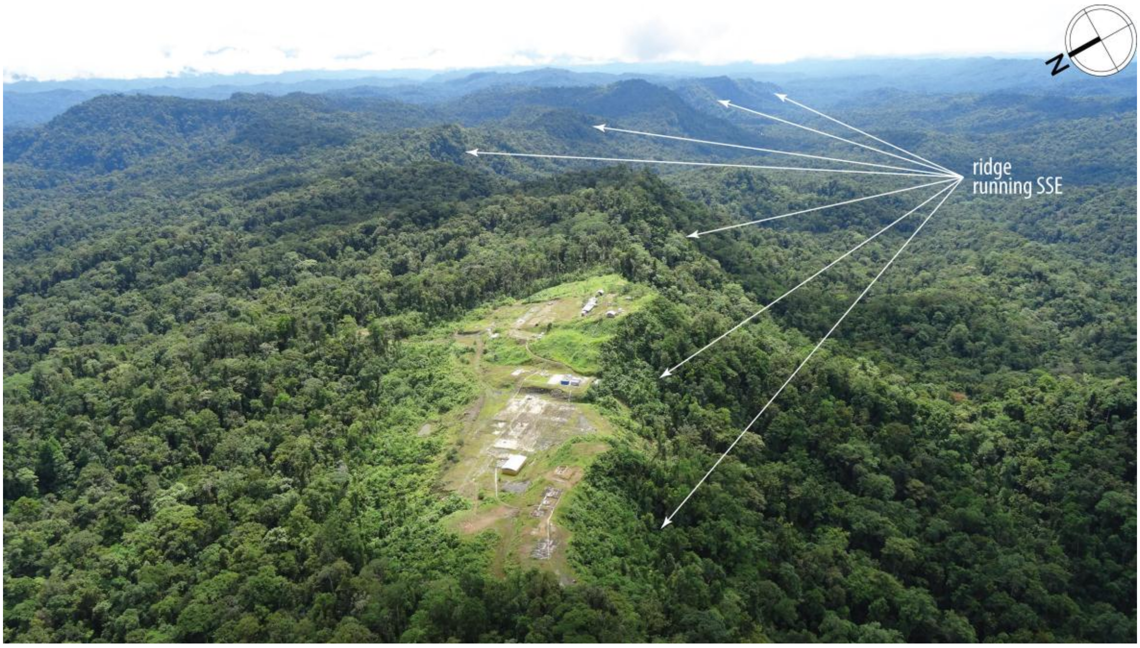

Figure 1: Triceratops 2 drill site, looking east south east along the ridge

The following day, the deputy chief pilot and a company engineer flew from Mt Hagen to Triceratops 2. They arrived in the late morning and the engineer then worked on HCY for approximately 2.5 hours during which he changed the fuel control unit and the fuel governor. Another company pilot (the 'other company pilot') who had been talking to the engineer while he worked on the helicopter noted [the engineer] 'replaced everything at once' i.e. he did not replace each component and then test-run the helicopter after each replacement.

The other company pilot recalled that he told the deputy chief pilot that there was no fuel at Triceratops 2 and that it was therefore necessary to refuel at Hou Creek (pronounced 'How Creek'; Figures 2 to 5), elevation 300 ft AMSL. He added that he had said to the deputy chief pilot 'you've still got over 300 lbs [on board HCY]' after which the deputy chief pilot switched on HCY's battery master to verify the fuel quantity indication himself.

When the fuel system component changes were finished, the deputy chief pilot test-ran HCY for approximately 40 min, both on the ground and in the hover above the landing pad, and then flew two circuits of Triceratops 2. The problem that had caused the engine surge was believed to have been resolved and the other company pilot recalled that the deputy chief pilot 'seemed perfectly happy with it [HCY]'.

Next, the deputy chief pilot was to fly HCY to Mt Hagen via Hou Creek for refuelling, taking as passengers the engineer who had come with him that morning from Mt Hagen, and the pilot who had experienced the surging during the previous day. He was also to take the fuel control unit (FCU) and power turbine governor (PTG) that the engineer removed from HCY to Mt Hagen. The flight from Triceratops 2 to Hou Creek would have taken approximately 15 min in HCY.

The other company pilot had been operating in the Triceratops 2 area during the day and was also about to fly to Hou Creek to refuel. Because he was familiar with the prevailing weather conditions, he advised the deputy chief pilot that the best way from Triceratops 2 to Hou Creek was 'past Bwata[1]' (Figure 2) rather than by the more direct route along the ridge line on which Triceratops 2 was located. This was because the weather on the south side of the ridge was 'getting fairly bad' with low cloud and heavy rain, while to the north of Bwata the weather was still 'fairly good'. The other company pilot said afterwards that 'there wasn't a weather problem as long as you didn't go [to] the [south] side of the ridge'. He recalled that he had said to the deputy chief pilot 'I'm going there now, follow me down' and that the deputy chief pilot, who knew the area, had replied 'OK, I'll be right behind you'.

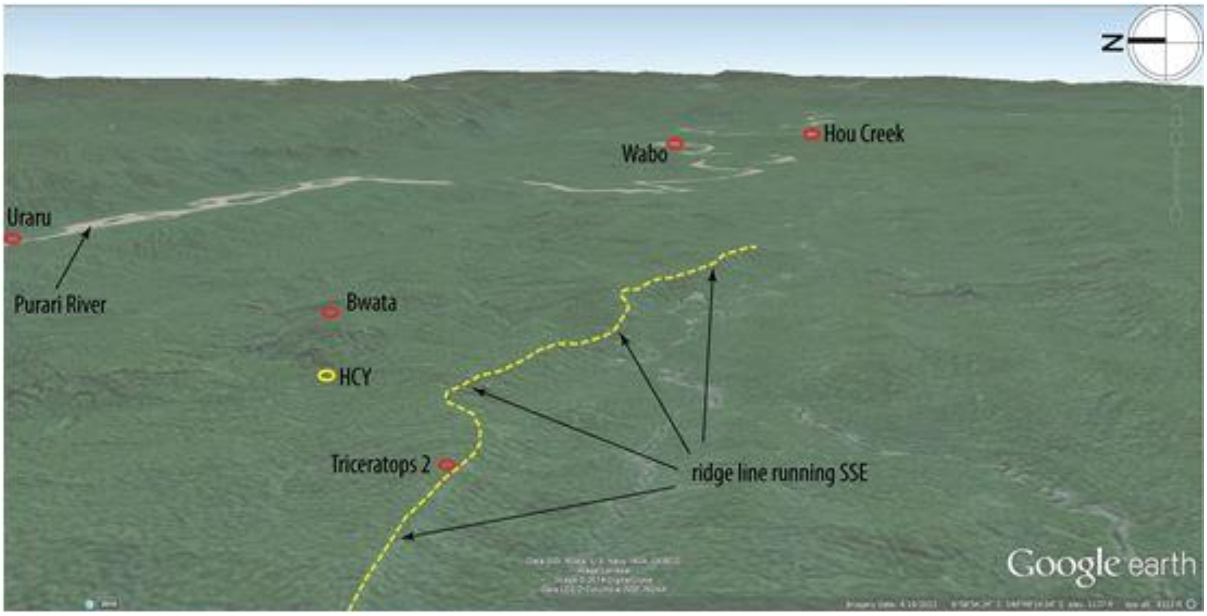

Figure 2: Area of the intended flight showing the ridge south of Triceratops 2 and Bwata

The other company pilot departed Triceratops 2 for Hou Creek at approximately 0510 UTC[2]. The deputy chief pilot departed Triceratops 2 for Hou Creek in HCY at 0520. At 0526 a MAYDAY broadcast from HCY was heard by the crews of other helicopters in the area, and by personnel on the ground at Triceratops 2 and Hou Creek.

It appears from the reports of several persons who heard the MAYDAY broadcast that it contained at least the following elements: 'MAYDAY MAYDAY MAYDAY', 'Hotel Charlie Yankee' [HCY], 'Bwata', 'engine failure'. The pilot of a Mil-8 helicopter who heard the distress broadcast while returning to Herd Base from Antelope 2 (Figure 3) reported hearing the 'ENGINE OUT' aural warning in the background during the transmission.

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[1] Bwata is another drill site in the same area as Triceratops 2.

[2] The 24-hour clock is used in this report to describe the local time of day, Local Mean Time (LMT), as particular events occurred. Local Mean Time was Coordinated Universal Time (UTC) + 10 hours.

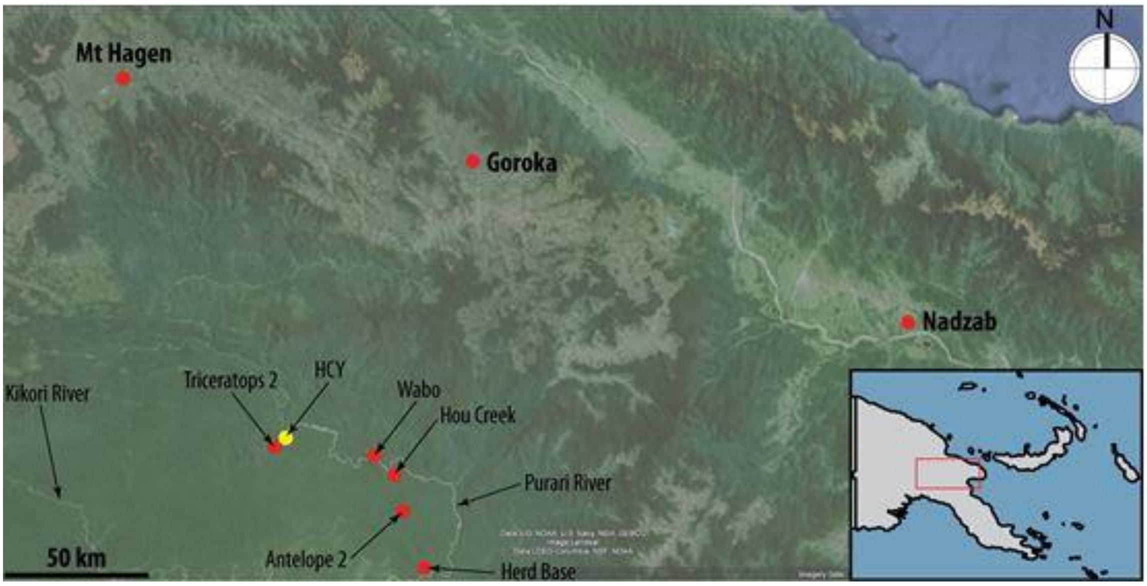

Figure 3: Area of the accident showing Mt Hagen, Triceratops 2, HCY, and Hou Creek

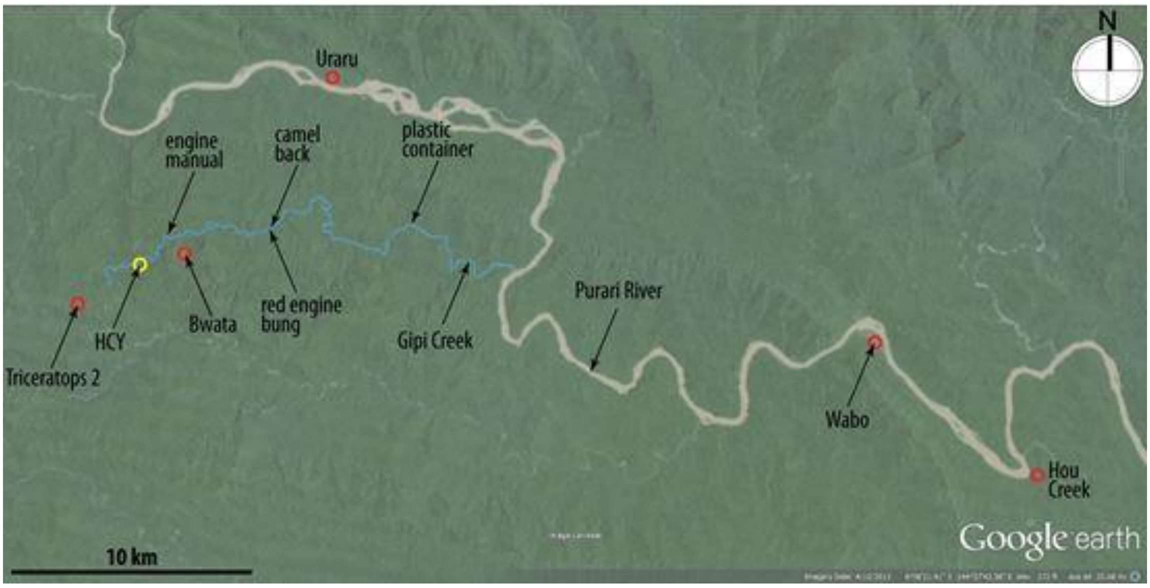

Figure 4: Area of the intended flight from Triceratops 2 to Hou Creek, with the location of items found downstream from the accident site

A large search effort involving numerous helicopters and fixed-wing aircraft was launched, but no signal was detected from HCY's emergency locator transmitter (ELT) making the search extremely difficult. No sign of HCY was found for several days. On 11 July 2012, the assistance of the local people was sought to search the waterways in the area. On 12 July 2012, items from HCY were found in Gipi Creek (Figure 4) by villagers from Uraru. Following these items progressively upstream led to the discovery of the wreckage of HCY in the early morning of 13 July 2012, when it was confirmed there were no survivors.

Figure 5: Hou Creek base on the Purari River

1.2 INJURIES TO PERSONS

Table 1: Injuries to persons

Injuries	Flight crew	Passengers	Total in aircraft	Others
Fatal	1	2	3	-
Serious	-	-	-	-
Minor	-	-	-	Not applicable
Nil injuries	-	-	-	Not applicable
TOTAL	1	2	3	-

The pilot was an Australian citizen. The other two occupants of the helicopter were also company employees; one was an Australian citizen and one was a New Zealand citizen.

1.3 DAMAGE TO AIRCRAFT

The helicopter was destroyed in the accident.

1.4 OTHER DAMAGE

The helicopter was destroyed during the impact with dense vegetation and subsequently the ground. There was no other damage reported to property or the environment.

1.5 PERSONNEL INFORMATION

1.5.1 Pilot in Command

Age : 50 years
Gender : male
Nationality : Australian
Type of licence : PNG Commercial Pilot Licence (Helicopter)
Licence number : P20258
Valid to : valid with medical certificate
Rating : single-engine: BH407, R22, AS350, BH206; multi-engine: BH212, BH412
Total flying time : 13,037 hours (25 May 2012)
Total on this type : 5,375 hours (25 May 2012)
Total last 90 days : 2.9 hours in April 2012; (May and June not known)
Total on type last 90 days : 2.7 hours in April 2012; (May and June not known)
Total last 7 days : flight and duty record not in company file
Total on type last 7 days : flight and duty record not in company file
Total last 24 hours : flight and duty record not in company file
Total on the type last 24 hours : flight and duty record not in company file
Last recurrent training : 10 May 2012
Last proficiency check : 10 May 2012
Last line check : 26 December 2011
Medical class : Class 1
Valid to : 14 August 2012
Medical limitation : prescription lenses required for reading

1.6 AIRCRAFT INFORMATION

The Bell Helicopter 206L-1/C30P ‘LongRanger’ was a single turboshaft[3] engine, seven-seat helicopter, with a two-blade main rotor and two-blade tail rotor system. HCY had been upgraded from the original Rolls-Royce Corporation 250 C28 turboshaft engine, to the Rolls-Royce Corporation 250-C30P turboshaft engine.

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[3] Gas turbine engine typically used in a helicopter.

1.6.1 Aircraft data

Aircraft manufacturer	: Bell Helicopter
Model	: 206L-1/C30P
Serial number	: 45333
Date of manufacture	: October 1979
Nationality and registration mark	: PNG, P2-HCY
Name of owner	: Hevilift Ltd
Name of operator	: Hevilift Ltd
Certificate of Airworthiness	: issued 9 August 2011
Certificate of Registration	: issued 8 August 2011
Total hours since new	: 16,329.4 hours (to 5 July 2012)
Total cycles since new	: 15,141 cycles
Total hours since overhaul	: not applicable
Total cycles since overhaul	: not applicable
Total hours since last inspection	: 51.5 hours (29 April 2012)
Total cycles since last inspection	: 386 cycles

1.6.2 Engine data

Engine Type	: Turboshaft
Manufacturer	: Rolls-Royce Corporation
Model	: 250-C30P
Serial number	: CAE890272
Total time since new	: 13,826.25 hours (to 5 July 2012)
Time since last inspection (150 hourly inspection)	: 38.85 hours

1.6.3 Airworthiness and maintenance

The purpose of the maintenance visit to Triceratops 2 was to troubleshoot HCY’s engine and the low rotor revolutions per minute (RRPM) audio alarm. The audio alarm was considered to be a commonly occurring problem relating to water ingress into the audio control box.

The pilot of HCY reported to the operator on 5 July 2012 (the day before the accident) that while accelerating the engine and rotor system up to flight RRPM it would initially reduce then increase in speed rather than accelerate smoothly. When in the cruise at 50 knots, the RRPM would decay and then, if power was reduced, the RRPM would recover to flight RRPM. During the troubleshooting and maintenance at Triceratops 2, the fuel control unit (FCU) and power turbine governor (PTG) were changed. It was confirmed that the serial numbers for these units differed between the aircraft log book and the components on the aircraft, indicating that these items had been changed (because the logbooks had not been updated by the time of the accident).

1.6.4 Fuel system

A detailed description of the Bell 206L-1 fuel system is at appendix 5.1.

1.6.5 Fuel information

HCY had been refuelled with Jet-A1 from Hou Creek in the days before the accident. Other helicopters had also been refuelled from the same source at Hou Creek with no reported fuel-related problems.

A small quantity of fuel (approximately 150 mL) from the wreckage of HCY was recovered from the airframe fuel filter in a glass jar, but the size of the sample was too small for any meaningful test to be conducted. The AIC does not consider fuel quality to have been a factor in the development of the accident.

The quantity of fuel on board HCY when it departed Triceratops 2 on the accident flight is not known; however, the other company pilot who was at Triceratops 2 while the engineer worked on HCY and who departed Triceratops 2 for Hou Creek approximately 10 minutes prior to HCY's departure, discussed his recollections with the AIC as follows. On the early afternoon of 5 July 2012 (the day before the accident) he had looked at the instrument panel of HCY after it was on the ground following the engine surge. He recalled that the fuel gauge reading had been '340-odd lbs'. He recalled that he had said to the deputy chief pilot 'you've still got over 300 lbs [on board HCY]', and that the deputy chief pilot had then switched on HCY's battery master to verify the fuel quantity indication himself.

After the fuel system component changes to HCY, the other company pilot reported that the deputy chief pilot ran the helicopter for approximately 40 minutes, both on the ground and in the hover above the landing pad, and then flew two circuits of Triceratops 2.

The other company pilot reported that, when he departed Triceratops 2 for Hou Creek on the day of the accident approximately 10 minutes before HCY, the engine of HCY was running while the deputy chief pilot waited for the third occupant of HCY to collect his belongings from the camp and board the helicopter. How long the engine was running in this manner before HCY departed is not known, but it must have been at least 10 minutes.

Ground-running to test the helicopter's fuel and related systems following the fuel system component changes would have involved power settings between idle and 100% with the main rotor in flat pitch. Fuel burn during ground running is estimated to have been in the range 160 lbs/hr to 180 lbs/hr; fuel burn during hovering and flight is estimated to have been in the range of 230 lbs/hr to 250 lbs/hr. These figures are 'rules-of-thumb' reported by pilots of Bell B206L-1/C30/P for operations in the Triceratops 2 and similar areas in PNG; see also the Fuel flow vs airspeed chart in the Appendix 5.2.

The calculations in tables 3 and 4 below are based on: witness testimony of fuel on board HCY before ground-running began, witness testimony of ground-running, hovering, and circuit flying around Triceratops 2, and the fuel burn ranges given above. On the basis of this information, HCY may have had between 198 lbs and 212 lbs of fuel on board at the time of the accident.

Table 2: Estimate of fuel on board HCY (lower estimated fuel burns)

event	lower estimated fuel burn (lbs/hr)	estimate of fuel burned (lbs)	fuel remaining (lbs)
End of the flight on 5 July 2012 during which the surge occurred	--	--	340
Estimated 25 minutes ground running, between idle and 100% flat pitch	160	67	273
Estimated 5 minutes in the hover above the landing pad	230	19	254
2x circuits of Triceratops 2 drill site = 5 minutes estimated flight time	230	19	235
10 minutes at idle waiting for third person to board			
6 minutes flight time (accident flight)	230	23	<u>212</u>

Table 3: Estimate of fuel on board HCY (higher estimated fuel burns)

event	higher estimated fuel burn (lbs/hr)	estimate of fuel burned (lbs)	fuel remaining (lbs)
End of the flight on 5 July 2012 during which the surge occurred	--	--	340
Estimated 25 minutes ground running, between idle and 100% flat pitch	180	75	265
Estimated 5 minutes in the hover above the landing pad	250	21	244
2x circuits of Triceratops 2 drill site = 5 minutes estimated flight time	250	21	223
10 minutes at idle waiting for third person to board			
6 minutes flight time (accident flight)	250	25	<u>198</u>

Further fuel-related evidence came from witnesses involved in the search for the wreckage in Gipi Creek. The pilot of a Bell B407, who was flying up Gipi Creek searching for additional items from HCY once the white box that held the flyaway kit had been found by villagers from Uraru, recalled that

> '… it wasn't long before we could smell jet fuel. It was quite a strong smell, not just a hint, and as it turns out we were still a few km from the crash site.'

> ‘Below the old Bwata rig site (Triceratops 1) we saw what looked like a red tie down stuck on a rock in the creek. The area was large enough for us to land nearby and one of our passengers was able to retrieve the item. It turned out to be [an] orange camel back. […] Once this was brought back to the helicopter it was unmistakably soaked in Jet-A1.’
>
> ‘We could smell fuel over such a large length of creek that there was no doubt that fuel had been or was currently running into the creek.’

The loadmaster from the Bell B407 recalled that when he went into the creek to retrieve various items from HCY

> ‘the banks [of the creek] were steep, and the smell of Jet-A1 was overpowering’.

He said that the crew of an Australian Army Blackhawk helicopter involved in the search had lowered someone into the creek on the previous day (11 July 2012) and that they had also reported ‘a very strong smell of fuel’.

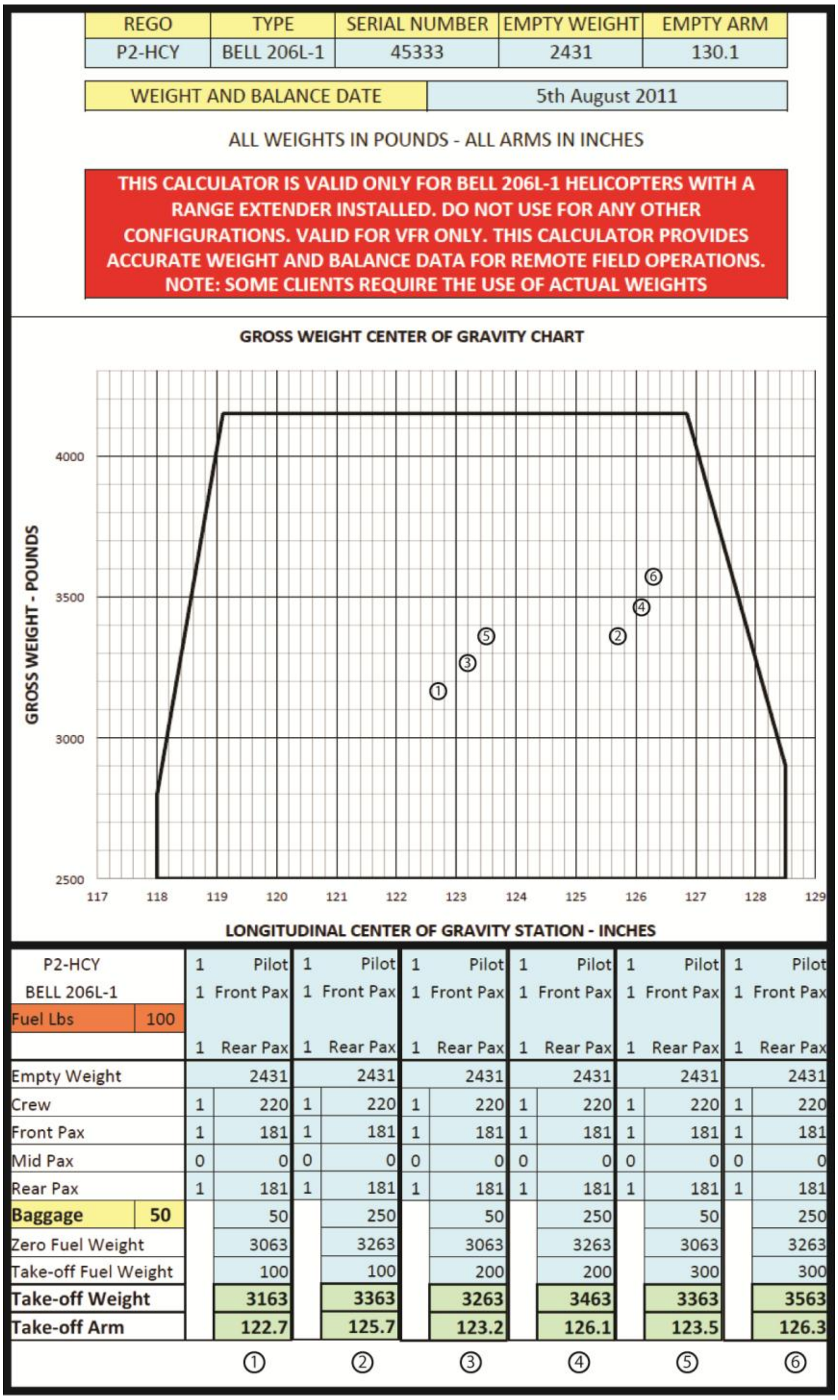
The AIC was not able to reconcile this witness evidence with the fact that it rained heavily several times in the area in the time between the accident on 6 July 2012 and when the wreckage was found in the early morning of 13 July 2012. During this time, the wreckage of HCY and Gipi Creek itself – and any jet fuel in them – would have been well-flushed several times by the elevated flows in the creek.

1.6.6 Weight and balance data

It is not known exactly how much baggage/cargo was on board HCY, nor exactly how much fuel was on board. However, using ranges for the baggage/cargo and fuel figures, the B206L-1 Standard Load and Trim Calculator showed the helicopter would have been within its permitted flight envelope (Figure 6) during the accident flight on the basis of the weights in Table 2.

Table 4: Estimate of weight of pilot, passengers, cargo, and fuel

pilot	220 lbs
front passenger	181 lbs
rear passenger	181 lbs
baggage/cargo	50 – 250 lbs
fuel	100 – 300 lbs
total	**732 – 1132 lbs**



REGO	TYPE	SERIAL NUMBER	EMPTY WEIGHT	EMPTY ARM
P2-HCY	BELL 206L-1	45333	2431	130.1

WEIGHT AND BALANCE DATE	5th August 2011

ALL WEIGHTS IN POUNDS - ALL ARMS IN INCHES

THIS CALCULATOR IS VALID ONLY FOR BELL 206L-1 HELICOPTERS WITH A RANGE EXTENDER INSTALLED. DO NOT USE FOR ANY OTHER CONFIGURATIONS. VALID FOR VFR ONLY. THIS CALCULATOR PROVIDES ACCURATE WEIGHT AND BALANCE DATA FOR REMOTE FIELD OPERATIONS. NOTE: SOME CLIENTS REQUIRE THE USE OF ACTUAL WEIGHTS

P2-HCY		1	Pilot	1	Pilot	1	Pilot	1	Pilot	1	Pilot	1	Pilot
BELL 206L-1		1	Front Pax	1	Front Pax	1	Front Pax	1	Front Pax	1	Front Pax	1	Front Pax
Fuel Lbs	100												
		1	Rear Pax	1	Rear Pax	1	Rear Pax	1	Rear Pax	1	Rear Pax	1	Rear Pax
Empty Weight			2431		2431		2431		2431		2431		2431
Crew		1	220	1	220	1	220	1	220	1	220	1	220
Front Pax		1	181	1	181	1	181	1	181	1	181	1	181
Mid Pax		0	0	0	0	0	0	0	0	0	0	0	0
Rear Pax		1	181	1	181	1	181	1	181	1	181	1	181
Baggage	**50**		50		250		50		250		50		250
Zero Fuel Weight			3063		3263		3063		3263		3063		3263
Take-off Fuel Weight			100		100		200		200		300		300
Take-off Weight			**3163**		**3363**		**3263**		**3463**		**3363**		**3563**
Take-off Arm			**122.7**		**125.7**		**123.2**		**126.1**		**123.5**		**126.3**
			①		②		③		④		⑤		⑥

Figure 6: Estimate of weight and balance on the accident flight. Hevilift Ltd weight & balance chart for Bell 206L-1 helicopters.

Although the fuel quantity on board HCY when it departed on the accident flight is not known, the calculations in Section 1.6.5. *Fuel information* below suggest that it may have been approximately 200 lbs. On this basis, the range 100 lbs to 300 lbs of fuel has been considered for the purpose of these weight-and-balance calculations.

1.6.7 Caution and warning panel

The caution and warning panel was mounted just below the glare shield across the top of the instrument panel. Individual lights, either amber or red, illuminate to provide the pilot with a visual cautions/warnings related to the status of helicopter systems (Figure 7).

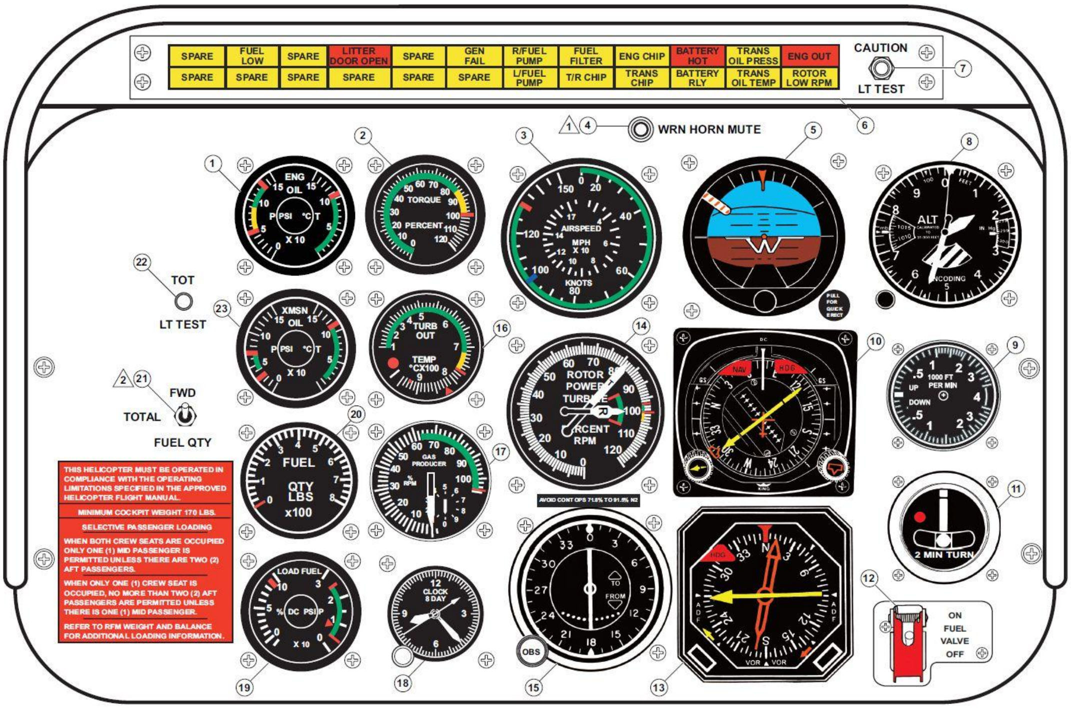


Figure 7: Caution warning panel mounted above the instrument panel

Source: Bell Helicopter

1.6.8 N1 tacho-generator

The N1 tacho-generator supplies signal (electrical current) to the N1 gauge and to the ENGINE OUT warning system (aural warning and caution warning panel light).

1.6.9 Emergency locator transmitter

This section sourced from ATSB Engineering Group Report AE-2012-094

The aircraft was fitted with an Airtex C406N-HM 406 MHz emergency locator transmitter (ELT) and two of the persons on board were each carrying a personal locator beacon (PLB). No satellite detections were received from the ELT nor from the two PLBs by the Australian Search and Rescue (AusSAR) Rescue Coordination Centre in Australia.

The antenna for the helicopter ELT was found to have been separated from its base, probably as a result of the impact sequence. The battery for the ELT was tested and found to be at a low voltage value. This was most likely due to the extended operation of the unit following the impact. The ELT battery was due for replacement in August 2016.

The ELT switch on the instrument was identified as being in the ARM position in the initial on-site Australian Army photographs, however, due to the dynamics of the accident, its position prior to impact could not be determined (Figure 8). Neither of the two PLBs was found at the accident site, and neither could be found in the wreckage after it was moved to Port Moresby.

Figure 8: ELT switch in the ARM position

Source: Australian Army

1.6.10 Engine out warning system and rotor low RPM warning system

The caution and warning system included the caution and warning panel, engine RPM sensor and warning horn, rotor low RPM sensor and warning horn, associated components, and interconnecting wiring.

Engine out warning system. The ENGINE OUT warning system provided simultaneous visual and audible indications of an engine out condition. The warning was triggered by the engine RPM sensor closing when the gas producer RPM (N_1) dropped below 55% ± 3%, activating the ENG OUT warning light on the caution panel an intermittent audio signal.

Rotor low RPM system. The ROTOR LOW RPM warning system provided simultaneous visual and audible indications of a low rotor RPM condition. If the NR sensor detects the rotor RPM decelerating below 90% ± 3% (Ng), regardless of the collective position, the rotor low RPM system would activate causing the ROTOR LOW RPM light on the caution panel to illuminate and a steady audio signal to be produced.

1.6.11 Starter-generator

A starter generator is an electrical motor that uses the helicopter’s battery power to start the engine. During normal engine operation it acts as an electrical generator, charging the battery and powering the helicopter’s electrical systems.

1.7 METEOROLOGICAL INFORMATION

The weather forecast issued by the Bureau of Meteorology for all areas of PNG valid from 0300 local time on 6 July 2012 to 1500 local time on 7 July 2012 was for areas of thunderstorms, rain, and drizzle, with severe turbulence in the vicinity of cumulonimbus clouds and other moderate turbulence.

Cloud was forecast to be isolated cumulonimbus cloud with bases at 1,800 ft and tops up to 45,000 ft; 5 to 7 oktas[4] of stratus cloud with bases at 800 ft and tops up to 3,000 ft in rain; 3 to 4 oktas of cumulus cloud with bases at 1,500 ft and tops up to 15,000 ft; 3 to 4 oktas of stratocumulus cloud with bases at 2,500 ft and tops up to 8,000 ft in rain; 3 to 4 oktas of altocumulus/altostratus with bases at 12,000 ft and tops up to 18,000 ft in cumulonimbus.

Visibility was forecast to be 500 m in fog, 3,000 m in thunderstorms, rain, and drizzle, and 8,000 m in showers and rain.

The AIC was unable to obtain forecast weather information more specific to the area in which the accident occurred.

Pilots operating in the vicinity of Triceratops 2 and in the vicinity of Antelope 2 and Herd Base (Figure 3) on the afternoon of 6 July 2012 described the weather at the time. The pilot who departed Triceratops 2 shortly before HCY and who had operated in the area during the day reported that the weather on the south east side of the ridge from Triceratops 2 was ‘getting bad’ with low cloud and fairly heavy rain, and with the top of the ridge in cloud, while on the north side of the ridge the weather remained ‘fairly good’. He stated that there was no problem with the weather conditions as long as one remained to the north of the ridge.

A Mil-8 helicopter pilot operating from Herd Base said that in the morning the weather had been ‘good’. He had made several flights into Antelope 2 and reported that at the time he heard the MAYDAY broadcast from HCY he was returning to Herd Base because the weather was ‘getting very bad’.

1.8 AIDS TO NAVIGATION

There were no ground-based navigation aids in the area, and ground-based and on-board navigation aids and their serviceability were not considered to have been factors in the development of this occurrence.

The helicopter was fitted with a Garmin AERA 500 portable global positioning system (GPS) which Hevilift personnel reported they searched for at the accident site, although it was never found. It was probably flung from the helicopter during the impact sequence.

1.9 COMMUNICATIONS

The helicopter was fitted with two Bendix/King KY196A VHF radios, one TFM-138 VHF FM radio, and one Codan 2000 HF radio.

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[4] In meteorology, an okta is a unit of measurement used to describe the amount of cloud cover. Sky conditions are estimated in terms of how many eighths of the sky are covered in cloud, ranging from 0 oktas (completely clear sky) through to 8 oktas (completely overcast).

1.9.1 Comprehension of the nature of the distress call

The AIC was not aware of any audio recordings of the MAYDAY broadcast from HCY. The pilots who reported hearing the MAYDAY understood at once what it signified. This was not the case with the majority of the ground-based staff at Triceratops 2 and Hou Creek who heard the transmission. Most were non-aviation staff who did not understand what the word ‘MAYDAY’ meant in a transmission from an aircraft. Some of them thought it was a joke transmission, while others had dismissed it as unimportant when they brought it to the attention of colleagues.

1.10 AERODROME INFORMATION

The accident flight departed Triceratops 2 (Figure 1) for Hou Creek (Figure 5), both of which were suitable for helicopter access only.

1.11 FLIGHT RECORDERS

HCY was not fitted with a flight data recorder or cockpit voice recorder. Neither recorder was required by current PNG aviation Civil Aviation Rules.

The GPS might have contained information about the track flown on the accident flight. Although it was searched for at the accident site, it was never found.

Some company aircraft were fitted with the SkyTrak[5] system, but HCY had not yet been fitted with SkyTrak at the time of the accident.

1.12 WRECKAGE AND IMPACT INFORMATION

1.12.1 General description of the wreckage

The AIC did not attend the accident site. Images of the accident site and wreckage were provided to the AIC by the Australian Army. Significant vertical impact forces had severely disrupted the helicopter’s structure when it impacted with boulders on the creek bed (Figure 9).

1.12.2 Impact sequence and distribution of the wreckage

The Australian Army images indicated that the helicopter descended through the dense jungle tree canopy, then continued a vertical descent of about 100 ft to the rocky creek. Between the time of the accident and the time the wreckage was recovered from the creek, there had been several heavy rains, and the water in the creek had flowed over and through the wreckage.

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[5] A system that tracks aircraft in real time and relays their location to operators etc.

Figure 9: Wreckage of HCY
Source: Australian Army

Some items of special interest to the investigation, such as the canopy-mounted GPS unit, the power turbine governor (PTG) and fuel control unit (FCU) (that had been removed during the maintenance at Triceratops 2 and were being taken to Mt Hagen on HCY), and the cockpit caution and warning panel, were not found after the accident. The FCU removed from HCY at Triceratops 2 by the engineer was found about seven weeks after the wreckage was first located, but this discovery was unknown to the AIC until much later and therefore was not tested in Australia with the FCU from the wreckage.

Figure 10: HCY instrument panel at the accident site
Source: Australian Army

In some of the photographs of the wreckage, the caution and warning panel was visible hanging from the instrument panel by its wiring (Figure 10, left image, caution and warning panel outlined in yellow). In photographs taken a few minutes later[6], the wiring appeared to have been cut and the caution and warning panel was gone (Figure 10, right image, yellow circle shows the cut end of the caution and warning panel's wiring).

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[6] Times derived from the digital photo image time 'stamp'.

The AIC was unable to establish what happened to the caution and warning panel despite extensive questioning of parties who were present at the accident site at the time.

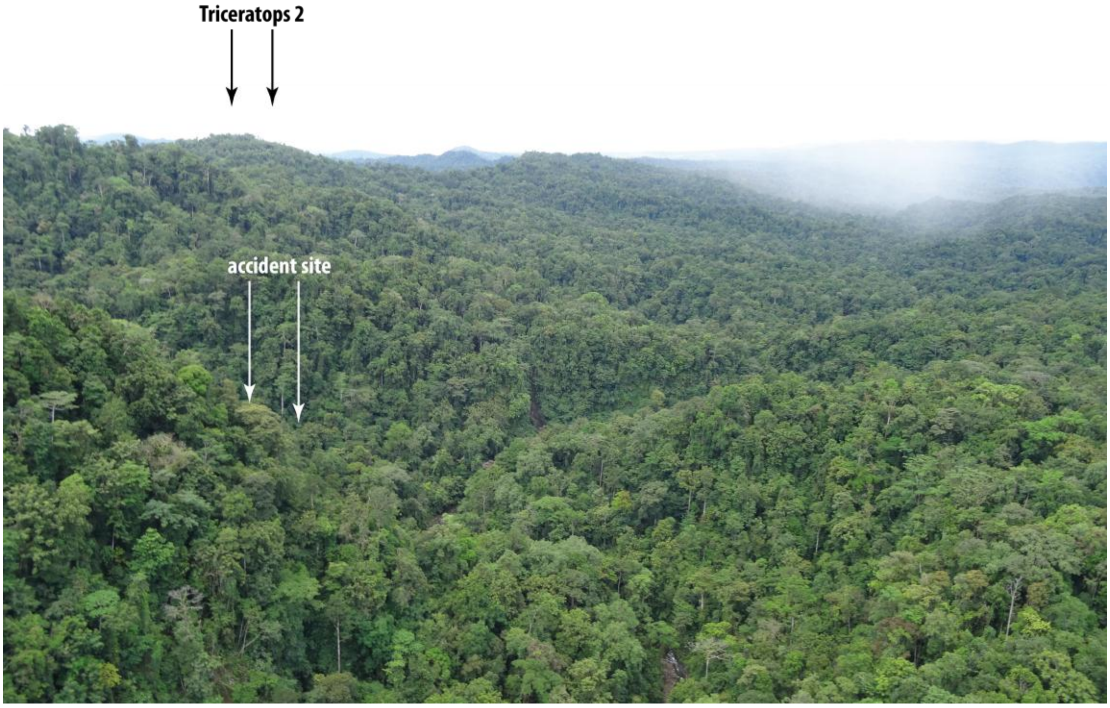

Figure 11: Aerial view of the accident site area, looking west; the Triceratops 2 drill site is behind the ridge in the middle distance

1.12.3 General Information

The wreckage of HCY was removed from the accident location and was transported to Port Moresby for examination by the AIC, the ATSB, and representatives of the helicopter and engine manufacturers. On arrival, the wreckage was removed from the shipping container and cleaned with high pressure water before being stored in the Papua New Guinea Defence Force (PNGDF) hangar at Jacksons Airport, Port Moresby. The examination commenced once the wreckage was established in the PNGDF hangar. The caution and warning panel was not found amongst the wreckage recovered to Port Moresby.

1.12.4 Airframe

The airframe had been severely disrupted and had been broken into several sections as a result of the collision with terrain. The principal separated structures were the rear section of the main cabin, the transmission deck and roof, the tail boom, and the nose section. The majority of the crushing-type damage to the airframe was through the vertical axis.

1.12.5 Main and tail rotor systems

1.12.5.1 *Main rotor system*

This section sourced from ATSB Engineering Group Report AE-2012-094

The helicopter was fitted with a 2-blade main rotor system. The main rotor mast nut was identified as being installed and locked. The main rotor pitch links had both failed as a result of bending overstress. Both of the main rotor blades had fractured outboard of the blade root doubler fingers (Figure 12).

Figure 12: Main rotor blade roots

Source: ATSB

The significant majority of all the observable damage sustained by the two main rotor blades was consistent with gross bending and blade flail at the time of impact with terrain. The absence of blade spar fracturing and leading edge impacts was consistent with the rotor system having a very low rotational energy state at that time (Figure 13).

The coning-up action of the main rotor blades that occurs when the main rotor system is rotating under low rotational energy can leave a permanent upward bend deformation in the blade. If a pitch link fails, the blade is free to rotate about its feathering axis[7] and therefore to bend in the opposite direction. The main rotor blades were bent in opposite directions.

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[7] The straight-line axis between the root of the blade and its tip about which the blade can alter its blade angle.

The blades showed the characteristics of having stopped rotating altogether within a very short time after the first physical contact with terrain, and the blade root separations showed little evidence of the in-plane directional deformation expected if the rotor was being positively driven with torque from the engine and transmission.

Figure 13: Main rotor blade deformation upward and downward respectively

Source: ATSB

The main rotor transmission remained attached to its suspension nodal-beam system, and this remained attached to the cabin roof and box-beam structure. Drive integrity through the transmission was confirmed from the input coupling to the mast. The filter, magnetic chip detectors for the transmission, mast and freewheel unit were examined and found to be free of metallic debris. The free-wheel unit was confirmed to be capable of normal operation. The engine-to-transmission KAflex drive shaft had failed at the engine/freewheel unit coupling although the forward coupling remained intact. Rotational scoring was observed on the KAflex driveshaft where it passed through the engine firewall. This was most likely due to the movement of the transmission while the main rotor RPM decreased and the main rotor blades impacted terrain. The KAflex shaft also had a large dent where it ran above the transmission restraint (Figure 14). The dent had fore-aft scoring, indicating that the driveshaft was not rotating at the time of the dent formation, which was most likely at the time of impact with the creek bed.

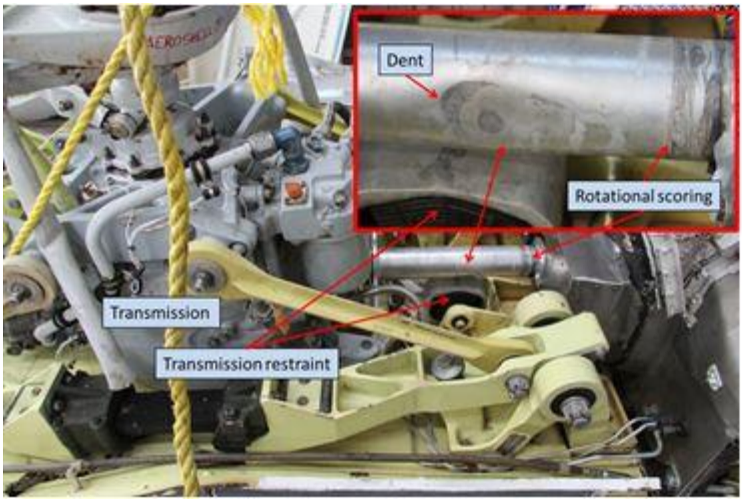

Figure 14: Engine to transmission KAflex driveshaft

Source: ATSB

The main rotor mast was examined around the main rotor head static stop contact area. No evidence of excessive static stop contact or mast bending (mast bump) on the main rotor mast was observed, and only paint deformation consistent with normal static contact was visible (Figure 15).

The main rotor mast had been bent at the base of the mast, in the swashplate support area (Figure 16). The swashplate support had fractured as a result of overstress at the lower radius, most likely as a result of the mast deformation. The deformation in the lower part of the mast was most likely as a result of the impact with terrain.

Figure 15: Static stop contact area on either side of the main rotor mast

Source: ATSB

Figure 16: Fractured swashplate support

Source: ATSB

1.12.5.2 *Tail rotor system*

This section from ATSB Engineering Group Report AE-2012-094

The helicopter was fitted with a 2-blade tail rotor system. One of the tail rotor blades had separated just outboard of its root end doubler as a result of overstress, and was located with the main wreckage. Wood fibres had been forced into the exposed blade root end, between the outer skin and its honeycomb core (Figure 17). Both tail rotor blades displayed compression from their tips towards their root ends (Figures 18 and 19). The leading edges of the blades were unremarkable, with no impact damage evident.

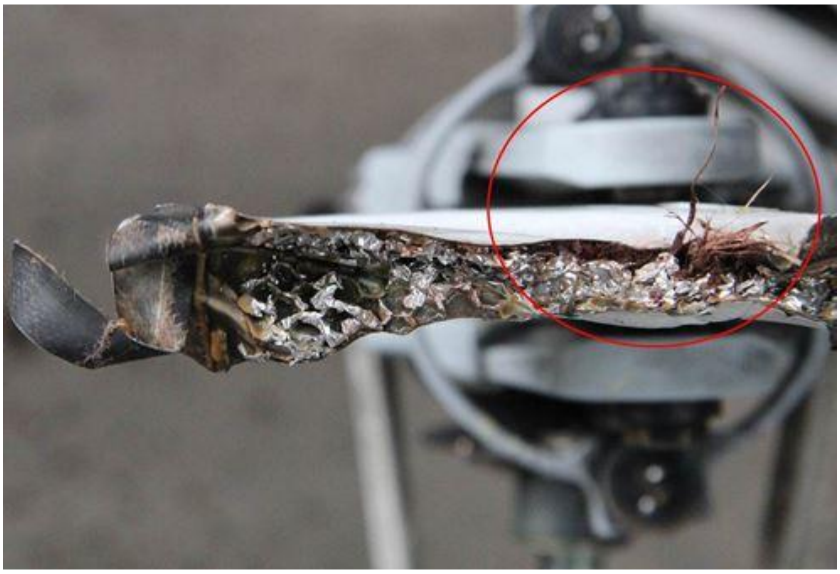

Figure 17: Tail rotor blade root with wood fibres in the fracture surface

Source: ATSB

There was a lack of in-plane directional deformation, unlike what would be expected if the rotor was being positively driven with torque from the engine and tail rotor gearbox. Continuity of the drive was confirmed through the tail rotor gearbox, and the magnetic chip detector for the tail rotor gearbox was examined and found to be free of metallic debris.

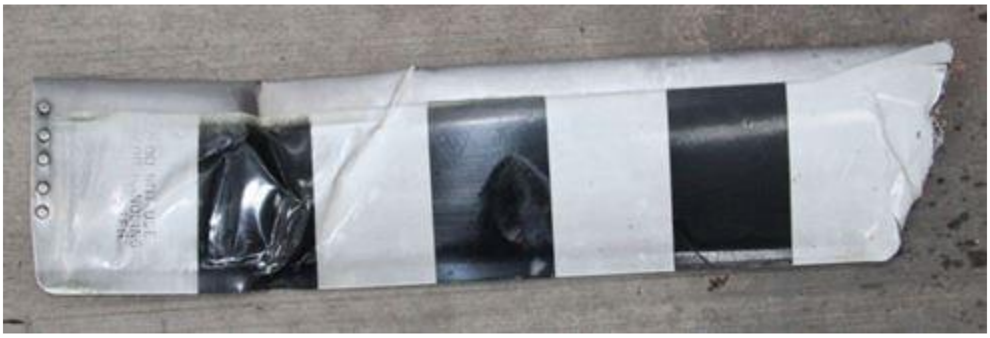

Figure 18: Tail rotor blade displaying a compression load from tip to root

Source: ATSB

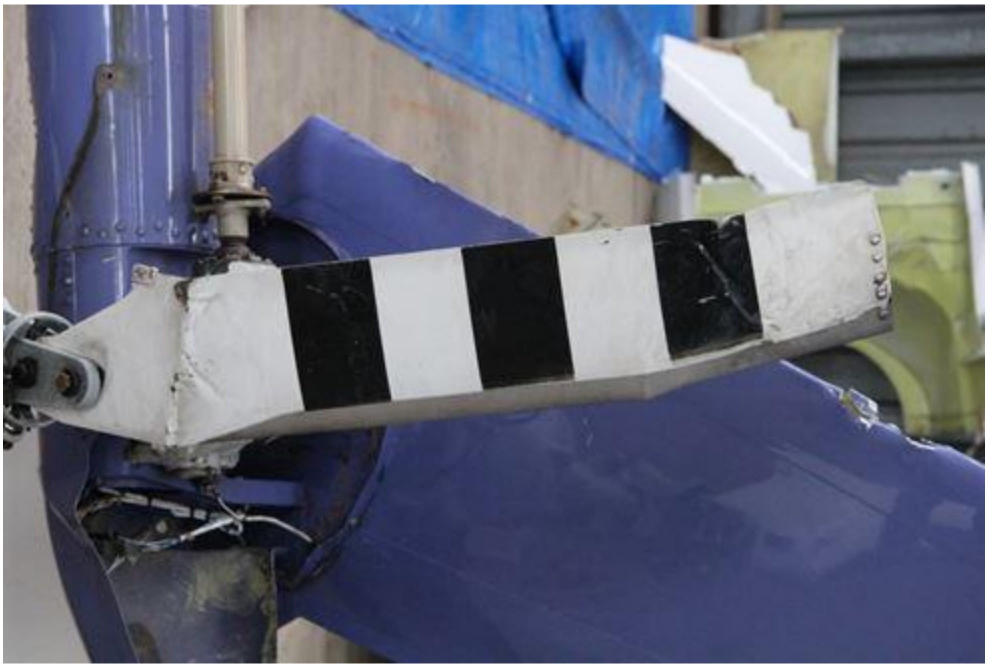

Figure 19: Fractured and compressed tail rotor blade

Source: ATSB

The rear three tail rotor driveshaft segments, associated hangers, and flexible couplings were all intact and displayed minimal damage (Figure 20). The forward driveshaft segment had been broken away from the forward hanger and rear flange.

Figure 20: Tail rotor driveshaft segments

Source: ATSB

The flexible couplings (flex plates) indicated axial distortion, but no torsional distortion was identified (Figure 21). The tail rotor drive shaft had been pulled vertically through the tail rotor driveshaft cover. The lack of torsional damage to the flexible driveshaft couplings was consistent with minimal torque being provided by the engine and main rotor transmission to the tail rotor drive shaft at the time of impact.

Figure 21: Flex plates

Source: ATSB

The tail rotor gearbox could be rotated smoothly and freely. The magnetic chip detector was examined and found to be free of metal debris.

1.12.6 Flight controls

This section from ATSB Engineering Group Report AE-2012-094

The flight control system was inspected from the main rotor head through to the cockpit, as well as from the tail rotor to the cockpit. All control rods were found to be connected correctly and split-pinned as required. Of the control rods that had separated, two separation modes were identified. They had either fractured as a result of overstress or had been cut, most likely as a result of the recovery effort (Figure 22).

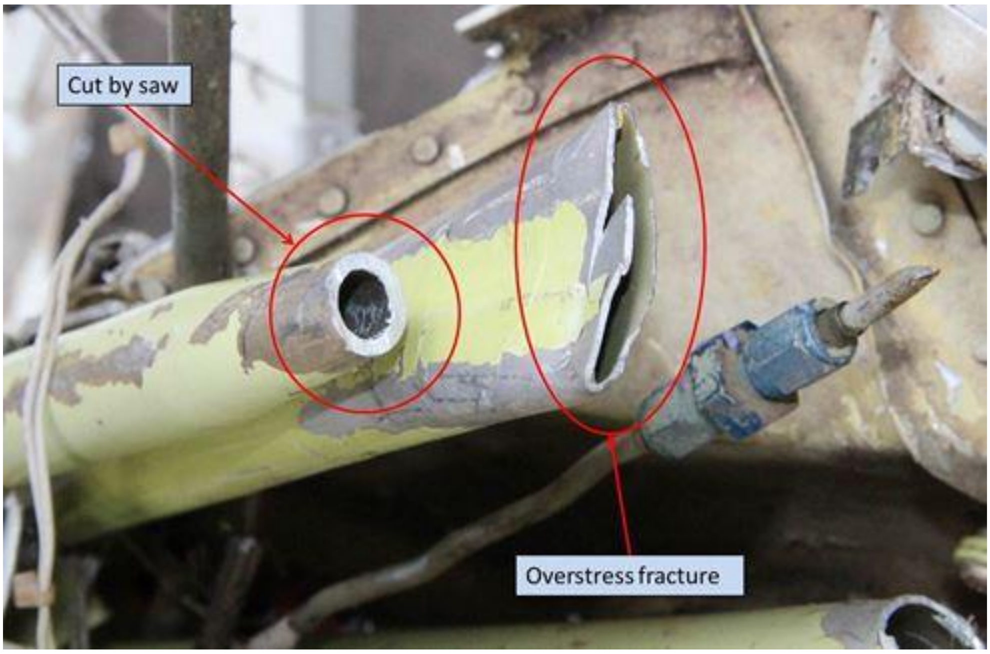

Figure 22: Flight control tubes

Source: ATSB

The main rotor system hydraulic actuators could be moved smoothly through their operating range. The hydraulic pressure and return system filters were inspected and found to be clean, and the bypass indicators had not 'popped' (Figure 23). Minimal hydraulic fluid was present in the hydraulic reservoir. However, the helicopter spent some time rolled on its side during the wreckage recovery, so some fluid loss was expected.

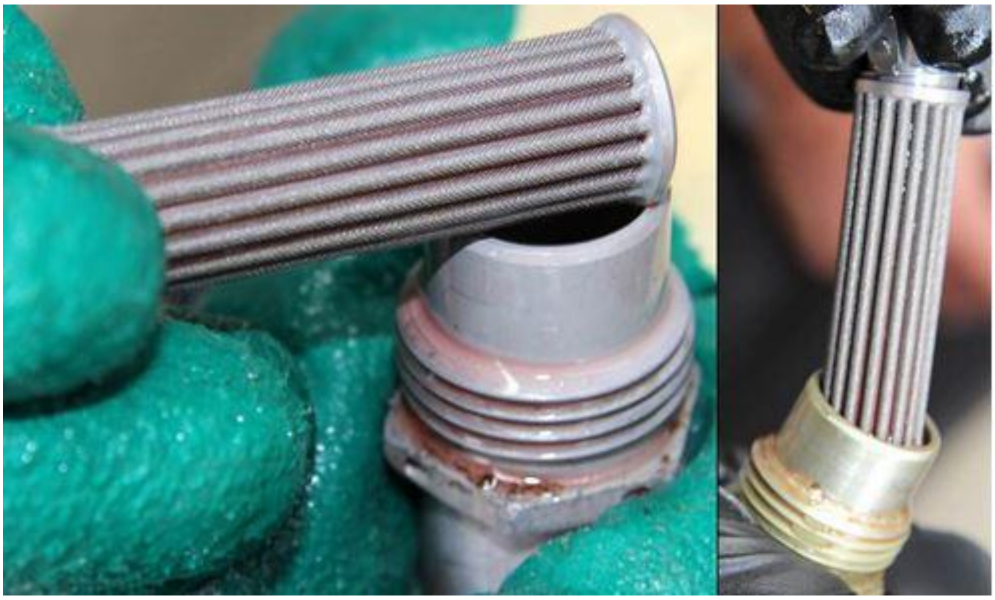

Figure 23: Hydraulic filters

Source: ATSB

1.12.7 Fuel system

This section from ATSB Engineering Group Report AE-2012-094

All three rubber bladder type fuel cells fitted to the helicopter had been breached as a result of the impact sequence. The helicopter came to rest in a small creek with flowing water, which would have reduced the probability of any fuel remaining in the tanks. The only possible source of fuel remaining that could be tested was from the airframe fuel filter bowl. That fuel was taken as a sample [by a AIC investigator and remained in his custody], but it was too small for testing purposes. The airframe fuel filter was opened and the filter was found to be clean. Minor particles were observed in the bottom of the fuel filter bowl, of a size that would have been captured by the filter.

The fuel system utilised two electrically driven boost pumps to provide positive fuel pressure to the engine, as well as providing fuel pressure to two ejector pumps. The ejector pumps were used to provide a motive flow to transfer fuel from the forward tanks to the rear fuel tank. The fuel boost pumps were tested for operation using an external battery and by placing the pumps in a bucket of fuel. A positive flow from each pump was confirmed. The jets were removed from the ejector pumps and confirmed to be clean. The under floor in-line fuel filters and check valves were disassembled and residual fuel was observed. The filters were found to be clean and the check valves were installed correctly and were also clean.

An electrically-activated fuel shut-off was incorporated to isolate the fuel supply to the engine if required. The fuel valve was removed and confirmed to be in the full open position, therefore being capable of allowing fuel transfer from the main tank to the engine.

1.12.8 Engine

This section from ATSB Engineering Group Report AE-2012-094

The helicopter was fitted with a Rolls-Royce 250-C30P engine. The engine was recovered from the accident site and transported to the PNG Defence Force hangar at Jacksons Airport, where it was examined by AIC and ATSB investigators (Figure 24).

Figure 24: Engine after transport to Port Moresby

Source: ATSB

Dirt [sand/silt] was found in the engine compressor inlet, which was most likely deposited while the wreckage was immersed in the creek (Figure 25). The engine's rotating assemblies could not be rotated easily; however, with some force, the Rolls-Royce investigator was able to rotate the N_1[8] and N_2[9] drivetrains. All of the pipes and flexible lines were checked and confirmed to be secure. An initial inspection of the engine confirmed that all of the required components were installed and secure. The two magnetic chip-detector plugs were removed and examined. No metallic debris was present. Fuel was identified in the flexible fuel line from the lower fire shield to the fuel nozzle.

Figure 25: Sand/silt in the compressor inlet

Source: ATSB

The AIC elected to have the engine disassembled at a Rolls-Royce approved facility. The engine was shipped to Asia Pacific Aerospace at Pinkenba, Queensland, Australia, for a detailed disassembly and examination under the supervision of the AIC and ATSB (refer 1.16 Tests and research, Engine examination).

The fuel control unit (FCU), power turbine governor (PTG), and engine driven fuel pump (EDFP) were removed from the engine in Pinkenba during the engine examination and shipped to Standard Aero at Bankstown, New South Wales, Australia for a bench test and detailed disassembly and examination under the supervision of the ATSB.

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[8] N_1 drivetrain: the engine compressor and gas producer turbine drivetrain.

[9] N_2 drivetrain: the power turbine drivetrain.

1.13 MEDICAL AND PATHOLOGICAL INFORMATION

Post mortem examinations of the occupants of HCY were conducted in Australia and it was concluded that they had died due to extensive multiple injuries as a result of the impact during the accident.

1.14 FIRE

There was no evidence of pre- or post-impact fire.

1.15 SURVIVAL ASPECTS

Examination of the wreckage showed significant damage from a high-energy, vertical impact. The accident was not considered survivable due to the severity of the impact and the level of airframe disruption and corresponding reduction of survivable space.

1.16 TESTS AND RESEARCH

1.16.1 Engine examination[10]

This section sourced from ATSB Engineering Group Report AE-2012-094

1.16.1.1 *Parties represented*

Several parties were represented at the engine examination including Rolls-Royce, the insurer, the operator, next-of-kin of the pilot, the AIC, and the ATSB.

1.16.1.2 *Initial examination*

Consideration was given to the possibility of running the engine. Initial inspection by Rolls-Royce in Papua New Guinea indicated that an engine run was possible. During the removal from the engine shipping container and installation into the work stand, it was noted that the exhaust collector was deformed. This may have resulted in an N_1 and N_2 drivetrain misalignment, and therefore an unsafe condition for running the engine. The N_1 and N_2 drivetrains were locked and could not be rotated. This was also considered an unsafe condition for an attempted engine run. This was confirmed with the Rolls-Royce representative, and it was decided to disassemble and examine the engine without attempting to run it.

1.16.1.3 *Disassembly and examination*

Before any disassembly was carried out, the Pc[11] air system was pressure-tested to confirm integrity. Pc air senses the compressor discharge pressure, providing controlled air for the fuel control and governing circuits. Reliable Pc air is a requirement for engine operation. The Pc system was pressure-tested for leaks and found to be satisfactory.

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[10] This AIC Investigation report draws on the Rolls-Royce Corporation report dated 1 November 2012 and ATSB Engineering Group Report AE-2012-094

[11] Compressor discharge air pressure.

An aftermarket Pc valve safety kit[12] was fitted to the engine (Figure 26). The valve was isolated from the Pc system for the purpose of checking for leaks. A slight slow leak was noted around the selector of the valve.

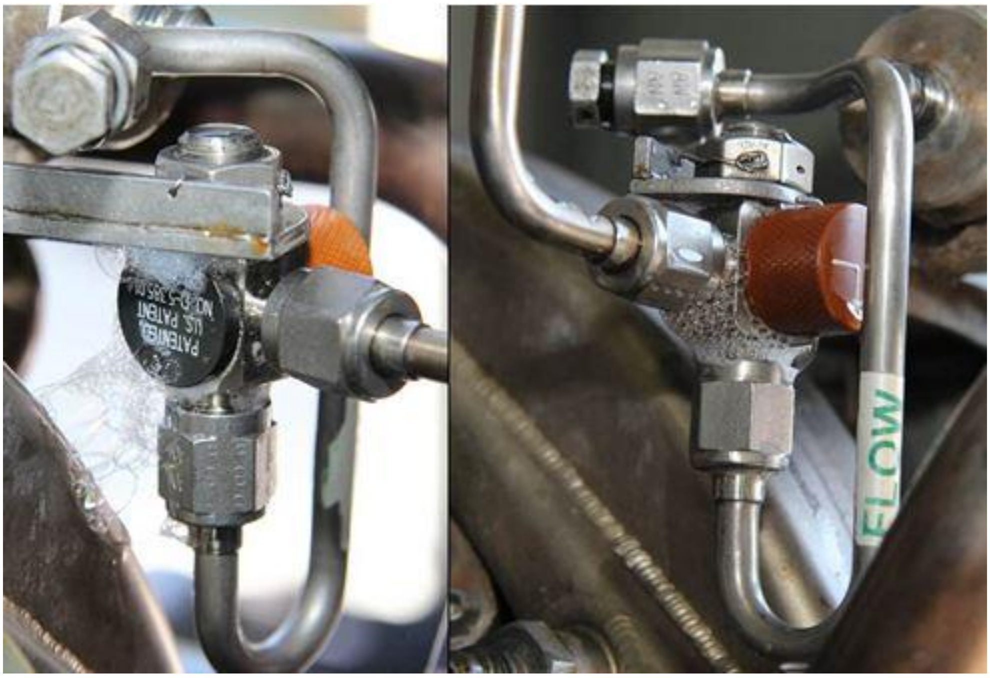

Figure 26: Pc valve safety kit leak identified by a soapy solution
Source: ATSB

Oil was identified throughout the engine. Water was also present within the oil system. The water ingress into the oil system was most likely due to the time the wreckage spent immersed in the creek. The magnetic chip detectors from the gearbox were inspected and found to be clean, with residual oil present. The Pc filter was inspected and found to be clean. The oil check valve was installed in the correct orientation. It was disassembled and found to be clean, with residual oil present, and was assembled correctly.

The engine was disassembled in stages, starting with the compressor, then the turbine and the gearbox. Each of these modules had evidence of oil present in the oil passages and bearings. While the engine was initially being repositioned in the work-stand, a small quantity of fuel was observed to run from the engine driven fuel pump inlet. When the fuel components were removed, no further fuel was identified.

When the turbine and compressor modules were removed, the module alignment shimming was confirmed.

The outer combustion case was dented and prevented the inner combustion case from being removed. The inner combustion case was oriented and installed correctly, with the dowel aligned correctly.

The fuel nozzle was shimmed correctly, and appeared to be clean. A spray pattern test was carried out on the fuel nozzle and was found to be within serviceable limits.

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[12] Maintenance action selectable valve designed to prevent water entering the air circuit to the FCU and PTG during compressor washing.

The oil pump was disassembled and found to be serviceable, with oil present and a small amount of sludge. The small amount of sludge identified was considered to have had no effect on the engine operation due to the presence of oil throughout the engine oil passages and bearings, and the bearings being found to be functional.

The bleed valve was operationally checked on a test rig, however, it failed to close until a significantly high pressure value was reached. The bleed valve was disassembled and was found to be water-contaminated, and the filter to the pressure bellows was blocked.

That blockage was considered to be a post-impact artefact and also the reason why the bleed valve did not function correctly. The bleed valve was cleaned and retested with satisfactory results.

The examination confirmed that the engine was assembled correctly and there was no evidence of any internal failures.

1.16.2 Engine fuel components examination

This section sourced from ATSB Engineering Group Report AE-2012-094

The fuel control unit, power turbine governor, and engine driven fuel pump were examined under AIC and ATSB supervision at the facilities of Standard Aero in Bankstown, NSW.

1.16.2.1 *Parties*

Attendees at the examination included representatives of the previous component overhaul organisation fuel control unit (FCU) and power turbine governor (PTG), the helicopter insurer, and the next-of-kin of the pilot.

1.16.2.2 *General observations*

Water contamination was evident on all of the components. The fuel control unit and the engine driven fuel pump had no obvious external impact damage. The power turbine governor had minor impact damage on its housing as well as a bent throttle shaft.

1.16.2.3 *Power turbine governor*

Considering the level of damage, the PTG responded reasonably well under test, and no evidence of major failure was noted. Excessive RPM was noted at two test points, however, this was most likely due to the bent throttle shaft. Some of the readings were outside the overhaul tolerances[13] although they were found to be within the in-service operating tolerances[14].

Disassembly of the power turbine governor did not identify any failures. There was a level of contamination throughout the power turbine governor. This mainly consisted of sand/silt within the unit deposited while the wreckage was in the creek. Also, a small amount of contamination that resembled dried compressor wash solution was identified on the Pg fitting filter.

This contamination did not affect the power turbine governor operation while under test. No pre-accident defects were identified.

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[13] Overhaul tolerances are set to confirm that the component will continue to operate correctly - allowing for in-service wear - for the entire overhaul period.

[14] In-service tolerances take into consideration normal in-service wear, while allowing correct operation.

1.16.2.4 *Fuel control unit*

The majority of the test tolerances for the fuel control unit were found to be satisfactory during the test, and N_1 governing was found to be normal. Acceleration flows were found to be marginally low, and one test was over its maximum limit. The fuel control unit (FCU) manufacturer (Honeywell) was consulted regarding this high value and it was considered to have no effect on the operation of the unit.

The FCU was disassembled and a small amount of water, sand [silt] and dirt was found throughout the unit. The contamination was most likely due to ingress [of the material] post-accident, and did not affect the operation of the FCU under test. The FCU inspection did not identify any pre-accident defects.

1.16.2.5 *Engine driven fuel pump*

The engine driven fuel pump (EDFP) was bench-tested and performed within the test tolerances.

Upon disassembly, the gear set was noted to be in good condition and showed no evidence of the local heating that would have been associated with fuel starvation [meaning following a fuel starvation event]. The carbon seals, which also rely on fuel for lubrication, were in good condition. Disassembly of the EDFP did not identify any pre-accident failures or deficiencies.

1.16.3 Instrument examination

This section sourced from ATSB Engineering Group Report AE-2012-094

At the request of the AIC, several instruments were shipped to the ATSB in Canberra, Australia for detailed examination. The purpose of the examination was to identify instrument pointer contact marks on the face of the instruments, and to examine any associated warning lamps.

The caution and warning panel was visible in the Australian Army photographs, hanging from the instrument panel by its wiring harness in earlier photographs, although in later photographs it was missing. This most likely occurred during the recovery of the deceased, when the wreckage was cleared from the cockpit area. The caution and warning panel was not identified among the wreckage recovered to Port Moresby.

Witness marks can form on the faces of aircraft instruments by a contact event between the instrument pointer and the instrument face during the impact sequence. They can be used to determine an approximate reading for the instrument at the moment the contact event occurred.

Light globe filament stretch can be an indication of illumination of a light globe at impact. Many factors need to be considered during the examination of light globe filaments, for example, the magnitude and direction of impact, aircraft crumple characteristics, the age of the light globe, illumination time both at the time of impact and total illumination time since new, and cold stretch characteristics.

The following instruments were received by the ATSB in Canberra.

- turbine outlet temperature gauge (with over-temperature indicator lamp)
- electrical load/fuel pressure combined gauge
- transmission oil pressure/temperature combined gauge
- torque gauge (instrument panel mounted)
- torque gauge (door mounted)

- engine oil temperature/pressure combined gauge
- fuel quantity gauge
- dual tacho main rotor/power turbine gauge
- gas generator (N_1) gauge.

Some of the instrument pointers were in a position that may have coincided with an operational range (Figure2 7), but these positions could not be confirmed due to the instruments being subjected to airframe disruption, sand/silt and water, and the subsequent recovery effort. There was no evidence of pointer contact on any of the instrument faces, and no evidence of filament stretch on the turbine outlet temperature (over-temperature) gauge lamp. There was no evidence of faults in the N_1 gauge.

Figure 27: Examples of instruments coinciding with operational values

Source: ATSB

Figure 28: N_1 (gas generator) gauge

Source: AIC

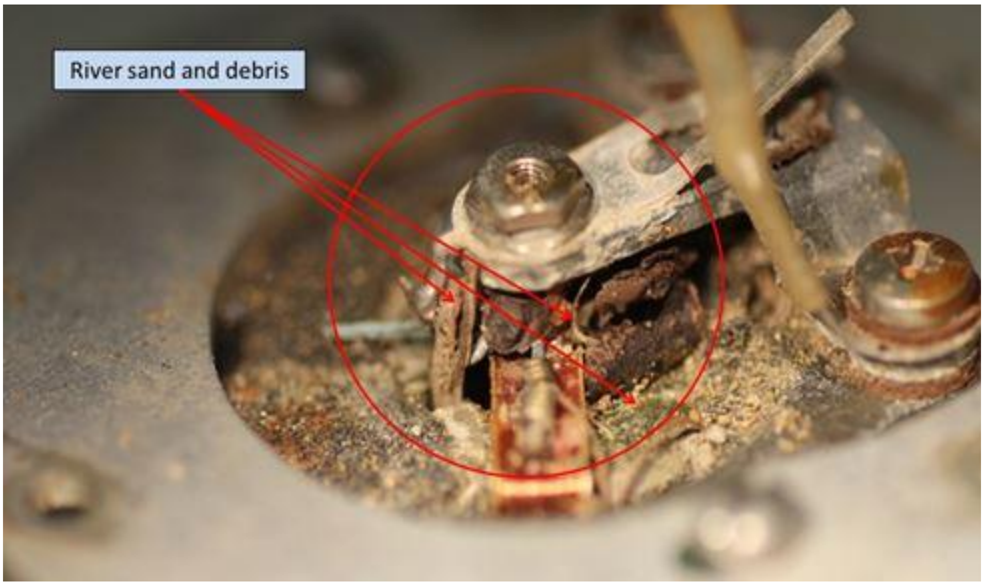

Figure 29: Debris jamming the fuel quantity indicator gauge pointer movement mechanism
Source: ATSB

1.17 ORGANISATIONAL AND MANAGEMENT INFORMATION

Hevilift Ltd provides rotary wing and fixed wing aviation charter services, principally to the natural resources sector, in Papua New Guinea, Indonesia, Malaysia, and Myanmar.

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1.18 ADDITIONAL INFORMATION

The Bell B206L Flight Manual states in Section 3 *Emergency/malfunction procedures*

> 3-1 INTRODUCTION
>
> The following procedures contain indications of failures or malfunctions which affect safety of crew, helicopter, ground personnel or property; use of emergency features of primary and backup systems; and appropriate warnings, cautions, and explanatory notes. [...]
>
> Helicopter should not be operated following any emergency/malfunction procedure or precautionary landing until cause of malfunction has been determined and corrective maintenance action taken.

1.19 USEFUL OR EFFECTIVE INVESTIGATION TECHNIQUES

The investigation was conducted in accordance with Papua New Guinea Civil Aviation Act, Commissions of Inquiry Act, the Civil Aviation Rules, and the PNG Accident Investigation Commission’s approved policies and procedures, and in accordance with the Standards and Recommended practices of Annex 13 to the Chicago Convention.

2 ANALYSIS

2.1 INTRODUCTION

A Bell B206L-1/C30P helicopter registered P2-HCY (HCY) was returning to a drill site in a remote area of Gulf Province, Papua New Guinea, on 5 July 2012 when the engine surged. The pilot landed at the drill site and the next day a company engineer was flown in to work on and troubleshoot the helicopter. The fuel control unit and power turbine governor were both changed together, and the helicopter was test-run on the ground and in the air for approximately 40 minutes. It departed shortly afterwards with three persons on board to refuel at Hou Creek, about 15 min flight time to the east south east. Six minutes after it departed, a MAYDAY broadcast was heard. The wreckage of the helicopter was found on 13 July 2012, when it was confirmed there were no survivors.

The engine and fuel system were examined and tested in Australia at an approved Rolls-Royce Corporation overhaul facility, with the oversight of the PNG Accident Investigation Commission (AIC) and the Australian Transport Safety Bureau (ATSB). The fuel control unit and power turbine governor removed in the field by the engineer were not found at the accident site and were therefore not tested by the AIC and the ATSB.

Evidence from examination of the engine and main rotor blades indicted that the engine had not been producing power at the time of impact.

Three principal hypotheses to explain why the engine had stopped were considered (see below) but the AIC was unable to identify the factor or factors underlying the accident.

2.2 AIRFRAME EXAMINATION

This section sourced from ATSB Engineering Group Report AE-2012-094

Based on the photographs of the accident site and examination of the wreckage in Port Moresby, all major components were accounted for and were in close proximity to the main wreckage. That evidence showed that the accident was not the result of an in-flight breakup. The wreckage examination showed significant damage from a high-energy, vertical impact.

The lack of evidence of rotational damage to the main and tail rotor blades indicated that the rotor system had little to no rotational energy at the time of impact. Both of the main rotor blades had failed in gross bending overstress at their respective root ends. The bulk of the damage on the main rotor blades was axial buckling, consistent with excessive flapping motion. While that suggested the overstress failures at the blade root doubler fingers may have been significantly influenced by aerodynamically-induced stresses, the blade failures probably resulted from the gross bending overstress conditions induced by the combined effects of terrain impact and the gross blade flapping and flail associated with low-rotor RPM and reduced centrifugal stiffness.

The dent identified on the engine-to-transmission KAflex driveshaft indicated that the drivetrain was not rotating at the time of the final ground impact. Rotational scoring was evident on the driveshaft where it passed through the forward engine firewall. This was most likely to have been a consequence of movement of the main rotor transmission as a result of the low rotor energy in flight, initial impact of the blades with vegetation, or a combination of both these factors.

The lack of tail rotor leading edge damage also indicated that the tail rotors had low rotational energy at the time they came in contact with terrain. The tail rotor drivetrain had failed in several sections from bending gross overload, most likely due to the ground impact. No torsional failures were identified so the drivetrain was probably not rotating, or rotating with minimal energy at impact. The lack of rotational damage signatures on the main and tail rotor blades and lack of torsional bending of the drive system indicated that the engine was providing little to no power to the drive system at the time of impact.

Both of the airframe fuel system electric boost pumps were capable of delivering fuel under pressure to the engine. The fuel shut-off valve was confirmed as being in the open position. The inline fuel filters and ejector pumps were also confirmed to be free of debris, therefore able to provide the required motive flow to transfer the fuel contents from the forward fuel cells to the rear tank. Providing that fuel was available in the fuel cells and the boost pumps were turned on, the fuel system was able to provide fuel to the engine.

2.3 ENGINE EXAMINATION

This section sourced from ATSB Engineering Group Report AE-2012-094

The engine examination confirmed that the engine had been assembled correctly. There was no evidence to indicate it was not capable of normal operation prior to the impact.

No rotation damage was noted on the gas generator and power turbine discs. Some evidence of rotation was identified on the compressor impellor and shroud, and this damage was consistent with the engine operating or rotating while spooling-down. Dirt identified in the inlet of the engine was a result of immersion in the creek. This dirt was restricted to the inlet system and none was identified beyond that point, confirming it was not ingested during engine operation.

2.3.1 Pc safety valve leak

The leak identified at the Pc safety valve during the Pc system leak check was considered for its possible effect on engine operation and performance. The operation of the fuel control unit and power turbine governor relies on signal air, not air pressure. The air pressure supplied to the fuel components is in excess of that required for normal operation, being bled off in a regulating circuit to achieve this signal air. Rolls-Royce was consulted regarding the leak, and the following information was returned.

- There is no airflow restrictor used in the Pc supply line and as a result no related additional pressure drop is generated when a leak increases the airflow in the supply line.
- A decrease in Pc pressure as a result of a leak would have little effect on Power Turbine Governor (PTG) operation unless the leak was large. A large leak would result in a high side failure or loss of Power Turbine (N_2) speed governing. Due to the arrangement of the Pc supply lines, Pc air cannot be lost to the PTG without also being lost to the FCU. A smaller leak would have a noticeable operational effect on the FCU before it would have an effect on the PTG.
- A decrease in Pc pressure to the Fuel Control Unit (FCU) results in lower starting, acceleration and deceleration fuel flows. Field reports and accident investigations have shown that a Pc line would need to be near or completely disconnected before there is a sudden and major decrease in power during flight.

After consultation with the Rolls-Royce representative, the leak was considered to be minor and would most likely have had no effect on the engine's operation.

2.4 FUEL SYSTEM COMPONENTS

This section sourced from ATSB Engineering Group Report AE-2012-094

The examination of fuel system components confirmed that the fuel control unit (FCU), engine driven fuel pump (EDFP), and power turbine governor (PTG), had been fitted correctly and there was no evidence to indicate that these components were not capable of normal operation prior to the impact.

Some contamination was found in the fuel control unit and the governor. This was a combination of sand and dirt, most likely from the river system at the accident site, and what appeared to be consistent with dried compressor wash solution. Compressor wash solution can make its way into these components if the Pc air system is not isolated correctly during a compressor washing procedure. Considering the small amount of internal contamination, impact damage of the components, and shock-loading sustained during the accident sequence, the test results confirmed that these components were capable of performing at a level that would allow normal engine operation.

A lack of internal overheating and seal damage in the engine driven fuel pump indicated that there was a reasonable amount of fuel available within the unit for internal lubrication. Prolonged operation of the engine driven fuel pump without adequate lubrication would have damaged the gear-set shafts with localised overheating, along with damage to the carbon seals.

2.4.1 AIC comment

The AIC and ATSB were not able to examine the fuel control unit (FCU) and power turbine governor (PTG) that the engineer removed from HCY in the field, and being carried on HCY to Mt Hagen as cargo, because it was not located at the accident site. It is therefore not known if either of these components was defective at the time they were removed from HCY. It is possible that these components were not defective, and that removing them made no difference to another, unrelated condition that caused the engine to surge on 5 July 2012.

Consideration was given to the possibility of air leaks in the aircraft fuel system. Even if there had been such leaks in the fuel system, the fact that both boost pumps were found to be serviceable after the accident discounts this as a possible explanation for either the engine surge on the day prior to the accident, or the accident flight itself. This is because if the boost pumps were operating normally and supplying positive pressure to the engine-driven fuel pump, this would override the effect of suction of air through any leaks in the system.

2.5 FUEL QUANTITY ON BOARD HCY

Section 1.6.5 *Fuel information* presents calculations of how much fuel may have been on board HCY at the time of the accident. These calculations contain several variables that are unknown, so how closely the calculation approximates the actual fuel situation in HCY is uncertain. The variables include

- the exact quantity of fuel on board before the ground-running commenced after the component changes were completed;
- the length of time spent ground-running and the power settings used during ground-running;
- the length of time spent in the hover and power setting used during hovering;

- the length of time spent conducting two circuits of Triceratops 2 and power setting used during the circuits;
- the length of time spent waiting for the third person to board, with the engine at idle, before the accident flight began (not less than 10 minutes); and
- any other engine running before the accident flight began.

The deputy chief pilot was highly experienced in operations in PNG, and he knew the area around Triceratops 2 and Hou Creek well. He would have known how much fuel was required to depart safely from Triceratops 2 for Hou Creek in HCY. It is unlikely therefore that the deputy chief pilot would have knowingly departed Triceratops 2 with insufficient fuel for the flight to Hou Creek. Nevertheless, given the lack of evidence from the filament of the FUEL LOW caution light bulb, discussed in Section 2.5 above, the AIC was not able to determine whether fuel exhaustion occurred during the accident flight and could not discount fuel exhaustion[15] as a possible explanation for why the engine stopped producing power in flight.

2.6 INSTRUMENTATION

2.6.1 General

The ATSB found no witness marks on the faces of the instruments caused by pointer contact with the instrument faces during the impact sequence.

Filament stretch in any bulb in the caution warning panel or other instruments would indicate that that bulb was illuminated at the time of impact and *vice versa*. The over-temperature indicator lamp from the turbine outlet temperature gauge was examined for filament stretch, but none was identified and this was consistent with other evidence indicating that the engine was not producing power at the time of the impact.

2.6.2 Caution warning panel lost

The AIC was unable to examine the caution warning panel because, as Figure 12 shows, although the panel was present during the recovery phase at the accident site, the wiring bundle to the caution warning panel was cut by persons unknown, for reasons the AIC could not determine and the panel was not recovered. Whether the caution warning panel was moved from the wreckage by water running through it or by other means is not known.

The loss of the caution warning panel deprived the AIC of important evidence. In particular, filament stretch, or lack of it, in the FUEL LOW caution light bulb would have indicated whether there had been 50 lbs to 70 lbs (28.5 L to 39.8 L) or less fuel remaining in the rear tank (see Figure 7) at the time of impact. The status of the filament in the FUEL LOW caution light bulb would therefore be strong evidence for or against the hypothesis that the engine stopped because of fuel exhaustion. Without knowing the status of the filament in this bulb, the AIC was unable to determine if the FUEL LOW caution light was on, and therefore if the rear tank contained 50 lbs to 70 lbs (or less) of fuel at the time of impact.

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[15] Evidence from searchers who recovered wreckage ‘smelling’ of Jet-A1 fuel, and evidence from the examination of the engine driven fuel pump gear set and carbon seals that rely on fuel for lubrication (showing them to be in good condition with no evidence of deficiencies) sheds an element of doubt on the likelihood of fuel exhaustion being a contributing factor.

The status of the filament in the ENGINE OUT caution light bulb would also have provided evidence that the engine had, or had not, stopped in flight (in addition to the evidence from the physical examination of the engine and the main rotor system, and from the pilot of the Mil-8 helicopter who reported hearing the ENGINE OUT aural warning in the background during the MAYDAY broadcast).

2.6.3 N_1 tacho-generator

If the N_1 tacho-generator fails (either through electrical malfunction in the system or through a physical failure of the tacho-generator e.g. the drive shaft) the ENGINE OUT warning system will activate, even though the engine is still running normally and other engine indications will be normal (oil pressure, torque, N_2). Instances are known in which these circumstances have caused a pilot to roll-off power and initiate an auto-rotation. However, unless the pilot then presses the IDLE detent button, which allows him to roll the throttle to OFF, the engine will not stop.

In HCY there was no indication of faults in the N_1 tacho-generator and it is highly unlikely the pilot of HCY would have rolled the throttle to OFF causing the engine to stop. The AIC does not consider N_1 tacho-generator problems to be a factor in this accident.

2.7 ENGINE SURGE

It was suggested to the AIC that in Bell 206L helicopters an imbalance in the starter-generator may affect the bellows in the fuel control unit during normal operations, with the consequence that the engine surges. The mechanism by which this occurs is thought to be through starter-generator vibrations causing the flyweights on the fuel control unit to move faster/slower than they are supposed to.

There is no evidence from HCY to support or discount this hypothesis and the AIC is unable to assess whether it could be an explanation for the engine surge on the day before the accident. Even if such a mechanism did underlie the engine surge on the day before the accident, it would not explain why the engine stopped on the accident flight.

2.8 WEATHER

The ‘other company pilot’ preceded HCY towards Hou Creek past Bwata by only 10 minutes. When interviewed, he said that he did not think the weather on the route would have deteriorated significantly between his departure from Triceratops 2 and HCY’s departure, nor did he consider the weather would have been problematic for the pilot of HCY. Although the deteriorating weather conditions to the south of the ridge line between Triceratops 2 and Hou Creek were the reason the route past Bwata was taken, it is likely that weather conditions on the route flown were not a factor in the development of the accident.

2.9 TIME, DISTANCE, AND TRACK FLOWN

The canopy-mounted GPS unit in HCY was not recovered from the wreckage, nor from the accident site. If it had been found, it may have been possible to download data from it and to see the actual track flown by HCY between Triceratops 2 and the accident site.

Even without knowledge of the actual track flown, the location of the accident site near Bwata (Figure 4) indicates that the pilot of HCY was taking the route past Bwata to Hou Creek i.e. the route that had been flown 10 minutes previously by the other company pilot. In addition, the pilot of HCY is reported to have included the word 'Bwata' in his MAYDAY broadcast.

It is likely that HCY flew some distance east of the accident site before being turned by the pilot and flown back towards Triceratops 2.

This is because the accident flight lasted 6 min and, at a cruise speed of 90 kt[16], the helicopter would have flown 9 nm (16.7 km) in that time. The distance from Triceratops 2 to the accident site was just 1.6 nm (3 km), so the pilot of HCY may have flown up to 3.5 nm (6.5 km) in an easterly direction from Triceratops 2 towards Hou Creek before turning back.

The other company pilot stated that the drill site at Bwata had recently been cleared of vegetation and that it therefore provided a good potential landing site along the route. Further, the pilot of HCY knew the area well and was aware of this fact.

Taken together, these pieces of information suggest it is likely that HCY passed east of Bwata towards Hou Creek and was then turned and flown back towards Triceratops 2. If this is so, then it is also likely that a decision was taken to return to Triceratops 2 instead of to land at Bwata, which in turn suggests that whatever led the pilot to turn back towards Triceratops 2 was not, at the point the decision to turn back was made, sufficiently serious to cause the pilot to land at the nearest suitable landing site i.e. at Bwata.

2.10 FACTOR OR FACTORS UNDERLYING LOSS OF ENGINE POWER IN FLIGHT

On the day of the engine surge – the day before the accident – the pilot of HCY reported that while accelerating the engine and rotor systems up to flight rotor revolutions per minute (RRPM) the system would initially reduce and then increase in speed rather than accelerate smoothly. In the cruise at 50 kt the RRPM would decay and then recover if power was reduced.

The Bell 206L-4 Flight Manual (Section 3 *Emergency/malfunction procedures*) page 3-3 stated that:

> Helicopter should not be operated following any emergency/malfunction procedure or precautionary landing until cause of malfunction has been determined and corrective maintenance action taken.

While HCY was a Bell 206L-1/C30P, the AIC considers that this is prudent advice for any helicopter or aircraft.

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[16] The testimony of the 'other company pilot', who preceded HCY on the route between Triceratops 2 and Hou Creek by 10 minutes, indicated that the weather on that route would not have been a limiting factor for HCY. It is therefore likely that HCY was flown at the 'normal' cruising speed of 90 knots.

In the case of HCY, although the factor(s) underlying the engine surge were thought to have been rectified, what the factor(s) actually were had not been determined before HCY was returned to service[17] on the accident flight: the fuel control unit (FCU) and power turbine governor (PTG) were both changed together and no test-running was performed after the replacement of each individual component to link the symptoms described above with either of the components replaced. In addition, the two fuel system components removed from HCY were not found at the accident site during the recovery phase. A consequence of this was that they were not tested in Australia together with the two replacement fuel system components the engineer fitted to HCY, and which were tested in Australia under AIC and ATSB supervision.

It is possible that both components the engineer removed from the helicopter were defect-free and functioning properly, and that the problem underlying the engine surge on 5 July 2012 originated from another, unidentified part of the engine and fuel systems.

This led the AIC to consider the following possibilities.

1. The factor underlying the loss of engine power on the accident flight was a ‘new’ mechanical problem which developed during the accident flight and was not related to the factor underlying the engine surge. It may or may not have been related to the fuel control unit and power turbine governor.
2. The factor underlying the engine surge remained ‘latent’ in the helicopter’s systems and was not rectified by replacement of the two components by the engineer. It did not manifest itself again until HCY was airborne on the accident flight, and it led to the loss of engine power in flight.
3. The factor underlying the loss of engine power on the accident flight was a non-mechanical factor, of which fuel exhaustion[18] could not be discounted.

On the evidence available, the AIC was unable to eliminate any of these hypotheses and considers them all to be possible explanations for the loss of engine power in flight.

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[17] Why the helicopter was not test-run after the change of each individual component at Triceratops 2 is not known. It is possible that the deputy chief pilot and engineer considered that it would have been too time consuming. It is also possible that they judged that three periods of ground running would have consumed too much fuel and left them unable to depart with sufficient fuel to reach Hou Creek. Whatever the reason for not attempting to isolate the problem to a single component, after conducting the ground running, hovering, and circuits, the deputy chief pilot and the engineer presumably believed that the problem had been rectified.

[18] Evidence from searchers who recovered wreckage ‘smelling’ of Jet-A1 fuel, and evidence from the examination of the engine driven fuel pump gear set and carbon seals that rely on fuel for lubrication (showing them to be in good condition with no evidence of deficiencies) sheds an element of doubt on the likelihood of fuel exhaustion being a contributing factor.

3 CONCLUSIONS

3.1 FINDINGS

From the evidence available, the following findings are made with respect to the accident 80 km north east of Kikori, Gulf Province on 6 July 2012 involving a Bell Helicopter B206L-1/C30P, registered P2-HCY. They should not be read as apportioning blame or liability to any organisation or individual.

1. AIRCRAFT

a) The aircraft had a valid Certificate of Airworthiness.

b) The aircraft was certified as being airworthy when dispatched for the flight.

c) The mass and the centre of gravity of the aircraft were within the prescribed limits.

d) There was no evidence of any defect or malfunction in the aircraft that could have contributed to the accident.

e) There was no evidence of airframe failure or system malfunction prior to the accident.

f) The aircraft was structurally intact prior to impact.

g) All control surfaces were accounted for, and all damage to the aircraft was attributable to the severe impact forces.

h) The rotor system was rotating in a low rotational-energy state when the helicopter contacted the tree canopy, and was probably stationary at the time of impacting the creek bed.

i) The aircraft was destroyed by impact forces.

j) There was no evidence of pre- or post-impact fire.

2. PILOT

a) The pilot was licensed and qualified for the flight in accordance with existing regulations.

3. FLIGHT OPERATIONS

a) The flight was conducted in accordance with the procedures in the company Operations Manual.

b) The pilot carried out normal radio communications with the relevant ATC units.

c) The duration of the accident flight suggests the pilot flew some distance past Bwata in an easterly direction before turning back towards Triceratops 2 for reasons that could not be determined.

d) If the pilot did turn back towards Triceratops 2 from a position to the east of Bwata, then, when HCY passed Bwata heading west, whatever caused the pilot to decide to turn back appears not to have been serious enough to cause him to land at Bwata. Instead, it appears probable the pilot judged he could return to Triceratops 2.

4. COMMUNICATIONS

a) The MAYDAY broadcast included the words ‘engine failure’.

b) Another helicopter pilot reported hearing the ENGINE OUT aural warning in the background of the MAYDAY broadcast from HCY.

5. OPERATOR’S MAINTENANCE ORGANISATION

a) The engineer trouble shooting the reported engine malfunction prior to the accident flight, changed two major engine components, the fuel control unit and power turbine governor at the same time.

b) The helicopter was not test-run after each component change to isolate the source of any malfunction to one component.

c) The engine was not tested to ascertain if the defect had been rectified until after both components had been replaced.

6. MEDICAL

a) There was no evidence that incapacitation or physiological factors affected the pilot’s performance.

b) A post-mortem examination of the pilot showed that the cause of death was multiple injuries as a result of the impact with terrain.

7. SURVIVABILITY

a) The accident was not survivable due to the magnitude of the deceleration forces.

8. INVESTIGATION

a) The loss of the caution warning panel and the fuel control unit and the power turbine governor deprived the AIC of important evidence.

3.2 CAUSES [CONTRIBUTING FACTORS]

- The factor(s) underlying the engine surge on 5 July 2012 were not determined before the helicopter was returned to service on the accident flight.
- The AIC was unable to determine why the helicopter’s engine failed.

3.3 Other factors

‘Other factors’ refers to safety deficiencies or concerns that are identified during the course of the investigation that while not causal to the accident, nevertheless should be addressed with the aim of accident prevention. The following ‘other factor’ was identified:

- The fuel control unit and power turbine governor were both changed at the same time and the helicopter was not test-run after each component change to isolate the source of any malfunction to one component.

4 SAFETY ACTIONS AND RECOMMENDATIONS

4.1 SAFETY ACTION

At the time of publishing the Report, the Accident Investigation Commission (AIC) had been informed of the following safety actions taken by the operator.

4.1.1 Hevilift

Hevilift has installed Skynet Global System GPS satellite flight tracking on all its aircraft, providing the locations of all its aircraft worldwide. All Hevilift flights are tracked live with this system to reduce the likelihood of search and rescue delays in the event of aircraft emergency landings or accidents.

Hevilift has introduced a flight data monitoring system supported by Plane Sciences, Ottawa, Canada using data downloaded from aircraft FDR systems. Fifteen of the company's aircraft are now under the Hevilift Flight Data Monitoring Program.

Hevilift has committed to install Appareo Vision 1000 cameras to all company aircraft www.appareo.com/aviation/flight-data-monitoring/vision-1000/. In addition to cockpit video and sound, Appareo Vision 1000 cameras record flight data that may be used in the case of aircraft not fitted with flight data recorders. They will be used for both accident/incident investigation as well as for a line operations safety assessment (LOSA)-style program. All Hevilift aircraft will be fitted with the Appareo Vision 1000 camera by the end of June 2016.

The following table indicates the status of the Hevilift fleet with respect to flight data recorders, cockpit voice recorders, and Appareo Vision 1000 cameras.

Aircraft type	Total in fleet	No. with FDR	No. with CVR	No. with video camera
ATR 42 320/500	4	4	4	--
DHC-6 300/400	8	3	8	8
Bell 412EP	2	2	2	--
412HP	2	--	--	1
Bell 212	7	--	--	4
Bell 407	5	--	--	3
Bell 206	3	--	--	--
Mi-8MTV-1	2	2	2	2

Notes:

Although DHC-6 aircraft in PNG are not required to have flight data recorders installed, Hevilift has installed a FDR in one of its DHC-6 aircraft.

One of Hevilift's Bell 412 helicopters does not have an Appareo Vision 1000 camera fitted; this aircraft is leaving the Hevilift fleet by the end of November 2015.

All Hevilift employees have undergone ‘Take 5’ risk analysis training. This initiative stresses the importance of identifying possible risks and planning for them.

Hevilift has introduced a compulsory daily “toolbox talk” safety meeting, which is minuted and the minutes signed by all personnel present.

Hevilift Maintenance procedures were reviewed following the accident involving HCY. The company now places particular emphasis on issues surrounding ‘field maintenance’ in remote locations and any associated pressures, and the importance of verifying the cause of malfunctions before planning for flight.

4.2 RECOMMENDATIONS

As a result of the investigation into the accident involving a Bell B206L-1 80 km north east of Kikori, Gulf Province, on 6 July 2012, the AIC issued the following recommendation to address safety issues identified in the AIC’s Preliminary Report. The recommendation stated:

> The AIC recommends that the operators of Bell B206L helicopters in Papua New Guinea review the wording of Section 3 *Emergency/malfunction procedures* in the Bell B206L Flight Manual and ensure that, following a malfunction, the cause or causes underlying the malfunction are positively identified before a helicopter is returned to service.

In the pre-accident trouble shooting of the reported engine malfunction prior to the accident flight, the engineer changed two major engine components, the fuel control unit and power turbine governor, at the same time. The helicopter was not test-run after each component change to isolate the source of any malfunction to one component.

The AIC believes that it is vitally important that operators are assured that the underlying cause of a malfunction in any aircraft or helicopter is identified before the aircraft or helicopter is returned to service. Accordingly the AIC makes the following recommendation.

4.2.1 Recommendation number AIC 15-R11/12-1007 to the Civil Aviation Safety Authority of PNG

The Accident Investigation Commission recommends that the Civil Aviation Safety Authority of PNG (CASA) should bring this safety concern to the attention of all aircraft and helicopter operators in PNG, specifically highlighting the importance of being assured that the underlying cause of a malfunction in any aircraft or helicopter is identified before the aircraft or helicopter is returned to service.

5 APPENDICIES

5.1 APPENDIX 1: BELL 206L-1/C30P FUEL SYSTEM

5.1.1 General description

The B206L cockpit fuel gauge was calibrated in pounds (lbs). The fuel system was comprised of three interconnected crash-resistant rubber bladder fuel cells with a combined capacity of 672 lbs, of which 665 lbs were useable (equivalent to 376.3 L total / 372.5 L useable). The two forward cells were located under the mid-passenger seats and the rear cell was located below and behind the rear passenger seat. All fuel cells were serviced through a single filler port on the right side of the aircraft, with fuel filling the rear fuel cell until it reached the top of the gravity feed standpipe at a quantity of 270.6 lbs (153.8 L) at which point it would begin to fill the two forward cells through the standpipe until the fuel level in the forward cells was equal to the level in the rear fuel cell at a quantity of 425.0 lbs (241.5 L). All fuel cells were vented overboard by a common vent line.

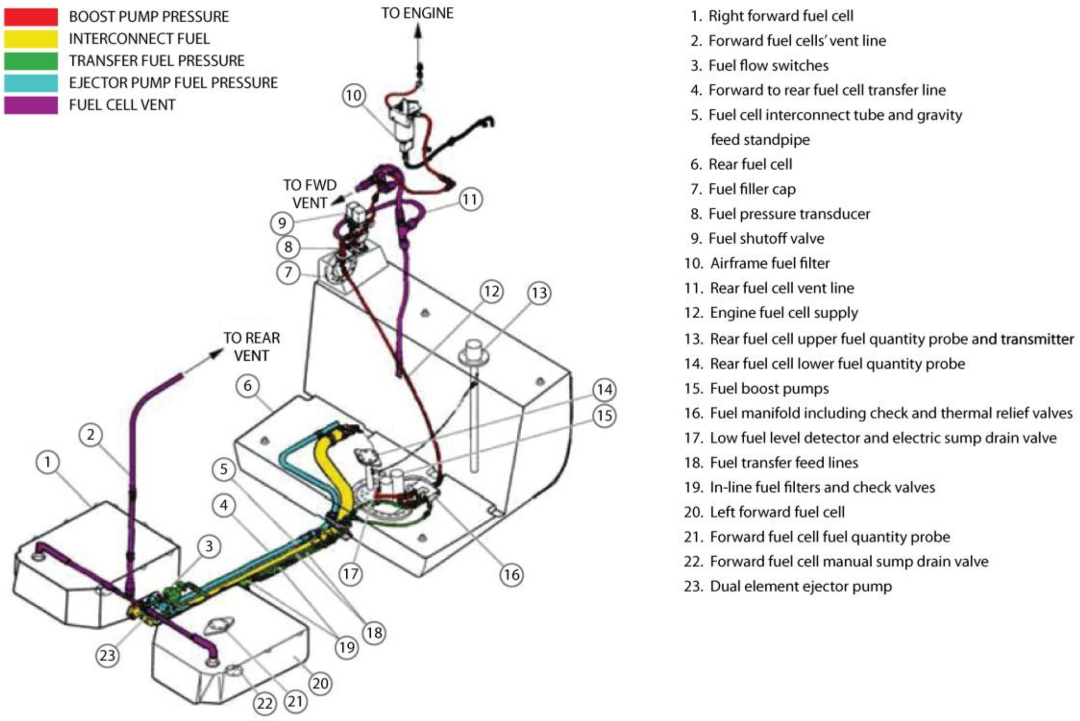


Figure 7: Fuel system 3-dimensional diagram

Source: Bell Helicopter

Fuel from the rear cell was provided to the engine by two electric boost pumps mounted on a sump plate assembly at the bottom of the rear cell. Pressurised fuel from the pumps was fed through a fuel manifold, fuel shutoff valve, and airframe mounted fuel filter before reaching the engine.

Pressurised fuel was also directed forward by the manifold through a one-way check valve to a dual element ejector pump, which in turn transferred fuel from the forward cells to the rear fuel cell.

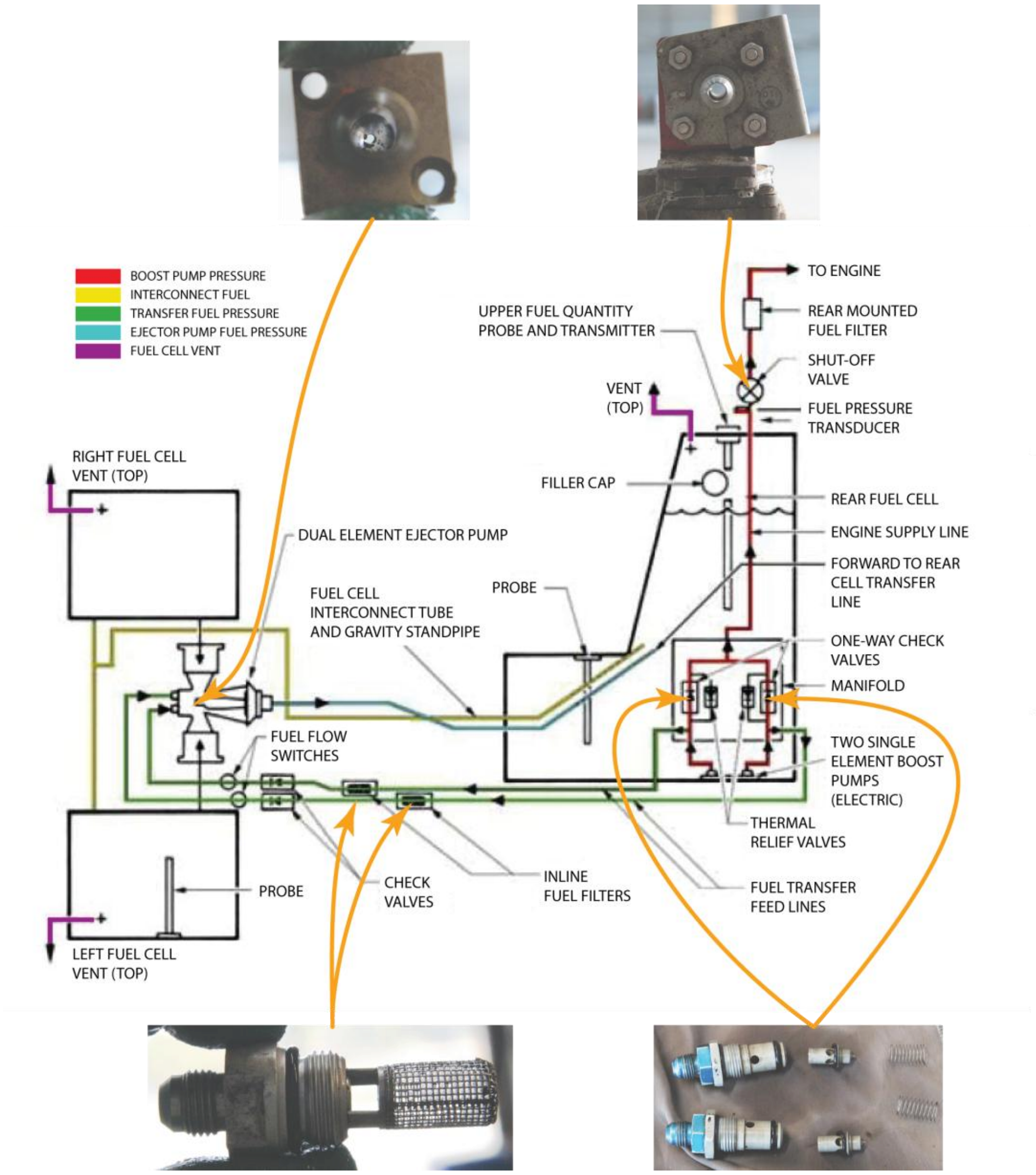


Figure 8: Fuel system schematic

Source: Bell Helicopter and ATSB

Some fuel from each boost pump was routed out of the manifold through a transfer feed line, an in-line check valve, a flow switch, and into the respective side of the dual element ejector pump.

A low fuel level detector and electrically-operated sump drain valve were mounted on the sump plate assembly at the bottom of the rear cell. The low level detector would activate the FUEL LOW caution light at 50 to 70 lbs (28.5 to 39.8 L) and the drain valve was activated by a switch on the lower right side of the rear fuselage. The switch was deactivated when the fuel valve switch was ON to prevent inadvertent activation during flight.

A capacitance-type fuel quantity gauging system with three probes was used to provide a signal to the fuel quantity indicator. One probe was located in the left forward fuel cell and there were two in the rear fuel cell. The upper probe in the rear fuel cell was also used as a transmitter to send electrical signals from the three probes to the fuel quantity indicator.

The fuel pressure transducer, installed in the engine supply line prior to the fuel shut-off valve, measured the combined fuel boost pump pressure to the engine, with this information displayed on the fuel pressure gauge in the cockpit.

The fuel valve was controlled electrically by the FUEL VALVE switch in the cockpit. When the switch was ON, fuel flowed through the open valve and into the airframe fuel filter. With the switch in the OFF position, the fuel valve would close and fuel flow to the engine would stop.

The airframe fuel filter was on the right side of the forward engine firewall. It was equipped with a built-in filter bypass valve and impending bypass switch that was electrically connected to an amber caution light on the caution and warning panel in the cockpit. At approximately 1 PSID differential fuel pressure, the fuel filter caution light would illuminate, indicating that fuel was about to begin bypassing the fuel filter. The fuel filter would bypass at approximately 4 PSID, with no further cockpit indications.

5.1.1.1 *Fuel system circulation*

Fuel flow to the engine

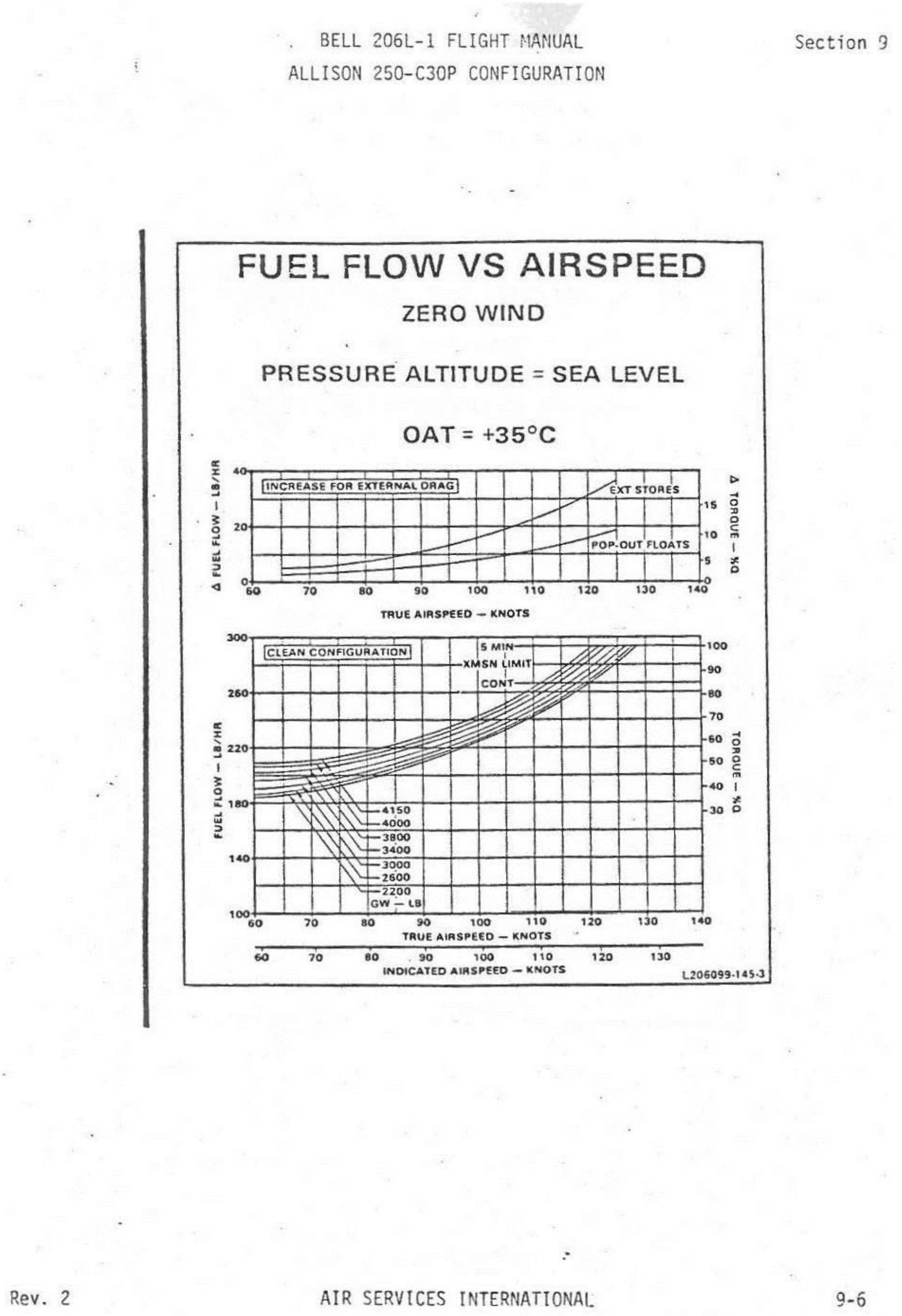
When the battery switch was turned ON, the boost pumps would begin to operate, pumping pressurised fuel into the fuel manifold. The fuel entered the manifold through the boost pump one-way check valves and was directed into the engine supply line and the pressurised fuel transfer feed lines servicing the ejector pump. The engine supply line fuel flowed past the fuel pressure transducer, then past the fuel valve. When the fuel valve was opened, the fuel flow continued through to the airframe fuel filter, into the engine driven fuel pump, and into the fuel control unit. When the throttle was opened the fuel would flow from the fuel control unit through the fuel nozzle and into the combustion chamber.

Fuel flow to the ejector pump

When the battery switch was turned ON, the boost pumps would begin to operate, pumping pressurised fuel into the fuel manifold. The fuel entered the manifold through the boost pump one-way check valves and was directed into the engine supply line and the pressurised fuel transfer feed lines servicing the dual element ejector pump. Two pressurised lines moved fuel forward, one for each fuel boost pump connected to its respective side of the ejector pump. The portion of the fuel flowing to the ejector pump flowed through a screen mesh filter, an in-line check valve, through a flow switch and into the dual element ejector pump. The movement of the pressurised fuel through the ejector pump created a venturi effect inside the pump. This venturi effect would cause the transfer of fuel from the forward cells to the rear cell through the transfer return line. If the gravity standpipe was submerged in fuel and the boost pump(s) were running, there would be a constant circulation of fuel between the forward and rear cells.

5.2 APPENDIX 2: BELL 206L-1/C30P FUEL SYSTEM

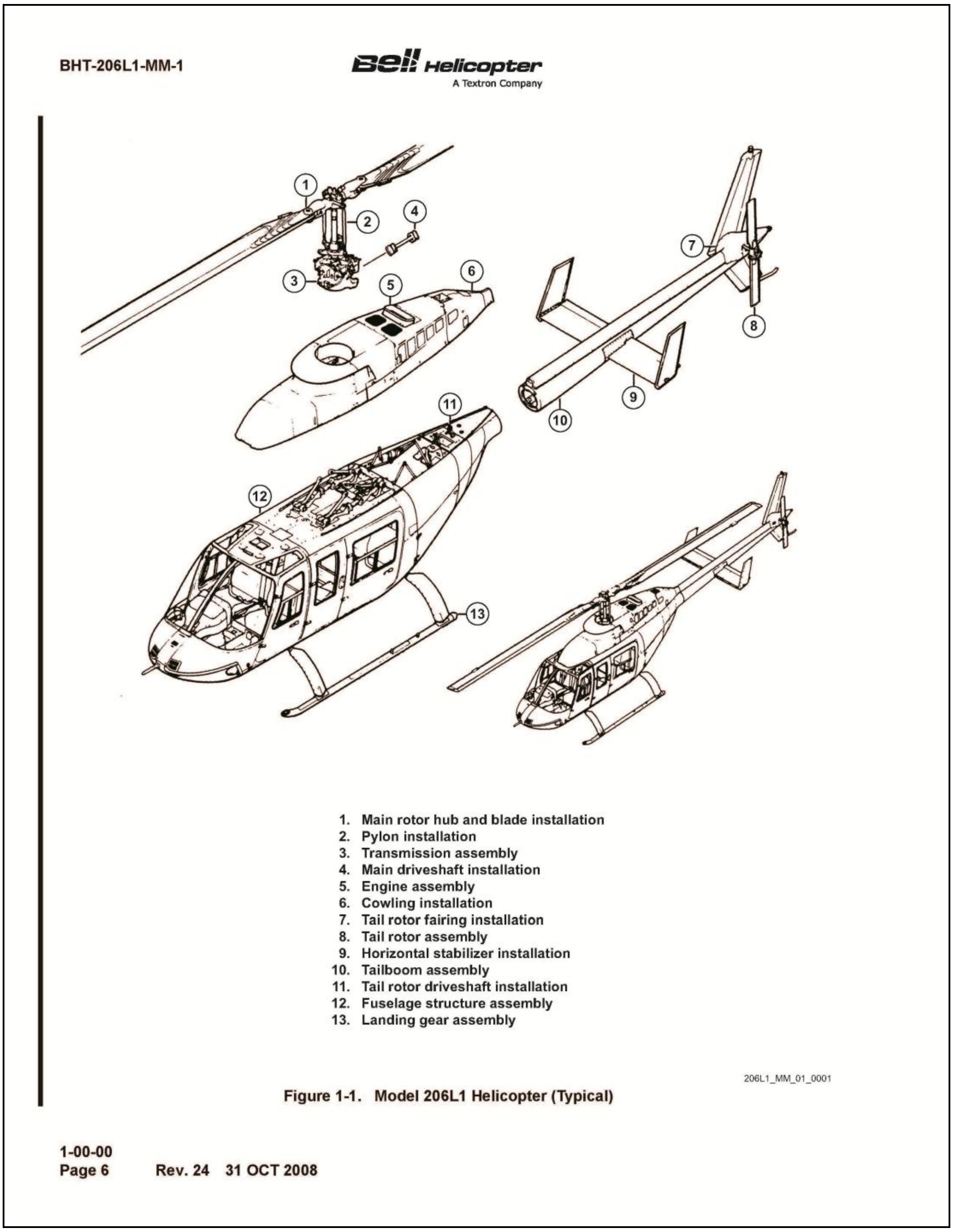
Fuel flow vs airspeed chart from the Bell B206L-1/C30P Flight Manual Section 9, page 9-8 Rev. 2.



BELL 206L-1 FLIGHT MANUAL Section 9
ALLISON 250-C30P CONFIGURATION

Rev. 2 AIR SERVICES INTERNATIONAL 9-6

5.3 APPENDIX 3: 3-DIMENSIONAL DRAWING OF A BELL 206L1



BHT-206L1-MM-1

Bell Helicopter
A Textron Company

1. Main rotor hub and blade installation
2. Pylon installation
3. Transmission assembly
4. Main driveshaft installation
5. Engine assembly
6. Cowling installation
7. Tail rotor fairing installation
8. Tail rotor assembly
9. Horizontal stabilizer installation
10. Tailboom assembly
11. Tail rotor driveshaft installation
12. Fuselage structure assembly
13. Landing gear assembly

206L1_MM_01_0001

Figure 1-1. Model 206L1 Helicopter (Typical)

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Source: Bell Helicopter