CAA Safety Investigation Report

Collision with terrain

ZK-HWJ, Robinson R22 Mariner

Benmore Station, Canterbury

11 December 2013

CAA Final Report 13/6223
24 September 2018

Executive summary

On the morning of 11 December 2013, the pilot of a Robinson Helicopter Company (RHC) R22 Mariner, registration ZK-HWJ, was conducting an agricultural spraying operation on farmland in the Hurunui District of Canterbury. The helicopter departed the loading area and a few minutes later the ground loader heard a loud bang. The ground loader went on foot toward the treatment area and located the helicopter wreckage. The wreckage, located at the bottom of a steep slope below the treatment area, was on fire. The post-impact fire had enveloped most of the cabin and airframe. The pilot was found deceased in the wreckage.

A scene examination revealed that the helicopter had touched down heavily in the treatment area, and travelled along rising ground in a level, yawing attitude. The resultant unstable condition caused the main rotor blades to make contact with the tail-boom, followed by the helicopter rolling three times downhill.

Factors contributing to the accident included:

- the inherent risks of low level operational manoeuvres
- the helicopter's weight and balance being outside the Flight Manual limitations
- inaccurate weight and balance information being provided to the pilot, post installation of role equipment, including spray equipment and GPS systems
- inaccurate data provided to CAA during the testing and certification of the Helipod III spray system modification
- a lack of robust CAA appraisal and approval of the Helipod III modification.

No mechanical discrepancies were identified as having contributed to the accident.

Safety Findings and Observations

CAA regulatory oversight of modifications

Safety Findings[1] (CAA 18F579 and 18F589) were made regarding CAA oversight of modification processes for installations which could adversely affect the aerodynamic and performance limitations of an aircraft (in this case the Helipod III spray system). All available data should be included in modification assessments, giving due consideration to the original airframe manufacturer's design and certification data.

[1] Subject to a further internal CAA Safety Investigation Unit report to the Airworthiness Unit (formerly Aircraft Certification Unit) (dated 27 September 2017).

CAA oversight of licensed engineers exercising additional privileges

A Safety Finding[2] (CAA 18F581) was made regarding the responsibilities of licensed engineers and those exercising the additional privileges associated with a Certificate of Inspection Authorisation, when releasing aircraft to service and carrying out Reviews of Airworthiness.

A referral report was provided to the CAA Personnel Licensing and Flight Training Unit detailing non-compliance by the engineer responsible for the installation of the Helipod III and GPS system. Enquiries found that the engineer, who held privileges in both Australia and New Zealand, was now operating in Australia. The Civil Aviation Safety Authority (CASA) for Australia was advised of the CAA concerns and would manage this information in respect to CASA requirements or concerns.

CAA continuing airworthiness considerations

On 16 August 2017 a Continuing Airworthiness Notice[3] (CAN) was issued by CAA advising operators and pilots to ensure accurate weight and balance calculations are made when using the subject spray system.

A Safety Finding (CAA 18F587) was made to support the aircraft manufacturer's fuel system modification, which includes an internal bladder system[4], by mandating through an Airworthiness Directive the installation of this safety modification. On 2 February 2018 a CAN[5] was issued by CAA advising operators and maintainers about the RHC R22 Service Bulletin for the retrofit of bladder fuel tanks.

On 22 March 2018 the CAA issued Airworthiness Directives[6] supporting both the CANs and promulgated them as:

- DCA/R22/50 *Helipod III Spray System STC 7/21E/9 – Removal from Service*
- DCA/R22/51 *Helipod NZ Limited STCs – Report of Installation*
- DCA/R22/49 *Bladder Fuel Tanks – Retrofit*

The CAA Airworthiness Unit is continuing to assess the use of spray equipment on helicopters and the application process and regulatory oversight required for approval of modifications.

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[2] Subject of further internal CAA Safety Investigation Unit report to the Personnel and Flight Training Unit (dated 17 September 2017).

[3] CAA Continuing Airworthiness Notice 14-002 *Robinson R22 Series Helicopters fitted with Helipod Spray System.* https://www.caa.govt.nz/assets/legacy/Airworthiness_Directives/Continuing_Airworthiness_Notices/CAN_14-002.pdf

[4] Robinson Helicopters Company, Service Bulletin 109 *Bladder Fuel Tank Retrofit.* https://robinsonheli.com/wp-content/uploads/2015/12/r22_sb109.pdf

[5] CAA Continuing Airworthiness Notice 28-010 *Robinson R22 Helicopter Fuel Tanks.* https://www.caa.govt.nz/assets/legacy/Airworthiness_Directives/Continuing_Airworthiness_Notices/CAN-28-010.pdf

[6] CAA Airworthiness Directives issued on 22 March 2018: https://www.caa.govt.nz/assets/legacy/Airworthiness_Directives/R22.pdf

CAA oversight of pilot licence holders with restrictions imposed upon them

A Safety Observation (CAA 18F582) was made regarding the robustness of the regulatory oversight of pilot licence holders when restrictions are put in place around their medical certificate e.g. not to carry passengers.

Safety advice

Agricultural helicopter operations are inherently hazardous, as they are predominately conducted at low levels above terrain and at relatively low airspeeds. Adherence to aircraft weight and balance limitations as detailed in the aircraft Flight Manual is critical when considering aircraft performance.

Contents

Factual information

The Operation

The pilot and ground loader commenced duty about 0430 hours, travelling by road to collect the helicopter which had been left overnight at the [accident] property. Residual work from the previous day was firstly carried out on an adjoining property between 0730 and 0900 hours. Having completed this work, the pilot flew the ground loader back to where the helicopter had been parked overnight. Here they prepared the equipment, herbicide and other items required for the upcoming spray operation. The ground loader was then flown to the loading area. The pilot returned to collect and deliver back the necessary equipment and chemicals.

The ground loader decanted measured amounts of *Kamba* and *Glyphosate* herbicides and *DuPont Input* (a penetrant[7]) into the Helipod III[8] tank fitted to the underneath of the helicopter. Water from a nearby concrete holding tank was then pumped into the spray system tank using a stand-alone pump. The pilot monitored the water uptake while standing next to the helicopter, using a hose fitted with a digital flow meter. There was also a calibrated integral sight gauge located in the side of the spray system tank providing fluid level indications. When the desired level was indicated the pilot signalled to the ground loader to shut off the water supply.

The treatment area to be sprayed comprised approximately seven hectares of sloping land, situated approximately half a mile to the southwest of the loading site (Figure 1 overleaf).

[7] Used to enhance the effects of the pesticide being used.

[8] New Zealand Supplemental Type Certificate 7/21E/9.The Helipod III spray system includes: an underslung belly tank, spray booms, skid-mounted pump and associated piping.

Figure 1. Treatment area depicted in bounds of blue line. (Arrow indicates north) (adapted Google Earth).

A short time after the pilot had left for the treatment area, the ground loader, who was readying the next quantity of herbicide, heard a sound described as a "loud bang". The ground loader then ran toward the direction the helicopter had travelled, and subsequently found the burning wreckage of the helicopter at the foot of a steep slope below the treatment area. The pilot was found in the wreckage and could not be assisted.

The Rescue Coordination Centre of New Zealand did not detect any emergency locator transmitter activation and, due to fire damage, it is not known whether the transmitter activated.

Meteorological information

There was no direct weather reporting information available for the area of operations. The METAR[9] for Christchurch Airport, 46 nautical miles southwest from the treatment area, issued at 1000 hours on 11 December 2013 reported a light[10] westerly wind with light showers and rain. The visibility was unlimited.

Weather conditions at the treatment area at the time of the accident were described by the ground loader as overcast with a light but freshening northwest wind with "puffs".

A few days after the accident, the spray treatment was completed by another agricultural operator, in a turbine helicopter. The operator noted that having been operating in the area at the time of the

[9] Coded weather report detailing conditions at an aerodrome, predominantly used by pilots for flight planning purposes and issued every hour.

[10] Guidance on the Beaufort scale measures 'light' as 1-6 knots. Beaufort, F (c.1805)

accident, the prevailing conditions were similar to those on the accident day. The operator, who had previously operated RHC R22 helicopters on agricultural operations, considered the conditions had been suitable for the operation.

Weather was not considered to be a contributing factor in the accident.

The Pilot

The pilot was appropriately licensed for the flight, being the holder of a Commercial Pilot Licence (H) issued on 3 May 2004, a current Class 1 Medical Certificate and a current Grade 2 Certificate of Agricultural Competency, checked on 31 January 2013. On 23 October 2013 the pilot was advised by letter that, following a CAA medical review, a restriction had been placed on the medical certificate precluding the carriage of passengers. On 28 November 2013 further information had been requested from the pilot regarding the conditions for which the restriction had been imposed. (CAA Safety Observation 18F582).

A review of the pilot's Pilot Logbook showed the last entry was made on 25 November 2013 and that the pilot had logged a total of 1304 hours flight experience. Flight experience logged on RHC R22 was 1302.2 hours. The pilot had accumulated approximately 543.3 hours on agricultural operations. The pilot had also completed the requisite biennial Robinson Safety Awareness Training[11] course which was due to expire on 17 January 2014.

The post-mortem examination revealed that the pilot had not received substantial injuries during the accident sequence and had succumbed to the effects of fire. The pilot was not wearing, or required to wear, fire-resistant protective clothing[12] or a flight helmet. There was no evidence of any substance(s) in the pilot's toxicology information that were determined to have contributed to the accident.

The Aircraft

The helicopter was initially registered in New Zealand on 22 June 2010 and was used predominately as a flight trainer. Between 22 August 2012 and 23 April 2013 the helicopter's airframe and engine were overhauled at the accumulated hours of 2199.7[13]. In addition to the overhaul, the helicopter was fitted with the Helipod III Supplemental Type Certificate (STC) and a Trimble AgEZ500 GPS[14] for use on agricultural operations.

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[11] Requirement to complete an approved course forms part of the CAA R22 Flight Manual Supplement and was revised under Airworthiness Directive DCA/R22/48.

[12] Robinson Helicopter Company recommend the use of fire retardant Nomex® apparel per Safety Notice SN-40 Post Crash Fires (July 2006). https://robinsonheli.com/wp-content/uploads/2015/12/rhc_sn40.pdf

[13] Mandatory service requirement to be carried out at airframe total time of 2000 hours or 12 years, whichever occurs first.

[14] Installation of Aviation Design Solutions modification CHCHFO-2.

The helicopter had been owned and operated by the pilot since 28 June 2013. A review of the helicopter records showed the last recorded flight was on 25 November 2013, producing a cumulative time of 2283.7 hours on the airframe and 84 hours since the engine overhaul. While the investigation found that the helicopter had been operated after 25 November 2013, it is plausible that other records were on board the helicopter and destroyed in the accident.

The last recorded maintenance event was carried out on 27 November 2013 which was a requirement to comply with a RHC Service Bulletin[15] inspection. This inspection was found to be satisfactory.

Scene investigation

It was apparent from ground marks that the helicopter initially contacted rising terrain, on sloping ground, in a level yawing attitude. Significant depressions made by both the skids in the topsoil, were evident for a distance of 31 ft. It was also apparent that the landing gear skids had splayed from their normal dimension of 76 inches (at MAUW[16]) to 91.3 inches at the furthest point of ground contact (refer Figure 2 below and Figure 3 next page).

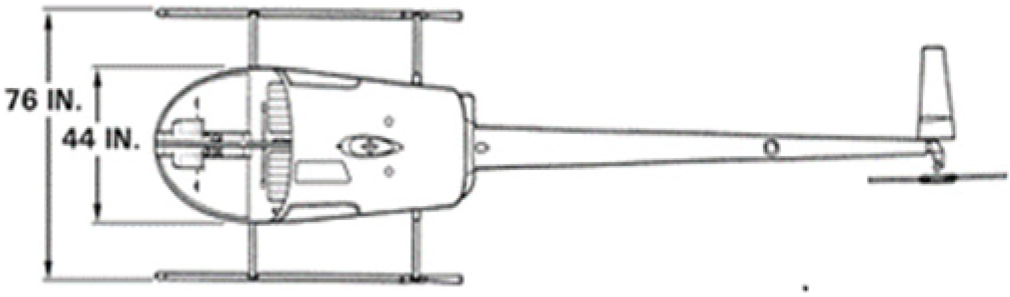

Figure 2. Plan view of RHC R22 (Source RHC).

With ground contact of this nature and the subsequent dynamic loading[17] effects on the helicopter airframe, it is typical that the tail boom flexes downward (due to the weight of the tail rotor gearbox and empennage) and the landing gear splays. This flexing and splaying causes energy[18] to be stored in these areas, that would eventually either release – attempting to return to a state of equilibrium –

[15] Robinson Helicopter Company Service Bulletin R22 SB 108 Rotor RPM Sender Magnets. https://robinsonheli.com/wp-content/uploads/2015/12/r22_sb108.pdf

[16] The maximum certificated all-up weight of the RHC R22 Mariner, including role equipment as specified in the Type Certificate Data Sheet, is 1370.0 lb.

[17] Dynamic loading occurs when loads are applied fast enough to prevent the structure from carrying the load, while remaining in equilibrium as the load is being applied. *R.H. Wood and R.W. Sweginnis, 2006. Aircraft Accident Investigation (2nd Edition).* Casper, WY: Endeavour Books

[18] "Energy"- The capacity for performing work. There are two basic types, potential (stored) and kinetic (motion).D.Crane (1997) *Dictionary of Aeronautical Terms (3rd edition).*Newcastle, Washington.

or fail in overload. The conditions of this accident indicate that once contact with the ground ceased, the tail boom oscillated and contact was made with the main rotor blades, severing the tail boom. The helicopter became uncontrollable, rolling over a downward slope approximately three times.

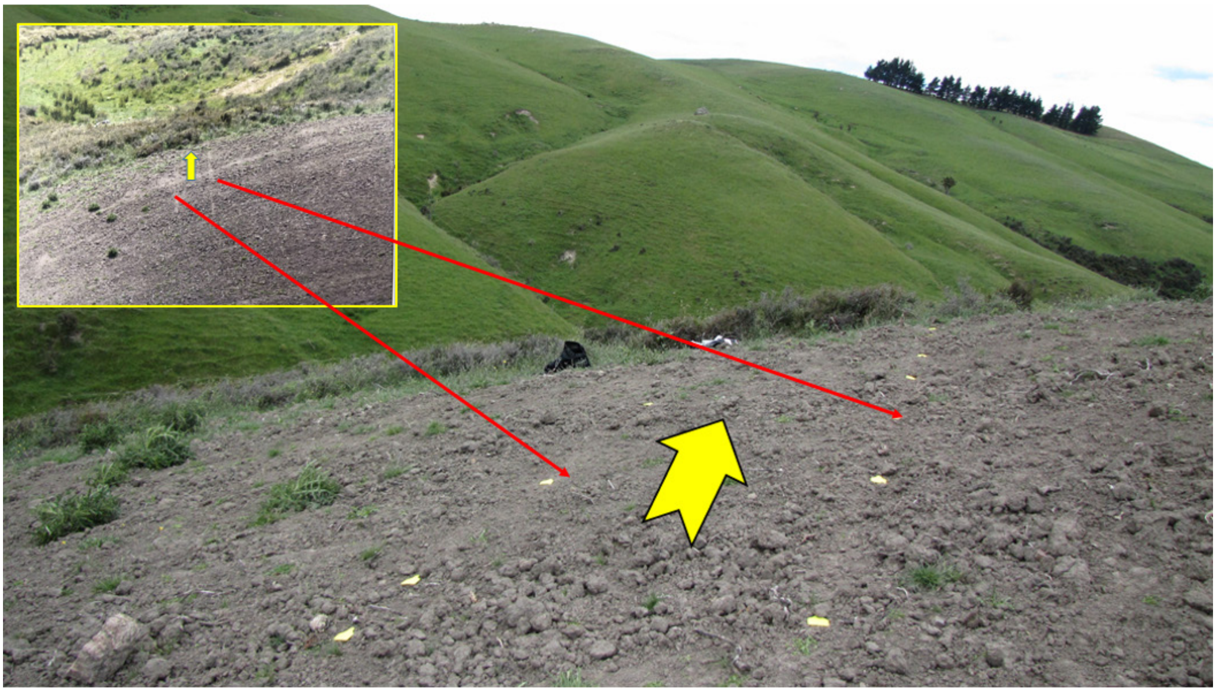

Figure 3. Ground marks shown with yellow arrow indicates direction of travel. (inset overhead view)

The majority of the helicopter forward of the tail boom to fuselage bulkhead, including the cabin, was severely damaged by a post-impact fire. Whilst there was disruption to the helicopter flight control mechanisms, all damage was considered to have occurred during the accident sequence.

The engine was removed to a certificated maintenance facility where it was dismantled and inspected. No pre-existing mechanical defects were found. Observations made regarding cracking of a number of the valve spring caps were considered to be as a consequence of the engine over-speeding[19] during the break-up sequence. This being the only observation, and attributed to the accident sequence, the engine and its supporting systems were considered to have been capable of normal operation prior to the accident.

The Helipod III was also substantially damaged during the accident sequence resulting in many components being severely fragmented, including the underbelly tank. The end sections of the spray booms and the ancillary pump were the only large items which were recovered.

A wide search of the accident scene provided no evidence that the product load had been actively jettisoned by the pilot prior to or during initial contact with terrain.

[19] Lycoming Service Bulletin No. 369N, first issued 11 Jan 1974 revised 10 Jan 2017.
https://www.lycoming.com/sites/default/files/SB369N%20Engine%20Inspection%20after%20Overspeed%20.pdf

Post-impact fire

During the accident sequence, which included three roll-overs, the structure of the fuel tanks, associated fuel lines and components were severely compromised. When the helicopter finally came to rest it was consumed by a fire. Post-mortem analysis revealed that the pilot had not suffered substantial injuries and died from the effects of the fire.

A number of post-impact fire events had been under consideration by RHC concerning the RHC R44, resulting in a retrofit internal fuel bladder system being made available in December 2010[20]. While this was issued as a Service Bulletin[21] by RHC, it was following an accident in Australia in 2013 – investigated by the Australian Transport Safety Bureau[22] – which led to the installation requirement being mandated by CAA through an Airworthiness Directives.

At the time of the ZK-HWJ accident a retrofit internal fuel bladder system was also being prepared for release for RHC R22 helicopters. Service Bulletin SB-109[23] was released by RHC on 8 January 2014 advising that the retrofit was now available and stipulating a compliance time frame of *"As soon as practicable, but no later than 2200-hour overhaul or 12-year inspection"*. It is conceivable that had the retrofit fuel bladders been installed, the risk of post-impact fire could have been reduced. An RHC R22 accident in Australia in 2015[24] demonstrated the effectiveness of the installation. In that accident the fuel tanks were ruptured but the fuel was retained in the retrofit bladders and no fire occurred. (Figure 4 next page).

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[20] Robinson Helicopter Company Service Bulletin SB-78B, Bladder Fuel Tank Retrofit
https://robinsonheli.com/wp-content/uploads/2015/12/r44_sb78.pdf

[21] Service Bulletins are issued by manufacturers and are generally product improvements. It is not mandatory in New Zealand to comply with Service Bulletins.
https://www.caa.govt.nz/Airworthiness_Directives/Continuing_Airworthiness_Notices/CAN_05-002.pdf

[22] Australian Transport Safety Bureau, Aviation Occurrence Investigation AO-2013-055
https://www.atsb.gov.au/media/5571014/ao2013055_final.pdf

[23] Robinson Helicopter Company SB 109, issued 8 Jan 2014, revised 15 Jan 2018.
https://robinsonheli.com/wp-content/uploads/2015/12/r22_sb109.pdf

[24] Australian Transport Safety Bureau, Aviation Occurrence Investigation AO-2015-055,
https://www.atsb.gov.au/media/5770486/ao-2015-055_final_.pdf

Source: ATSB

Figure 4. Bladder fuel tanks for compliance with SB-109 and post-impact evidence.

Investigation Research (Appendix A)

The safety investigation revealed latent failures in the functions of the Design and Manufacturing Organisation, CAA certification oversight, maintenance and engineering practices. There was a continuum of these failures in the operational practices. Due to the complexities of reporting this information, independent safety reports were provided to portray this information. Appendix A provides detailed information regarding:

- The inaccurate Helipod III spray system STC data provided to CAA for approval.
- Information used in the STC data for standard weights was inaccurrate.
- The weight and balance information used by the engineer and pilot was incorrect.

- The design information used by the engineer for the GPS installation was not approved.
- Spray load weight calculations used during operations placed the helicopter above the manufacturer's weight limit.

Helipod III installation and operation on ZK-HWJ

Table 1 shows a possible weight configuration for the accident flight using payload and fuel details located in recovered company records and declared by the pilot at a CAA audit on 23 November 2013:

Aircraft-lb (Helipod III and GPS installed)	Pilot-lb	Product-Load lb/kg	Fuel-lb Minimum (15 mins[25])	MAUW-1370 lb
1013.46	185.18	165.34/75.0	18.41	1382.39

Table 1. Possible weight configuration for accident flight.

The spray equipment and herbicide mix were destroyed in the accident sequence. Due to the loss of the herbicide mix, accurate weight calculations could not be determined. Retrospective estimative calculations were applied to the possible load and therefore weight carried. The methodology included using details from the property owner for the required application rates versus the evidence found at the loading site.

Based on information provided by an agronomist the property owner had requested the following application rate of herbicide per hectare as: 3000 ml Glyphosate, 600 ml Kamba and 100 ml of penetrant. When interviewed, the property owner could not recall what water rate, per hectare, was required.

Evidence found at the loading site showed herbicide products measured out into three separate plastic jugs (Figure 5 overleaf). The herbicides were in two five L and a single one L jugs made up of the following: 5000 ml Glyphomax XRT (Glyphosate), 800 ml Kamba and 330 ml of penetrant. These measurements were identified by the ground loader as being identical amounts to those loaded into the Helipod III prior to the accident. These measured amounts varied considerably from those requested by the property owner and the higher concentration would have required a larger amount of water, and therefore a heavier load of water additive. (CAA Findings 18F579 and 18F580 refer.)

[25] Minimum fuel and max product weights declared by pilot during CAA Audit 14/INSG/8 conducted on 27 November 2013.

Figure 5. Measured quantities of herbicide found at loading site.

Water is the diluting medium used for the application and is measured into the tank using a flow meter. A flow meter was found at the scene and examined for relevant load records. Whilst a cumulative load count of 132662 L was recorded, there was no lesser amount recorded which would have been considered in respect to the last water load carried. No other supporting information was found indicating that water loads were recorded. (CAA Finding 18F579 refers.)

Based on the lack of information regarding the required 'L per hectare' being recalled by the property owner, the lack of records for the water amounts [from the flow meter] and the quantity differential of herbicide found at the loading site, it was not possible to calculate the actual load carried on the accident flight.

The on-board agricultural GPS contained data which permitted examination of the swath records, including the location of the commencement and termination of the swath. The tracking of each spray run by the GPS unit was triggered by the spray activation toggle switch on the pilot's cyclic control. The GPS data revealed that, during the spray run, herbicide was sprayed onto an area approximating half a hectare, until the point at which the spray was discontinued.

Track logging was discontinued approximately 70 meters before the landing gear contacted the ground. It was not possible to identify why the application was ceased at this point.

Spray load volumes were witnessed at 120 liters, a common commercial practice

Eyewitness information provided by both the current and past ground loader indicated that each chemical load was measured out separately into measuring jugs, e.g. not multiple loads taken from the same jug (Figure 5 above). Chemical was loaded into the Helipod III from the opposite side of the system from where the pilot loaded the water. Loads were identified in the pilot's records as being between 75-80 L. The ground loaders reported regularly seeing loads up to 120 L. Anecdotal information from operators who had used the same configuration of helicopter and spray equipment reported that it would not be commercially viable to operate loads of 75-80 L, and admitted having to regularly carry loads to the maximum fill point of 123 L.

Helicopter performance considerations

All aircraft are subject to four forces during flight: lift, drag, thrust and weight. These four forces act in equilibrium when an aircraft is in a steady state of flight i.e. straight and level. With regard to helicopters, variance in any of the forces or a change in the flight profile can lead to a considerable difference in all of them[26]. Of particular consideration in this accident is the relationship between lift and weight. For the helicopter to operate away from the surface, e.g. in a hover, the amount of lift must be greater or equal to the weight. Similarly when the helicopter transitions into forward flight, the lift and thrust need to be greater or equal to the weight and drag otherwise the helicopter will descend toward the surface.

Consider the forces described above on a helicopter conducting agricultural operations close to the ground. The pilot must be ever vigilant to manoeuvring the helicopter in the air relative to the changes in the terrain being overflown. This is a particular consideration when carrying out low level turns over descending and rising ground. When a helicopter is in a turn it is subject to combined forces of lift and weight; centrifugal force acting away from the turn radius and centripetal force acting into the turn radius (Figure 6).

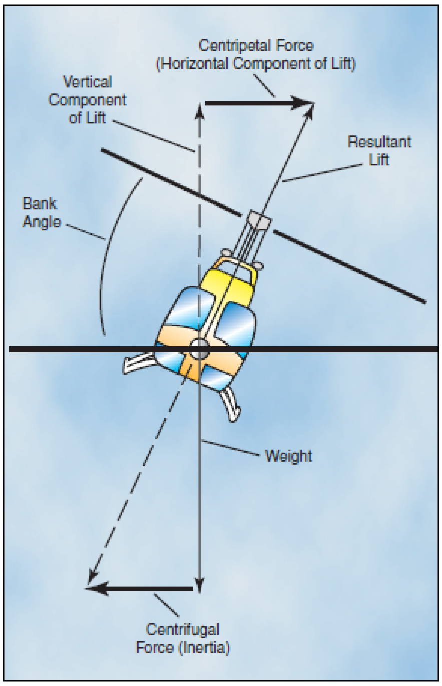

Figure 6. Forces acting on a helicopter in a turning manouver (source FAA).

[26] Federal Aviation Authority *Aerodynamics of Flight* https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/helicopter_flying_handbook/media/hfh_ch02.pdf

As discussed above, should the helicopter weight exceed the available lift (horsepower available v horsepower required[27]) the helicopter will descend. For a small light helicopter such as the RHC R22, the addition of weight above that for which it was designed can have a significant adverse effect on the performance of the helicopter.

CAA Advisory Circular AC146-1 *Aircraft Design Organisations*[28] requires that *'Unless the design change results in a negligible weight change then weights and moment arms should be calculated in the description of the change. Alternatively, a complete reweigh could be requested of the aircraft after embodiment.'* The negligible weight change differential for aircraft under 5700 kg, such as ZK-HWJ should be carried out if the weight change exceeds one per cent of the Maximum Certified Take-off Weight (MCTOW). Despite the combined weight of the Helipod III and GPS being 118.69 lb, 8.68 % of the MCTOW, no reweigh was carried out. (CAA Finding 18F581 refers.)

At all times, aircraft should be operated within the certified weight and balance limits to avoid performance degradation or component failure.

Analysis

Incident development

Significant contributing factors to the accident included

- Helipod III STC data omissions and inaccuracies
- inaccuracies affecting the weight and balance of the RHC R22
- operational practices.

Inaccuracies and omissions, dating back to 2006, were made during the certification process of the Helipod III. The installation of a Helipod III and GPS on to ZK-HWJ, introduced further omissions and inaccuracies. These cumulative errors resulted in the helicopter likely being regularly operated above the permissible maximum all up weight (MAUW)[29].

The veracity of accurate weight and balance calculations to ensure the helicopter performance remains within the prescribed safety limitations, were compromised due to the lack of accurate data for weights of the installed role equipment.

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[27] FAA Rotorcraft Handbook Chapter 7 Helicopter Performance
https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/helicopter_flying_handbook/media/hfh_ch07.pdf

[28] CAA Advisory Circular AC146-1 Aircraft Design Organisations, Rev 2 (2007)
https://www.caa.govt.nz/assets/legacy/Advisory_Circulars/AC146_1.pdf

[29] MAUW- the maximum allowable weight for the aircraft per the Type Certificate Data Sheet.

Post development the manufacturer will stipulate a MAUW at which the helicopter should be effectively and safely operated. Any exceedance in the MAUW places the helicopter and performance parameters outside of the design specifications. Exceedance of the MAUW can lead to an inability to maintain stable flight and cause latent mechanical defects by subjecting components to loads in excess of that for which they were tested and certified by the manufacturer.

Due to the loss of the spray load during the accident sequence, the load weight could not be accurately determined. Scene evidence showed that the load preparation was not in accordance with the property owner's request.

The installation of any equipment which affects the flight characteristics of any aircraft should be done so with regard to the original design. At all times the aircraft should be operated within the aircraft's specified weight and balance limitations. The original design and proposed use of the RHC R22 helicopter was not as an agricultural spray platform. Weight and balance considerations were based on the carriage of a maximum of two persons in the cabin, a light internal baggage load and fuel sufficient for a proposed flight period.

The Accident

The parallel ground scars found along the hillside fall line, made after initial contact with the terrain, were likely attributed to the pilot levelling the aircraft and discontinuing the spray run after finding adequate clearance from terrain had been significantly compromised. The actions of the pilot to recover appear consistent with realising a problem existed then electing to fly out of the situation. An immediate jettison of the load may have been beneficial to avoid contact with terrain, however this did not occur. Having contacted terrain, the helicopter's tail boom flexed sufficiently to make contact with the main rotor blades which subsequently led to the total destruction of the helicopter.

Observation

From evidence provided by eyewitnesses, it was found that the pilot ferried the helicopter to the worksite with a passenger on board.

It is the responsibility of the CAA to ensure that the public are accorded every safety measure when being carried in an aircraft as a passenger. Part of the aviation safety system is the requirement for pilots to hold a current medical certificate. The Director of Civil Aviation has delegated responsibility to manage the oversight of medical certificates to Principal Medical Officer (PMO). The delegation to the PMO includes the issuing and should it be necessitated, placing of restrictions on a medical certificate.

Due to information disclosed to the PMO by the pilot, a determination was made to restrict the pilot from carrying passengers while operating an aircraft. This was advised to the pilot by letter on 23 October 2013, with an effective period to 29 January 2015. A proviso was given stating that this date could be reviewed if the CAA was satisfied that the condition (medical) was not likely to affect flight safety.

Adherence to restrictions placed is mandatory, and is aimed at reducing the risks to other persons. (CAA Observation 18F582 refers)

Conclusions

The following conclusions have been determined during the safety investigation:

1. The helicopter contacted the ground heavily during an agricultural spray application, became unstable resulting in the main rotor blades and tail boom contacting each other. A post-impact fire followed.
2. The pilot was appropriately licensed and qualified to conduct the commercial agricultural spray operation.
3. The pilot carried a passenger in the helicopter when restrictions prohibiting this were in place on the pilot's medical certificate.
4. The modification and certification processes for the Helipod III revealed a number of anomalies regarding weight and balance information, critical for safe operation.
5. After installation of the Helipod III and GPS, it was mandatory for a reweigh to have been carried out to provide up-to-date weight and balance information.
6. Due to inaccurate weight and balance information being available to the pilot it is likely that the helicopter was regularly operated above MAUW.
7. CAA appraisal and approval of the Helipod III STC data and information was insufficiently robust, allowing non-standard weights and inaccurate data to be accepted.
8. The measured herbicide and additives located at the scene differed significantly from those requested by the property owner and would have required a higher dilution rate above that disclosed by the pilot of 75-80 L recorded in the pilot's load records.
9. While the water supply hose did have a digital flow meter attached, no records were found for individual load amounts.

10. An Airworthiness Directive promulgated by the CAA subsequently prohibited the use of the Helipod III spray systems on RHC R22.

11. During the accident sequence the fuel tanks were ruptured resulting in a fire. Post-mortem information indicates that the pilot likely died as a result of the fire.

12. In January 2014, retrofit fuel bladders became available to install in the fuel tanks of the RHC R22. An Airworthiness Directive has been promulgated by CAA mandating the installation of the fuel bladders per RHC SB-109.

Glossary of abbreviations

amsl	above mean sea level
CAN	Continuing Airworthiness Notice
CAR	Civil Aviation Rules
CPL (H)	Commercial Pilot Licence (Helicopter)
ELT	Emergency Locator Transmitter
FAA	Federal Aviation Administration
ft	feet(s)
FMS	Flight Manual Supplement
GPS	Global Positioning System
hPa	hectopascal
ha	hectare
kg	kilogram(s)
lb	pound(s)
L	litre(s)
ml	millilitre
MAUW	Maximum All Up Weight
MCTOW	Maximum Certificated Take-off Weight
NZDT	New Zealand Daylight Time
POH	Pilot Operating Handbook
RHC	Robinson Helicopter Company
s/n	serial number
STC	Supplementary Type Certificate
WGS 84	World Geodetic System 1984

Data summary

Aircraft make and model, registration and serial number:	Robinson Helicopter Company R22 Mariner, ZK-HWJ, s/n 2595M
Year of manufacture:	1996
Engine (s) make and model, type of engine(s) and serial number(s):	1x Lycoming O-360-J2A, piston engine 145 HP (derated), s/n L-34819-36A
Year of manufacture:	1995
Accident date and time:	11 December 2013, 0930 hours
Location:	Latitude: S42° 51'25.2"
	Longitude: E173° 07'44.82"
Altitude:	1118 feet amsl
Type of flight:	Commercial (Agricultural)
Persons on board:	Crew: 1
Injuries:	Crew: 1 fatal
Nature of damage:	Aircraft destroyed
Pilot's licence:	Commercial Pilot Licence (Helicopter)
Pilot's age:	48 years
Pilot's total flying experience:	1304 hours total flight time
	1302.2 hours on type
	545.5 hours of agricultural operations (approx)
Information sources:	Civil Aviation Authority field investigation.
Investigator in Charge:	Mr P B Breuilly

About the CAA

New Zealand's legislative mandate to investigate an accident or incident are prescribed in the Transport Accident Investigation Commission Act 1990 and Civil Aviation Act 1990 (the CA Act). Following notification of an accident or incident, TAIC may conduct an investigation. CAA may also investigate subject to Section 72B (2)(d) of the CA Act which prescribes the following:

72B Functions of Authority

(d) (2) The Authority has the following functions:

(e) To investigate and review civil aviation accidents and incidents in its capacity as the responsible safety and security authority, subject to the limitations set out in section 14(3) of the Transport Accident Investigation Commission Act 1990:

The purpose of a CAA safety investigation is to determine the circumstances and identify contributory factors to an accident or incident with the purpose of minimising or reducing the risk to an acceptable level to prevent a similar occurrence arising in the future. The investigation does not seek to ascribe responsibility to any person but to establish the contributory factors to the accident or incident based on the balance of probability.

A CAA safety investigation seeks to provide the Director of Civil Aviation with the information required to assess which, if any, risk-based regulatory intervention tools may be required to attain CAA safety objectives.

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Appendix A

Helipod III Supplemental Type Certificate 7/21E/9

The Helipod III was designed, developed and manufactured in New Zealand by a CAR Part 146 Design Organisation and a CAR Part 148 Manufacturing Organisation. Regulatory oversight and consultation was carried out by the CAA Airworthiness Unit.

Documentation and data provided to CAA for the Helipod III STC for RHC R22s was based on a similar design for the Helipod III (STC 4/21E/4) installed on RHC R44s. The Helipod III system was capable of holding 223 L. For installation on RHC R22s the specified load was limited to a maximum 123 L. The CAA approved the Helipod III R22 STC on 12 December 2006.

Helipod III Installation

The image below shows the installation of a Helipod III spray system on the test aircraft, ZK-IAF. An open alloy spout aft of the belly tank allows the loading of water and herbicide into the tank. A quantity sight gauge on the same side, halfway along the spray tank, allows the content level to be viewed.

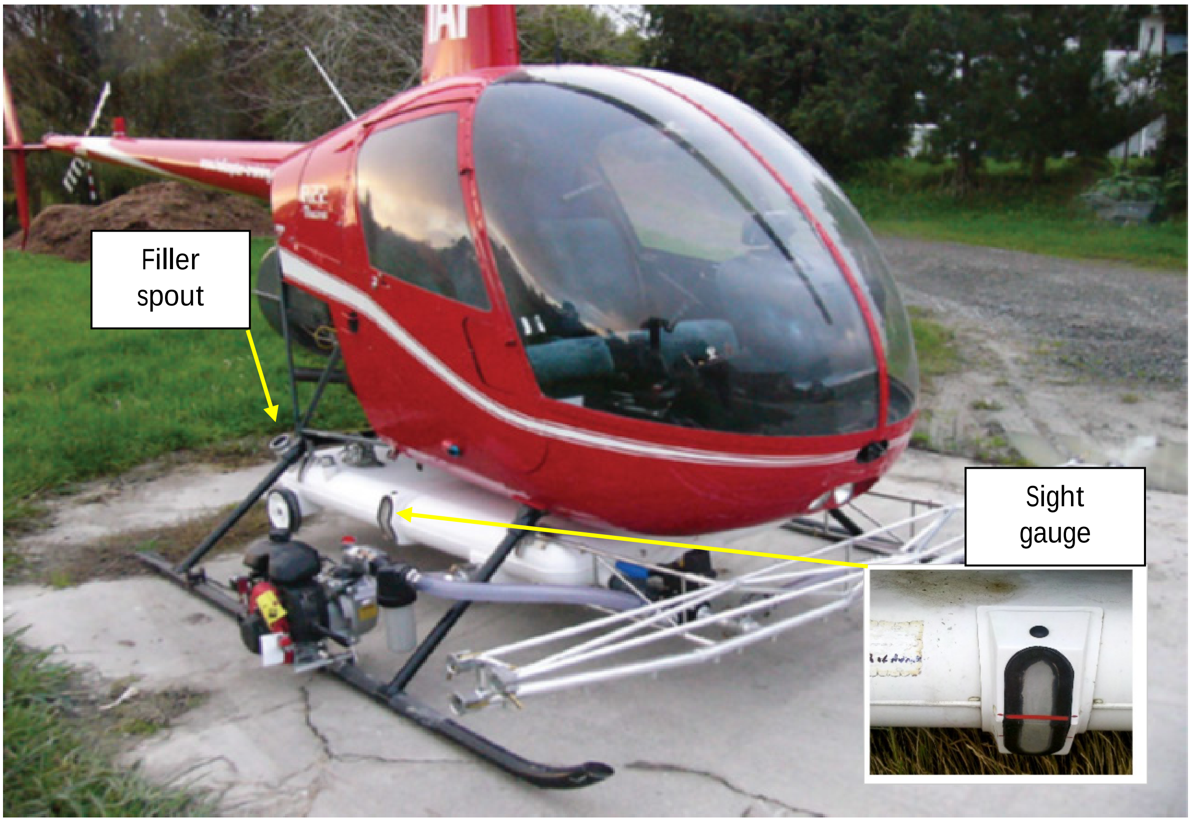

Figure 1. Helipod III spray system installed on a helicopter during testing and certification phase.

Helipod III STC review

The safety investigation review and re-examination of information used in the Helipod III STC process included: flight test data, weight simulations, static load tests. A number of anomalies and inaccuracies in the information included:

- RHC R22 aircraft weights that differed from the Type Certificate Data Sheet [1](TCDS).
- use of non-standard aviation pilot weights[2] used for certification and design
- variances in actual weights of components installed versus data provided in Flight Manual Supplement[3] (FMS)
- inaccurate Helipod III test flight data for weight and balance
- weight and balance information that was favourable to the Helipod III STC.

Variances in weights of RHC R22

FAA TCDS identifies the minimum weight for an RHC R22 Mariner such as ZK-HWJ and ZK-IAF (used for flight tests 893.6 lb) as 920 lb. CAA 2173 'Weight and Balance Data' for ZK-HWJ dated 01 November 2010[4] showed the weight to be 894.5 lb.

The Helipod III STC weight for the certification calculations gave an aircraft weight of 830 lb and referenced the POH Section 6-7. This "sample weight" related to a revision of the POH dated 15 September 1987. This "sample weight" was revised on 23 February 2004 to 850 lb. It is considered that the revised weight would have been the more prudent weight to use.

Prior to the issuing of the STC, the CAA identified to the STC applicants that "...a random survey of several R22beta's [sic] gave an average aircraft weight of 846 lbs.[5]" Even with this information supplied and subsequent interactions taking place between the applicant and CAA, this discrepancy went unchecked.

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[1] Type Certificate Data Sheet information from the Federal Aviation Administration shows aircraft minimum weight as 920 lbs. http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgMakeModel.nsf/0/3a27e3925f44c55486257bc9005dca07/$FILE/H10WE_Rev_15.pdf

[2] New Zealand accepts the standardisation of the Federal Aviation Authority, regarding pilot weight as 170 lb. Federal Aviation Regulations Part §27.785 (f) *Seats, berths, litters, safety belts and harnesses.* refers https://www.ecfr.gov/cgi-bin/text-idx?SID=6225c09cfb06ca89a2a0f93d2d11c2bf&mc=true&node=pt14.1.27&rgn=div5#sg14.1.27_1755.sg18

[3] A Flight Manual Supplement is required for all modifications and provides information to the pilot including that required to calculate weight and balance. CAA Advisory Circular AC146-1, Pg. 24 https://www.caa.govt.nz/assets/legacy/Advisory_Circulars/AC146_1.pdf

[4] This weight was a result of calculation not actual weighing of the helicopter. Actual weighing was last completed on 28/10/2010

[5] Email from CAA to STC applicant dated 6 December 2006 talked to the variance in standard aircraft and pilot weights.

Non-standard pilot weight used for calculations

The New Zealand aviation system accepts much of the standardisations contained in the FAA Federal Aviation Regulations (FAR). An example is in regard to FAR Part 27 *Airworthiness Standards: Normal Category Rotorcraft*. This FAR prescribes airworthiness standards for type certificates relating to rotorcraft such as the RHC 22.

FAR Part 27.785 (f) *Seats, berths, litters, safety belts and harnesses* prescribes that each seat must be designed for an occupant weight of 170 lb. The application for the Helipod III STC used a figure of 150 lb. This is the mean value between the FAR weight and the minimum solo pilot weight of 130 lb in the *Limitation* section of the RHC R22 POH[6]. The value of 170 lb should have been used as a start point for calculated versus actual pilot weight. This was also advised in the email to the STC applicant by CAA.

The actual weight of components contained in the Helipod III STC differed from those installed

The essential componentry make-up of the Helipod III consists of a belly tank, spray booms and a remote motorised pump. The individual operator can opt to have an 80-100% boom system and a left or right hand side pipe fittings (refer Figure 1.)

The pump, a Honda QP154S, was identified in the component list for the STC at a weight of 8.5 kg. The actual weight specification of the pump given by the manufacturer Honda was 9.8 kg.

The STC also specifies the weight of the 100% spray booms as (installed on ZK-HWJ) as 3.4 kg. The original booms were destroyed in the accident, however an identical set belonging to the operator were weighed and found to be 4.4 kg.

The cumulative variance of weights for the parts equates to an extra 2.3 kg or 5 lb installed on the aircraft.

Ground simulations and flight test data were inaccurate

Ground simulations

The STC applicant provided data on aircraft ground load simulations using Helipod III HRP22III25201-402 (-402). The Helipod III was configured with limited components which would have been considered appropriate when in normal use. These items such as wheels, jettisoning door assembly

[6] Robinson Helicopters Company Section 2 *Limitations* Center of Gravity Limits, Note https://robinsonheli.com/wp-content/uploads/2016/03/r22_poh_2.pdf

and a yoke were excluded. A fluid load of 126 L was included which was in excess of the subsequent 123 L limit.

The simulations did not use the TCDS weight for RHC R22s or FAR Part 27 standard pilot weight, preferring 830 lb and 150 respectively. A fuel load of 30 minutes is detailed as 20.538 lb. However the fuel consumption for 30 minutes per the engine manufacturer's operator manual[7], would weigh 23.24 lb.

Flight tests

Three flight tests were carried out using ZK-IAF. Two on 29 June 2006 (Test #1 and #2), and one on 29 September 2006 (Test #1A). On all flight tests the pilot weight was recorded as 200 lb. For Test #1 and #2 a monitoring engineer was a passenger and weighed 143 lb. ZK-IAF weighed 893.6 lb.

Test #1 data: Installation of the -402 was described to be with "(100% spray booms fitted)", however these were not detailed in the weight and balance calculations. The total weight of the -402 was given as 82.24 lb. With the addition of 30 lb of fuel, the total aircraft weight was 1348.84 lb. The missing weight for the 100% spray booms of 7.48 lb would have put the helicopter within 13.36 lb of the MAUW of 1370 lb.

Test # 2 data: This detailed that the 100% booms which had supposedly been installed for Test #1 had been removed. The weight of the helicopter was therefore 1342.06 lb. This was within 27.94 lb of the MAUW of 1370 lb.

Test #1A data: For this flight the pilot was alone. While the Helipod III is described as having "100% booms", these are not portrayed in the weight and balance data. However a weight value is shown for "Fluid in RH valve & pipes" and "Fluid in spray boom". Without the 100% booms installed the weight shown is 1365.88 lb. The inclusion of the booms corrects the weight to 1373.36 lbs, which exceeds the MAUW of 1370 lb.

Miscalculations, non-recording of equipment installed and non-operational realities found in the ground simulations and flight tests, provided favourable outcomes to the useable load and effective use of the Helipod III, but did not represent real operational application.

Calculation of the Helipod III weight using the FMS

The preceding sections have identified that the weights of components were heavier than that identified in the FMS. The FMS detailed other items that are required to be used in the calculation of

[7] Textron Lycoming Operator's Manual 60297-12, Section 3 3-13 ,O-360-J2A 100% fuel consumption equates to 12.4 USG/h https://www.lycoming.com/sites/default/files/O-HO-IO-HIO-AIO%20%26%20TIO-360%20Oper%20Manual%2060297-12.pdf

the cumulative weight of the Helipod III. These include wheels, axels and a yoke. The total weight, including the belly tank and components, equate to approximately 108.96 lb (49.4 kg).

Installation of Helipod III on ZK-HWJ

Given the anomalies found in the certification data used for the Helipod III installation on the RHC R22, the safety investigation conducted a full review of ZK-HWJ's aircraft logbooks, maintenance work packs, the aircraft Pilot Operating Handbook (POH), the pilot's personal aviation records and the installed Helipod III equipment. (CAA Findings 18F589 refers).

The Helipod III was installed on ZK-HWJ at 2200 hour inspection

During the 2200-hour maintenance inspection on ZK-HWJ, a Helipod III was installed along with a Trimble AgEZ-500 GPS (GPS). The designator or model number identified for the Helipod III installed on ZK-HWJ was HRP22III25201-401 (-401). This required the pump to be installed on the left hand landing gear skid along with the associated pipe fittings.

The FMS in the POH was not for the Helipod III installed

As part of the STC certification process, an FMS must be created to provide information and guidance to the pilot. The FMS is placed in the POH and includes information required for weight and balance calculations.

The FMS located in the POH for ZK-HWJ referred to Helipod III serial number 1273. This Helipod III had been damaged during shipping and had been replaced by serial number 1560. While the FMS recorded a weight of 121.25 lb (55 kg), this did not relate to the Helipod III installed. (CAA Finding 18F581 refers.)

ZK-HWJ should have been reweighed after installation

Following installation of the Helipod III and an agricultural GPS, ZK-HWJ should have been reweighed.

CAA Advisory Circular AC146-1 *Aircraft Design Organisations*[8] requires that *'Unless the design change results in a negligible weight change then weights and moment arms should be calculated in the description of the change. Alternatively, a complete reweigh could be requested of the aircraft after embodiment.'* The negligible weight change differential for aircraft under 5700 kg, such as ZK-HWJ should be carried out if the weight change exceeds one per cent of the Maximum Certified Take-off

[8] CAA Advisory Circular AC146-1 Aircraft Design Organisations, Rev 2 (2007) https://www.caa.govt.nz/assets/legacy/Advisory_Circulars/AC146_1.pdf

Weight (MCTOW). Despite the combined weight of the Helipod III and GPS being 118.96 lb, 8.68% of the MCTOW, no reweigh was carried out. (CAA Finding 18F581 refers.)

The GPS installed was not approved for installation on ZK-HWJ

The agricultural GPS installed on ZK-HWJ was a one-off modification originally issued to ZK-HWU and could not be installed on ZK-HWJ without CAA approval. (CAA Finding 18F581 refers.)

The GPS was identified on the Form CAA2129 *Aircraft Radio Station*. The Form CAA2173 *Weight and Balance Data* did not reflect the installation of either the GPS or Helipod III.

Weight information used by the pilot was inaccurate

A “Spray Weights” information card (Figure 2 overleaf) was located in the debris trail and identified as belonging to ZK-HWJ. The card was a quick reference source used by the pilot when calculating fuel loads versus spray loads. This information was repeated in a number of other documents recovered from the company including the POH and Pilot Maintenance Records.


SPRAY WEIGHTS

EMPTY WEIGHT = 894.5lbs + Spray gear = 84.04lbs + Pilot weight =185.5lbs

= ZFW- 1163.5

Fuel	Max Spray Load

15 min = 9.9 litres = 15.8 lbs = 190.7lbs (86.6 litres)

20 min = 13.3 litres =20.9 lbs =185.6 lbs (84.3 litres)

25 min=16.6 litres = 26.39 lbs =

30 min= 19.9 litres =31.6 lbs =

35 min =23.3 litres = 36.7 lbs =

MAUW 1370 lbs

Figure 2. Spray Weights quick reference card found at scene (Inset: card pictured in ZK-HWJ).

The card shows the empty weight of the aircraft as 894.5 lb and the Helipod III as 84.0 lb (38.1 kg), a total weight of 978.5 lb. The safety investigation revealed that with the addition of the Helipod III and the GPS, ZK-HWJ would weigh 1013.46 lb.

Fuel and weight calculation were also inaccurate

The pilot recorded on the “Spray Weights” card, fuel loads comparable to desired spray loads. For example in Figure 2: 15 minutes @ 9.9 L[9] (39.6 L/PH fuel) equates to 86.6 L (spray load), however the fuel consumption calculation was incorrect.

The O360-J2A Textron Lycoming (Textron) engines installed on the RHC R22 has a rated fuel consumption of 12.4 USG/PH (74.27 lb). Table below shows the fuel consumption per hour rate (/PH) comparisons between Textron and the pilot’s values.

	USG/PH	L/PH	lb
Textron Lycoming	12.4	46.87	74.05
Spray Weight card	10.4	39.6	62.57

Table 1. Fuel consumption rate /PH comparing Textron and pilot values.

There is approximately 16% differential across all aspects, and it is not known why this consumption rate was being used. In reviewing the original fuel load/consumption example, Table 2 below shows that had the correct /PH been used then it would have increased the weight considerations.

15 minutes fuel	USG/PH	L/PH	lb
Textron Lycoming	3.1	11.7	18.6
Spray Weight card	2.6	9.9	15.8

Table 2. Corrected fuel consumption rate /PH comparing Textron and pilot values.

[9] Specific gravity weight of aviation fuel is 0.72 Kg. For fuel calculations a conversion sum is used: 1 L (x 1.58) = 1.58 lb

Summary of Helipod III STC and weight and balance

In terms of the Helipod III STC process and weight and balance calculations, the following key discoveries are identified:

- The basic helicopter empty weight and pilot weight used for the STC approval were not per standards accepted by CAA.
- Ground simulations did not accurately reflect real operational considerations.
- The Helipod III R22 test flights were not carried out with a fully configured Helipod III or with a maximum permissible load analysis.
- Test flight data and weight computations were inaccurate and favourable to the STC not exceeding the MAUW.
- Actual weights of the Helipod III components were not correct.
- The spray booms and pump installed on ZK-HWJ were heavier than the weight specified in the STC and FMS documentation.
- CAA appraisal and approval of the Helipod III STC data and information was insufficiently robust, allowing non-standard weights and inaccurate data to be accepted.
- The FMS weight in the POH for the Helipod III installed on ZK-HWJ was for a different serial numbered product that had been returned to the manufacturer, therefore the FMS information was invalid.
- There was no accurate weight and balance information recorded in the required documentation for the replacement Helipod III that was installed in ZK-HWJ.
- The GPS modification for RHC R22 Beta ZK-HWU was not permitted to be embodied on ZK-HWJ.
- Installation of the Helipod III and GPS role equipment weighing 118.96 lb and representing 8.68 % of the MAUW, should have prompted an aircraft reweigh.
- On the day of the accident the maximum allowable weight for the flight was likely exceeded due to the inaccurate basic empty weight, plus the weights of the pilot, fuel, and spray load.