



Australian Government

Australian Transport Safety Bureau

Loss of control Robinson Helicopter Company R44 Astro, VH-HFH

Cessnock Aerodrome, New South Wales | 4 February 2011



Investigation

ATSB Transport Safety Report

Aviation Occurrence Investigation

AO-2011-016

Final



Australian Government
Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY REPORT

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SAFETY SUMMARY

What happened

At 1115 Eastern Daylight-saving Time on 4 February 2011, a Robinson Helicopter Company R44 Astro helicopter (R44), registered VH-HFH, commenced circuit operations at Cessnock Aerodrome, New South Wales. On board the helicopter were a flight instructor, a pilot and a passenger.

Following a landing as part of a simulated failure of the hydraulic boost system for helicopter's flight controls, the instructor elected to reposition the helicopter to the apron. As the helicopter became airborne, it became uncontrollable and collided with the runway and caught fire. The pilot exited the helicopter; however, the instructor and passenger were fatally injured.

What the ATSB found

The Australian Transport Safety Bureau (ATSB) identified that a flight control fastener had detached, rendering the aircraft uncontrollable. The helicopter manufacturer had not recorded any previous instances of separation of this fastener. A number of separated components could not be located, preventing the identification of the specific reason for the separation.

A number of human factors contributed to the accident, including that the 'feel' of the flight control fault mimicked a hydraulic system failure.

Finally, the ATSB identified that fatal injuries sustained by the instructor and passenger were due to the post-impact fire and that a large number of R44s had not been modified to include upgraded bladder-type fuel tanks that reduce the risk of post-impact fuel leak and subsequent fires.

What has been done as a result

In response to the identification of a number of failures of the same type of self-locking nuts in other aircraft, the helicopter manufacturer and Civil Aviation Safety Authority have highlighted the issue to operational and maintenance personnel.

The helicopter manufacturer also reduced the compliance time on a current service bulletin requiring that all-aluminium fuel tanks fitted to older R44 helicopters be replaced with more impact-resistant bladder-type fuel tanks. A second bulletin aimed at removing a possible impact-related ignition source was also issued.

Safety message

This accident reinforces the importance of thorough inspections by maintenance personnel and pilots. It is also a powerful reminder not to take off after identifying a possible problem with an aircraft. In addition, the accident highlights the risk of carrying unnecessary personnel during practice emergencies, and reinforces the safety benefits of incorporating the requirements of manufacturer's service bulletins in their aircraft as soon as possible.

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Figure 1: Google Earth
Figure 2: Lars Baek
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Figure 7: United States National Transportation Safety Board

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an independent Commonwealth Government statutory agency. The Bureau is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers. The ATSB's function is to improve safety and public confidence in the aviation, marine and rail modes of transport through excellence in: independent investigation of transport accidents and other safety occurrences; safety data recording, analysis and research; fostering safety awareness, knowledge and action.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to identify and reduce safety-related risk. ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated. The terms the ATSB uses to refer to key safety and risk concepts are set out in the next section: Terminology Used in this Report.

It is not a function of the ATSB to apportion blame or determine liability. At the same time, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Developing safety action

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to initiate proactive safety action that addresses safety issues. Nevertheless, the ATSB may use its power to make a formal safety recommendation either during or at the end of an investigation, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation.

When safety recommendations are issued, they focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on a preferred method of corrective action. As with equivalent overseas organisations, the ATSB has no power to enforce the implementation of its recommendations. It is a matter for the body to which an ATSB recommendation is directed to assess the costs and benefits of any particular means of addressing a safety issue.

When the ATSB issues a safety recommendation to a person, organisation or agency, they must provide a written response within 90 days. That response must indicate whether they accept the recommendation, any reasons for not accepting part or all of the recommendation, and details of any proposed safety action to give effect to the recommendation.

The ATSB can also issue safety advisory notices suggesting that an organisation or an industry sector consider a safety issue and take action where it believes appropriate, or to raise general awareness of important safety information in the industry. There is no requirement for a formal response to an advisory notice, although the ATSB will publish any response it receives.

TERMINOLOGY USED IN THIS REPORT

Occurrence: accident or incident.

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

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

Other safety factor: a safety factor identified during an occurrence investigation which did not meet the definition of contributing safety factor but was still considered to be important to communicate in an investigation report in the interests of improved transport safety.

Other key finding: any finding, other than that associated with safety factors, considered important to include in an investigation report. Such findings may resolve ambiguity or controversy, describe possible scenarios or safety factors when firm safety factor findings were not able to be made, or note events or conditions which ‘saved the day’ or played an important role in reducing the risk associated with an occurrence.

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

Risk level: the ATSB’s assessment of the risk level associated with a safety issue is noted in the Findings section of the investigation report. It reflects the risk level as it existed at the time of the occurrence. That risk level may subsequently have been reduced as a result of safety actions taken by individuals or organisations during the course of an investigation.

Safety issues are broadly classified in terms of their level of risk as follows:

- **Critical** safety issue: associated with an intolerable level of risk and generally leading to the immediate issue of a safety recommendation unless corrective safety action has already been taken.
- **Significant** safety issue: associated with a risk level regarded as acceptable only if it is kept as low as reasonably practicable. The ATSB may issue a safety recommendation or a safety advisory notice if it assesses that further safety action may be practicable.
- **Minor** safety issue: associated with a broadly acceptable level of risk, although the ATSB may sometimes issue a safety advisory notice.

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

FACTUAL INFORMATION

History of the flight

At 1115 Eastern Daylight-saving Time¹ on 4 February 2011, a Robinson Helicopter Company R44 Astro helicopter, registered VH-HFH, commenced circuit operations at Cessnock Aerodrome, New South Wales (NSW) (Figure 1). On board the helicopter were a flight instructor, who was seated in the front left seat; a pilot, who was seated in the front right seat; and a passenger, who was also a qualified pilot and was seated in the right rear seat. The flight was a biennial helicopter flight review (HFR) for the pilot. It was to be followed by the transfer of the instructor and pilot to Newcastle, 38 km to the east of Cessnock. The passenger, who had no role during the HFR, was scheduled to return the helicopter to its Cessnock base from Newcastle, following the transfer of the instructor and pilot.

The HFR was the second of two consecutive flight reviews conducted in the helicopter by the instructor that day. The first review had been conducted for the owner of the helicopter with the pilot on board as an observer in preparation for his HFR. The passenger was not on board the helicopter during the first HFR.

Figure 1: Cessnock Aerodrome



The pilot stated that, following a landing on the western grass area parallel to runway 35 as part of a simulated failure of the hydraulic boost system for the helicopter's flight controls (see the section titled *Aircraft specifications*), it appeared that the hydraulic system could not be re-engaged. The pilot identified the issue to the instructor and handed over control of the helicopter to the instructor. The pilot reported that following a number of apparently unsuccessful attempts to re-engage the system, the instructor assessed that the hydraulic system had failed.

¹ Eastern Daylight-saving Time was Coordinated Universal Time (UTC) + 11 hours.

The pilot stated that the instructor asked the passenger, who was the normal pilot of the helicopter, if there had been any problem with the hydraulic system. The passenger advised that the system had been leaking and that he had added hydraulic fluid to the reservoir that morning, prior to the commencement of the day's flying activities. The instructor announced that he would reposition the helicopter to the apron (Figure 1) to facilitate examination of the hydraulic system and, if necessary, maintenance action.

The pilot recalled that, as the helicopter became airborne, the instructor experienced immediate and increasing difficulty controlling the aircraft. At 1141, the helicopter collided with the runway in a steep left bank before coming to rest on its left side at the intersection of the runway and a taxiway (Figures 1 and 10). The pilot reported that, shortly after the helicopter came to rest, a fire commenced and rapidly engulfed the helicopter. He stated that, while his egress was delayed by difficulty in locating his seat belt release, he was able to exit the helicopter through a large opening in the fractured canopy. The instructor and passenger were fatally injured.

Personnel information

The instructor and pilot each held Australian Commercial Pilot (Helicopter) Licences that were issued by the Civil Aviation Safety Authority (CASA) in 1983 and 1998 respectively. Both were appropriately endorsed to operate the R44.

The instructor held a CASA Class 1 Aviation Medical Certificate with the requirement to have corrective reading glasses available for use during flight. The pilot held a Class 1 Aviation Medical Certificate without restriction.

The instructor's flying logbook indicated that he had in excess of 11,000 hours flight time, including experience in R44 helicopters. The instructor had in excess of 4,000 hours of instructional flying experience and had undertaken a renewal of his Grade 1 instructor rating on 30 March 2009, which satisfied the requirements of an HFR.

Prior to the accident flight, the pilot's flying logbook indicated that he had accrued 249.8 hours flight time, of which 31.5 hours were in R44 helicopters. The pilot was undergoing the HFR following a 20-month absence from flying and in preparation for commencing employment with the operator of the helicopter.

Aircraft information

Aircraft specifications

The R44 is a four-seat, single main and tail rotor helicopter that is powered by a six-cylinder piston engine, and equipped with skid-type landing gear.

The helicopter (Figure 2), serial number 0505, was manufactured in the United States (US) in 1998 and first registered in Australia in November 2005. The certificate of registration was transferred to the current owner in March 2006.

Hydraulic system

All R44 helicopters, with the exception of the Astro² model, were manufactured with hydraulically-boosted main rotor flight controls. VH-HFH was retrofitted with the hydraulic-boost system during scheduled overhaul by the helicopter manufacturer in 2005. The pilot's operating handbook (POH) required the hydraulic system to be operational for flight.

Figure 2: VH-HFH



The POH described the R44 hydraulic system as follows:

Hydraulically-boosted main rotor flight controls eliminate cyclic and collective^[3] feedback forces. The hydraulic system consists of a pump, three servos [Figure 3], a reservoir, and interconnecting lines...The pump is mounted on and driven by the main rotor gearbox to maintain hydraulic pressure in the event of an engine failure. A servo is connected to each of the three [flight control] push-pull tubes that support the main rotor swashplate [Figure 4]. The reservoir...includes a filter, pressure relief valve, and pilot-controlled pressure shut-off valve...The pressure shut-off valve is solenoid-actuated and controlled by the hydraulic switch on the pilot's cyclic [Figure 5].

² The R44 Astro was manufactured with a pilot-adjustable cyclic trim to reduce the main rotor feedback forces. The cyclic is a primary helicopter flight control that is similar to an aircraft control column. Cyclic input tilts the main rotor disc varying the attitude of the helicopter and hence the lateral direction.

³ A primary helicopter flight control that simultaneously affects the pitch of all blades of a lifting rotor. Collective input is the main control for vertical velocity.

Figure 3: Hydraulic-boost servo

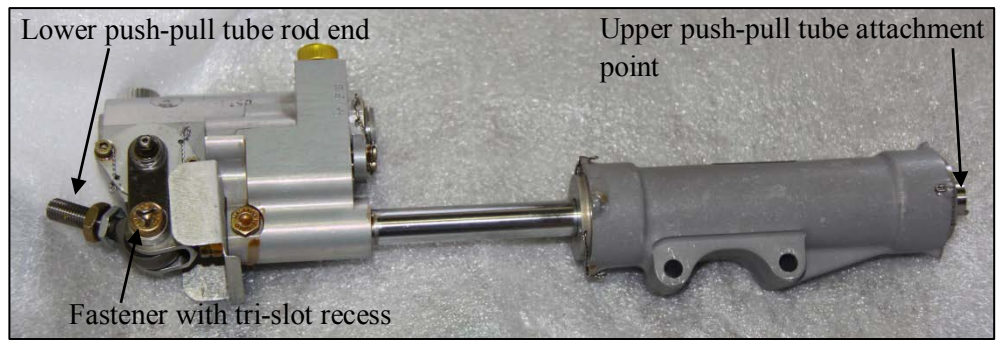


Figure 4: Main rotor flight controls (cowls removed for clarity)

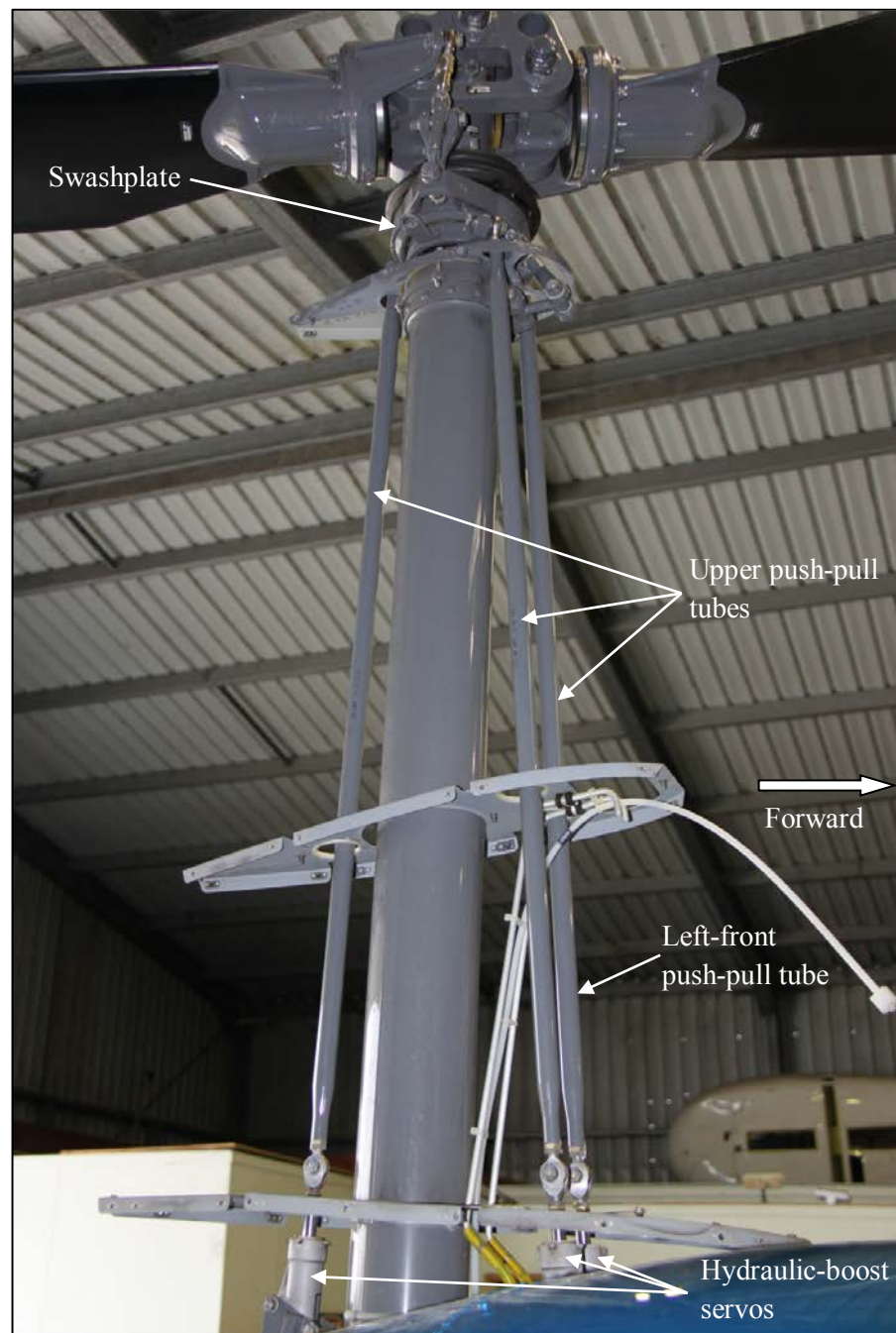
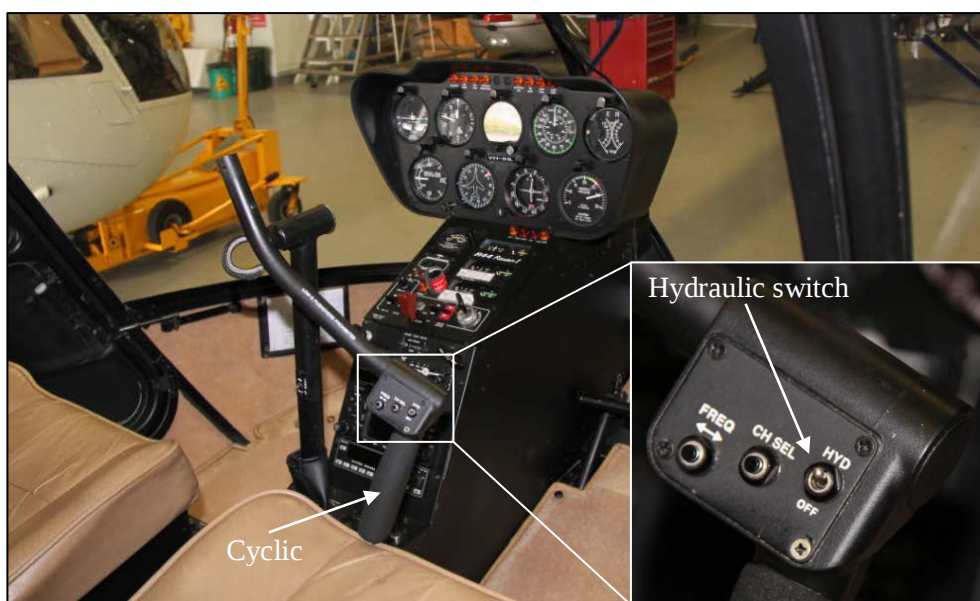


Figure 5: Hydraulic switch



The POH required the hydraulic system to be checked prior to flight. Specifically, there was a requirement to visually confirm that the hydraulic fluid level in the reservoir showed full and that the system was not leaking. The physical location of a number of the flight control components, including the hydraulic-boost servos and associated push-pull tube attachments, prevented their visual examination without the removal a number of aircraft panels and major components. The owner of the helicopter stated that he conducted a visual inspection of the main rotor transmission, hydraulic system and drive belts prior to his HFR but after the addition of hydraulic fluid that morning by the passenger. He recalled that the hydraulic fluid level showed full and that the inspection did not reveal anything of concern.

The POH also required a functional check of the hydraulic system with the rotors turning under engine power. The POH described this check, and the expected difference in control feel with and without hydraulic assistance as follows:

For hydraulic system check, use small cyclic inputs. With hydraulics off, there should be approximately one half inch of freeplay before encountering control stiffnesss and feedback. With hydraulics on, controls should be free with no feedback or uncommanded motion.

The POH authorised the simulated failure of the hydraulic system via the cyclic mounted switch for emergency training purposes (Figure 5), but the hydraulic system was otherwise required to be operational for flight. The owner advised that, during his HFR, two sequences involving the simulated in-flight failure of the hydraulic system were conducted. Both exercises were concluded via a landing on the western grass area at Cessnock Aerodrome and the owner reported that the hydraulic system, including the cyclic-mounted switch, operated normally throughout those exercises.

In respect of the identification of a hydraulic system failure, the 'Emergency Procedures' section of the POH stated:

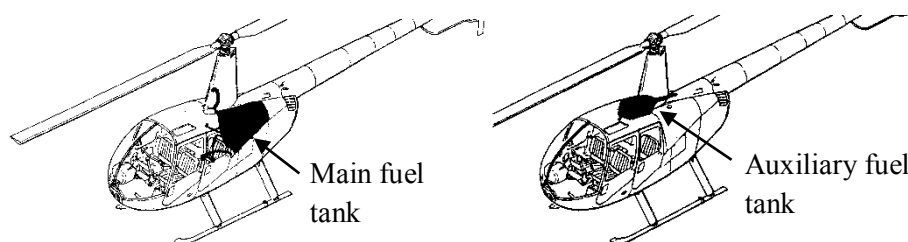
Hydraulics system failure is indicated by heavy or stiff cyclic and collective controls. Control will be normal except for the increase in stick forces.

The helicopter was not fitted with any independent cockpit indication, such as a visual and/or aural caution or warning, to assist in the identification of a hydraulic system failure.

Fuel system

The R44 was originally manufactured with two all-aluminium fuel tanks that were installed above the engine firewall, either side of the main transmission (Figure 6).

Figure 6: Fuel tanks



On 20 December 2010, the manufacturer issued R44 Service Bulletin 78 (SB-78) requiring that R44 helicopters with all-aluminium fuel tanks be retrofitted with bladder-type tanks as soon as practical, but no later than 31 December 2014. The background information to the service bulletin stated:

To improve the R44 fuel system's resistance to a post-accident fuel leak, this retrofit must be performed as soon as possible.

The manufacturer advised that, compared to the all-aluminium tanks, the bladder-type tanks provided improved resistance to post-accident fuel leaks due to their improved cut and tear resistance and the ability of the bladders to sustain large deformations without rupture. SB-78 also incorporated the fitment of:

- reinforced fuel filler caps, to increase their ability to retain fuel under internal pressure loads
- roll-over vent valves, designed to minimise fuel spillage should the helicopter come to rest at an attitude that permitted fuel to reach a fuel tank vent opening.

The helicopter manufacturer advised that about 4,000 helicopters were initially manufactured with the all-aluminium fuel tanks. At the time of writing, about 500 of these helicopters had been retrofitted with the bladder-type tanks and other components detailed in SB-78.

The helicopter manufacturer also advised that they were aware of four accidents involving R44 helicopters with bladder-type tanks that were of sufficient severity to result in fatal or serious injury to the occupants. The manufacturer advised that three of these accidents did not result in a post-accident fire (for example, see Figure 7). At the time of writing, the manufacturer was unable to confirm whether a post-accident fire occurred in the fourth instance.

On 4 February 2012 another accident involving an R44 fitted with all-aluminium fuel tanks occurred at Jasper's Brush, NSW. While that accident is currently the

subject of an Australian Transport Safety Bureau (ATSB) investigation, preliminary assessment identified that:⁴

Soon after lifting off, the pilot's door opened. The helicopter abruptly pitched nose-up and the tailskid struck the ground. The helicopter then abruptly pitched forward and rolled to the right before the main rotor blades struck the ground. A fuel-fed fire started in the vicinity of the fuel tanks and lower mast area. The fuselage then hit the ground. Both occupants were fatally injured and the helicopter was destroyed.

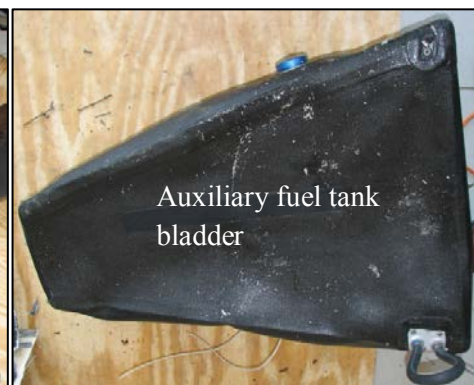
On 21 February 2012, the helicopter manufacturer released Service Bulletin 78A (SB-78A) that brought forward the date of compliance in SB 78 from 31 December 2014 to 31 December 2013.⁵ The manufacturer also released SB-82 that day, requiring the replacement of the rotor brake switch to reduce the chance of a possible ignition source in the event of a fuel leak.⁶ The stated time of compliance was 'within the next 150 flight hours or by 31 May 2012, whichever occurs first'.

⁴ ATSB investigation AO-2012-021, available at http://www.atsb.gov.au/publications/investigation_reports/2012/aoir/ao-2012-021.aspx

⁵ SB-78A applied to R44 models with serial numbers 0001 to 2064, and R44 II models with serial numbers 10,001 to 12,890.

⁶ SB 82 applied to R44 models with serial numbers 0001 to 2126, and R44 II models with serial numbers 10,001 to 13,139.

Figure 7: Accident involving an R44 fitted with bladder-type fuel tanks



Prior to the issue of SB-78/SB-78A, the manufacturer had issued service bulletins 67⁷, 68 and 69 (SB-67, SB-68 and SB-69) that were similarly designed to reduce the likelihood of post-accident fuel leaks. SB-67 and SB-68 involved modifications

⁷ Service bulletin 67 was not applicable to VH-HFH.

that increased the allowable movement of the fuel lines during an accident. Service bulletin 69 (SB-69) detailed a modification designed to improve retention of the gascolator⁸ sediment bowl under impact loads.

At the time of the accident, VH-HFH had been modified to include SB-68 and SB-69. The bladder-type fuel tank retrofit had not been incorporated.

Maintenance history

The aircraft last underwent maintenance at a CASA-approved maintenance organisation at 3,599.7 airframe hours on 21 December 2010. That maintenance consisted of a 50-hourly engine inspection. The last 100-hourly maintenance inspection was conducted by the same maintenance organisation at 3,549.6 airframe hours on 15 October 2010. In addition to routine maintenance items, this inspection included the replacement of the front-left hydraulic-boost servo due to a hydraulic fluid leak. The history of the replacement servo is summarised in Table 1. Prior to the first HFR that day, the helicopter had accrued 3,643.2 airframe hours.

Table 1: Replacement hydraulic-boost servo history

Date	Event
23 March 2007	The servo was assembled by the helicopter manufacturer.
11 February 2009	The servo was returned to the manufacturer ⁹ for repair due to a hydraulic fluid leak that developed after 648.0 hours time in service, ¹⁰ while fitted to another R44 helicopter.
25 February 2009	Repair and functional testing of the servo was completed by the manufacturer. The repair required the disassembly of the lower flight control push-pull tube rod end securing fastener (Figures 8 and 9). The repair documentation indicated that, with the exception of the components associated with the leak, all of the original parts of the servo were re-used, ¹¹ and that the servo was repaired and tested in accordance with established procedures. That included duplicate inspections where required.
5 March 2009	The servo was returned to one of the manufacturer's Australian distributors and stored as an available spare part for about 17 months. The distributor's documentation indicated that the servo was not used during this time period.

⁸ Fuel filter fitted at the lowest point of the fuel system.

⁹ The manufacturer did not permit repair of the servo by external organisations.

¹⁰ The hydraulic-boost servos have a 2,200 hour interval between mandatory overhaul.

¹¹ The manufacturer permitted the re-use of hardware components, such as fasteners, provided they were assessed as serviceable.

18 August 2010	The distributor delivered the servo to the maintenance organisation for the helicopter.
15 October 2010	The servo was fitted to the helicopter and accrued 93.6 hours time in service prior to the accident on 4 February 2011.

The approved method of replacing the hydraulic-boost servo was detailed in the manufacturer's R44 maintenance manual. The procedure involved the disassembly of a number of major components, including the fuel tanks, to gain access to the servos. In addition, the upper and lower flight control push-pull tubes needed to be disconnected from their servo attachment points (Figure 3).

The manual required the removal of the lower push-pull tube from the servo by unthreading it from its rod end (Figures 3 and 8) and stipulated that disconnection of the tube by disassembling the rod end securing fastener (Figure 8), was prohibited. The manufacturer advised that correct assembly of that fastener was critical to the proper operation of the servo and that the helicopter would be rendered uncontrollable if there was a disconnection of any of the upper or lower push-pull tubes.

The securing fastener consisted of seven individual components, including a self-locking nut and a secondary stamped locking nut (Figures 8 and 9). The assembly of the fastener only permitted detachment of the spacers if the bolt moved free of the rod end. The washer that was located under the bolt head could only detach if the bolt completely separated from the servo. In order to discourage removal of this fastener, the bolt head had an uncommon tri-slot recess that required a specific tool to disassemble/assemble the fastener (Figures 3 and 14).

Figure 8: Lower flight control push-pull tube rod end

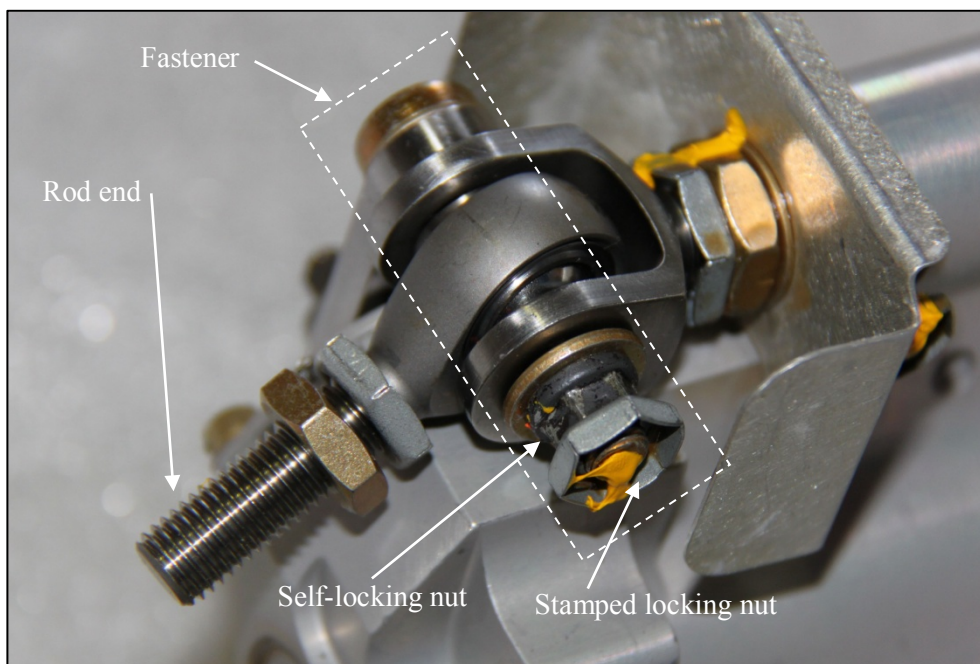
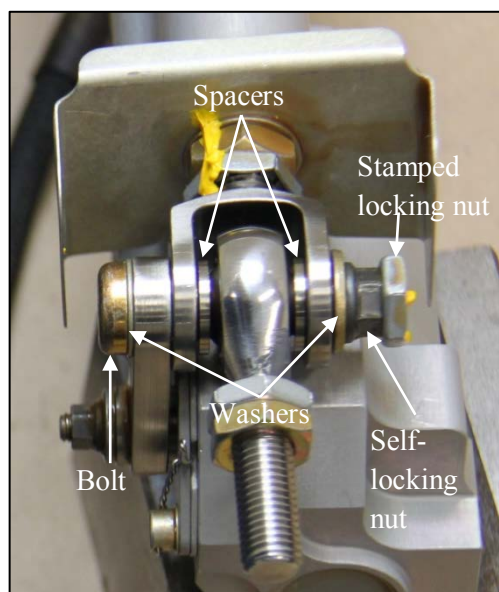


Figure 9: Lower flight control push-pull tube rod end securing fastener components



The maintenance personnel who replaced the front left hydraulic-boost servo in the helicopter advised that they were aware that the fastener was not to be removed. Additionally, they stated that they did not remove the fastener during that replacement, and that they did not possess the tri-slot tool bit required to disassemble/assemble the fastener.

Aircraft weight and performance

Weight and balance calculations indicated that the helicopter was being operated about 160 kg below the maximum allowable gross weight of 1,089 kg, and within the centre of gravity limits at the time of the accident. The helicopter manufacturer's performance data indicated that, at the time of the accident, the helicopter was capable of hovering out of ground effect¹² in zero wind conditions.

Meteorological information

Aerodrome weather reports provided by the Bureau of Meteorology indicated that, shortly prior to the accident, the temperature at Cessnock Aerodrome was 31 °C and the wind was from the north-north-east at 6 kts (11 km/h). The pilot's recollection of the weather was consistent with the reported conditions. Other pilots who were operating in the circuit area at the time reported that there were no significant weather conditions.

¹² Helicopters require more power to hover out of ground effect due to the absence of a cushioning effect created by the main rotor downwash striking the ground. The distance is usually defined as more than one main rotor diameter above the surface.

Wreckage and impact information

On-site examination

The accident site was located on the runway adjacent to a taxiway intersection (Figures 1 and 10). Main rotor blade contact marks indicated that the helicopter initially contacted the runway while banked to the left at 53° and travelling to the south-west at about 56 kts (103 km/h). The helicopter continued rolling to the left and the fuselage contacted the runway at a bank angle in excess of 110°. The helicopter travelled a further 17 m before coming to rest on its left side, orientated north. An intense post-accident fire consumed the majority of the helicopter (Figure 10).

Examination of the main rotor blades showed that they contacted the runway with significant rotational energy. This was consistent with the pilot's recollection that the engine was operating normally prior to the accident.

Figure 10: Accident site



On-site wreckage examination identified that the securing fastener that retained the lower flight control push-pull tube rod end to the left-front hydraulic-boost servo was missing (Figures 11 and 13).

The lower push-pull tube rod end was subsequently found in the vicinity of the front servos (Figure 13). The bolt was also located within the wreckage close to the cabin floor (Figures 13 and 14) and about 1 m from the installed position of the front servos.

The orientation of the front hydraulic-boost servos was consistent with the resting position of the helicopter and would not have permitted the bolt to fall free of the servo due to the position of the bolt head (Figure 12). In addition, the relative positions of the front servos in the wreckage (Figure 11), would have impeded detachment of the bolt as it would have fouled on the right-front servo (see the section titled *Testing conducted by the helicopter manufacturer* and Figure 16).

Despite a thorough search of the wreckage, accident site and the estimated departure point using a sieve and a metal detector, the remaining fastener components were not located.

The continuity of the remainder of the flight control system was confirmed and all major parts of the helicopter were accounted for at the accident site.

Examination of the wreckage and aircraft documentation confirmed that the helicopter was fitted with all-aluminium fuel tanks.

Figure 11: Front hydraulic-boost servos

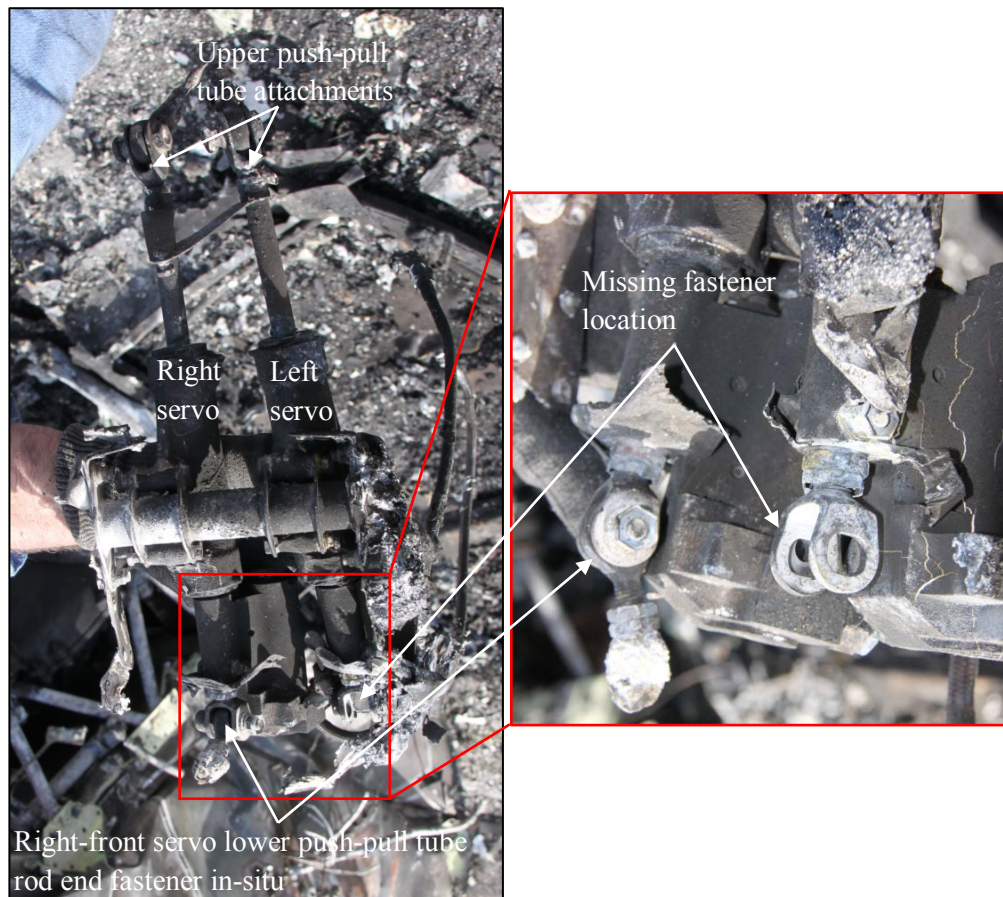
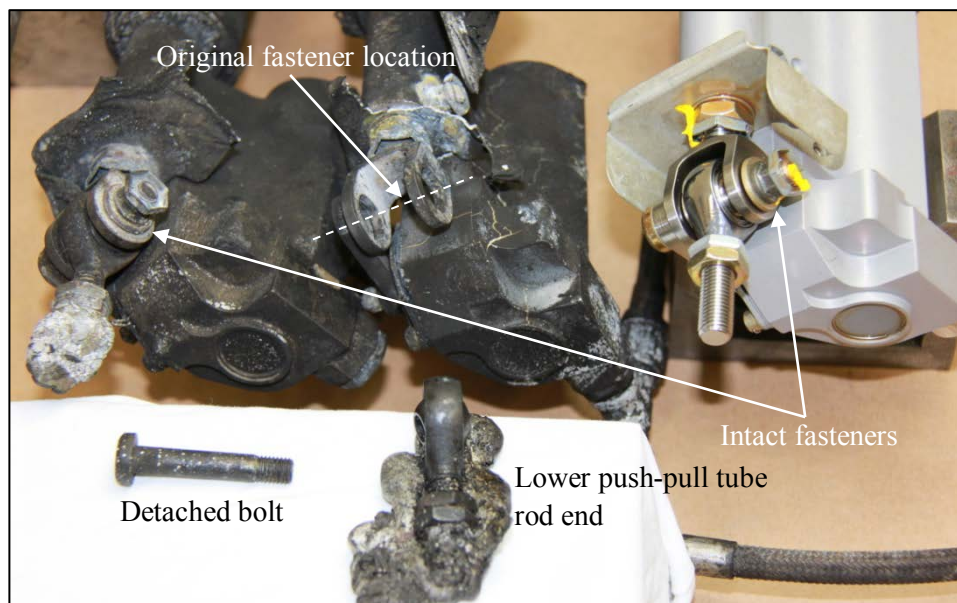


Figure 12: Position of the front hydraulic-boost servos in the wreckage



Figure 13: Right-front, left-front and exemplar hydraulic-boost servos



Examination of recovered components

The detached bolt and lower push-pull tube rod end, together with a number of hydraulic system components, were examined at the Australian Transport Safety Bureau's (ATSB) technical facility in Canberra. In addition, a large proportion of the melted helicopter structure and surrounding runway surface were also recovered and x-rayed at an external facility in an attempt to locate the missing fastener components. That process did not identify any of the missing parts.

Detached bolt and lower push-pull tube rod end

Initial examination of the detached bolt showed that it had not been subjected to significant force (Figure 14), such as that associated with the accident sequence. There was no distortion of the bolt and its threads and shank were visually undamaged. Detailed examination identified that the bolt conformed to its specification with regard to dimension and thread profile.

The hardness of the bolt was found to be less than that specified; however, this may have been due to the post-impact fire as the bolts from the right-front and aft servos were similarly affected. There was no evidence of damage to the bolt head that might suggest tampering (see the section titled *Testing conducted by the ATSB*). Some of the witness marks on the bolt's thread and tri-slot head indicated that a self-locking nut had previously been fitted to the bolt and that the fastener had previously been disassembled. This was consistent with the documented repair history of the left-front servo.

Examination of the lower push-pull tube rod end found no evidence that it had been subjected to significant force. There were no witness marks on the rod end.

Figure 14: Detached bolt



Hydraulic system components

The recovered hydraulic system components consisted of the servos, pump and remnants of the fluid reservoir (including the solenoid-actuated pressure shut off valve). Examination of those components did not identify any pre-impact defect or anomaly that would have prevented the hydraulic system operating normally. However, due to the degree of fire damage, it was not possible to verify the integrity of the entire hydraulic system, including the serviceability of the cyclic-mounted hydraulic switch.

Examination of the left-front servo in the vicinity of the detached fastener found no evidence that it had been subjected to significant force. There were no witness marks identified in this area.

Cracked nuts

During the examination of the hydraulic-boost servos, a number of cracked self-locking nuts that secured the servos to the helicopter were identified (Figure 15). These nuts were of the same type as those fitted to the detached fastener. Detailed analyses of these nuts identified that they had failed due to the effect of the post-impact fire and not a pre-existing defect (see the section titled *Liquid-metal embrittlement*). No cracks were identified in any of the stamped locking nuts.

Figure 15: Cracked self-locking nuts



Medical and pathological information

The examining pathologist identified that, while the instructor received incapacitating injuries during the collision sequence, the fatal injuries received by both the instructor and the passenger were due to the post-impact fire.

Toxicological analysis detected a very low level of alcohol in the instructor's blood. Given that a number of the factors that can influence the post-mortem production of alcohol were present following the accident,¹³ the assessing pharmacologist concluded that the blood alcohol concentration was most likely due to post-mortem generation of alcohol rather than the result of alcohol consumption by the instructor.

Testing also identified low levels of carbon monoxide saturation in the blood of the instructor and passenger. The detected levels were considered by the pathologist to be consistent with a very short time interval between the collision and the receipt of fatal injuries due to the fire. Additionally, the pharmacologist considered that the levels of carbon monoxide were insufficient to have resulted in impairment, had they been present before the accident.

¹³ See the research paper Dr Shelley Robertson (2005). *Interpretation of Measured Alcohol Levels in fatal Aviation Accident Victims*:
http://www.atsb.gov.au/publications/2005/Measured_alcohol_lev.aspx

Survival aspects

The R44 POH contained a number of safety notices relating to operation of the manufacturer's helicopters. In particular, Safety Notice SN-40¹⁴, advised that:

There have been a number of cases where helicopter or light plane occupants have survived an accident only to be severely burned by fire following the accident. To reduce the risk of injury in a postcrash fire, it is strongly recommended that a fire-retardant Nomex flight suit, gloves, and hood or helmet be worn by all occupants.

The manufacturer of clothing containing NOMEX® fibre described its effectiveness as follows:¹⁵

Inherently flame-resistant, fabric made of NOMEX® will not continue to burn after the flame source is removed. It also creates an insulating barrier against the heat of a fire, slowing the transfer of heat and giving the wearer time to escape. Something else to consider: NOMEX® chars when exposed to intense heat, increasing the protective barrier and reducing the chance of injuries from burns.

Tests and research

Testing conducted by the helicopter manufacturer

In response to this accident, the helicopter manufacturer conducted an assessment of the behaviour of an R44's flight controls following the removal of the detached fastener. Due to safety considerations, the tests were conducted on the ground using an R44 with the hydraulic system pressurised by means of an external pump rather than via the helicopter's main rotor system-driven pump.

Testing was initially conducted following the removal of the fastener from the right-front servo.¹⁶ In this configuration, aft movement of the cyclic to the degree normally associated with the functional check of the hydraulic system (see the section titled *Aircraft specifications*) resulted in strong control resistance. The testing was repeated with the fastener removed from the left-front servo with similar results observed.

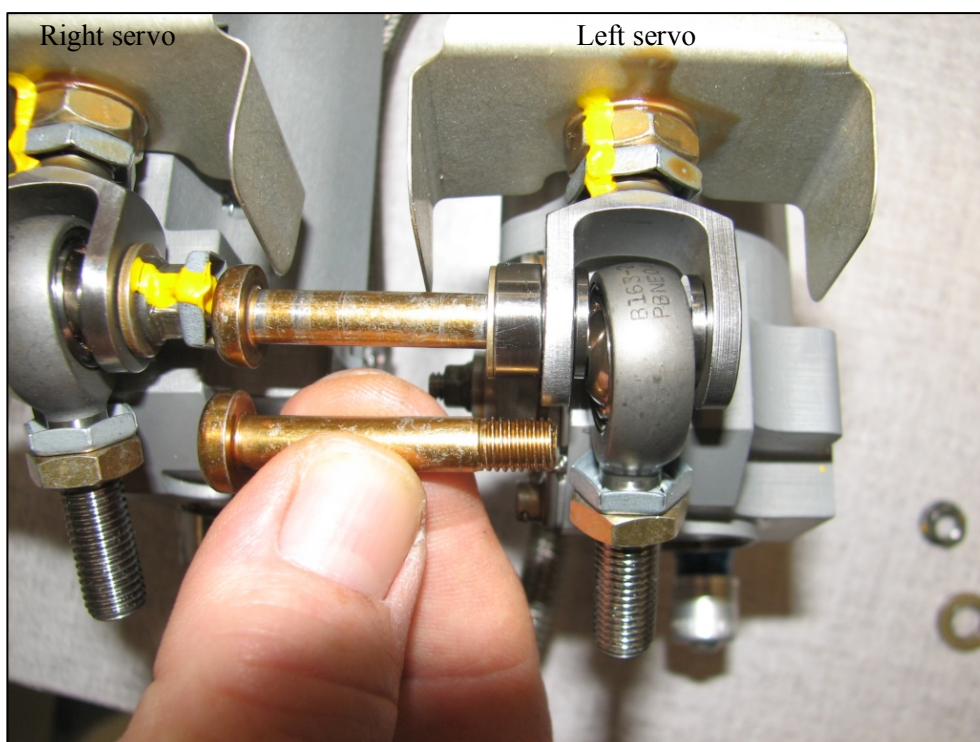
The testing also identified that the relative position of the installed front servos allowed a detaching bolt from the left servo to contact the right servo (Figure 16). This permitted the movement of the right servo to interfere with the normally independent movement of the left servo.

¹⁴ Issued July 2006

¹⁵ http://www2.dupont.com/Nomex/en_US/assets/downloads/Military_Brochure_5.2005

¹⁶ The right-front servo was more accessible on the test helicopter.

Figure 16: Front hydraulic-boost servos



As a result of the testing, the manufacturer considered the similarity of the behaviour of the cyclic and collective flight controls following the removal of the detached fastener, as compared to the control feel described by the pilot of VH-HFH before handing control to the instructor. The manufacturer concluded that the behaviour of the controls in that case was sufficiently similar to those associated with the disengagement of the hydraulic system to allow the conclusion by an affected pilot that the hydraulic system had failed.

Testing conducted by the ATSB

A number of tests were conducted by the ATSB to establish the characteristics of the fastener that was found to have detached. The testing utilised new and/or serviceable fastener components supplied by the helicopter manufacturer.

Multiple use of fastener components

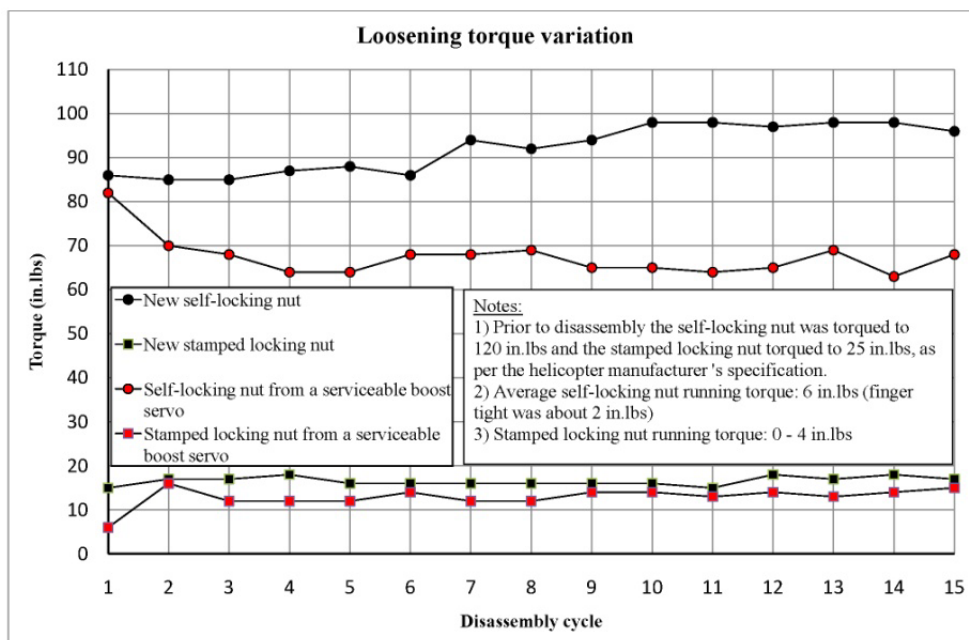
The helicopter manufacturer permitted the re-use of serviceable fastener components. In order to assess the behaviour of the fastener following repeated use, two complete sets of fastener components were disassembled and reassembled multiple times. The torques that were required to loosen both the self-locking and stamped locking nuts were recorded together with the torques required to overcome the friction associated with unthreading both nuts (known as running torque). The results of that testing identified that (Figure 17):

- Following 15 assembly/disassembly cycles,¹⁷ the components retained their locking capability and the running torques did not vary significantly.

¹⁷ The self-locking nut manufacturing specification required 15 assembly/disassembly cycles to confirm the quality of each batch.

- The average running torque of one of the stamped locking nuts was about 4 in.lbs. The running torque of the other stamped locking nut rapidly fell to zero within one quarter of a turn during each of the multiple assembly/disassembly cycles.
- The average running torque of the self-locking nuts was about 6 in.lbs.

Figure 17: Loosening torque variation



Fastener testing to failure

Torque in excess of the 120 in.lbs specified by the helicopter manufacturer was applied to the self-locking nut in order to ascertain the strength of the bolt and nut. That testing was conducted on the two sets of fasteners that were subject to repeated assembly/disassembly cycles. Failure of one of the fasteners occurred via shearing of the bolt following the application of 276 in.lbs of torque. The second fastener failed at 240 in.lbs due to self-locking nut thread damage that prevented subsequent disassembly of the nut and bolt. In both instances, the tri-slot tool bit could only apply up to about 192 in.lbs of torque before distorting the bolt head sufficiently to drive the bit out of the recess.

Disassembly using unauthorised tools

A final test involved the disassembly of the fastener using masked¹⁸ multi and locking-type grips. That testing identified that only the locking-type grips could secure the bolt head sufficiently in order to allow removal of the self-locking nut. Both types of grips left distinctive contact marks on the bolt head (Figure 18). No comparable marks were identified on the detached bolt from the accident helicopter.

¹⁸ The jaws of both types of grips were wrapped in three thicknesses of masking tape.

Figure 18: Typical contact marks left by masked multi-grip-type hand tools



Additional information

Carriage of passengers

The requirements prohibiting the carriage of passengers on certain flights are detailed in *Civil Aviation Regulations 1988* (CAR) r. 249. CAR 249 (1) (b) stated:

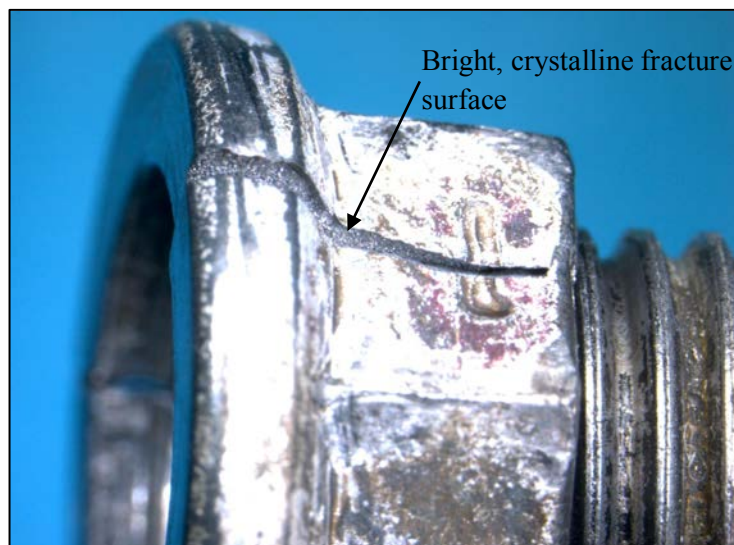
...The pilot in command of an aircraft that carries a passenger must not engage in any of the following types of flying:

...practice of emergency procedures in the aircraft...

Hydrogen embrittlement

During the course of this investigation, three cracked self-locking nuts (Figure 19) from R22 helicopters, of the same specification as that fitted to the detached fastener, were subjected to detailed examination. This examination identified that they had cracked due to hydrogen-induced delayed cracking.

Figure 19: Cracked self-locking nut following paint removal



When high-strength steel, which has been exposed to hydrogen is sufficiently stressed, it can fail prematurely in a sudden, brittle manner. In the case of the examined self-locking nuts, the source of hydrogen was likely to have been from the cadmium plating process that was specified during manufacture for corrosion resistance. Under conditions of sustained stress, such as that associated with an assembled fastener, plus any residual tensile stresses from manufacturing, the presence of hydrogen can result in brittle cracking, typically less than 1 week from the time of application of the sustained stress.

The helicopter manufacturer advised that two of the self-locking nuts that were examined were from a different lot number to that of the locknut that was fitted to the detached servo fastener. The origin of the third cracked self-locking nut could not be established.

Liquid-metal embrittlement

Liquid-metal embrittlement is a sudden, brittle failure that occurs when a normally ductile metal is coated with a thin film of liquid metal while sufficiently stressed. An examination of the fracture surface of one of the self-locking nuts from VH-HFH identified a pattern that was characteristic of liquid metal embrittlement. In a cross-section of another of the nuts, cadmium was detected remote from the originally-plated surface, indicating that it had flowed in the liquid form. The source of the liquid metal was the cadmium plating that normally plated the nuts, but had melted during the post-impact fire.

ANALYSIS

Introduction

This analysis will examine the operational and technical factors and risks in the development of this accident in the context of the crew being qualified for the flight and the weather being benign. In addition, a number of survivability issues will be discussed.

Failure and detachment of the fastener

In assessing the circumstances that led to the detachment of the bolt from the cyclic and collective flight control system, the investigation firstly considered when the separation was likely to have occurred. The absence of physical damage to the detached bolt, lower push-pull tube rod end, and the relevant area of the left-front servo indicated that the bolt did not detach due to the impact forces associated with the collision sequence that preceded the fire.

The presence of cracked self-locking nuts, which were identified to have failed due to liquid metal embrittlement, introduced the possibility that the fastener failed during the post-impact fire. Assuming that the fastener was correctly assembled, a failure mechanism would have been required that enabled both nuts to separate from the bolt. While cracked self-locking nuts were identified in the wreckage, no cracked stamped locking nuts were identified. In any event, given the orientation and relative position of the front servos, it was unlikely that the bolt could have fallen free of the servo, even if both the nuts were absent. Finally, the distance that the bolt was found from the virtually co-located front servos and lower push-pull tube rod end was not consistent with it having detached during the post-impact fire.

The manufacturer's testing identified that the behaviour of the flight controls with the fastener removed was similar to that associated with a disengaged hydraulic system. Based on that result, and the lack of any identified fault with the hydraulic system, it was considered likely that the pilot's description of the inability to re-engage the hydraulic system was due to the bolt having already detached. The advice from the manufacturer that the helicopter would be uncontrollable with the fastener removed, and the pilot's account of the final moments of the flight, further supported that contention.

The absence of physical damage or defect on the detached bolt, combined with the testing conducted by the Australian Transport Safety Bureau (ATSB), identified that the fastener likely failed as a result of its incorrect assembly, or a material defect that affected the serviceability of the retaining nuts, or a combination of both.

There was no evidence that the fastener had been incorrectly assembled or tampered with by any of the organisations that had handled the servo. Given the difficulty in accessing the fastener with the servo assembly installed, sabotage of the helicopter by an external party was considered unlikely.

The identification of a number of hydrogen-embrittled self-locking nuts from other aircraft, of the same specification as that used to secure the detached flight control fastener, raised the possibility that such a defect may have also affected the fastener in VH-HFH. The manufacturer's repair documentation indicated that there had been

sufficient time for hydrogen embrittlement to have affected the self-locking and stamped locking nuts prior to the servo leak repair that was conducted in 2009. Had any cracks been present, however, the leak repair also provided an opportunity for their identification. Although a full visual examination of the self-locking nut was not possible on an assembled servo, the installation of the repaired servo in the helicopter provided a second, if limited, opportunity to identify the presence of any cracked nuts.

As discussed previously in the case of liquid-metal embrittlement-related failure of the self-locking nuts, failure of the fastener via hydrogen embrittlement would have required cracking in a manner that enabled both nuts to separate from the bolt. While cracked self-locking nuts were found during the course of the investigation, no instances of hydrogen embrittled stamped locking nuts were identified. The instance of very low running torque that was identified during testing of the stamped locking nut raised the possibility that a cracked self-locking nut may have loosened over the intervening 93.6 hours of operation of the helicopter. That could have led to the unthreading of the stamped locking nut. However, in the absence of either the self-locking or stamped locking nut, it was not possible to determine the circumstances that led to the failure of the fastener.

Operational considerations

Identification of hydraulic system failure in the R44 relied on a pilot's assessment of the 'feel' of the cyclic and collective controls. Testing conducted by the helicopter manufacturer identified that the behaviour of the cyclic and collective pitch control systems, following removal of the detached bolt, were sufficiently similar to those associated with disengagement of the hydraulic system to explain the conclusion that the hydraulic system had failed. In the absence of any identified fault with the hydraulic system, it was probable that the instructor and pilot mis-diagnosed the behaviour of the flight controls as being associated with a failure of the hydraulic system, rather than the result of the detached bolt. While the absence of an independent caution or warning indication removed an opportunity to separately assess the serviceability of the hydraulic system, the extent to which this influenced the development of the accident could not be determined.

The decision to relocate the helicopter, following the assessment that the hydraulic system had failed, was contrary to the requirement in the R44 pilot's operating handbook (POH) that the hydraulic system was to be operational for flight. Although that decision was probably influenced by a desire to facilitate troubleshooting of the hydraulic system, and possibly also by the instructor's experience operating an R44 with a disengaged hydraulic system, it directly contributed to the accident.

Carriage of a passenger during the flight was contrary to *Civil Aviation Regulations 1988* r. 249, as the flight included the practice of a sequence that was contained in the *Emergency Procedures* section of the POH. Based on the previous carriage of the pilot during the helicopter owner's flight review, it appears that the motivation for the carriage of the passenger may have been to increase his knowledge by observation of the flight sequences. However well intentioned, the decision to carry the passenger resulted in the fatal injuries sustained following the loss of control.

Survivability

As detailed in the post-mortem reports, the instructor and the passenger received fatal injuries due to the post-accident fire. The degree of injury sustained by the instructor during the collision sequence prevented him exiting the helicopter when the helicopter came to rest.

Based on the difficulties described by the pilot when exiting the helicopter, the passenger's exit may also have been impeded by his seat belt restraint. The passenger's position in the rear of the helicopter, and the orientation of the helicopter would have compounded any difficulty experienced.

The use of fire-retardant clothing and equipment, as detailed in Safety Notice SN-40, has the potential to enhance post-accident survivability. However, in this instance the intensity of the fire and the impeded egress meant that the use of such equipment would probably not have reduced the severity of the outcome.

The degree of fire damage prevented identification of the ignition source. Therefore, the investigation was unable to determine if the fitment of bladder-type fuel tanks and other modifications associated with manufacturer's service bulletin 78 (SB-78) would have prevented or impeded the progress of the fire on this occasion.

Despite that, advice provided by the manufacturer indicated that incorporation of the SB-78/SB-78A modification has been effective in reducing instances of post-accident fuel-fed fires. Based on that information, and in the interest of enhanced survivability, consideration should be given by R44 operators to incorporate SB-78A and SB-82 in their helicopters as soon as possible.

FINDINGS

From the evidence available, the following findings are made with respect to the loss of control that occurred at Cessnock Aerodrome, New South Wales on 4 February 2011 and involved Robinson Helicopter Company R44 Astro, registered VH-HFH. They should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing safety factors

- The bolt securing the lower flight control push-pull tube to the left-front hydraulic servo detached while the helicopter was on the ground in the western grass area, rendering the helicopter uncontrollable as it became airborne for repositioning.
- The instructor and pilot probably mis-diagnosed the behaviour of the cyclic and collective flight controls as being associated with failure of the hydraulic system.
- The decision to relocate the helicopter, following the assessment of a hydraulic system failure, was contrary to the requirement in the R44 pilot's operating handbook and resulted in the loss of control and subsequent collision with terrain.
- The carriage of a passenger during a flight that incorporated the practice of emergency procedures was contrary to *Civil Aviation Regulations 1988* r. 249 and resulted in the fatal injuries sustained by the passenger following the loss of control.
- The post-impact fire resulted in the fatal injuries sustained by the instructor and passenger.

Other safety factors

- A significant number of R44 helicopters, including VH-HFH, were not fitted with bladder-type fuel tanks and the other modifications detailed in the manufacturer's service bulletin 78 that were designed to provide improved resistance to post-impact fuel leaks. [*Significant safety issue*]
- A number of self-locking nuts from other aircraft, of the same specification as that used to secure safety-critical fasteners in VH-HFH, were identified to have cracked due to hydrogen embrittlement. [*Significant safety issue*]

Other key findings

- Examination of the recovered hydraulic system components found nothing, with the exception of the detached fastener, that would have prevented the normal operation of the hydraulic system prior to the accident.
- Testing conducted by the helicopter manufacturer identified that the behaviour of the cyclic and collective, following removal of the detached bolt, were sufficiently similar to those associated with the disengagement of the hydraulic

system to have allowed the pilot and instructor to conclude that the hydraulic system had failed.

- The helicopter was fitted with flexible fuel lines and a modified gascolator assembly, in accordance with the manufacturer's service bulletins 68 and 69, to reduce the likelihood of post-accident fuel leaks.
- The absence of physical damage or defect that affected the detached bolt, combined with the testing conducted by the Australian Transport Safety Bureau, indicated that failure of the fastener was only likely to occur following incorrect assembly, a material defect that affected the retaining nuts, or a combination of both.
- The inability to locate either the self-locking or stamped locking nuts prevented the determination of the specific circumstances that led to the failure of the fastener.
- The very low level of alcohol detected in the instructor's blood was most likely due to post-mortem generation of alcohol, rather than the result of alcohol consumption.

SAFETY ACTION

The safety issues identified during this investigation is listed in the Findings and Safety Actions sections of this report. The Australian Transport Safety Bureau (ATSB) expects that all safety issues identified by the investigation should be addressed by the relevant organisation(s). In addressing those issues, the ATSB prefers to encourage relevant organisation(s) to proactively initiate safety action, rather than to issue formal safety recommendations or safety advisory notices.

All of the responsible organisations for the safety issues identified during this investigation were given a draft report and invited to provide submissions. As part of that process, each organisation was asked to communicate what safety actions, if any, they had carried out or were planning to carry out in relation to each safety issue relevant to their organisation.

Self-locking nut failure

Significant safety issue

A number of self-locking nuts from other aircraft, of the same specification as that used to secure safety-critical fasteners in VH-HFH, were identified to have cracked due to hydrogen embrittlement.

Background

During the course of the investigation the ATSB was provided with three self-locking nuts from other aircraft that had cracked in service. Detailed examination of those nuts identified that they had failed due to hydrogen embrittlement. In response to that finding, the ATSB notified the helicopter manufacturer, the Civil Aviation Safety Authority (CASA) and the United States National Transportation Safety Board and Federal Aviation Administration.

Action taken by the Robinson Helicopter Company

In response to the identification of hydrogen-embrittled self-locking nuts during this investigation, the helicopter manufacturer issued service letters: SL-58, SL-38 and SL-01 that were applicable to the R22, R44 and R66 helicopter types respectively. These service letters detailed the hydrogen-embrittlement risk, including the expected failure characteristics. The service letters reminded pilots and maintenance personnel of the importance of serviceable hardware and advised that any cracked or corroded nuts should be replaced. The manufacturer also requested that they be advised of any identified instances of cracked locknuts.

ATSB assessment of action

The ATSB is satisfied that the action taken by the helicopter manufacturer adequately addresses the safety issue.

Action taken by CASA

In response to the identification of hydrogen-embrittled self-locking nuts, CASA issued airworthiness bulletin (AWB) 14-002 on 12 October 2011 alerting aircraft owners, operators and maintenance personnel to the possibility of in-situ failures of MS 21042 and NAS 1291-series self-locking nuts. The AWB provided background information on previous occurrences and the mechanism and hazards associated with hydrogen embrittlement, and recommended that:

- (a) Pilots and maintenance personnel closely monitor the occurrence of hydrogen-induced delayed cracking in high-strength steel standard aircraft hardware, such as nuts via close inspection following installation and thereafter at Daily / Preflight and periodic inspections.
- (b) Before simply replacing cracked/failed nuts with new items, consider contacting the manufacturer for advice regarding replacement of associated fasteners which may have suffered over-loading as a result of the failure of one or more nuts.
- (c) Report all MS 21042 and NAS 1291 series nut failures to CASA via the SDR [Service Difficulty Reporting] system.

ATSB assessment of action

The ATSB is satisfied that the action taken by CASA adequately addresses the safety issue.

Bladder-type fuel tank retrofit

Robinson Helicopter Company

Significant safety issue

A significant number of R44 helicopters, including VH-HFH, were not fitted with bladder-type fuel tanks and the other modifications detailed in the manufacturer's service bulletin 78 that were designed to provide improved resistance to post-impact fuel leaks.

Action taken by the Robinson Helicopter Company

In response to the collision with terrain that occurred at Jaspers Brush, New South Wales on 4 February 2012, the helicopter manufacturer released Service Bulletin 78A (SB-78A) on 21 February 2012. This bulletin brought forward the date of compliance as stated in the earlier Service Bulletin 78 from 31 December 2014 to 31 December 2013.

In addition, the manufacturer has advised that, in conjunction with the United States Federal Aviation Administration (FAA), the manufacturer is examining other methods to ensure greater compliance with that upgrade. This examination will take into account the rate at which the bladder-type fuel tanks, and the other associated components, are able to be manufactured. In respect of the rate of production of the bladder-type tanks, the manufacturer advised that they were:

...also in the process of acquiring FAA certification for an additional manufacturer of the bladder type tanks to increase the availability of the upgraded tanks.

The issue of an Airworthiness Directive is being considered.

Also on 21 February 2012, the manufacturer released Service Bulletin 82 that required the replacement of the rotor brake switch to reduce the chance of a possible ignition source in the event of a fuel leak.

ATSB assessment of action

The ATSB is satisfied that the action taken by helicopter manufacturer will, when completed, adequately address the safety issue.

Other safety action

Flight control fasteners

Although no safety issue was identified, the following safety action was taken by CASA and by the ATSB in response to the detachment of the bolt from the lower flight control push-pull tube to the left-front hydraulic servo.

Safety action taken by CASA

CASA issued airworthiness bulletin (AWB) 67-004 on 24 March 2011 alerting R44 aircraft owners, operators and maintenance personnel to the potential for loss of control resulting from insecure fasteners in the flight control system linkages.

The AWB also requested that any identified defects or anomalies be advised to CASA and the ATSB.

Safety action taken by the ATSB

On 18 March 2011, the ATSB issued the following Safety Advisory Notice to all operators and maintainers of hydraulic system-equipped R44 helicopters:

The Australian Transport Safety Bureau encourages all operators of hydraulic system-equipped R44 helicopters, and organisations performing inspection, testing, maintenance and repair activities on the flight control systems of those helicopters, to note the circumstances detailed in this preliminary report. It is suggested that those operators and maintenance organisations consider inspecting the security of the hydraulic-boost servos on all hydraulic system-equipped R44 helicopters.

APPENDIX A: SOURCES AND SUBMISSIONS

Sources of Information

The sources of information during the investigation included:

- the pilot of the helicopter
- the owner of the helicopter
- witnesses to the accident
- the personnel that conducted maintenance on the helicopter
- the chief pilot of the instructor's former company
- the helicopter manufacturer and one of its Australian distributors
- the United States National Transportation Safety Board (NTSB)
- the New South Wales Police Force and Coroner
- the Bureau of Meteorology
- the Civil Aviation Safety Authority (CASA)
- Avdata Australia

References

American Society for Metals (ASM) (1992). *ASM Handbook Volume 11: Failure Analysis and Prevention*.

Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the *Transport Safety Investigation Act 2003* (the Act), the Australian Transport Safety Bureau (ATSB) may provide a draft report, on a confidential basis, to any person whom the ATSB considers appropriate. Section 26 (1) (a) of the Act allows a person receiving a draft report to make submissions to the ATSB about the draft report.

A draft of this report was provided to the pilot, owner and maintainer of the helicopter, the helicopter manufacturer and one of their Australian distributors, the chief pilot of the instructor's former company, CASA and the NTSB. Submissions were received from the manufacturer and maintainer of the helicopter. The submissions were reviewed and, where considered appropriate, the text of the report was amended accordingly.

ATSB Transport Safety Report

Loss of control - Robinson Helicopter Company R44 Astro
VH-HFH, Cessnock Aerodrome New South Wales,
4 February 2011

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Final

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