Australian Government
Australian Transport Safety Bureau

Engine failure and collision with terrain involving Robinson R44, VH-KJJ

154 km south-west of Timber Creek, Northern Territory | 14 June 2015

Investigation

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Addendum

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Safety summary

What happened

On 14 June 2015, the pilot of a Robinson Helicopter Company R44 helicopter, registered VH-KJJ, was conducting cattle mustering operations at Waterloo Station, about 154 km south-west of Timber Creek, Northern Territory. After refuelling from drum fuel supply, the helicopter took off and, a short time later, experienced a loss of engine power at low altitude. The loss of engine power was a result of fuel starvation due to contaminants introduced into the helicopter's fuel system during the drum refuelling. The loss of engine power required the pilot to conduct an autorotation and forced landing.

For reasons that could not be determined, the pilot was unable to satisfactorily reduce the rate of descent before the helicopter impacted the ground heavily. The pilot survived the impact but later succumbed to their injuries. The helicopter was destroyed.

What the ATSB found

The ATSB identified that the operator did not have adequate procedures to ensure fuel quality during drum refuelling.

The pilot was overdue for a helicopter flight review for low-level helicopter mustering operations. This potentially reduced the pilot's familiarity and proficiency with managing engine failures and autorotations from low altitude. Had the pilot been able to satisfactorily reduce the rate of descent before touchdown, the impact forces would have been reduced.

The helicopter was likely 'hot refuelled', meaning that as a pilot only operation, the pilot had to exit the helicopter to refuel while it was operating. This increased the risk of loss of control of the helicopter as the flight controls were unmonitored.

What's been done as a result

The operator has informed the ATSB that they now test fuel supplies with water detection paste, and have restricted any aviation fuelling activities to be performed by authorised personnel.

In addition, an operator trial of a filter monitor-type filter highlighted that, although filter monitors increased the probability of detecting water contamination while refuelling, operators should assess the suitability and practicality of the available filter monitors for their operations.

Safety message

A number of defences are available to eliminate or significantly reduce the chance of using contaminated fuel from drum fuel supplies. These include:

- application of appropriate aviation drum handling and storage methods
- testing drum fuel supplies for contaminants prior to undertaking refuelling activities
- use of filter monitors on drum hand pump supply lines
- conducting fuel drains from aircraft after each refuel to ensure fuel quality.

In addition, the ATSB cautions pilots and operators to conduct hot refuelling in accordance with the aircraft flight manual and Civil Aviation Safety Authority regulations. Further, leaving the flight controls of an operating Robinson Helicopter Company R44 helicopter to conduct refuelling increases the risk of a loss of control.

Finally, this accident provides a timely reminder that the conduct of recurrent flight training allows pilots to practice and better respond to time critical emergencies such as those that occur from a low altitude.

Contents

The occurrence

On 14 June 2015, the pilot of a Robinson Helicopter Company R44 Raven 1 helicopter, registered VH-KJJ (KJJ), was conducting cattle mustering operations at Waterloo Station, about 154 km south-west of Timber Creek, Northern Territory (Figure 1). At about 0700 Central Standard Time[1], the pilot reportedly refuelled KJJ from the station's main aviation gasoline (Avgas) fuel storage tank and conducted a daily inspection of the helicopter before commencing the days mustering activities.

Figure 1: Accident site location

Source: Google earth, modified by the ATSB

The mustering activities required two additional helicopters (Robinson R22 helicopters) to assist with drafting[2] cattle toward holding yards that were located about 19 km east-south-east of the Waterloo Station homestead. The pilots of the helicopters worked together to herd the cattle south along a dry creek bed that led toward the holding yards.

After operating the helicopter for about 3.5 hours, the pilot of KJJ radioed the R22 pilots to inform them of the need to refuel KJJ from a drum fuel supply that was close to the area of operation. This supply consisted of three 200 L Avgas fuel drums:

- an older, rusty drum that had been refilled from the station's main fuel supply prior to the mustering operations
- a newer, undamaged drum that was also refilled from the station's main fuel supply prior to the mustering operations
- a third drum, on which the manufacturer's bung seals were in place. These seals indicated that the drum had not been opened previously.

One of the R22 pilots responded by radio that as the drum fuel hand pump was on board their helicopter, they would refuel before KJJ. The R22 pilot reported using about 60 L of fuel from the oldest of the three fuel drums. About 10 minutes later the pilot of KJJ landed to refuel using most

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1 Central Standard Time (CST) was Coordinated Universal Time (UTC) + 9.5 hours.
2 'Draft out' or 'off'. To separate livestock from the herd or flock for a specific purpose (for example, branding).

of the remaining fuel from that drum and a smaller quantity from the newer, undamaged drum. The third drum remained unopened after the refuels, with the manufacturer's bung seals still in place.

A stockman, who was erecting the holding yards about 2 km south-east of the drum fuel supply, reported an awareness of the pilot of KJJ landing in the area of the drum fuel supply. The stockman confirmed being sure that the pilot landed to refuel the helicopter, although there was no-one near the landing area that observed the pilot refuelling KJJ.

The stockman indicated that, after spending about 5 minutes refuelling, the pilot of KJJ took off to the south to confirm the progress of the fencing activities at the holding yards. The pilot flew past the yards and reportedly continued south to check gates ahead of the cattle herd. The stockman at the holding yard recalled that the helicopter flew past at about 150 ft above ground level. This was broadly consistent with the aircraft's height of about 190 ft as derived from altitude data downloaded from the helicopter's global positioning system (GPS) equipment. The stockman also reported the engine noise of the helicopter as 'normal' and that the helicopter appeared to have been in normal flight at that time.

The stockman reported going back to work after the helicopter passed, only to be alerted seconds later by the 'spluttering' of the helicopter's engine. Looking toward KJJ's direction of travel, the stockman observed the helicopter in a nose-down attitude, just above the tree line. At about that time, they heard the pilot broadcast over the ultra high frequency radio that KJJ's engine had failed. The stockman recalled that the engine noise had stopped, which was followed shortly after by the sound of the helicopter impacting terrain.

The stockmen immediately drove to the accident site, which was located about 1 km south-east of the holding yard. The R22 pilots, who also heard the radio transmission, flew to that location. The stockman reported that on arrival at the site, the injured pilot was removed from the wreckage and comforted for about 2 hours until medical attention arrived.

The pilot later succumbed to their injuries. The helicopter was destroyed during the impact sequence.

Context

Personnel information

Pilot

The pilot held a Commercial Pilot (Helicopter) Licence and was endorsed on the Robinson Helicopter Company (Robinson) R44 (R44) helicopter. The pilot also held a valid Class 2 Aviation Medical Certificate.

The pilot's total aeronautical experience at the time of the accident could not be determined as the pilot's logbooks were incomplete. The last recorded entry was on 19 August 2013 and indicated a total of 6,592.5 flying hours, of which 214 hours were on R44 helicopters. The pilot also held a helicopter aerial stock mustering permission, sling approval and a low-level flying endorsement.

A review of the pilot's training file identified that the pilot had satisfactorily completed a helicopter flight review on 25 March 2013. The review was conducted under Civil Aviation Regulation (CAR) 1988, Part 5 and included a Robinson R44 type endorsement. This authorised the pilot to conduct helicopter operations until the end of the flight review period on 31 March 2015.

The aerial mustering component of the pilot's licence was valid if the pilot had completed at least 20 hours of aerial mustering in the previous 12 months. There was evidence that the pilot had likely completed at least 20 hours of aerial mustering in the previous 12 months. However, there was no evidence that the pilot conducted another flight review prior to the end of the flight review period.

Civil Aviation Safety Regulation 1998 (CASR) Part 61 was implemented on 1 September 2014, during the pilot's flight review period. This meant that the competencies in the CASR Part 61 Manual of Standards (MOS) were required to be met if, after that time, the pilot completed a flight review for the ratings they held (see *Training requirements*).

Stockmen

A number of stockmen or station hands were employed on the cattle station to perform various tasks. This included general station work, drafting and cattle yarding. Occasionally, the stockmen worked to support aerial mustering operations by refuelling empty aviation gasoline (Avgas) fuel drums and relocating them close to the area of operations.

Prior to the accident, the pilot of VH-KJJ (KJJ) tasked one of the stockmen to reposition three full Avgas fuel drums from the station's aircraft hangar for use in the muster. The stockman reported that two of the three drums selected from the hanger required refuelling from the station's main Avgas fuel supply before repositioning.

The stockman that repositioned the drums reported that, although familiar with the operation of the main fuel supply bowser to refuel the drums, they were not aware of any particular refuelling process, or trained to inspect the empty stored drums for contaminants and damage. As such, the stockman loaded the three drums onto a transport truck and refuelled the two empty drums without inspection or fuel quality testing.

Aircraft information

General information

The Robinson R44 Raven 1 is a four-seat, single main and tail rotor helicopter powered by a six-cylinder piston-engine and is equipped with skid-type landing gear. KJJ, serial number 1558, was manufactured in the United States in March 2006. First registered in Australia on 18 January 2012, KJJ had accumulated 1,009.9 flight hours total time in service at the time of the accident.

Maintenance history

The last recorded maintenance was a 100-hourly inspection at 916.4 hours total time in service on 24 February 2015 that resulted in the issue of a new maintenance release. Since that inspection, the helicopter had accumulated 93.5 hours. In that period:

- one daily inspection was annotated on the maintenance release
- there were no certifications for the required engine oil and filter changes in the helicopter's logbook or maintenance release.

Meteorological information

Nearby stockmen and other pilots operating in the area reported that the temperature at the time of the accident was about 30 °C. They recalled that generally the weather conditions were fine with a light breeze. The pilots reported good flying conditions with little or no in-flight turbulence.

Recorded meteorological information at Kununnurra Airport, about 110 km to the north-west, indicated the temperature at 0900 was 28.7 °C with a relative humidity of 38 per cent. The wind was from the south-south-east at about 13 km/h and there was no recorded rain for the period.

Wreckage information

Accident site and wreckage information

The wreckage of the helicopter was located just beyond the bank of a dry creek bed in a relatively flat, sandy area that was surrounded by trees (Figure 2).

Damage to the engine, airframe and skids indicated that the helicopter impacted the ground in an upright, relatively flat attitude, with some forward movement and a high rate of descent. Calculations based on impact damage to trees located along the flight path indicated a final descent angle of about 40°.

The main rotor blades sustained penetrating damage to the blade skins, with little evidence of impact damage to their leading edges. Upward bending of the main rotor blades was also evident.

All of the critical helicopter components were accounted for at the site.

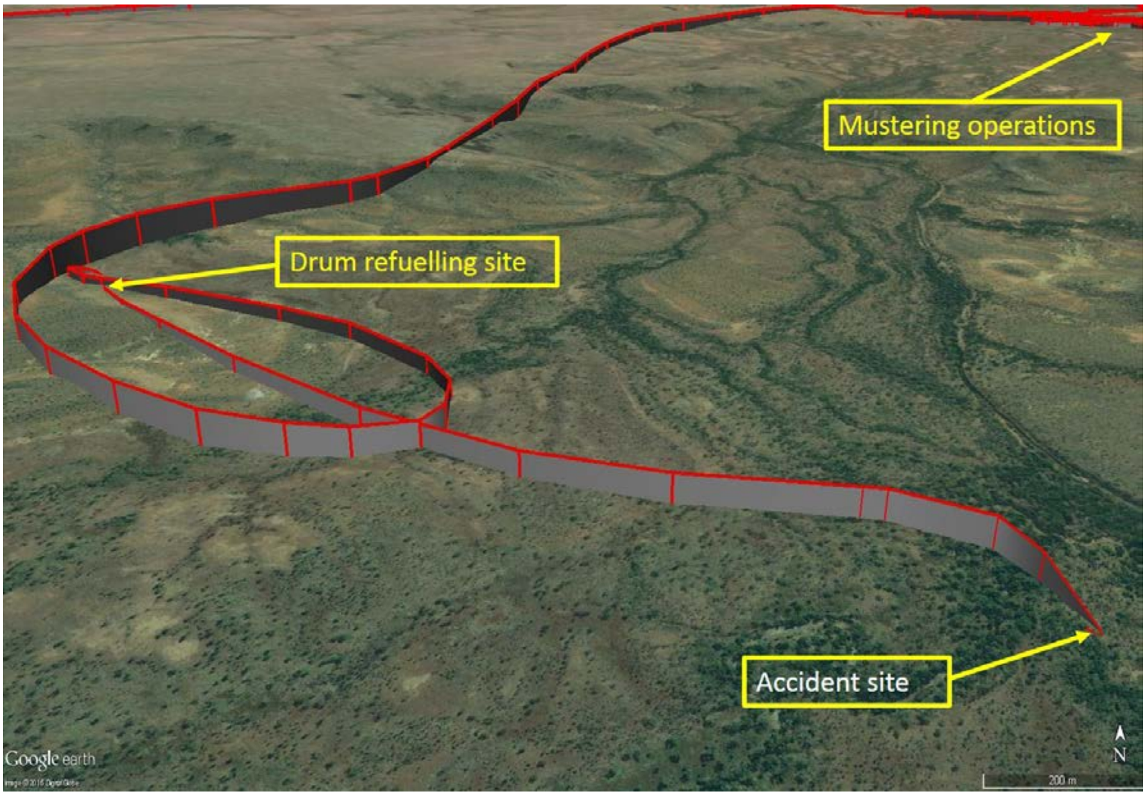
Figure 2: Accident site showing the surrounding terrain and wreckage distribution (looking south-east)

Source: ATSB

Functionality of the critical components was established. The two forward rotor drive vee-belts were intact and located in their respective upper and lower sheaves. The two rear rotor drive vee-belts were located in the upper rear sheaves but were displaced from the lower sheaves, probably due to impact forces.

The helicopter's GPS was recovered for further technical examination and download at the ATSB's technical facilities in Canberra, Australian Capital Territory. The downloaded data provided information about the operation of the helicopter on the morning of the accident including the final flight path (Figure 3).

Figure 3: KJJ's recorded GPS flight path, showing the helicopter's track from the drum refuelling site to the accident site



Source: Google earth, modified by the ATSB

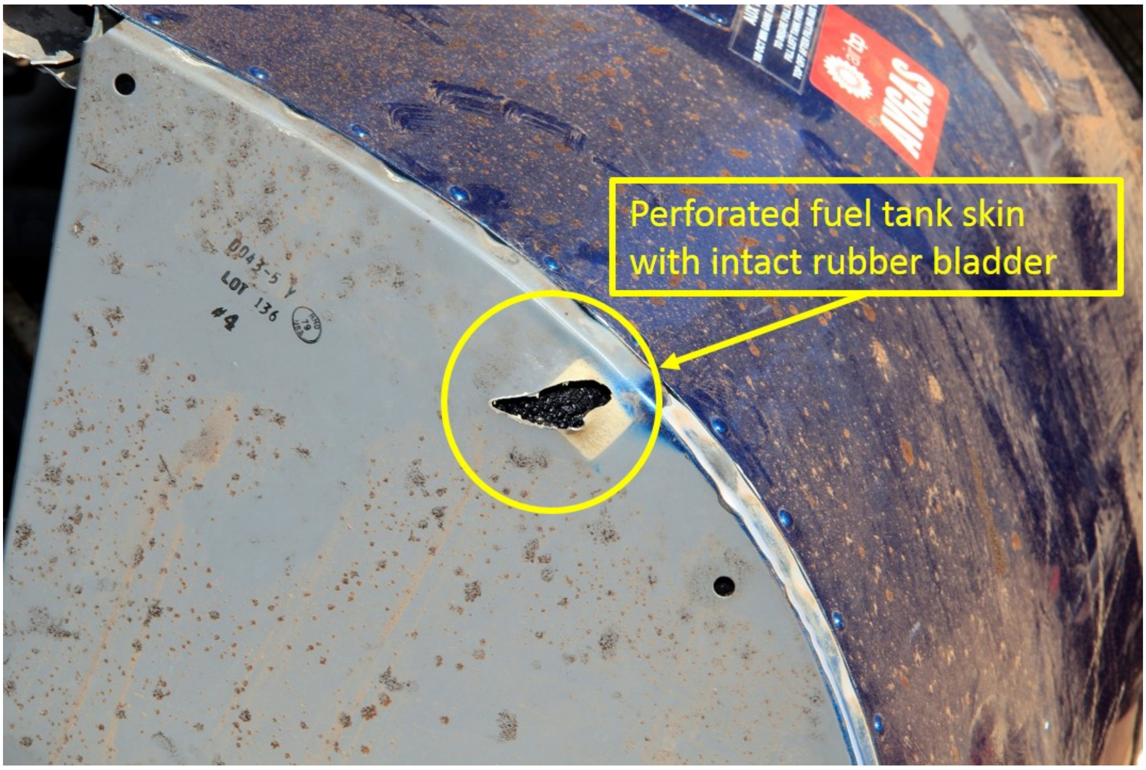
Engine examination

Other than impact damage, no mechanical defects or anomalies were noted that would have precluded normal engine operation. Evidence at the accident site indicated that the engine was not operating at the time of impact.

Aircraft fuel system

The R44 has two interconnected fuel tanks. The main fuel tank holds 112 L total useable fuel and the auxiliary fuel tank 64 L useable fuel. Both fuel tanks were fitted with fuel tank bladders, which remained intact despite the outer aluminium skin being perforated during the accident sequence (auxiliary tank shown at Figure 4). Both fuel tanks were almost full, consistent with the recent drum refuelling.

Figure 4: Perforated auxiliary fuel tank outer aluminium skin. Note the intact rubber bladder tank (circled in yellow)



Source: ATSB

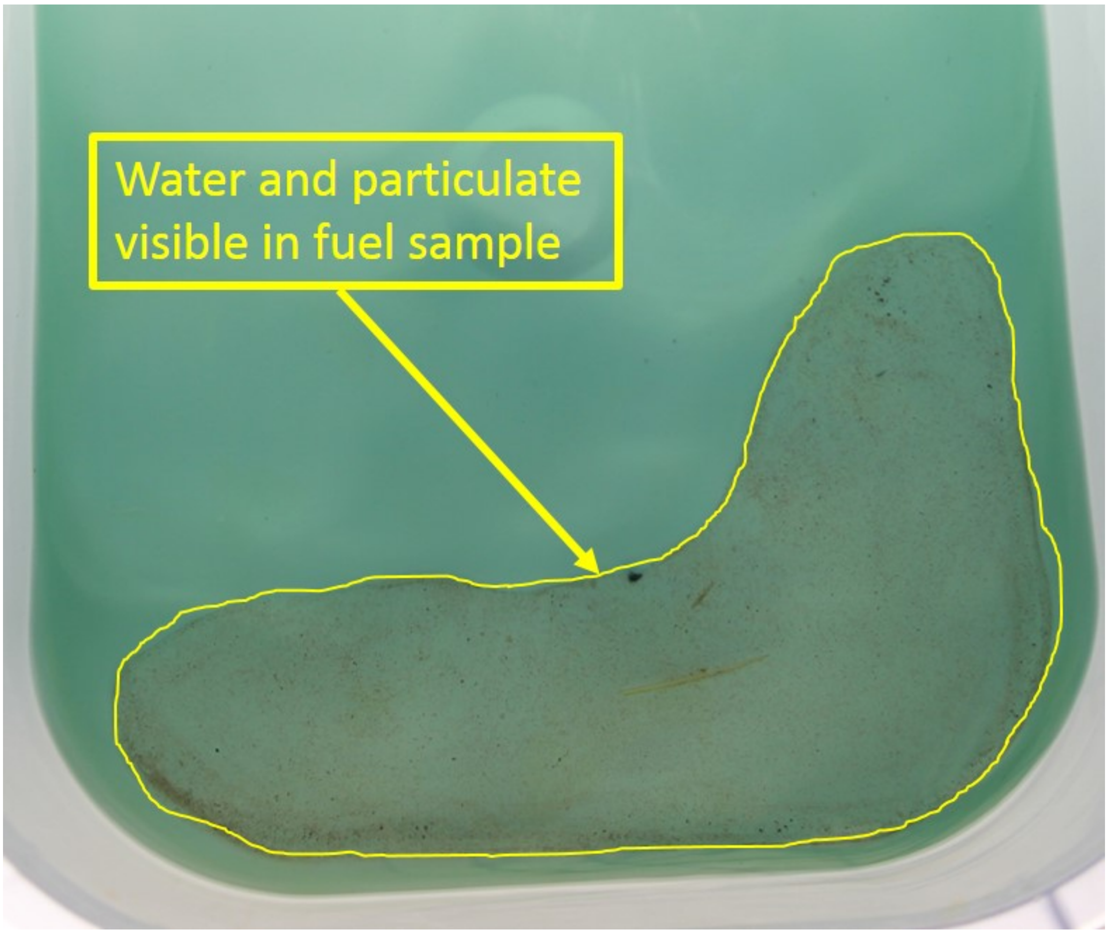
On-site samples from the helicopter's gascolator (fuel strainer), carburettor and fuel tanks identified the presence of water and particulates (Figure 5 and Figure 6). Approximately 800 mL of water was drained from the auxiliary fuel tank and water was also siphoned from the main tank. Residual water remained in the tanks and could not be drained due to the crush damage to the fuselage. A fuel tank dip test with water detecting paste confirmed that a depth of about 3.5 cm of water remained in the lower areas of each tank.

Fuel samples that were able to be recovered from the helicopter's fuel tanks were heavily contaminated with water and rust-like particles (Figure 6). This contamination was similar to that identified in the fuel sample taken from the older, rusted fuel drum that was first used by the pilot during the drum refuelling.

Figure 5: Gascolator (left) and carburettor (right) showing fuel contamination as indicated by the change in colour of the water detecting paste to red

Source: ATSB

Figure 6: Water and particulate matter identified in a fuel sample obtained from KJJ's fuel tanks



Source: ATSB

Drum fuel supply

The three 200 L drums of Avgas that were relocated from the station's aircraft hangar were found upright in an open paddock close to the mustering operations (Figure 7). The two open drums and their contents were examined by the ATSB to eliminate them as potential sources of fuel contamination. The drum fuel hand pump was found positioned in the newer of the two open drums.

The older, rusty and dented drum contained a mixture of about 6 L total of fuel, rust and water. The inside lining of that drum was heavily rusted and was considered not suitable for aviation use.

Water and particulate contamination was also identified in a sample of fuel taken from the fuel pump filter (Figure 8).

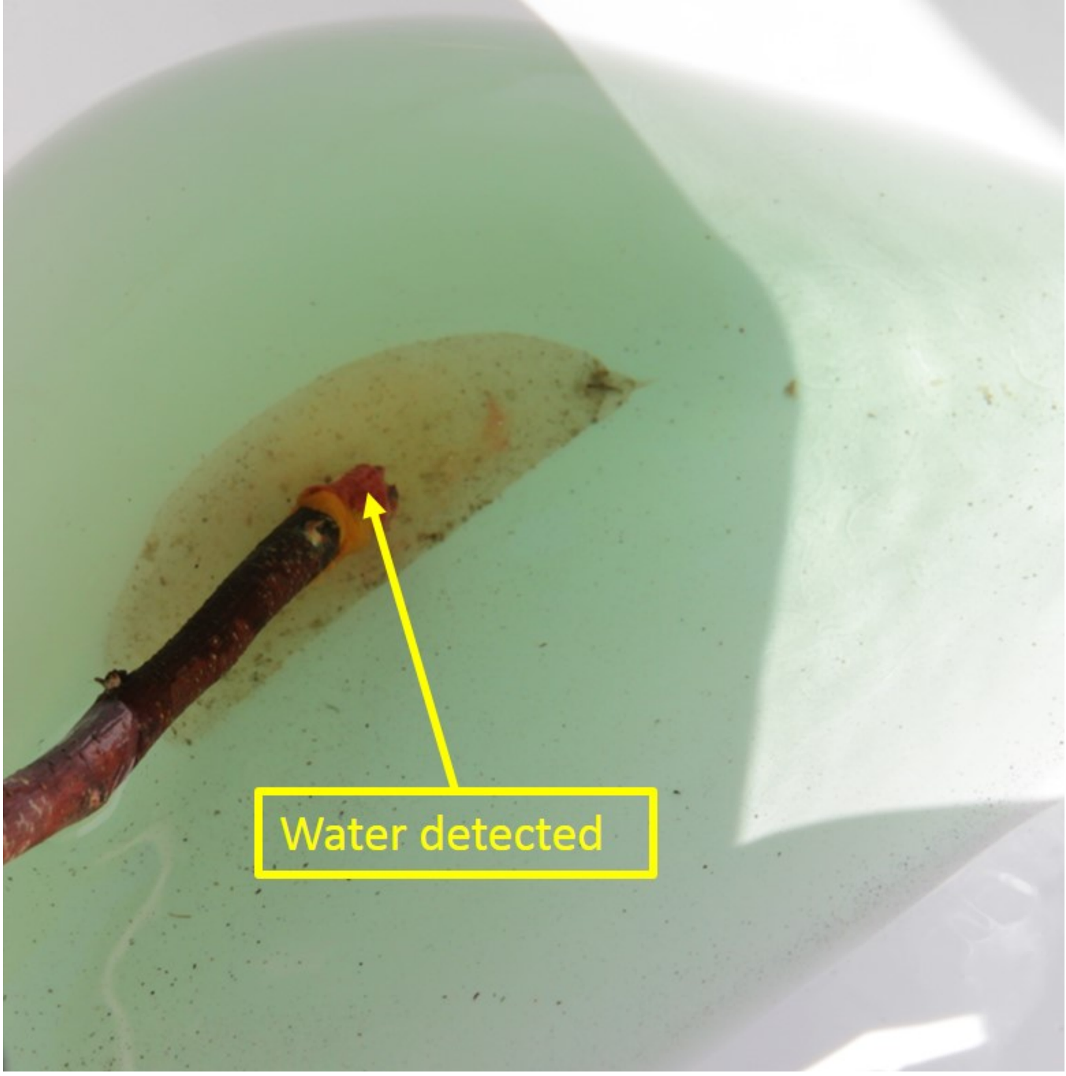
The second, newer-type drum used by the pilot of KJJ during the refuel was about 3/4 full of Avgas and contained negligible traces of water. Any water contamination was probably introduced from the hand pump after its use in the older, heavily-contaminated drum.

Negligible traces of water were identified in the station's main Avgas fuel supply that was used by the stockman to refill the two drums.

Figure 7: Drum fuel supply with a close-up (right) of the older, rusty and dented Avgas fuel drum. The left picture shows the drum fuel hand pump positioned in the newer of the two open drums

Source: ATSB

Figure 8: Fuel sample from the drum fuel hand pump filter showing the change in colour of the water-detecting paste to red indicating water contamination



Source: ATSB

Operational information

Petroleum industry fuel management and handling guidance

A petroleum company in Australia reported that although they supplied aviation drum fuel to their regional distribution depots, the quality of the drum fuel could not be assured once it left the depot. This was reported to be a consequence of varying procedures surrounding the management of drum fuel once out of the control of the supplier.

General information about aviation drum fuelling was published by some petroleum companies in an effort to maintain fuel quality. The information was available online and was last updated in 2013. It provided information about drum storage, pump filter standards, drum refuelling and precautions. The publications reinforced that users of aviation drum fuel should ensure that:

- the grade of drum and its labels are appropriate for the fuel it contains
- the drum and drum linings are intact and of suitable quality prior to refilling
- the drum contents are checked for water using a dipstick and water-detecting paste
- an appropriate aviation grade filter (filter monitor preferred) and pump is used during the delivery of fuel to an aircraft
- proper drum storage techniques are used.

Fuel filter monitors

Representatives from the petroleum industry advised that many companies involved with the supply of aviation fuel in Australia adopted the Joint Industry Group (JIG) and the Energy Institute (EI) standards. Those standards outlined the requirements for fuelling from drums, drum storage and the equipment required to ensure fuel quality during the refuelling process. This included filter standards. The relevant drum-refuelling standards at the time of the accident included JIG 4 and EI 1530 and EI 1583.

At the time of the accident, the Civil Aviation Safety Authority (CASA) was not aware of any fuel delivery filtration standard, however specific aircraft refuelling requirements were published that would provide a defence against fuel contamination (see the following section titled *Aircraft refuelling requirements*).

A number of filters were available for use with various fuel types. It was preferable to use filters meeting the EI standard for aviation fuel filters (EI 1583) during aircraft refuelling operations. Commonly used filter types included:

- particulate only (particulate)
- filter water separator
- particulate/water absorbing (filter monitor).

Figure 9 shows a particulate filter that has a relatively low particulate removal capability of about 10 µm. This filter type was used on the day of the accident and did not meet the requirements of EI 1583 or provide a suitable level of particulate screening during the helicopter refuelling. In addition, the filter did not have the capability to remove or separate water, although the ability to detect and remove water was not a requirement to meet the EI standard.

A filter monitor-type filter is also shown in Figure 9. This filter has a much higher capability to remove particulates than the particulate filter shown. It can also absorb any water present in aviation fuels, except that it is not recommended for use with fuel containing anti-icing additives. As water and/or particulates are absorbed within the filter, differential pressure increases and reduces the flow. The reduction in the flow depends on the level of contamination in the fuel.

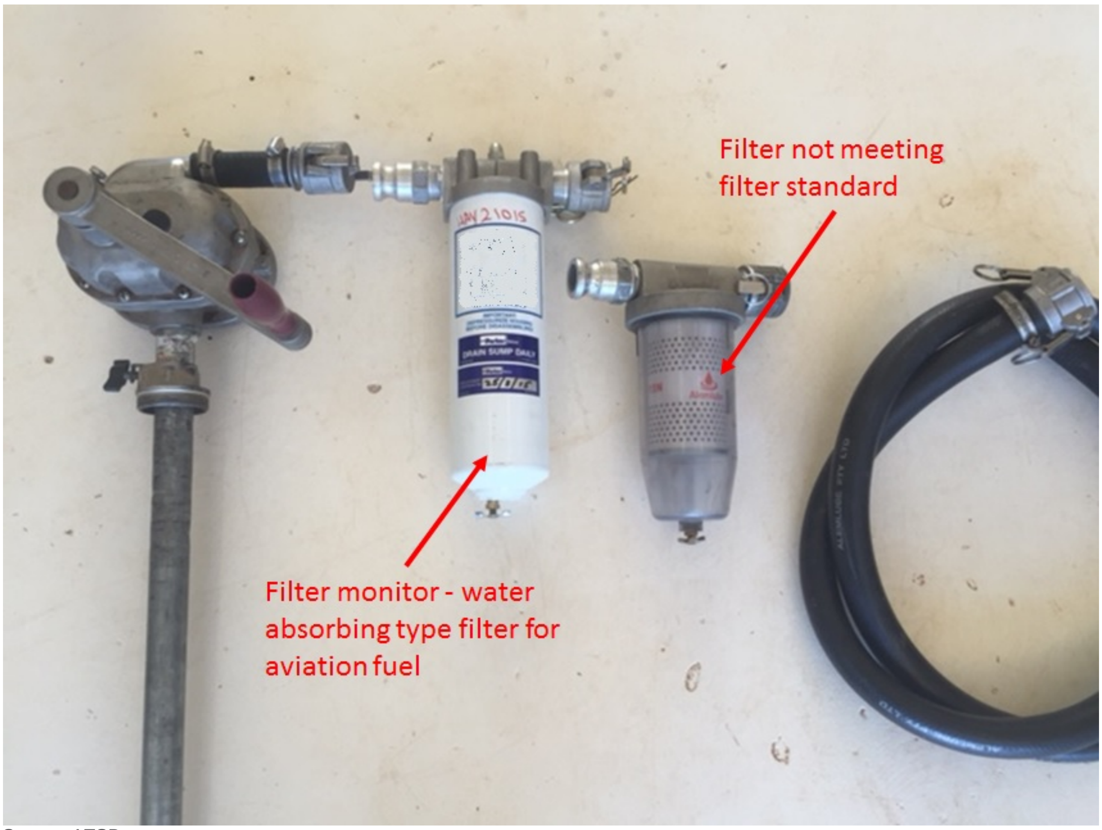
An operator reported trialling the effectiveness of aviation fuel filter monitors for use with drum hand pumps. The operator's trial identified that one type of filter monitor:

- had a non-transparent filter housing that reduced the ability to observe any contamination
- had non-standard thread fittings, making it difficult to adapt existing hand pump equipment
- was not a screw-on-type filter, which made changing contaminated filters difficult
- required re-priming after the drum hand pump unit was disassembled to facilitate transportation between drum fuel supply locations.

The operator indicated that, although the practicality of this particular type of filter monitor was not ideal, the effectiveness of the filter monitor-type filter to inhibit continued pumping of water-contaminated fuel was beneficial.

The results of the operator's test would suggest that it would be appropriate for individual operators to assess the suitability and practicality of the available filter monitors to their operations.

Figure 9: Examples of two types of filters used during drum refuelling. Note the off-white filter monitor (at left) meets the industry standard



Source: ATSB

Aircraft refuelling requirements

CASA Civil Aviation Order (CAO) 20.9, outlined the requirements for refuelling aircraft. Specifically, when refuelling using ground fuel stock (such as drum fuel), a pilot needed to ensure:

> …that the aircraft is not flown unless the aviation fuel… complies with the specification and grade required or approved for the purpose by CASA.

and that:

> All ground fuel stock shall be carefully checked for the presence of undissolved water before the fuelling operation is commenced.
>
> *Note 1* This precaution is particularly important when handling fuel from drum stocks.
>
> *Note 2* Attention is drawn to the necessity of using a positive method, such as suitable water detecting paste or paper, in testing for the presence of free water since sensory perceptions of colour and smell, if used alone, can be quite misleading…

and finally that:

> All fuel shall be strained or filtered for the removal of free or suspended water and other contaminating matter before entering the aircraft tanks.

CAO 20.9 also stated that when fuelling an aircraft, all fuelling equipment and the aircraft needed to be bonded[3] to allow for dissipation of static electricity that may have been present and reduce the chance of a fire. The fuelling equipment used to refuel KJJ did not have a bonding wire for that purpose. Further, there were no fire extinguishers at the refuelling area in case of fire.

[3] 'Bonding' the aircraft and fuelling equipment ensures that both have the same electrical potential.

Operator's refuelling processes

The operator maintained an 11,000 L Avgas bulk storage container at the station that was refilled on an as required basis. When needed, 200 L drums of Avgas were filled from the bulk storage and transported to the area of the mustering operation.

On the day of the accident, the pilots used another operator's drum fuel hand pump. Although the filter attached to that pump was reported changed on a regular basis, it was not the correct type for use with aviation fuel in accordance with EI standard 1583 (see the previous section titled *Fuel filter monitors*). In addition, the drum fuel hand pump bung fitting was not threaded into the drum (Figure 10). When secured, that fitting provided a barrier to prevent dust from entering the opened drum and located the hand pump shaft while in use. Some pilots reported that they preferred not to secure the bung fitting to allow for movement of the hand pump inlet pick-up to the higher side of the drum.[4]

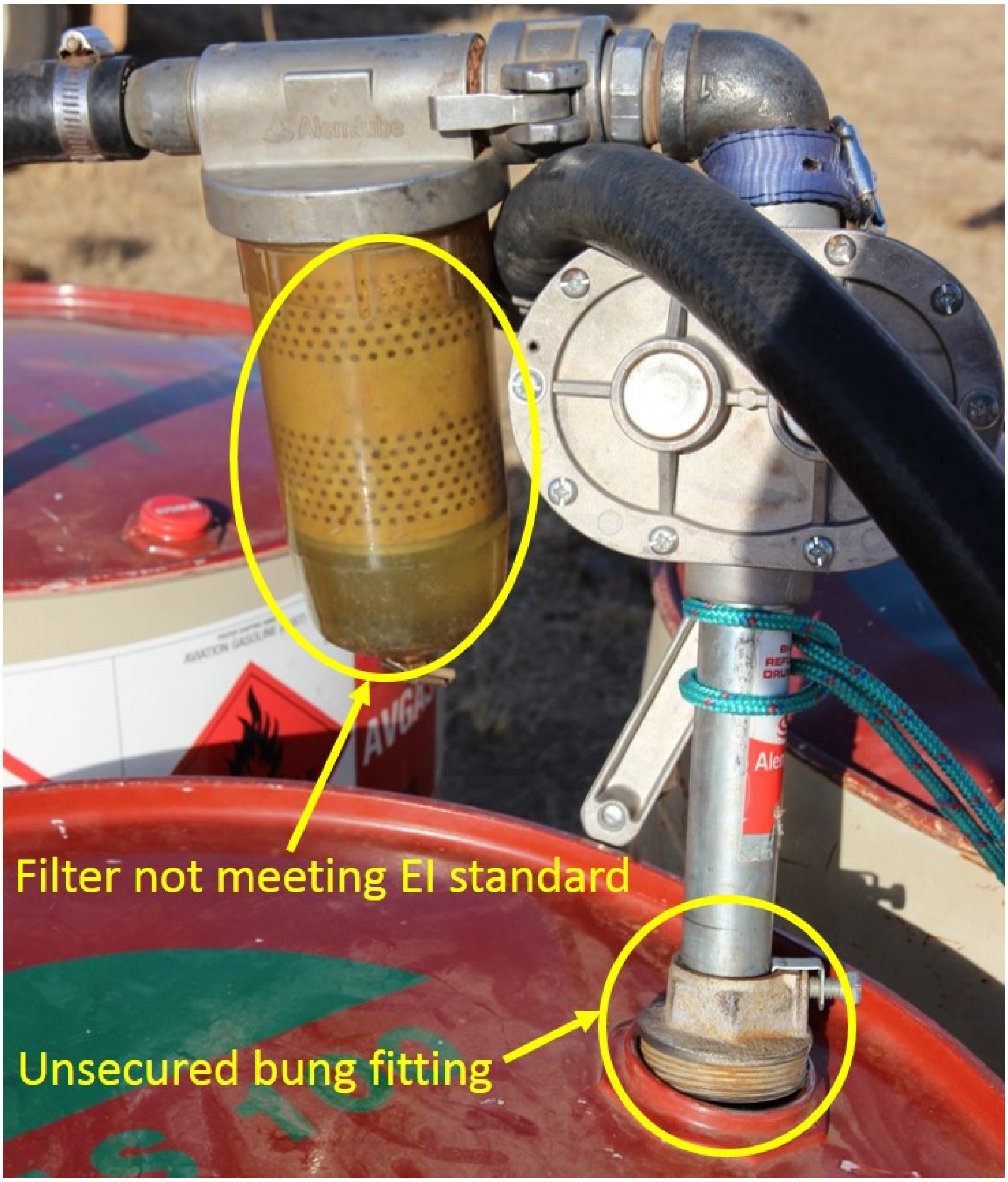
Operator fuel policy, procedures and practices

The ATSB could not identify any formal operator procedures for use in aerial mustering operations. This was consistent with the conduct of the muster as a private operation, which meant that there was no regulatory requirement for the operator to have an operations manual.

It was reported, however that the pilot replaced damaged or older fuel drums with new drum fuel stock supplied by the fuel distributer. Although there was evidence that new drum fuel supply was used, some older, damaged drums were in use at the time of the accident. It could be expected that an operations manual would help standardise procedures in relation to fuel management, refuelling and low-level helicopter operations among all personnel involved in those activities.

4 During refuelling, the practice of keeping the fuel drum tilted so that the large bunghole is on the high side ensures the hand pump inlet pick-up is away from potential contamination on the low side of the drum.

Figure 10: Drum refueling equipment used to refuel KJJ, showing the unsecured bung fitting



Source: ATSB

Risk of engine failure during mustering operations

Mustering operations entail operations at low level and at varying airspeeds. Such operations increase the risk associated with loss of engine power. More specifically, under certain height and airspeed combinations, it can be difficult to perform a safe landing in the event of an engine failure.[5] At the time of KJJ's engine failure, the helicopter was operated in an appropriate height-velocity region. All else being equal, it might be expected that an appropriately-qualified pilot might normally conduct a successful autorotation to touchdown from that region (appendix B).

5 The Robinson R44 Pilot's Operating Handbook contained a Height-Velocity diagram. This diagram highlighted 'avoid' areas, such as operations at high airspeed-low altitude or at higher altitude-low airspeed combinations.

Training requirements

Helicopter pilot training standards and guidelines

Given the pilot attained their Commercial Pilot (Helicopter) Licence in 2000, the associated training would have been in accordance with the CASA Day Visual Flight Rules (VFR) Syllabus-Helicopters. This syllabus was replaced from 1 September 2014 with the introduction of Civil Aviation Safety Regulation (CASR) Part 61, which incorporated a number of elements of the former Day VFR Syllabus-Helicopters.

A review of the Part 61 Manual of Standards (MOS) identified that for a flight review conducted after 1 September 2014, the pilot was required to demonstrate competency for the rating held. If the pilot held a low-level flight operational rating, this included:

- dealing with emergencies
- various helicopter handling techniques
- handling and avoiding overpitching
- low main rotor revolutions per minute (RPM).

The *Flight Instructors Manual – Helicopter*, which was published by CASA and the Civil Aviation Authority New Zealand, was a basic guide to elementary flight training. Although there was no specific guidance regarding overpitching, or low main rotor RPM avoidance and recovery in the manual, those areas were highlighted as key teaching points for instructors during autorotation, low-level and hazard-training exercises.

Civil Aviation Advisory Publication (CAAP) 5.81-1(1) titled *Flight Crew Licencing Flight Reviews* gave context to the value and limitations of a flight review and would have applied when the pilot last conducted their helicopter flight review. The CAAP suggested that although a flight review was required by the regulations, it was but one method that contributed to pilot proficiency and the safety of flight. Importantly, pilots were encouraged to continually identify hazards and manage the risks associated with their own aviation activities. This included regularly practicing piloting skills and actively applying threat and error management principles.

A flight review provided an opportunity for pilots to refresh their flying skills and knowledge, and to have an independent assessment of their abilities. It would be unrealistic to expect that all of a pilot's skills and knowledge would be assessed during a flight review. However, it would be expected that a number of safety critical aspects that, if not managed appropriately, could elevate the risk of damage or injury to persons, should be assessed. These could be expected to include:

- the management of engine failures leading to autorotation and forced landing
- awareness and avoidance of adverse aerodynamic situations, such as rotor stall
- management of emergencies.
- application of threat and error management and human factors practice.

While the CAAP included useful information about flight reviews prior to the introduction of CASR Part 61, the MOS was the current document that detailed the units of competency and standards for flight reviews after 1 September 2014.

Special Federal Aviation Regulation No.73 *Robinson R-22/R-44 Special Training and Experience Requirements* was introduced by the United States Federal Aviation Administration in 1995. CASA has subsequently introduced many of the R-22/R-44 special training and experience requirements into the CASR Part 61 MOS.

The United States Special Federal Aviation Regulation that was current at the time of the accident required specific awareness training, aeronautical experience, endorsements, and flight reviews for pilots operating Robinson helicopters. Specifically, this training included:

- enhanced training in autorotation procedures
- engine rotor RPM control without the use of the governor
- low rotor RPM recognition and recovery
- the effects of low G[6] manoeuvres and proper recovery procedures.

Low-level flying

Prior to the introduction of CASR Part 61, Civil Aviation Regulation (CAR) 5 required pilots holding a flight crew licence to undertake a biennial flight review for each category of aircraft on their licence. Guidance as to what constituted an acceptable flight review was contained in CAAP 5.81 1 (1), which emphasised the importance of flight safety through the application of the standards stipulated in the Day VFR Syllabus. There was no mandated requirement for pilots to demonstrate low-level flying or mustering in a flight review under the CAR 5 regulations.

With the introduction of CASR Part 61, pilots were required to conduct a flight review for low-level flying every 12 months. However, CASA subsequently changed this requirement under Regulation 61.1060, instrument number CASA EX92/15 on 25 May 2015. This instrument increased the low-level flight review requirement to 24 months.

Helicopter operation

Autorotation

In the case of an engine failure, a helicopter pilot is required to immediately enter autorotation. This is achieved by lowering the collective lever[7] to reduce the drag generated by the main rotor blades and establishing the appropriate speed for the autorotative descent. Robinson stated that if autorotation is not entered immediately, the rotor RPM rapidly decays, the main rotor system stalls and the results are likely fatal.

As the helicopter descends, there is an upward flow of air through the main rotor system. This upward flow provides an autorotative force to create rotor thrust that, if properly managed, maintains rotor RPM throughout the descent and provides for a steady rate of descent. Amongst other factors, the rate of descent in autorotation is affected by the forward airspeed of the helicopter. If the airspeed is zero, the rate of descent will be high. The rate of descent reduces with increasing airspeed until reaching the minimum rate of descent airspeed. The rate of descent again increases with increased airspeed beyond the minimum rate of descent speed. If managed correctly, the pilot can maintain the rotor RPM within limits by manipulating the collective lever.

In general, autorotative descents are carried out at an optimum forward airspeed that approximates the minimum rate of descent airspeed. When landing from an autorotation:

- Initially the forward airspeed is reduced by raising the nose of the helicopter (flaring) with aft cyclic.[8] This has the added benefit of reducing the ground speed and rate of descent and increasing (or recovering) the main rotor RPM.
- At an appropriate height above the ground, the helicopter is established in the landing attitude with cyclic.

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6 G load: the nominal value for acceleration. In flight, g load represents the combined effects of flight manoeuvring loads and turbulence and can have a positive or negative value.

7 Collective lever: 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.

8 Cyclic: 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.

- As the aircraft settles towards the ground, the pilot raises the collective lever to 'cushion' the aircraft onto the ground. Critically, this action decays the main rotor RPM and therefore rotational energy stored in the main rotor.

The final stages of an autorotation rely heavily on pilot judgement. In addition to the height and speed on entry into autorotation, factors such as uneven and/or wooded terrain, ploughed fields, the ambient conditions and the availability of suitable landing areas can all combine to affect the likelihood of a successful autorotation and touchdown.

If the pilot does not respond quickly and appropriately to a low rotor RPM situation, the main rotor RPM decreases further and the helicopter's rate of descent increases. If the collective is maintained or raised further in an effort to decrease the rate of descent, the rotor RPM reduces to a point where the main rotor blades cone up.[9] The result is a loss of lift, an increased rate of descent and a further reduction in rotor RPM. The situation can rapidly deteriorate into a vicious cycle that culminates in the rotor blades effectively stalling and losing all lift. Once the blades are aerodynamically stalled, in-flight recovery is almost impossible.

The R44 helicopter is equipped with a low rotor RPM warning horn and caution light, which activates at 97 per cent main rotor RPM. The R44 pilot's operating handbook (POH)[10] emergency procedure in response to the activation of the low RPM horn and associated caution light stated:

> A horn and an illuminated caution light indicate that rotor RPM may be below safe limits. To restore RPM, immediately roll throttle on, lower collective and, in forward flight, apply aft cyclic. The horn and caution light are disabled when collective is fully down.

That procedure decreases main rotor blade pitch and reduces blade drag in an effort to increase rotor RPM. This may be counter instinctive to the pilot of a helicopter at low altitude.

Robinson safety notices SN-10 *FATAL ACCIDENTS CAUSED BY LOW ROTOR STALL* and SN-24 *LOW RPM ROTOR STALL CAN BE FATAL* discussed blade stall and the associated risks and recovery actions and were available for inclusion in owner/operators' R44 POHs. These safety notices are reproduced at appendix A.

Hot refuelling

Although pilots were permitted to hot refuel[11] helicopters in accordance with Civil Aviation Amendment order (No. R11) 2004, the operator and pilot had a number of responsibilities to ensure the safety of operations. Schedule 1, Substitution of section 20.10 of the CAOs included that, before authorising the hot refuelling of a helicopter, the operator should satisfy themselves that it can be done safely by considering the:

> (a) the configuration of the helicopter and it's engine or engines; and
> (b) the location of the components of the helicopter's fuel system; and
> (c) the refuelling system or systems to be used and it's or their components; and
> (d) the helicopter's flight manual [POH].

Additionally, the operator was required to include appropriate procedures in their operations manual. As the operator was conducting the mustering operations under the Private Category, there was no requirement for an operations manual.

In relation to fuel testing, the regulations stipulated that the operator should ensure that the pilot in command inspected and tested the helicopter's fuel system for the presence of water on

9 Coning of the main rotor blades: the upwards movement of the main rotor blades while they are rotating. This is usually in response to an increase in aerodynamic force as a result of a control input from the pilot. It is more pronounced at high weights and/or low main rotor speed.

10 The Robinson R44 1 *PILOT'S OPERATING HANDBOOK AND FAA APPROVED ROTORCRAFT FLIGHT MANUAL* is also the helicopter's flight manual. Robinson prefer to term this publication the Pilot's Operating Handbook. This preference is reflected in this investigation report.

11 Hot refuelling means the refuelling of a helicopter with its engine or engines running

completion of each hot refuelling. This was because there was no fuel quality audit program or system for monitoring the quality of fuel used by the helicopter.

Additional pilot responsibilities during hot refuelling included that, unless they were exempted under CAO 95.7, the pilot must remain at the controls of the helicopter while refuelling was carried out. Under that order, exiting an operating R44 helicopter to conduct refuelling was not a valid reason to leave the flight controls.

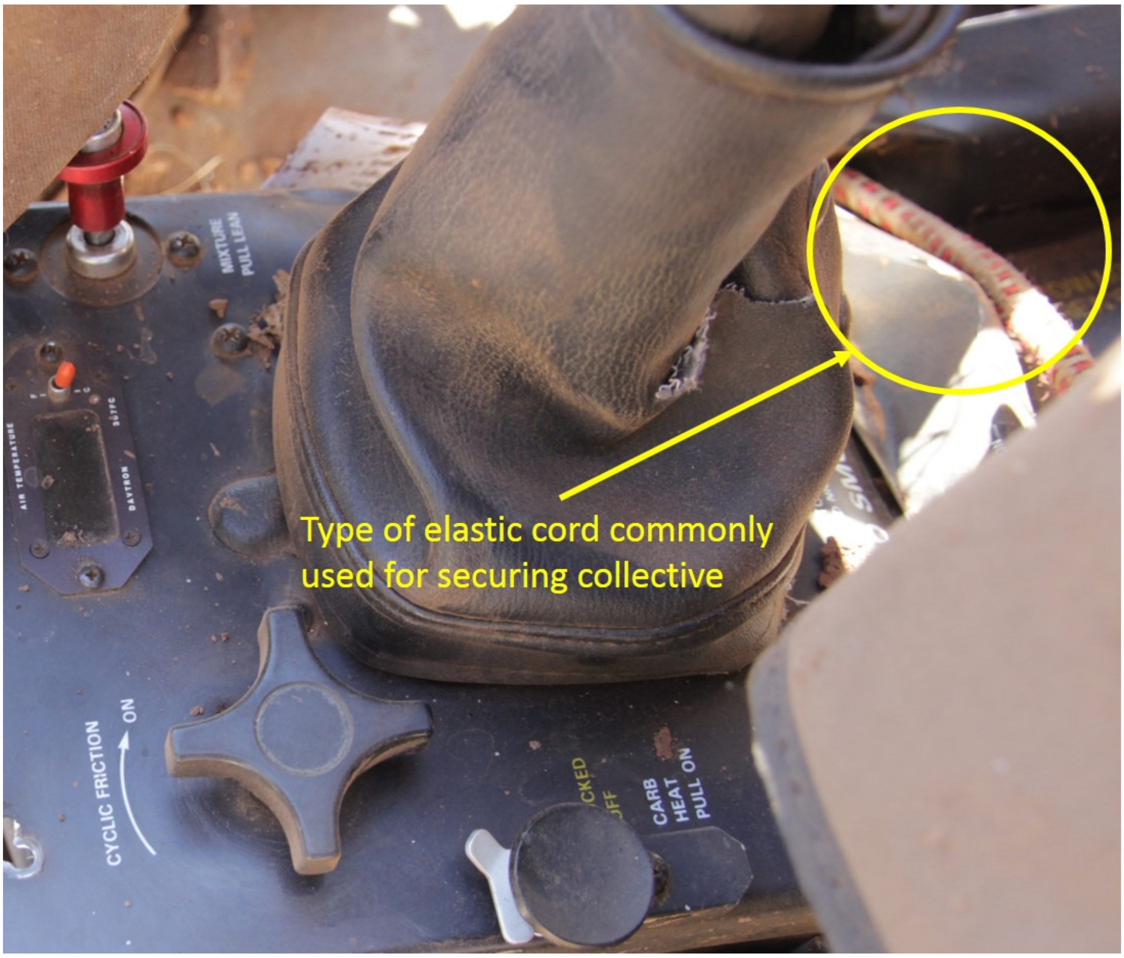
Safety notice SN-17 *NEVER EXIT HELICOPTER WITH ENGINE RUNNING* was included in the R44 POH and highlighted that a number of accidents have occurred when pilots momentarily left an operating helicopter (appendix A). The notice advised that, unmonitored, the collective lever could creep up, increasing pitch and throttle and allowing the helicopter to lift-off without pilot control.

To prevent inadvertent upward movement of the collective lever, it was reported by a number of helicopter pilots that an elastic strap was commonly positioned over the lever. There was evidence that the pilot of KJJ may have used this technique while not at the controls of the helicopter during ground operations (Figure 11). However, no approval for this method of securing the flight controls was found in the helicopter's maintenance documentation. In any case, the POH stipulated that pilots must not leave flight controls unattended while the helicopter is operating. Civil Aviation Regulation 138 *Pilot to comply with requirements etc of aircraft's flight manual etc* required Australian pilots to comply with that requirement.

CASA flight safety article titled *Don't walk away* and an ATSB safety investigation highlighted the risks associated with leaving flight controls unattended while the helicopter was still operating. They can be viewed at:

- Flight Safety Australia Don't walk away issue 91 of March – April 2013
- ATSB investigation *Robinson Helicopter Co R22 BETA, VH-HTZ* of July 2002.

Figure 11: Elastic strap found positioned near the collective (such as reported used by some pilots to secure the collective lever)



Source: ATSB

Related fuel contamination occurrences

A search of the ATSB's occurrence database revealed that in the 10-year period from 2004 there was an average of about three reported fuel contamination-related occurrences per year. A number of the occurrences identified issues with water bypassing the aircraft's fuel tank cap seals after periods of rain or entering the fuel system during the refuelling process. In many cases, the effects of water contamination remained unnoticed until the aircraft experienced an in-flight engine power loss requiring the pilot to conduct a forced landing or return to an aerodrome.

The following occurrence investigations that relate to fuel contamination are available from the ATSB website at www.atsb.gov.au:

Total power loss - Cessna 152, registered VH-HCE (AO-2011-118)

At an altitude of approximately 200 ft above ground level, the instructor heard the engine noise reducing and observed the engine RPM decreasing. The instructor immediately assumed control, lowered the nose of the aircraft to maintain airspeed and performed a successful emergency landing.

Water contamination was identified in the post-accident fuel samples taken from the aircraft's fuel filter and the right fuel tank. Surface rust on the right tank fuel cap receptacle indicated that water had most likely entered the system through that point during the heavy rainfall in the previous days. During that period, the aircraft was parked in the open. The water contamination was not identified during the pre-flight fuel drain check that was conducted by the instructor and witnessed by the student.

Total power loss - Robinson R22 helicopter, registered VH-FDL (AO-2010-107)

On 13 December 2010, at about 1500 Eastern Standard Time, a Robinson R22 Alpha helicopter, registered VH-FDL, departed the Georgetown aeroplane landing area, Queensland with one pilot and one passenger on board.

The pilot reported that, when 9 km to the north of Georgetown on descent from 1,000 ft above ground level and passing through 150 ft, engine power was applied before the engine spluttered twice. This was immediately followed by a decrease in engine RPM and the low rotor RPM warning horn sounding. The engine subsequently failed. The pilot reported that carburettor heat was not applied during the descent and the carburettor temperature was above the yellow arc.

The pilot regained control of the rotor RPM and conducted a forced landing. During the landing, the helicopter's skids struck a tree. The left skid then contacted the ground and the helicopter cartwheeled. The pilot was not injured, however the passenger sustained serious injuries.

The subsequent examination of the helicopter's engine and fuel system did not identify any anomalies. It was possible that the small amount of water that was found in the carburettor contributed to the reported engine failure.

Collision with terrain, registered VH-KZF, on 14 September 2010 (AO-2010-069)

The pilot commenced the take-off from an elevated, 700 m long gravel airstrip on the eleventh of 12 flights. During the take-off, the aircraft did not achieve the required take-off performance. In an attempt to become airborne before the end of the useable runway surface, the pilot elected to dump some of the chemical load and continued the take-off. The aircraft subsequently collided with terrain a short distance from the departure end of the airstrip.

The loader reported that the aircraft was refuelled at the airstrip from drums that were previously used to store aviation oil. The drums themselves were refuelled on the morning of the accident from a Geraldton, Western Australia fuel facility. Fuel sample tests of the drum stock fuel after the accident indicated higher-than-normal gum levels.

The pilot was reported to have refuelled the aircraft's left wing tank from those drums three times prior to the accident. The investigation concluded that the quality of the fuel for the flight was not a factor.

It could not be determined why the fuel samples from the load truck's fuel hose returned higher-than-recommended gum levels. However, the use by the pilot of fuel that was stored in disused aviation oil drums increased the risk that the fuel would not be suitable for the intended application.

Departure from controlled flight and collision with terrain involving Ayres Corporation S2R Thrush, VH-JAY, 17 km south-east of Hyden, Western Australia on 18 October 2013 (AO-2013-183)

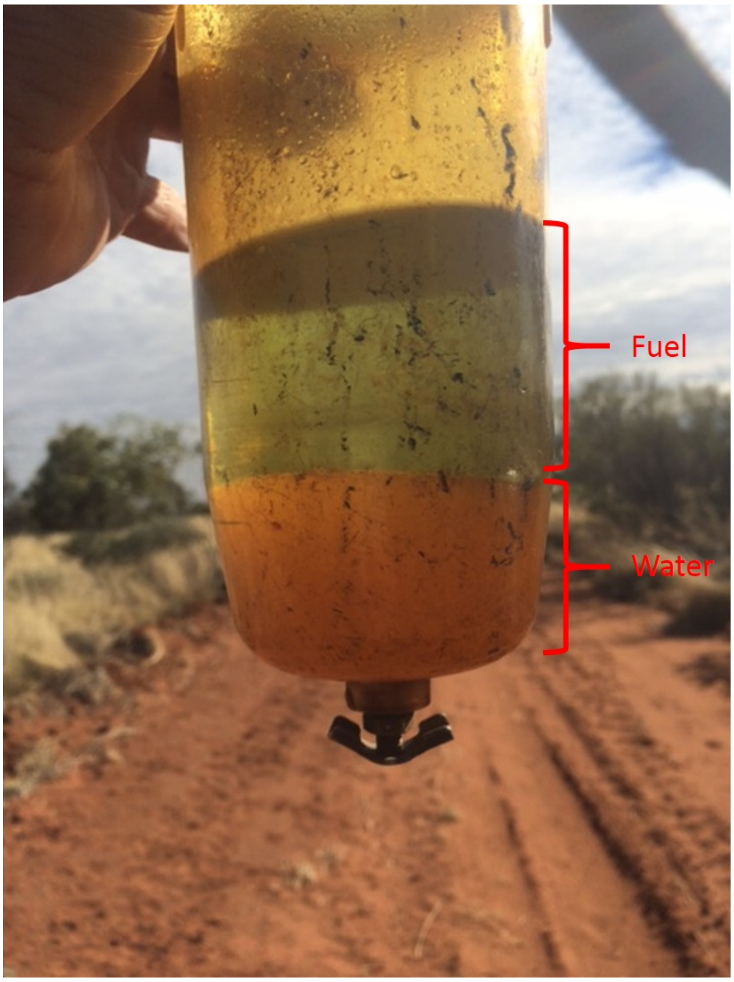
The ATSB found that the aircraft departed controlled flight from which the pilot was unable to recover, leading to a collision with terrain. Based on the available evidence, it was not possible to determine the reasons for the loss of control.

The ATSB identified two aspects of the aircraft's operation with the potential to affect safety. These were the use of an unapproved fuel mix and operation of the aircraft above its published maximum take-off weight.

Other research information

Although not captured in the ATSB's occurrence database, it was reported by a number of pilots using aviation drum fuel supply in Australia that they often identified water contamination in their fuel drums. The water contamination was normally identified using water detecting paste prior to refuelling, or by visually inspecting the hand pump filter bowl during the refuelling process (Figure 12). It was also reported that pilots would normally inspect fuel samples taken from the aircraft's fuel tanks after refuelling to confirm there was no contamination.

Figure 12: Unrelated example of a visual indication of water contamination in a fuel filter bowl



Source: Operator

Safety analysis

The pilot of VH-KJJ (KJJ) experienced a loss of engine power after a significant amount of water in the helicopter's fuel system interrupted the flow of fuel to the engine. The engine lost power while the helicopter was in low-level cruise flight, a short time after refuelling from a local drum fuel supply.

In response to the loss of engine power, the pilot entered autorotation and attempted a forced landing in a largely timbered environment. The impact damage to the helicopter from the forced landing was consistent with a high rate of descent at touchdown, most likely due to low main rotor revolutions per minute (RPM) in the latter stages of the autorotation.

This analysis will examine the circumstances surrounding the fuel contamination and the autorotation in response to the loss of engine power. It will also highlight a number of important operational safety considerations in respect of fuel-handling practices and low-level helicopter operations.

Response to the engine failure

Entry into and conduct of the autorotation

On-site evidence and data recovered from the helicopter's global positioning system equipment provided an understanding of the helicopter's operation on the day of the accident and, in particular, during the final stages of flight. This did not include the degree or sequence of control inputs by the pilot after the loss of engine power. However, it was evident that the pilot entered autorotation, established an initial speed of about 70 kt and completed a slight turn to the south-east. This was consistent with a turn towards the ultimate touchdown point. In response to a loss of engine power, helicopter pilots enter autorotation and normally turn into wind and select the most suitable landing area before planning their descent.

Evidence of coning of the main rotor blades was consistent with decreased main rotor energy. Although the reason for this loss of energy could not be determined, any loss of energy would have decreased the pilot's ability to arrest the helicopter's rate of descent. In addition, the wooded terrain and limited suitable landing areas would have increased the difficulty faced by the pilot.

Ultimately, for reasons that could not be established, but consistent with the difficulties faced by the pilot, the pilot was unable to satisfactorily reduce the rate of descent before impacting the ground. The heavier-than-normal forces experienced during the touchdown influenced the likelihood of survival from the autorotation.

Expectancy and training currency

The ATSB considered a range of factors that may have influenced the pilot's ability to conduct a successful autorotation touchdown from the low-level cruise height. These included expectancy and skill decay.

Pilots expect certain abnormal events during flight review and proficiency checks, and they are generally well prepared to respond to those scenarios. Research has shown that performance is slower, less effective and more variable when an abnormal event is not expected (Casner and others 2013, Hendrickson and others 2006).

Engine failures and power loss from fuel contamination are rare events and therefore they are generally not expected. In this case, the pilot had probably refuelled on many occasions from drum fuel supply without experiencing adverse in-flight effects from fuel contamination. Further, the pilot was aware that another helicopter had just refuelled using the same fuel supply without any reported engine-related difficulties. This likely reinforced the pilot's expectation that there would be no issues related to fuel contamination.

Low expectancy has been associated with many previous occurrences related to in-flight management of abnormal events. To help overcome these problems, pilots conduct regular flight reviews and proficiency checks to ensure they have, or can regain the operational skills to respond to those events.

In this case, the pilot had not conducted a flight review since March 2013. A flight review would likely have provided an opportunity for the pilot to practice low-level autorotation in response to simulated loss of engine power, and react to other risks associated with low-level mustering operations. In consequence of this lack of recency, the pilot's skill managing in-flight emergencies could be expected to have deteriorated, influencing their ability to execute and successfully recover from an autorotation.

Operators should not underestimate the value of regular emergency procedure training, flight reviews and the continual assessment of operational threats and risks. Some emergencies, like a loss of engine power at low level, require prompt and appropriate action. Importantly, recurrent flight training allows mustering pilots to review their low-level operations to increase the available options in the event of an in-flight emergency.

Fuel handling practices

Proper management of ground fuel supplies and assurance of fuel quality throughout the refuelling process should not be understated. There have been many aviation occurrences where pilots have experienced in-flight difficulties relating to fuel starvation or exhaustion. This includes instances of fuel starvation from contaminated fuel.

While there was industry guidance available to operators about acceptable fuel standards and practices to help prevent fuel contamination, it was evident that the application of, and adherence to those standards varied across the aviation industry. In this case, the mustering operation was conducted as a private operation. Therefore, it did not require an operations manual that would have outlined the drum-fuelling procedures and necessary equipment. Although some newer-type drums were being used on the day of the accident, the operator's reported procedure for renewing fuel drums did not include isolating damaged fuel drums from the main drum supply. This allowed the re-use of the damaged drum after refilling.

It was probable that most of the contamination was introduced into KJJ's fuel system while refuelling from the older, rusted and damaged drum. This was consistent with the negligible amounts of water, rust or particulates identified in the operator's other fuel supplies. The water and rust particulates in the old, rusted and dented drum may have resulted from its storage unused for a period in a hot and humid environment.

Previous ATSB aviation safety investigations have highlighted risks associated with the improper use of drums for storage of aviation fuel, and the absence of recommended aviation filters during refuelling operations. Although the regulations required pilots and operators to have a suitable means of testing fuel prior to and after filling an aircraft's fuel tanks, it was evident that no robust procedure was in place for testing fuel at the time of the accident.

A number of issues were identified with the refuelling procedures and use of drum fuel that, if addressed, could have prevented, or provided an opportunity to detect water and particulate contamination in the drum stock. The ability to detect contamination in fuel using visual inspection and smell can vary. As a result, it is recommended that pilots check for the presence of water using a positive test method, such as water-detecting paste. In this case, visual detection of water may have been difficult because of the amber colour of the fuel filter bowl, turbid colour of the contamination and quantity of water in the fuel. The use of water-detecting paste would have identified the contamination prior to refuelling the helicopter, indicating that the fuel was unsuitable for aviation use. It was therefore likely that during the last refuel, the pilot was unable to identify any visible water or particulates transferred into the helicopter's fuel from the drum fuel stock.

Alternately, the pilot did not test the fuel from the helicopter's fuel tanks and gascolator after refuelling.

Pilots from the other helicopters operating on the same muster reported no contamination when their helicopters' fuel tanks were examined after the accident. This was most likely due to their only using half of the older, damaged drum, along with their method of tilting the drum fuel pump toward the higher side of the drum. This meant that any contaminants were, if present, drained away from the fuel pump inlet. The pilot of KJJ used almost all of the remaining fuel in the older, rusted drum. This would require the pilot to position the fuel pump inlet at the base of the drum, near the water and particulate contamination.

The addition of a filter monitor would have provided another line of defence before the fuel entered KJJ's fuel tanks. Used correctly, a filter monitor meeting the petroleum industry standard would have inhibited the pilot from pumping the contaminated fuel once water contacted the filter membrane, as the pilot would feel increased pressure or resistance. The associated difficulty pumping fuel through the filter would have alerted the pilot of the potential water contamination. It could be expected that this would most likely have prompted testing and subsequent removal of any contamination from the helicopter's fuel tanks.

The use of a filter that met the petroleum industry standard would have reduced the size of particulate able to pass through the filter to as low as 1 µm. This compares with the larger 10 µm particulate size filtered by the filter that was used on the day of the accident. This would have minimised the amount of particulate identified in KJJ's fuel tank, carburettor and gascolator.

The use of appropriate fuel pump filters (filter monitors) and checks of the helicopter's fuel system would have increased the likelihood that the pilot would detect the contaminated fuel. The importance of operators having appropriate fuel handling and storage procedures to ensure fuel quality is also highlighted.

Hot refuelling

The timing of the refuel that was derived from the recorded global positioning system data suggested that the pilot of KJJ did not shutdown the helicopter prior to refuelling (hot refuelling). The time normally required for a refuel, compared to the time spent on the ground that day, was insufficient for completion of the:

- helicopter shutdown and start-up procedures
- the actual refuelling process.

While the R44 pilot's operating handbook did not exclude hot refuelling, there were regulations that stipulated the responsibilities of operators and pilots during such refuelling processes. Of note, the operator was required to have an operations manual that set out the operational circumstances and procedures to ensure the safe refuelling of aircraft. As the helicopter was being operated privately that day, and therefore there was no operations manual, hot refuelling should not have been conducted. In addition, the R44 pilot's operating handbook required the pilot to remain at the controls while the helicopter was operating.

Unmonitored helicopter flight controls with the rotors running, such as during hot refuelling, increases the risk of the helicopter unintentionally becoming airborne and subsequent injury to bystanders.

Findings

From the evidence available, the following findings are made with respect to the collision with terrain involving Robinson Helicopter Company R44, registered VH-KJJ, which occurred 153 km south-west of Timber Creek, Northern Territory on 14 June 2015. These findings should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing factors

- Following drum refuelling, fuel from the helicopter's fuel tanks and gascolator were likely not tested for the presence of contamination. This was a missed opportunity for the pilot to detect water and particulates introduced from the drum fuel supply.
- The helicopter’s fuel system was contaminated with water and particulates during the drum refuelling, preventing a combustible fuel supply to the helicopter’s engine during flight and causing it to stop shortly after take-off.
- During a low-level autorotation and forced landing, and for reasons that could not be determined, the pilot was unable to satisfactorily reduce the rate of descent before impacting the ground. The heavier-than-normal forces experienced during the touchdown influenced the likelihood of survival from the autorotation.

Other factors that increased risk

- The operator did not have an effective procedure for testing and managing drum fuel supply, increasing the risk of fuel contamination from that supply.
- The operator did not use a filter monitor that was recommended by the petroleum industry and was suitable for aviation use. Such a filter would have minimised the risk of water contamination during the drum refuelling.
- The pilot had not completed the stipulated helicopter flight review for low-level helicopter operations. This likely influenced the pilot’s familiarity and proficiency with managing time-critical emergencies that occur from a low altitude.
- The unmonitored flight controls during the hot refuelling increased the risk of the helicopter unintentionally becoming airborne and injuring bystanders.

General details

Occurrence details

Date and time:	14 June 2015 – 1110 CST	
Occurrence category:	Accident	
Primary occurrence type:	Operational	
Location:	154 km south-west of Timber Creek, Northern Territory	
	Latitude: 16° 40.02' S	Longitude: 129° 30.02' E

Aircraft details

Manufacturer and model:	Robinson Helicopter Company R44 Raven 1	
Year of manufacture:	2006	
Registration:	VH-KJJ	
Operator:	Private	
Serial number:	1558	
Total Time In Service	916 hours (as of the last 100 hourly inspection)	
Type of operation:	Private	
Persons on board:	Crew – 1	Passengers – Nil
Injuries:	Crew – 1 (fatal)	Passengers – Nil
Damage:	Destroyed	

Sources and submissions

Sources of information

The sources of information during the investigation included:

- the Civil Aviation Safety Authority
- a number of helicopter training providers
- a number of other helicopter operators
- a petroleum company that supplied aviation drum fuel in Australia
- a number of property station hands.

References

Casner, SM Geven, RW & Williams, RT 2013, 'The effectiveness of airline pilot training for abnormal events', *Human Factors: The Journal of the Human Factors and Ergonomics Society*, vol. 55, pp.477-485.

Hendrickson, SM Goldsmith, TE & Johnson, PJ 2006, 'Retention of airline pilots' knowledge and skill', *Proceedings of the Human Factors and Ergonomics Society 50th Annual Meeting*, pp.1973-1976.

Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the *Transport Safety Investigation Act 2003* (the Act), the 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 helicopter operators, the Civil Aviation Safety Authority and a petroleum company that supplied aviation drum fuel in Australia.

Submissions were received from the helicopter operators and a petroleum company that supplied aviation drum fuel in Australia. The submissions were reviewed and where considered appropriate, the text of the report was amended accordingly.

Appendices

Appendix A – Robinson Helicopter Company Safety Notices

ROBINSON
HELICOPTER COMPANY

Safety Notice SN-10

Issued: Oct 82 Rev: Feb 89; Jun 94

FATAL ACCIDENTS CAUSED BY LOW RPM ROTOR STALL

A primary cause of fatal accidents in light helicopters is failure to maintain rotor RPM. To avoid this, every pilot must have his reflexes conditioned so he will instantly add throttle and lower collective to maintain RPM in any emergency.

The R22 and R44 have demonstrated excellent crashworthiness as long as the pilot flies the aircraft all the way to the ground and executes a flare at the bottom to reduce his airspeed and rate of descent. Even when going down into rough terrain, trees, wires or water, he must force himself to lower the collective to maintain RPM until just before impact. The ship may roll over and be severely damaged, but the occupants have an excellent chance of walking away from it without injury.

Power available from the engine is directly proportional to RPM. If the RPM drops 10%, there is 10% less power. With less power, the helicopter will start to settle, and if the collective is raised to stop it from settling, the RPM will be pulled down even lower, causing the ship to settle even faster. If the pilot not only fails to lower collective, but instead pulls up on the collective to keep the ship from going down, the rotor will stall almost immediately. When it stalls, the blades will either "blow back" and cut off the tailcone or it will just stop flying, allowing the helicopter to fall at an extreme rate. In either case, the resulting crash is likely to be fatal.

No matter what causes the low rotor RPM, the pilot must first roll on throttle and lower the collective simultaneously to recover RPM **before** investigating the problem. It must be a conditioned reflex. In forward flight, applying aft cyclic to bleed off airspeed will also help recover lost RPM.

ROBINSON
HELICOPTER COMPANY

Safety Notice SN-15

Issued: Aug 83 Rev: Jun 94

FUEL EXHAUSTION CAN BE FATAL

Many pilots underestimate the seriousness of fuel exhaustion. Running out of fuel is the same as a sudden total engine or drive system failure. When that occurs, the pilot must immediately enter autorotation and prepare for a forced landing. Refer to Section 3 of the Pilot's Operating Handbook under Power Failure. If autorotation is not entered immediately, the RPM will rapidly decay, the rotor will stall, and the results will likely be fatal. Serious or fatal accidents have occurred as a result of fuel exhaustion.

To insure this does not happen to you, observe the following precautions:

1) Never rely solely on the fuel gage or the low fuel warning light. These electromechanical devices have questionable reliability in any airplane or helicopter. Always record the hourmeter reading each time the fuel tanks are filled.

2) During your preflight:

   a) Check the fuel level in the tanks visually.
   b) Be sure the fuel caps are tight.
   c) Drain a small quantity of fuel from each tank and the gascolator to check for water or other contamination.

3) Before takeoff:

   a) Insure that the fuel valve is full on.
   b) Be sure guard is placed on mixture control.
   c) Plan your next fuel stop so you will have at least 20 minutes of fuel remaining.

4) In flight:

   a) Continually check both hourmeter and fuel gages. If either indicates low fuel, LAND.
   b) Always land to refuel before the main tank fuel gage reads less than 1/4 full.
   c) NEVER allow the fuel quantity to become so low in flight that the low fuel warning light comes on.

Safety Notice SN-17

Issued: Nov 84 Rev: Feb 89; Jun 94

NEVER EXIT HELICOPTER WITH ENGINE RUNNING

Several accidents have occurred when pilots momentarily left their helicopters unattended with the engine running and rotors turning. The collective can creep up, increasing both pitch and throttle, allowing the helicopter to lift off or roll out of control.

HOLD CONTROLS WHEN BOARDING PASSENGERS

It is important to firmly grip both cyclic and throttle while loading or unloading passengers with the engine running in case they inadvertently bump the controls or slide across the throttle, rolling it open.

NEVER LAND IN TALL DRY GRASS

The engine exhaust is very hot and can easily ignite tall grass or brush. One R22 was completely destroyed by fire after a normal landing in tall grass.

ROBINSON
HELICOPTER COMPANY

Safety Notice SN-24

Issued: Sep 86 Rev: Jun 94

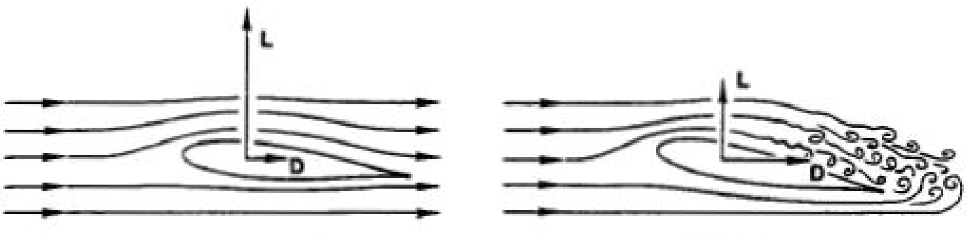
LOW RPM ROTOR STALL CAN BE FATAL

Rotor stall due to low RPM causes a very high percentage of helicopter accidents, both fatal and non-fatal. Frequently misunderstood, rotor stall is not to be confused with retreating tip stall which occurs only at high forward speeds when stall occurs over a small portion of the retreating blade tip. Retreating tip stall causes vibration and control problems, but the rotor is still very capable of providing sufficient lift to support the weight of the helicopter.

Rotor stall, on the other hand, can occur at any airspeed and when it does, the rotor stops producing the lift required to support the helicopter and the aircraft literally falls out of the sky. Fortunately, rotor stall accidents most often occur close to the ground during takeoff or landing and the helicopter falls only four or five feet. The helicopter is wrecked but the occupants survive. However, rotor stall also occurs at higher altitudes and when it happens at heights above 40 or 50 feet AGL it is most likely to be fatal.

Rotor stall is very similar to the stall of an airplane wing at low airspeeds. As the airspeed of an airplane gets lower, the nose-up angle, or angle-of-attack, of the wing must be higher for the wing to produce the lift required to support the weight of the airplane. At a critical angle (about 15 degrees), the airflow over the wing will separate and stall, causing a sudden loss of lift and a very large increase in drag. The airplane pilot recovers by lowering the nose of the airplane to reduce the wing angle-of-attack below stall and adds power to recover the lost airspeed.

The same thing happens during rotor stall with a helicopter except it occurs due to low rotor RPM instead of low airspeed. As the RPM of the rotor gets lower, the angle-of-attack of the rotor blades must be higher to generate the lift required to support the weight of the helicopter. Even if the collective is not raised by the pilot to provide the higher blade angle, the helicopter will start to descend until the



Wing or rotor blade unstalled and stalled.

Page 1 of 2

ROBINSON
HELICOPTER COMPANY

Safety Notice SN-24 (continued)

upward movement of air to the rotor provides the necessary increase in blade angle-of-attack. As with the airplane wing, the blade airfoil will stall at a critical angle, resulting in a sudden loss of lift and a large increase in drag. The increased drag on the blades acts like a huge rotor brake causing the rotor RPM to rapidly decrease, further increasing the rotor stall. As the helicopter begins to fall, the upward rushing air continues to increase the angle-of-attack on the slowly rotating blades, making recovery virtually impossible, even with full down collective.

When the rotor stalls, it does not do so symmetrically because any forward airspeed of the helicopter will produce a higher airflow on the advancing blade than on the retreating blade. This causes the retreating blade to stall first, allowing it to dive as it goes aft while the advancing blade is still climbing as it goes forward. The resulting low aft blade and high forward blade become a rapid aft tilting of the rotor disc sometimes referred to as "rotor blow-back". Also, as the helicopter begins to fall, the upward flow of air under the tail surfaces tends to pitch the aircraft nose-down. These two effects, combined with aft cyclic by the pilot attempting to keep the nose from dropping, will frequently allow the rotor blades to blow back and chop off the tailboom as the stalled helicopter falls. Due to the magnitude of the forces involved and the flexibility of rotor blades, rotor teeter stops will not prevent the boom chop. The resulting boom chop, however, is academic, as the aircraft and its occupants are already doomed by the stalled rotor before the chop occurs.

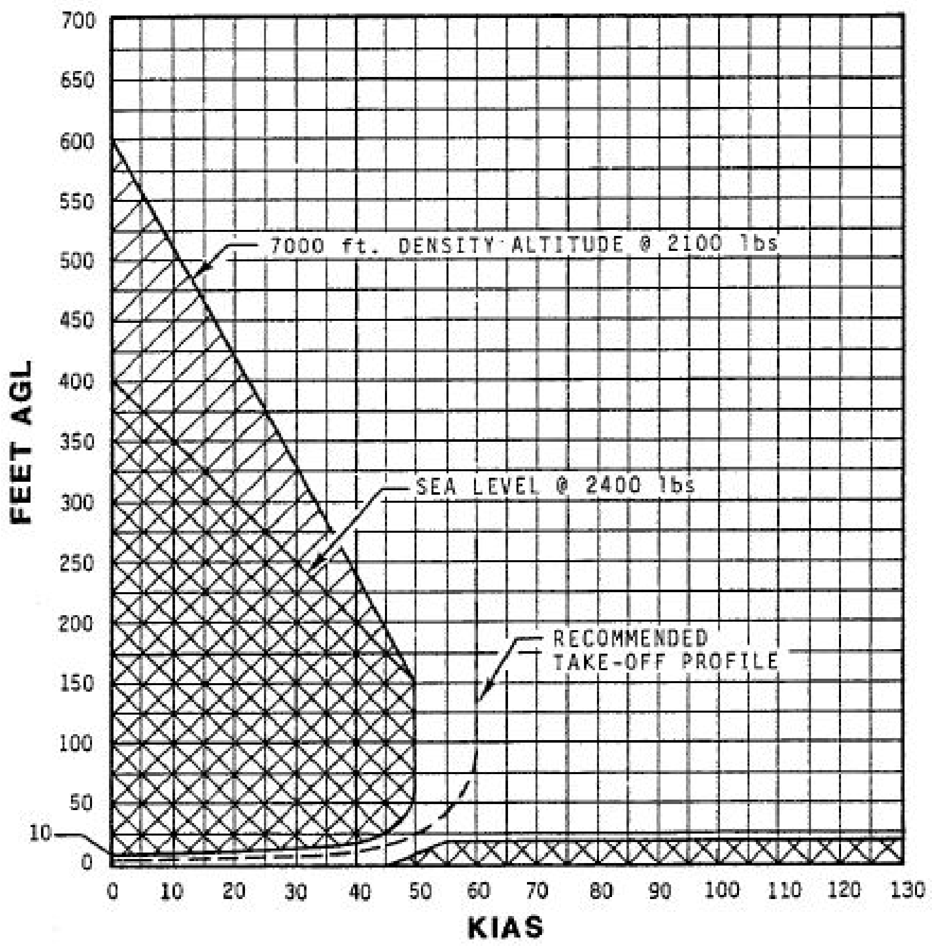
Appendix B – R44 Height – Velocity Diagram

ROBINSON
MODEL R44

SECTION 5
PERFORMANCE

DEMONSTRATED CONDITIONS:
SMOOTH HARD SURFACE
WIND CALM
GOVERNOR ON

AVOID OPERATION IN SHADED AREAS



HEIGHT - VELOCITY DIAGRAM

FAA APPROVED: 10 DEC 92

5-6

Australian Transport Safety Bureau

The ATSB is an independent Commonwealth Government statutory agency. The ATSB 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 operations involving the travelling public.

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 factors related to the transport safety matter being investigated.

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 it appropriate. There is no requirement for a formal response to an advisory notice, although the ATSB will publish any response it receives.

Australian Transport Safety Bureau

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Investigation

ATSB Transport Safety Report
Aviation Occurrence Investigation

Engine failure and collision with terrain involving Robinson R44, VH-KJJ, 154 km south-west of Timber Creek, Northern Territory on 14 June 2015

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