Inquiry AO-2014-002: Kawasaki BK117 B-2, ZK-HJC,
Double engine power loss, Near Springston, Canterbury, 5 May 2014

Final Report

Aviation inquiry AO-2014-002
Kawasaki BK117 B-2, ZK-HJC
Double engine power loss

Near Springston, Canterbury
5 May 2014

Approved for publication: February 2016

Transport Accident Investigation Commission

About the Transport Accident Investigation Commission

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

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Citations and referencing

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

Photographs, diagrams, pictures

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Kawasaki BK117 B-2, registration ZK-HJC
Photo courtesy of Garden City Helicopters Limited

Source: mapsof.net

Location of incident

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Abbreviations

CAA	Civil Aviation Authority of New Zealand
CAR	Civil Aviation Rules
Commission	Transport Accident Investigation Commission
kg	kilogram(s)
LED	light-emitting diode
NVIS	night vision imaging system
RPM	revolutions per minute

Glossary

annunciator	a light, or panel of lights, that provides information on the state or condition of systems, components and equipment
attitude	the orientation of an aircraft's axis with respect to the horizon
autorotation	a process of producing lift in an unpowered rotor system by inducing an airflow up through the main rotor blades as the helicopter descends
engine test cell	an engine ground testing facility, where an engine is fitted to a test stand, a test load is put on the engine to simulate operating conditions, and engine parameters can be recorded
fuel starvation	is where there is adequate fuel on board an aircraft to run the engines, but it is unable to be delivered to the engine, through either a blockage or failure in the fuel system or incorrect fuel system management by the pilot
light-emitting diode	an efficient and reliable light bulb that emits a brighter light than a standard incandescent light bulb
magnetic chip detector	a probe installed in an engine or gearbox oil system that attracts ferrous debris. It can be removed and inspected to detect the early signs of impending metal component failures
night vision goggles	normally a binocular device that pilots wear over their eyes to amplify the ambient light at night and enhance vision in low light conditions

Data summary

Aircraft particulars

Aircraft registration:	ZK-HJC
Type and serial number:	Kawasaki BK117 B-2, 1061
Number and type of engines:	two Lycoming LTS 101-750B-2, turboshaft
Year of manufacture:	1990
Operator:	Garden City Helicopters Limited
Type of flight:	hospital patient transfer
Persons on board:	five
Pilot's licence:	commercial pilot licence (helicopter)
Pilot's age:	49
Pilot's total flying experience:	9,336 hours
Date and time	5 May 2014, 0911[1]
Location	near Springston, Canterbury latitude: 43°38´40" longitude: 172°25´34"
Injuries	nil
Damage	minor

[1] Times in this report are New Zealand Standard Time (universal co-ordinated time + 12 hours) and in 24-hour format.

1. Executive summary

1.1. On 5 May 2014 the pilot of a BK117 helicopter with four other people on board experienced a double engine power loss during a hospital patient transfer flight between Ashburton and Christchurch. The pilot made an emergency landing without power onto farmland near Springston, with no injuries sustained by the occupants and minor damage to the helicopter.

1.2. It was later determined that the double engine power loss had been caused by lack of fuel flow to the engines, despite there being a large quantity of fuel in the main fuel tanks. The cause of the lack of fuel flow to the engines was the pilot's incorrect management and configuration of the aircraft's fuel supply system, which prevented the fuel in the main tanks getting to the engines.

1.3. The pilot's lack of recent experience on the BK117 was a contributory factor in this event, including the absence of any recent training or competency assessment on the aircraft type. The pilot did not refer to a checklist when carrying out the normal pre-flight, before-start and after-start procedures. Had he referred to a checklist he would have likely corrected the error in the fuel system configuration before flight. The company that operated the helicopter did not have any procedures in place to address the lack of recent experience, such as additional training, supervision or a policy on the use of written checklists in such a situation.

1.4. A contributing factor to the power loss was the pilot's inability to detect the caution lights that would have alerted him to the incorrectly configured fuel system, due to the cockpit lighting dimmer switch being left on in daylight. A modification of the helicopter to enable the use of night vision equipment was found to have adversely affected the readability of the caution lights during daylight, when the cockpit lighting dimmer was on. A design feature of the BK117 fuel system meant that both engines lost power within seconds of each other.

1.5. The Commission made the following findings:

- both engines lost power due to fuel starvation, because the pilot did not switch on the fuel transfer pumps after starting the engines
- the pilot should not have operated the flight because he had not been assessed for his type-specific knowledge or checked for competency on the BK117 in the previous five years, and he lacked recent experience on the aircraft type
- the operator's system for maintaining oversight of its pilots' proficiency and currency was not robust enough to ensure that this pilot was proficient and sufficiently current to fly the BK117
- a cockpit lighting modification to the helicopter had adversely affected the readability of the caution lights during daylight, when the dimmer switch was on. Brightly illuminated caution lights should have alerted the pilot to the incorrectly configured fuel system and the low fuel levels in the supply tanks, and could have prevented the incident
- the helicopter was not designed to generate an aural warning of a critically low fuel level in the supply tanks. An aural warning, as fitted to later designs, would have alerted the pilot to the potential loss of engine power, and could have prevented the incident
- the operator did not require pilots to refer to written checklists if they lacked recent experience on an aircraft type. The pilot did not refer to a written checklist; had he done so he would have been prompted to: switch the fuel transfer pumps on, which would have prevented the fuel starvation; and turn the dimmer switch off, which should have ensured the caution lights were visible to the pilot.

1.6. The Commission made the following recommendations:

- on 25 February 2016 the Commission recommended to the Director of Civil Aviation that he review all modifications to the cockpit lighting on BK117 helicopters for night vision use, to ensure they do not unduly increase the risk of a similar incident occurring. If they do introduce an unacceptable level of risk, changes to the installation, such as a low-fuel-level aural warning or brighter LED (light-emitting diode) caution lights, should be required

- on 25 February 2016 the Commission recommended to the Chief Executive Officer of Garden City Helicopters Limited that he amend company policies, procedures and practices relating to the management of pilot competency. These amendments should include annual recurrent training and regular proficiency checks for all pilots on all aircraft types flown. For pilots who lack recent experience on an aircraft type, the amendments should introduce increased supervision, additional training, and the use of written checklists
- on 25 February 2016 the Commission gave notice to the Director of Civil Aviation that the Commission had recommended to the Chief Executive Officer of Garden City Helicopters that he amend company policies, procedures and practices relating to the management of pilot competency

1.7. The key lessons identified from the inquiry into this occurrence were:

- pilots who lack recent experience on an aircraft type should refer to written cockpit checklists when carrying out normal and emergency procedures
- pilots who fly multiple aircraft types concurrently must remain vigilant to inadvertently transferring habits and procedures from one type to another
- operators who require their pilots to fly different aircraft types must have robust policies and procedures that ensure the pilots are appropriately experienced, trained and current on each aircraft type.

2. Conduct of the inquiry

2.1. On 6 May 2014 the Transport Accident Investigation Commission (Commission) was notified of the incident by the Civil Aviation Authority of New Zealand (CAA), and opened an inquiry under section 13 of the Transport Accident Investigation Commission Act 1990.

2.2. The next day the Commission's investigator in charge travelled to Christchurch to join another Commission investigator and begin the field investigation.

2.3. Interviews were held later the same day with the pilot and crewman on the flight, and the helicopter was inspected at the operator's maintenance hangar at Christchurch International Airport.

2.4. On 8 May 2014 further interviews were carried out with the doctor and nurse who were on board the helicopter. Maintenance documents were reviewed, as well as the operator's manuals and staff training records.

2.5. On 9 May 2014 a meeting was held with the operator's chief executive officer and the competency manager to discuss the incident and obtain background information on the company.

2.6. On 21 May 2014 the engines were operationally checked in an engine test cell[2] in Auckland, under the supervision of the investigator in charge and the engine manufacturer's local representative.

2.7. The design organisation that had validated the night vision imaging system lighting modification on ZK-HJC was contacted to clarify the certification process.

2.8. Comparisons were made between ZK-HJC and four other BK117 cockpit lighting installations: two NVIS (night vision imaging system) modified aircraft, and two unmodified aircraft with the original lighting installation.

2.9. On 28 October 2015 the Commission approved the circulation of the draft report to interested persons for comment.

2.10. Submissions were received from six of the interested persons. The Commission has considered all submissions and any changes as a result of those submissions have been included in this final report.

[2] An engine test cell is an engine ground testing facility, where an engine is fitted to a test stand, a test load is put on the engine to simulate operating conditions, and engine parameters can be recorded.

3. Factual information

3.1. Narrative

3.1.1. Garden City Helicopters Limited (the operator) operated several types of helicopters for a variety of commercial activities, which included medical evacuations and patient transfers between medical facilities. The operator's base was located at Christchurch International Airport.

3.1.2. On 5 May 2014 one of its twin-engine Kawasaki BK117 B-2 helicopters was required to conduct a patient transfer from Ashburton Hospital to Christchurch Hospital. The helicopter departed the base in Christchurch shortly after morning civil twilight[3] at 0715, with one pilot, one crewman and two medical staff on board.

3.1.3. During the flight to Ashburton a caution light for the rear door illuminated momentarily in the cockpit[4]. The pilot noted the caution light and cancelled the master warning light. Otherwise the flight was uneventful.

3.1.4. The pilot shut down the helicopter's engines after landing in Ashburton. The patient was taken on board, after which the pilot carried out the before-start procedures and started both engines. At 0852 the helicopter departed Ashburton with five people on board for the flight to Christchurch.

3.1.5. About 20 minutes later a loud bang was heard by everyone on board and an aural warning sounded in the cockpit. The pilot noticed the right engine low-revolutions-per-minute light had illuminated and that the instrument readings for the right engine were decreasing. Shortly afterwards a similar banging noise was heard and the helicopter started to descend rapidly. The pilot realised that both engines had now lost power and he entered the helicopter into autorotation[5] and chose a landing area.

3.1.6. The crewman, who was also a paramedic, made contact with the ambulance communication centre in Christchurch during the autorotation to advise it of the emergency and where they would be landing.

3.1.7. At 0912 the pilot made a firm landing in a paddock near Springston. The pilot then stopped the rotors turning and switched off electrical power to the helicopter.

3.1.8. Within half an hour an ambulance arrived to take the patient to hospital. Nobody was injured during the emergency landing and the helicopter suffered minor damage.

3.2. Post-incident tests and research

3.2.1. After the emergency landing the pilot checked the cockpit instruments and switches, and noted that:

- the two fuel prime pump switches were 'on' (these would normally be off during flight)
- the two fuel transfer pump switches were 'off' (these would normally be on during flight)
- there was a total of 380 kilograms (kg) of fuel indicated on the fuel quantity gauges
- the cockpit lighting dimmer switches were 'on'.

The pilot confirmed that these switch positions had not been changed during the flight.

3.2.2. Both engines were removed from the helicopter and sent to an engine maintenance facility in Auckland, where they were run in a test cell under the supervision of the investigator in charge

[3] Morning civil twilight is the time between dawn and sunrise, when the sun is just below the horizon.
[4] It was not uncommon to have this occur in flight. It often meant one of the micro-switches on the clamshell doors needed adjusting.
[5] Autorotation is a process of producing lift in an unpowered rotor system by inducing an airflow up through the main rotor blades as the helicopter descends.

and the engine manufacturer's local representative. Both engines ran successfully at different power settings, with the recorded parameters all within the manufacturers' specifications. The engines were subsequently returned to service and refitted to the helicopter.

3.2.3. Fuel samples were taken from the engines and from each fuel tank and tested. All samples conformed with the correct type of fuel for the engine type, and were free of contaminants. There were no signs of impending fuel filter bypass[6], and all the fuel and oil filters on the helicopter were free of blockages and contaminants. There were no signs of heat distress on the engine or main rotor gearbox. All magnetic chip detectors[7] on the helicopter were free of metallic debris.

3.3. Aircraft information

3.3.1. The Kawasaki BK117 helicopter type is a medium-sized, twin-engine helicopter developed jointly by aerospace companies from Germany (Bolkow) and Japan (Kawasaki). It first entered service in 1982 and is commonly used for search and rescue operations and air ambulance flights. At the time of the incident there were 23 BK117 helicopters on the New Zealand aircraft register, with around half of those being used for search and rescue and air ambulance flights.

3.3.2. The helicopter involved in this incident had been manufactured in Japan in 1990, and had been imported to New Zealand by the operator in 1996. At the time of the incident it had accrued 6,295 flight hours. There were no outstanding maintenance tasks or deferred defects recorded in the aircraft's logbooks, and it had a valid non-terminating airworthiness certificate.

Fuel system

3.3.3. The fuel tanks were located underneath the cabin floor (see Figure 1)[8]. The arrangement comprised two main tanks (front and rear) and two smaller supply tanks located between the main tanks, one for each engine (left and right). The front and rear main tanks were connected by tubes, and fuel from the rear main tank gravity-fed into the front main tank via these tubes. The helicopter normally cruised in a nose-down pitch attitude[9], which assisted the gravity feed from the rear to the front main tank. Non-return valves in the connecting tubes prevented fuel flowing back into the rear tank if the helicopter was flying or on the ground in a nose-up pitch attitude.

3.3.4. Each engine had an engine-driven fuel pump that would draw fuel from its respective supply tank; the left engine drew fuel from the left supply tank and the right engine from the right supply tank. Both of these supply tanks were connected by transfer tubes to the front main tank. To ensure the supply tanks remained full, two transfer pumps were fitted inside the front main tank (see Figure 2). The transfer pumps sent fuel into both supply tanks through the transfer tubes, meaning that if one transfer pump failed the other would still provide sufficient fuel to feed both engines. The fuel flow from these transfer pumps exceeded the amount required to run both engines, so the excess fuel was transferred back to the front main tank via overflow tubes near the top of the tanks.

3.3.5. It was therefore important that the transfer pumps were switched on during flight to ensure that an adequate supply of fuel to the supply tanks, and thus to the engines, was maintained (Figure 2).

[6] Fuel automatically bypasses the filter in the event of the filter becoming blocked in service.
[7] A magnetic chip detector is a probe installed in an engine or gearbox oil system that attracts ferrous debris. It can be removed and inspected to detect the early signs of impending metal component failures.
[8] All diagrams are sourced from the Bolkow BK117 systems training manual.
[9] Attitude is the orientation of an aircraft's axis with respect to the horizon, in this case the pitch or longitudinal axis.

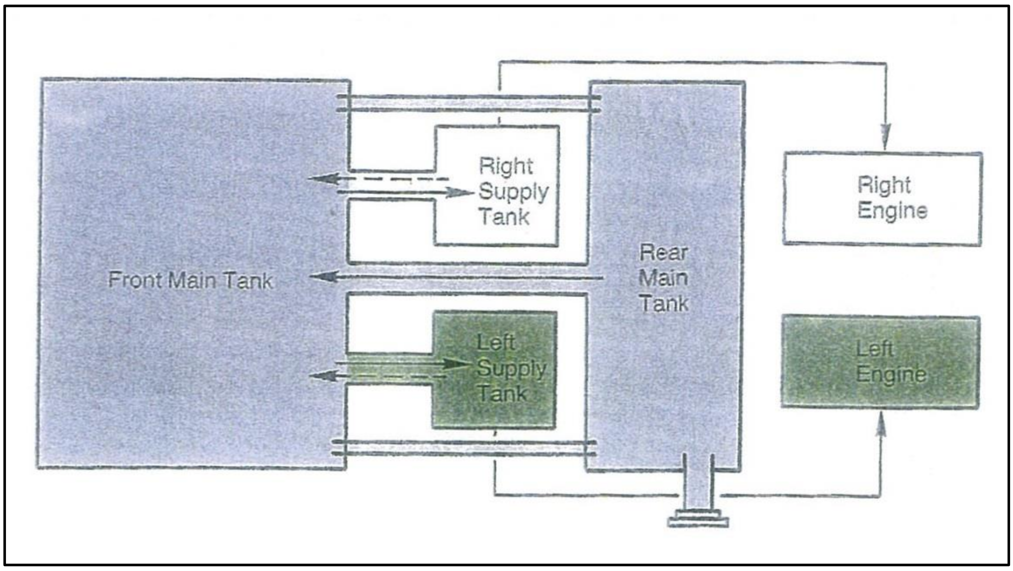

Figure 1
Fuel tanks

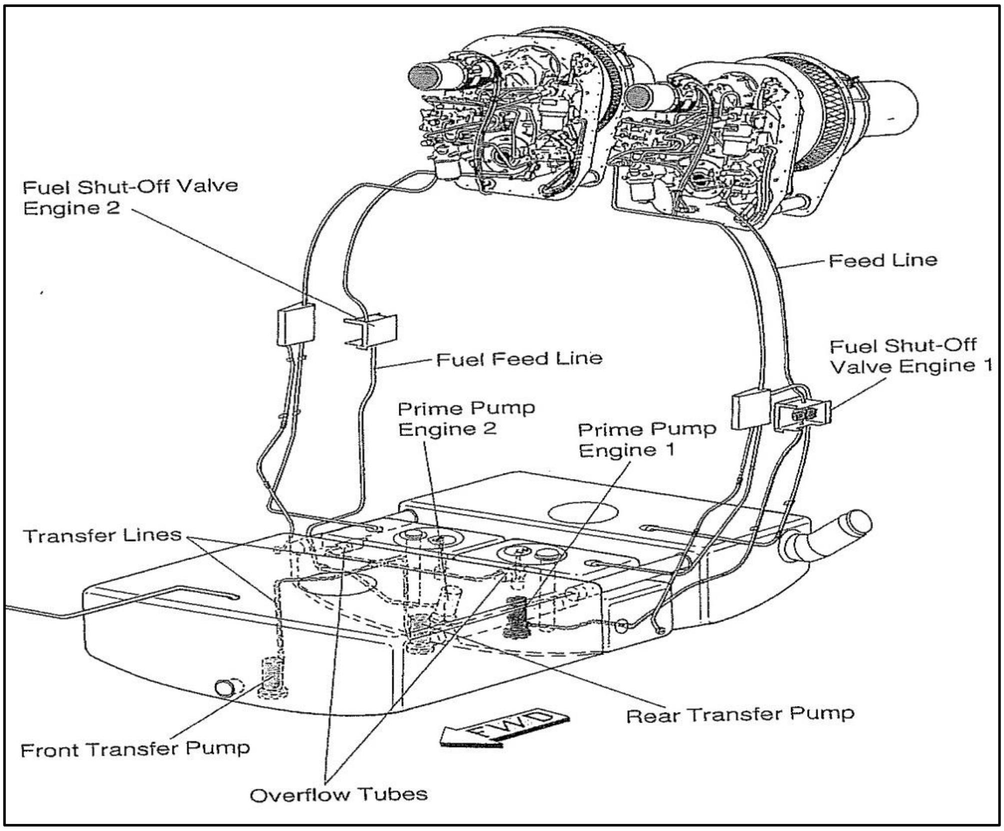

Figure 2
Fuel system

3.3.6. In order to supply fuel to the engines during engine starts, a prime pump was installed in each supply tank to deliver fuel under pressure to the engine until the engine was running. These prime pumps were not needed during flight as the engine-driven fuel pumps were able to draw the fuel out of the supply tanks once the engines were at operating speed. The normal before-start procedure was for the two prime pumps to be switched on for the engine start (see Figure 3). Once the engines were up to operating speed, the two transfer pumps would be turned on and the prime pumps would then be turned off. The engine-driven fuel pumps would now be drawing fuel from the supply tanks, and the transfer pumps would be topping up the supply tanks with fuel from the front main fuel tank.

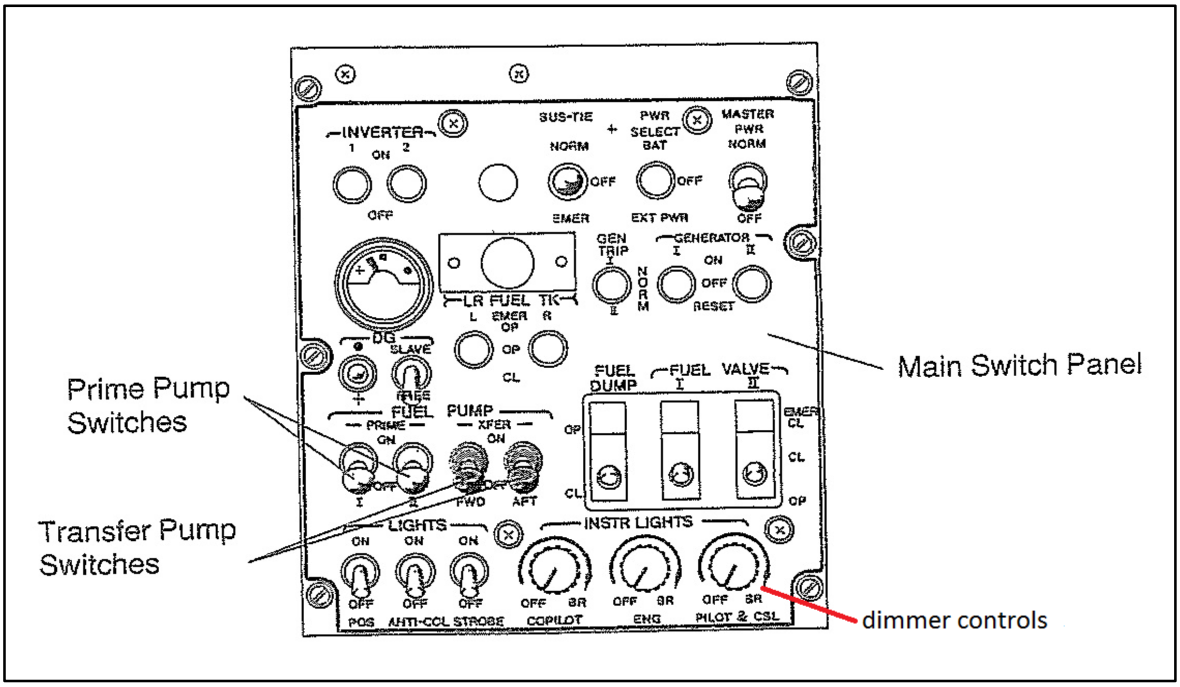

Figure 3
Fuel pump switches and dimmer controls

Central annunciator panel

3.3.7. A central annunciator[10] panel (see Figure 4) in the cockpit contained warning and caution lights to alert the pilot to any abnormal system conditions or failures. In normal flight operations there would be no lights illuminated on the panel. The panel was configured at manufacture with red warning lights and orange or amber caution lights. The warning lights were installed to indicate a hazard that required immediate attention from the pilot, and the caution lights were installed to indicate the possible need for future corrective action by the pilot.

3.3.8. The central annunciator panel had warning and caution lights for the fuel system, which indicated low fuel level and/or low fuel pressure conditions, as well as the status of the fuel transfer pumps. A 'FUEL LOW I' (left tank) or 'FUEL LOW II' (right tank) caution light illuminated if either the left or right supply tank (respectively) fuel level dropped to below 23 kg. A 'FUEL PRESS I' (left engine) or 'FUEL PRESS II' (right engine) warning light illuminated if the pressure in the left or right (respectively) engine fuel pump inlet dropped to below 5.8 pounds per square inch.

3.3.9. There were two caution lights for the fuel transfer pumps. The 'F PUMP XFER FWD' or 'F PUMP XFER AFT' light illuminated if either the forward or rear transfer pump switch respectively was selected to off. If any of the warning or caution lights came on in flight, a master warning light above the flight instruments illuminated to catch the pilots' attention and indicated that there was an annunciator panel light on.

3.3.10. All of the warning and caution lights of the fuel system were checked after the incident, and all of them were found to be serviceable and functioning as they were designed to.

[10] An annunciator is a light, or panel of lights, that provides information on the state or condition of systems, components and equipment.

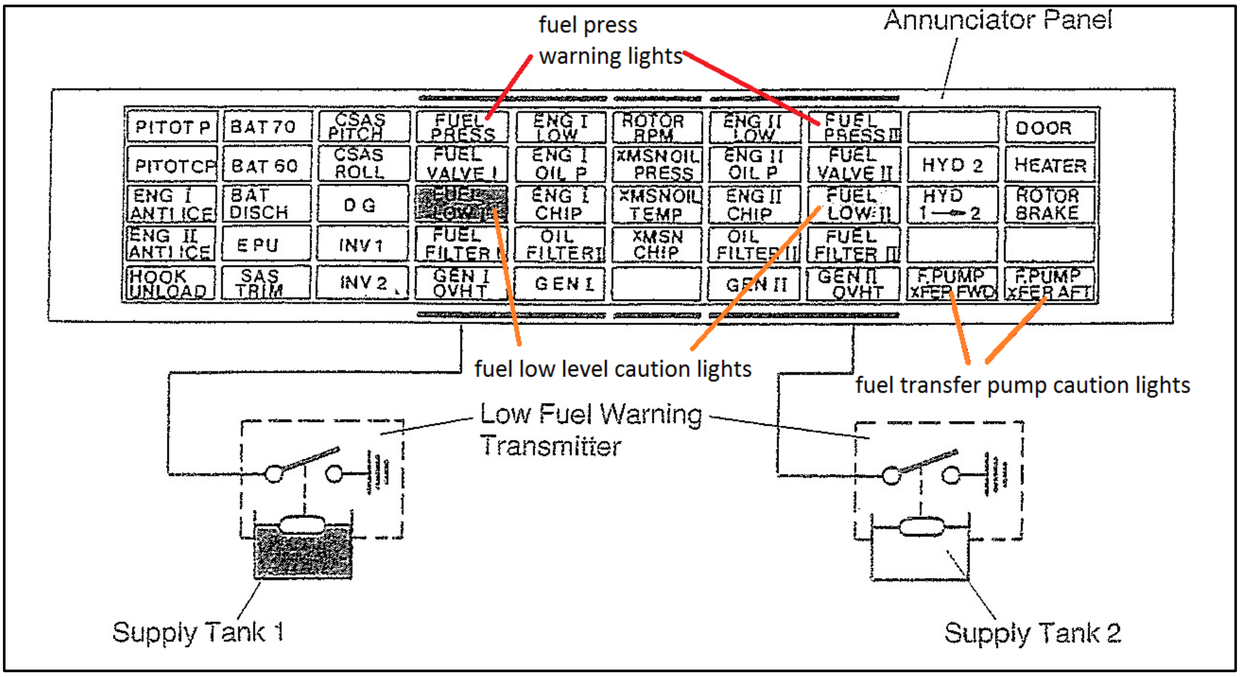

Figure 4
Central annunciator panel and low fuel warning system

3.4. Instrument lighting dimmer controls

3.4.1. The cockpit instrument lighting and annunciator panel lights had three dimmer switches located on the centre pedestal control panel next to the pilot (see Figure 3). The rotary switches had an off position that disabled the dimming function and set all the lights to full bright. If the knob was turned to the right (clockwise) out of the off position, the brightness of the instrument lights could be adjusted as required.

3.4.2. The annunciator panel lights had two settings only: bright when the dimmer switch was off, and dim when the dimmer switch was moved into the variable range. There was no way of manually adjusting the brightness of the warning or caution lights. The brightness of the flight instruments and engine indication gauges was adjusted through the dimmer switch, so that suitable levels of illumination could be set by the pilot for different ambient light conditions. To assist with the pilot's night vision a low setting was typically used for night-time operations, and a bright setting was used for daytime operations to make them more visible in direct sunlight.

3.5. Personnel information

3.5.1. The pilot held a commercial pilot licence (helicopter), which had been issued by the CAA in July 1988. He had gained a type rating on the BK117 series helicopter in September 2007, and at the time of the incident had 267 hours' flying experience on that type, and a total of 9,336 hours on helicopters.

3.5.2. The pilot had flown 25 hours in the previous 30 days and four hours in the previous seven days. Nearly all of this flying had been in another helicopter type, the AS350. The exception was a 12-minute flight in the BK117 the day before the incident flight, which included three take-offs and landings and made him legally current to operate the BK117.

3.5.3. The pilot said he had been well rested prior to duty on 5 May 2014 and had considered himself fit to fly that day. The three days leading up to the day of the incident had consisted of two days off at home, followed by an eight-hour duty the day before the incident that included 1.6 hours of flying.

3.5.4. Prior to the re-currency flight the day before the incident, the pilot had flown the BK117 on two occasions for a total of 1.6 hours in the preceding 12-month period.

4. Analysis

4.1. Introduction

4.1.1. The inquiry found no mechanical reason for the engines' loss of power on the incident flight. It was determined the power losses were due to fuel starvation[11].

4.1.2. The following analysis discusses the circumstances leading up to and contributing to the double engine power loss. It also discusses a number of safety issues that directly or indirectly contributed to the incident: actions and omissions by the pilot, the operator and those involved in the modification of the helicopter for night flying operations, namely:

- the pilot lacked recent experience and training on the aircraft type
- there was no aural warning to alert the pilot to the potential fuel starvation of both engines, which could have prevented the loss of power
- the modification of the cockpit lighting adversely affected the readability of the caution lights during daylight, when the dimmer was on
- the design of the BK117 fuel system meant that both engines would lose power at nearly the same time if a pilot mismanaged the fuel system and did not see the low-fuel-level warnings.

4.2. What happened

4.2.1. Following the emergency landing the pilot stated that the fuel prime pumps had been switched on and that the fuel transfer pumps had been switched off for the duration of the flight, and these switch positions were confirmed by the pilot on the ground.[12] The prime pumps supply fuel under pressure from the supply tanks to the engine during the start, then they are switched off. The fuel transfer pumps must always be switched on after engine start and remain on for flight, otherwise the small supply tanks from which the engines draw fuel will run dry.

4.2.2. It would have taken between 18 and 21 minutes for the engines to exhaust all the fuel from the supply tanks if they were not being replenished with fuel by the transfer pumps. Both tanks were the same size and normally both engines used the same amount of fuel, meaning the engines would have lost power within seconds of each other. The helicopter was about 20 minutes into the flight when both engines lost power within a short space of time. Therefore it is highly likely that the pilot had left the fuel transfer pumps off after starting the engines. This allowed the supply tanks to run dry, causing both engines to lose power.

4.2.3. A possible reason for the pilot's omission was his lack of recent experience on the BK117 helicopter. He had almost exclusively flown the AS350 helicopter type leading up to the incident flight. The AS350 is a smaller, single-engine helicopter made by a different manufacturer, and has a simpler fuel system than that of the BK117.

4.2.4. The fuel system in the AS350 comprises a single main tank with two fuel boost pumps that supply the engine with positive pressure at all times. A pilot turns the boost pumps on prior to engine start and they remain on for the entire flight. The pilot could have inadvertently applied the more familiar fuel management technique for the AS350. It is one explanation for his leaving the fuel prime pumps on and not turning the fuel transfer pumps on.

4.2.5. Inadvertently applying procedures specific to one operation to another similar but different operation is a recognised human error. In the context of human factors in aviation it is

[11] Fuel starvation is where there is adequate fuel on board an aircraft to run the engines, but it is unable to be delivered to the engine, through either a blockage or failure in the fuel system or incorrect fuel system management by the pilot.
[12] This was based on the pilot's recollection provided to the Commission.

sometimes called 'negative transfer'[13]. Having experience and currency on the helicopter type is one way of reducing the likelihood of it happening (refer to section 4.5). The use of checklists is another, more reliable method.

4.2.6. Commercial helicopter operators are required by Civil Aviation Rules (CAR) to have cockpit checklists available for flight crew to use, but unlike operators of larger aircraft that are crewed by two pilots, they are not required to ensure that pilots refer to them. It can be difficult for a single pilot in a helicopter to refer to a checklist during flight, because much of the time both hands are busy manipulating the flight controls and cockpit switches. However, there is no reason why checklists cannot be referred to during before-flight checks, which is when flight-critical systems and controls are set correctly prior to departure.

4.2.7. The starting-engine checklist for the helicopter included prompts for the pilot to switch off the fuel prime pumps and switch on the fuel transfer pumps after engine start. The pilot did not use this checklist. The use of this checklist should have captured his omission and prevented the helicopter taking off with the fuel transfer pumps switched off (see Appendix 1, starting engine check, items 14 and 20).

4.2.8. The following section discusses why, during the subsequent 20 minutes of flight, the pilot was not alerted to the fact that the fuel transfer pumps were not switched on and that the fuel level in the supply tanks was getting dangerously low.

4.3. Warning and caution lights and aural warnings

Aural warnings

4.3.1. The BK117 was not designed to have an aural warning to alert pilots to low fuel levels in the supply tanks. The first aural warning the pilot would have heard in this situation would have been the low-engine-speed warning horn as the engine lost power due to fuel starvation.

4.3.2. This issue was addressed in later helicopter designs that featured additional fuel caution lights to indicate reducing fuel levels in the supply tanks, and caution lights to indicate the prime pumps were on. The fuel-low-level caution was changed to a red warning light with an associated aural warning horn in the later designs.

Visual warnings

4.3.3. Like many helicopters used for emergency medical and search and rescue flights, ZK-HJC had had its cockpit lighting modified to enable a night vision imaging system to be used. The intensity and colours of the cockpit lights and displays were changed in order to be compatible with night vision goggles[14] and to avoid cockpit light interference[15]. The modification involved installing special lights and filters that removed any light that was incompatible with the use of night vision goggles. More recent modifications have incorporated light-emitting diode (LED) warning and caution lights that are more efficient and easier to read when dimmed.

4.3.4. Prior to the night vision imaging system modification (NVIS), the colours of the warning and caution lights of the central annunciator panel were red and orange respectively; after the modification they were changed to orange and yellow. The intensity of the lights was also changed, and the caution lights were noticeably less bright on the dim setting when compared with an unmodified lighting system (see Appendix 2).

4.3.5. Comparisons made between NVIS modified and unmodified aircraft (see Appendix 2) show that when dimmed, the unmodified annunciator panel lights (Figures 15 and 17) are significantly brighter than the modified lights (Figures 6 and 11), and that the caution lights

[13] The transfer from one cockpit to another -- of different design or configuration – of habits or responses that were appropriate in the former but are inappropriate in the latter, thereby posing a threat to flying safety. (Aviat Space Environ Med. 1982 Dec;53(12):1224-6.)
[14] Night vision goggles are normally a binocular device that pilots wear over their eyes to amplify the ambient light at night and enhance vision in low light conditions.
[15] Night vision goggles work by amplifying light within a certain wavelength band; if cockpit lights are left in this band they will also be amplified and blind the pilot.

are unreadable when the modified lights are dimmed. They also highlight the variations in the brightness, colours, size of the lettering and layout of the different installations, and that one of the modified aircraft (Figure 13) is brighter than the other two (Figures 6 and 11).

4.3.6. After each helicopter was modified the lighting system was assessed to check the brightness and attention-getting properties of the new lights, and to make sure that none of the warning or caution lights could be confused with another one.

4.3.7. The emphasis of this assessment was to ensure there was no light interference of the night vision goggles, and that the pilot could see and interpret all the lights in the cockpit at night with night vision goggles on or off. As part of this assessment there was a test to determine if the daylight readability of the lights had been adversely affected by the modification. These readability and attention-getting tests were subjective, involving representatives from the CAA and the organisation that designed the modification viewing the lights from the pilot's position in different ambient lighting conditions.

4.3.8. The test procedure guidelines for assessing daylight readability state that if the lights have brightness control (a dimmer) this test should be conducted at various settings. However, in practice this test is not normally done with the dimmer on, the rationale being that the pilot is unlikely to dim the lights during the day. While it might not be normal practice to select the dimmer switch on in daylight conditions, there is a risk that the dimmer switch could be left on inadvertently. In this case the pilot had conducted his pre-flight and before-start procedures at Christchurch in the early morning around dawn, and had turned the dimmer on. He had subsequently forgotten to turn the dimmer off for the daylight flight from Ashburton.

4.3.9. With reference to the use of checklists discussed in the previous section, if the pilot had used the checklists he would have been instructed to check that the dimmer was off (see Appendix 1, cockpit check, item 17) and check the annunciator panel lights (before-starting engine check, items 5, 10 and 17). However, the use of written checklists for the helicopter was not mandatory, and the risk of a pilot leaving the dimmer on during daylight remained.

4.3.10. Therefore the assessment of the night vision imaging system modification was not conducted in accordance with the test procedure guidelines, because the system was not assessed for daylight readability at various dimmer control settings.

4.3.11. Figures 5 and 6 are photographs of the modified central annunciator panel lights of the helicopter. Figure 5 shows the light dimmer switch off and the lights on full brightness. Figure 6 shows the same lights illuminated but with the dimmer switch on. It is clear that in daylight conditions with the dimmer switch on, the illuminated yellow caution lights are almost impossible to see.

4.3.12. Consequently, the two caution lights on the central annunciator panel that should have alerted the pilot to the fact he had forgotten to turn on the fuel transfer pumps at Ashburton would have been very difficult to see. To emphasise this point, during the first flight from Christchurch to Ashburton shortly after dawn, the pilot did notice the yellow caution light that came on for the rear door fault.

4.3.13. The first flight was longer in duration and was successfully completed without a fuel starvation event, which suggests the pilot either remembered to turn the fuel transfer pumps on after engine start or noticed that the fuel transfer pump caution lights were on some time during the first flight and turned the transfer pumps on. However, he did not notice during the return flight, in brighter ambient light, the illuminated caution lights for the fuel transfer pumps that indicated they were not switched on.

4.3.14. The fuel-low-level caution lights were successfully tested after the incident and should have illuminated when there was around 23 kg of fuel remaining in each supply tank, but due to the dimmer setting and the lack of an associated aural warning they were not detected by the pilot during the return flight. Had the pilot monitored the fuel levels in the supply tanks during the flight, he would have noticed that the levels were decreasing, which would have warned him that fuel was not being transferred from the main tanks into the supply tanks.

4.3.15. There had been two other incidents involving engine failures in BK117s that occurred in similar circumstances. One occurred in New Zealand in 2011 when a helicopter had an engine failure during a lifting operation, but landed safely. The other happened in the United States in 2001[16] when a BK117 operating a medical evacuation flight had double engine failure and crashed. In both cases the helicopters had been used at night or during the early morning prior to the incident, and the cockpit lighting dimmer switches had been left on for the subsequent flights in daylight conditions. It was also confirmed in one case, and suspected in the other, that the fuel transfer pumps had been left off for the flight, causing fuel starvation.

Figure 5
HJC annunciator panel dimmer off

[16] National Transportation Safety Board accident report FTW01LA166.

Figure 6
HJC annunciator panel dimmer on

4.4. Fuel system design

4.4.1. A pilot usually takes between four and six seconds[17] to recognise that an engine failure has occurred, and much longer to determine why it has happened. This delay did not allow enough time in this case for the pilot to detect and correct the fuel transfer pump switch positions before the second engine lost power. At this stage it was unlikely that power from either engine could be restored immediately due to the interruption of fuel flow and the air being drawn into the engines' fuel system. If this series of events had happened at a low altitude the only option would have been to carry out an autorotation.

4.4.2. Later helicopter designs that were developed from the BK117 incorporated fuel supply tanks of different capacities. This meant that in helicopters such as the EC135[18], if the transfer pumps were inadvertently left off, one engine would lose power at least a minute before the other. This would leave the pilot with one engine running and more time to recognise what the problem was and to recover the situation by turning the transfer pumps on before the second engine lost power.

4.5. Pilot training, competency and currency on aircraft type

4.5.1. The operator was required to comply with CAR Part 135[19], and it was therefore incumbent on it to ensure that each crew member was adequately trained and was current and proficient in each aircraft type and operation in which the crew member served. The CAR required the operator to maintain a flight crew training programme that included ongoing recurrent training on the aircraft types to be used, along with a crew member competency programme to ensure continual proficiency. As part of these ongoing programmes, each pilot had to pass a competency check flight in the preceding 12 months in one of the aircraft types normally flown

[17] Flight Safety Foundation, helicopter safety, 1999.
[18] The EC135 was a twin-engine helicopter that had a similar fuel tank arrangement, which first flew in 1994.
[19] Part 135 in the CAR covered commercial operations for all helicopters, and small aeroplanes with nine passenger seats or weighing less than 5,700 kg.

by the pilot. Each pilot also had to have successfully completed an annual written or oral test of their knowledge of the systems, performance and operating procedures for each aircraft type currently flown by the pilot.

4.5.2. It was normal and accepted practice for operators to conduct the annual competency check flights on one type of aircraft on a certain operation or route, then rotate types and operations each year so that pilots were tested in different types and on different routes, to ensure proficiency on all types of aircraft and operations. However, the pilot involved in this incident had not been tested or checked in this way, and according to his training records had not been assessed for his aircraft type knowledge or checked for competency on the BK117 since 2009. Most of his annual recurrent training and competency checks during this period had been carried out on the AS350 type of helicopter.

4.5.3. Pilots were required to be legally current in the aircraft type if they were to fly passenger or any other commercial operations. The currency requirement under CAR Part 61[20] was for pilots to make three take-offs and landings within the preceding 90-day period on the type of aircraft to be used. This was the minimum requirement for any aircraft type and for all pilots. It was common for operators to require a higher level of currency for their pilots of commercial operations, and if pilots did not meet these higher thresholds, recurrent training or supervision was normally required to regain competency on the type.

4.5.4. The operator in this case did not have any additional requirements or procedures above or beyond the legal currency required under CAR Part 61. A review of the pilots logbook revealed that in the three years preceding the incident he had flown the BK117 type on five occasions without having met these currency requirements.

4.5.5. The pilot had logged less than 15 hours on the BK117 since October 2010, and prior to the flight the day before the incident the pilot had flown it once in January 2014, once in June 2013 and before that in September 2012. Despite the lack of recent experience on the BK117, no additional training or check flights had been carried out on the type with the pilot during this period.

4.5.6. A pilot's knowledge, experience, proficiency and currency on an aircraft type are key factors in safe operations. Meeting the minimum requirements set out in the CAR, and following robust company procedures that ensure pilots are adequately trained and current on an aircraft type, are important factors in maintaining pilot competency within an organisation.

4.6. Organisational factors

4.6.1. The operator was authorised by the CAA to carry out commercial helicopter and fixed-wing flights under CAR Part 135, and to operate from bases at Christchurch, Greymouth and Nelson. The operator was also affiliated with sister helicopter charter companies in Vanuatu and Fiji. The types of operations carried out included general charter work such as scenic flights, air transport, commercial work and lifting, as well as search and rescue, medical transfers and flight training. Pilots rotated around the New Zealand and overseas bases as needed, and worked under different managers on a regular basis.

4.6.2. The operator used five different types of helicopter, and many of the pilots flew more than one aircraft type during their employment. Several pilots were flying multiple types on different operations on a regular basis, while some flew mainly one type with occasional flying on other types. The pilot involved in this incident was rated on all aircraft types used by the operator, and at the time of the incident was approved to carry out commercial operations in four of them. However, the majority of his flying had been carried out using the AS350 helicopter on daytime commercial and air transport operations. He did not regularly fly the BK117 type, and was only required to fly it when none of the three full-time BK117 pilots was available.

4.6.3. The company had seven senior people responsible for crew training, flight operations, competency assessment and quality management. For the helicopter fleet, the flight operations manager and training manager were both current BK117 pilots who did most of

[20] Part 61 of the CAR covered pilot licences and ratings.

the flying on the type for the company. The training manager had not conducted any check or training with the pilot on the BK117, and did not regularly fly with him. The competency manager, who was also the chief pilot, did not conduct the competency checks for the operator, and did not regularly fly with all the pilots who flew the BK117. He was, however, together with the operations manager and the training manager, responsible for maintaining the currency and competency of all pilots.

4.6.4. The shared delegation of training and competency responsibilities between three managers made it harder for the operator to ensure that all training and competency requirements under CAR Part 135 were being met. These responsibilities are traditionally held by one person, a training manager, who controls the pilots' annual recurrent training programme and competency checks and is normally a line pilot who flies with the pilots. It is easier for a training manager who flies with the pilots, maintains the training records and conducts the competency checks to maintain oversight of all pilots' proficiency and currency.

4.6.5. It was unclear from the company operations manual and check and training manual who within the company was ultimately responsible for ensuring that all pilots were adequately trained, current and competent. The duplication and overlapping of responsibilities meant there was no clear delineation of duties. This management arrangement made it difficult to work together cohesively to maintain an effective oversight of pilot currency and competency.

5. Findings

5.1 Both engines lost power due to fuel starvation, because the pilot did not switch on the fuel transfer pumps after starting the engines.

5.2 The pilot should not have operated the flight because he had not been assessed for his type-specific knowledge or checked for competency on the BK117 in the previous five years, and he lacked recent experience on the aircraft type.

5.3 The operator's system for maintaining oversight of its pilots' proficiency and currency was not robust enough to ensure that this pilot was proficient and sufficiently current to fly the BK117.

5.4 A cockpit lighting modification to the helicopter had adversely affected the readability of the caution lights during daylight, when the dimmer switch was on. Brightly illuminated caution lights should have alerted the pilot to the incorrectly configured fuel system and the low fuel levels in the supply tanks, and could have prevented the incident.

5.5 The helicopter was not designed to generate an aural warning of a critically low fuel level in the supply tanks. An aural warning, as fitted to later designs, would have alerted the pilot to the potential loss of engine power, and could have prevented the incident.

5.6 The operator did not require pilots to refer to written checklists if they lacked recent experience on an aircraft type. The pilot did not refer to a written checklist; had he done so he would have been prompted to: switch the fuel transfer pumps on, which would have prevented the fuel starvation; and turn the dimmer switch off, which should have ensured the caution lights were visible to the pilot.

6. Safety actions

General

6.1. The Commission classifies safety actions by two types:

(a) safety actions taken by the regulator or an operator to address safety issues identified by the Commission during an inquiry that would otherwise result in the Commission issuing a recommendation

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

Safety actions addressing safety issues identified during an inquiry

6.2. Nil.

Safety actions addressing other safety issues

6.3. Nil.

7. Recommendations

General

7.1. The Commission may issue, or give notice of, recommendations to any person or organisation that it considers the most appropriate to address the identified safety issues, depending on whether these safety issues are applicable to a single operator only or to the wider transport sector. In this case recommendations have been issued to the Director of Civil Aviation and the Chief Executive Officer of Garden City Helicopters.

7.2. In the interests of transport safety it is important that these recommendations are implemented without delay to help prevent similar accidents or incidents occurring in the future.

Recommendations

7.3. The cockpit lighting modification carried out on the helicopter was found to have adversely affected the readability and attention-getting properties of the warning and caution lights of the central annunciator panel, in certain conditions. These caution and warning lights are designed to alert the pilot to any unsafe conditions or failures of flight-critical systems.

On 25 February 2016 the Commission recommended to the Director of Civil Aviation that he review all modifications to the cockpit lighting on BK117 helicopters for night vision use, to ensure they do not unduly increase the risk of a similar incident occurring. If they do introduce an unacceptable level of risk, changes to the installation, such as a low-fuel-level aural warning or brighter LED caution lights, should be required. (006/16)

On 9 March 2016, Civil Aviation Authority replied:

> On 14 December 2015, the CAA responded to the draft final report and made observations and specific comment to the proposed recommendation.
>
> Based on those observations and comments, the Director considered that the weight of evidence indicated pilot mismanagement of the engine start process not the annunciator lighting. Therefore, the subsequent safety lessons are more aligned to the pilot and the operator's adherence to the recommended practices contained within the aircraft flight manual and the observance of rules. Therefore, the Director will not implement the recommendation.

7.4. The operator's management of pilot competency was found to be insufficiently robust to ensure that pilots who lacked recent experience on an aircraft type were given additional training and increased supervision. In this case a pilot who was not proficient or sufficiently current on the aircraft type was allowed to operate the flight.

On 25 February 2016 the Commission recommended to the Chief Executive Officer of Garden City Helicopters that he amend company policies, procedures and practices relating to the management of pilot competency. These amendments should include annual recurrent training and regular proficiency checks for all pilots on all aircraft types flown. For pilots who lack recent experience on an aircraft type, the amendments should introduce increased supervision, additional training and the use of written checklists. (007/16)

On 6th April 2016 Garden City Helicopters replied:

> In response to your letter dated the 25th February 2016 Garden City Helicopters would like to confirm that the following changes have been incorporated into the company;
>
> - GCH have implemented a new standard operating procedure requiring all pilots conducting EMS work to complete six monthly competency checks.- *Effective immediately following incident*
>
> - Additional pilots have been added to the EMS roster. –*December 2014*

- The company SOP regarding pilot's competency has been revised. A matrix has now been incorporated to effectively track pilot currency and competency on all aircraft types they are rated to fly. This also records the aircraft type that the preceding check was completed in, to ensure where possible competency checks are rotated through the aircraft types a pilot is rated to fly. – *August 2015*

- GCH replaced its training manager with an experience Airline Flight Examiner – *October 2015*

- GCH carried out a comprehensive review of its CAA 141 Check and Training Procedures Manual. The manual has been rewritten and submitted to CAA for approval. – *March 2016*

Garden City Helicopters would like to thank TAIC for the considerable time and resources that have been allocated to compiling the report. GCH have fully implemented all recommendations outlined in the TAIC letter dated 25th of February 2016.

Since the incident GCH have devoted a considerable amount of time and resources into reviewing and where necessary modifying our systems and procedures to ensure our personnel and clients will not be exposed to the circumstances that led to this incident again.

In addition to the recommendations found in the report, GCH have completely rewritten the company 141 Check and Training Procedures Manual. This was carried out in consultation with industry professionals to ensure compliance with CAA regulations and industry best practice.

7.5. On 25 February 2016 the Commission gave notice to the Director of Civil Aviation that the Commission had recommended to the Chief Executive Officer of Garden City Helicopters that he amend company policies, procedures and practices relating to the management of pilot competency. (008/16)

On 9 March 2016, Civil Aviation Authority replied:

The Director acknowledges that the Commission has recommended to the Chief Executive of Garden City Helicopters, that he amends company policies and practices relating to the management of pilot competencies.

8. Key lessons

8.1. Pilots who lack recent experience on an aircraft type should refer to written cockpit checklists wherever practicable.

8.2. Pilots who fly multiple aircraft types concurrently must remain vigilant to inadvertently transferring habits or procedures from one type to another.

8.3. Operators who require their pilots to fly different aircraft types must have robust policies and procedures that ensure the pilots are appropriately experienced, trained, current and competent on each aircraft type.

9. Citations

Bolkow, BK117 systems training manual

Civil Aviation Authority (2011), Civil Aviation Rules, Part 61, Pilot Licences and Ratings

Civil Aviation Authority (2015), Civil Aviation Rules, Part 135, Air Operations – Helicopter and Small Aeroplanes

Flight Safety Foundation (1999), Helicopter Safety, Volume 25 No. 2

National Transportation Safety Board (2009), FTW01LA166, Accident Report N313LS

Aviat Space and Environmental Medicine (1982), article Dec;53 (12): 1224-6, Rayman RB

COCKPIT CHECK

1. Seat and pedals	—	Adjust
2. Safety belts and shoulder harness	—	Fasten
3. Inertia real	—	Check
4. Free movement of flight controls	—	Check
5. Cyclic stick neutral holder	—	Lock
6. Collective pitch	—	Full down and lock
7. Pedals	—	Neutral
8. Rotor brake lever	—	Full down
9. PWR SELECT sw	—	OFF
10. GENERATOR sw (2)	—	OFF
11. GEN TRIP sw	—	NORM
12. INVERTER sw (2)	—	OFF
13. BUS-TIE sw (2)	—	OFF
14. DG control sw	—	SLAVE
15. FUEL VALVE sw (2)	—	OP and guarded
16. FUEL PUMP sw (4)	—	OFF
17. INST LIGHTS sw (3)	—	OFF
18. ANTI-COL LIGHT sw	—	OFF
19. POS LIGHT sw	—	OFF
22. VENT FAN sw (2)	—	OFF
23. STATIC HTR sw	—	OFF
25. PITOT HTR sw (2)	—	OFF

Figure 7
Pre-flight cockpit check

BEFORE STARTING ENGINE

1.	EXT PWR	—	Connect (If utilized)
2.	PWR SELECT sw	—	BAT
3.	Voltmeter	—	Check (about 26V)
4.	PWR SELECT sw	—	EXT PWR
5.	MASTER warn light	—	RESET
6.	BUS-TIE sw (2)	—	ON
7.	INVERTER sw (2)	—	ON
8.	ICS	—	Check
9.	All instruments	—	Check and set
10.	Annunciator panel test sw	—	Push to TEST
11.	FIRE DET sw	—	TEST then NORM
12.	Mast moment indicator	—	TEST
13.	Fuel quantity indication	—	Check
14.	Fuel PUMP sw (4)	—	Check then OFF
15.	MASTER warn light	—	Reset
16.	FUEL VALVE sw (2)	—	CL then OP
17.	CHIP DET TEST sw	—	TEST
18.	Cyclic stick	—	Un lock
19.	Cyclic trim	—	Check
20.	SPAS sw	—	TEST then OFF/RESET
21.	Cyclic stick	—	Neutral and lock
22.	VHF (TWR, RDO)	–	Moniter

Figure 8
Before-starting-engine checklist

STARTING ENGINE

1. Fire guard	—	Posted
2. Rotor area	—	Clear
3. ANTI-COL light sw	—	ON
—No.1 ENG start—		
4. No.1 FUEL PRIME PUMP sw	—	ON
5. Starter button (Start clock simultaneously)	—	Depress and hold
After reaching 10% N_1 RPM		
6. Power lever	—	Slowly advance to idle
7. TOT	—	Monitor
8. ENG oil pressure positive indication	—	Check, otherwise shutdown engine
9. N_2/N_R RPM increase	—	Monitor
After reaching N_1 RPM of 40~42%;		
10. Starter button	—	Release
11. ENG instruments	—	Monitor
12. Stabilized N_1 ground idle RPM	—	Check (67~70%)
13. XMSN oil pressure	—	Check
14. No.1 FUEL PRIME PUMP sw	—	OFF
15. Voltmeter indication	—	Check (about 26V)
16. GEN No. 1	—	ON
17. GEN No. 1	—	OFF (b/w 80A)
—No.2 ENG start—		
To start the No.2 ENG, repeat above procedures from 4.~14.		
16. GENERATOR sw (2)	—	ON
17. AMM SEL sw	—	GEN II
18. PWR SELECT sw (Only EPU stating)	—	BAT
19. EXT PWR	—	Disconnect
20. FUEL XFER PUMPS sw (2)	—	ON

Figure 9
Starting-engine checklist

Appendix 2 : BK117 lighting installation comparisons

Figure 10
NVIS modified bright

Figure 11
NVIS modified dim

Figure 12
NVIS modified bright

Figure 13
NVIS modified dim

Figure 14
Unmodified bright

Figure 15
Unmodified dim

Figure 16
Unmodified bright

Figure 17
Unmodified dim

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AO-2013-005	In-flight loss of control, Robinson R22, ZK-HIE, near New Plymouth, 30 March 2013
AO-2013-007	Boeing 737-838, ZK-ZQG, stabiliser trim mechanism damage, 7 June 2013
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11-003	In-flight break-up ZK-HMU, Robinson R22, near Mount Aspiring, 27 April 2011
12-001	Hot-air balloon collision with power lines, and in-flight fire, near Carterton, 7 January 2012
11-004	Piper PA31-350 Navajo Chieftain, ZK-MYS, landing without nose landing gear extended, Nelson Aerodrome, 11 May 2011
11-005	Engine compressor surges, 18 September 2011
11-001	Bell Helicopter Textron 206L-3, ZK-ISF, Ditching after engine power decrease, Bream Bay, Northland, 20 January 2011
11-002	Bombardier DHC-8-311, ZK-NEQ, Landing without nose landing gear extended Woodbourne (Blenheim) Aerodrome, 9 February 2011
10-010	Bombardier DHC-8-311, ZK-NEB, landing without nose landing gear extended, Woodbourne (Blenheim) Aerodrome, 30 September 2010

Price $16.00

ISSN 1179-9080 (Print)
ISSN 1179-9099 (Online)