Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY REPORT

Occurrence Investigation Report AO-2007-046

Final

Collision with terrain Doongan Station, WA 25 September 2007 VH-HCN Robinson Helicopter Company R22 Beta II

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Aviation Occurrence Investigation

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Collision with terrain
Doongan Station, WA
25 September 2007
VH-HCN
Robinson Helicopter Company R22 Beta II

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Figure 1: Airservices Australia
Figures 3 and 4: Robinson Helicopter Company
Figure 5: Western Australia Police

Abstract

On 25 September 2007 at about 0600 Western Standard Time, a Robinson Helicopter Company R22 Beta II helicopter, registered VH-HCN, departed under the visual flight rules (VFR) from Doongan Station in the Kimberley region of Western Australia. The purpose of the flight was to conduct a stock survey in the vicinity of the station. On board the helicopter were the pilot and one passenger.

About 5 to 10 minutes into the flight, the passenger detected a rubber-like burning smell, combined with a smell he associated with hot metal. The passenger informed the pilot who immediately landed the helicopter in a clear area adjacent to a nearby road. The pilot visually inspected the helicopter with the engine and rotor turning, and remarked that one of the rotor system drive belts appeared to be damaged. The pilot decided to return the helicopter to the station, while the passenger elected to remain at the landing site and await recovery by motor vehicle.

The passenger watched the helicopter take off and, owing to the calm conditions, continued to hear the engine noise of the helicopter for some time. The passenger reported hearing variation in the engine noise before it ceased abruptly. In response, the passenger began walking along the road in the direction of the station and discovered the wreckage of the helicopter adjacent to the road. The helicopter had been destroyed by impact forces and fire and the pilot had been fatally injured.

The investigation determined that the helicopter's main rotor system drive belts probably failed or were dislodged, resulting in a loss of drive to the rotor system that necessitated an autorotative landing over inhospitable terrain. The investigation also identified a number of safety factors relating to unsafe decision making, including the operation of the helicopter beyond the allowable weight and centre of gravity limits, as well as evidence of the recent use of cannabis by the pilot.

As a result of this accident, and a number of other similar events that were identified during this investigation, the Australian Transport Safety Bureau has commenced a Safety Issue investigation to determine if there are any design, manufacture, maintenance or operational issues that increase the risk of a failure of the rotor system drive belt in the R22 helicopter.

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 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 enhance safety. To reduce safety-related risk, ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated.

It is not a function of the ATSB to apportion blame or determine liability. However, 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 proactively initiate safety action rather than release formal recommendations. However, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation, a recommendation may be issued either during or at the end of an investigation.

When safety recommendations are issued, they will focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on the 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, the person, organisation or agency must provide a written response within 90 days. That response must indicate whether the person, organisation or agency accepts 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.

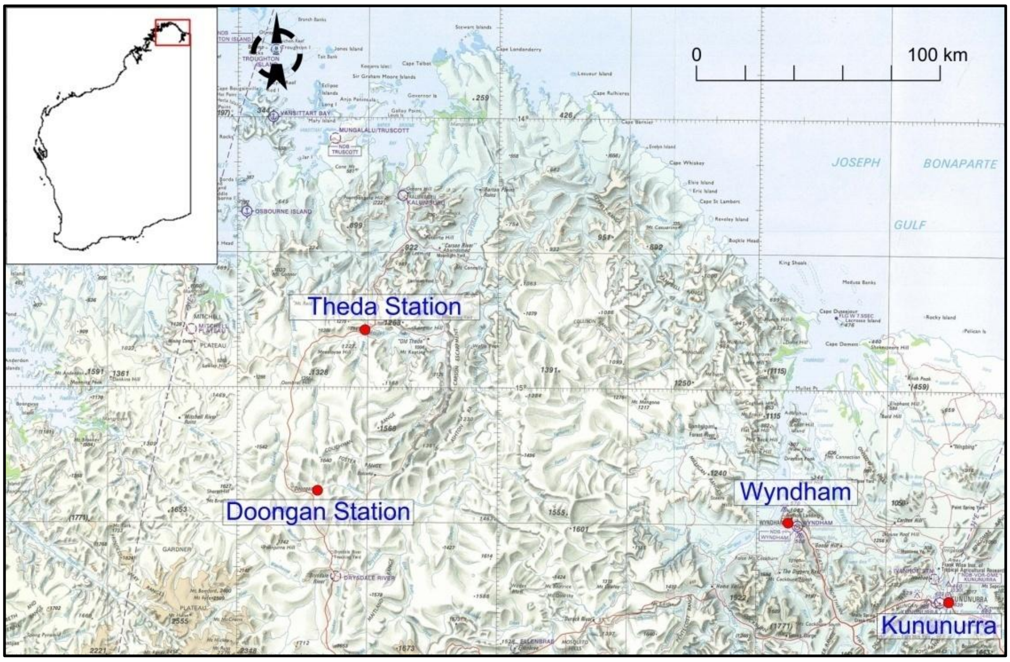
About ATSB investigation reports: How investigation reports are organised and definitions of terms used in ATSB reports, such as safety factor, contributing safety factor and safety issue, are provided on the ATSB web site www.atsb.gov.au

FACTUAL INFORMATION

History of the flight

On 25 September 2007 at about 0600 Western Standard Time[1], a Robinson Helicopter Company R22 Beta II helicopter, registered VH-HCN (HCN), departed under the visual flight rules (VFR) from Doongan Station in the Kimberley region of Western Australia. The purpose of the flight was to conduct a stock survey in the vicinity of the station before proceeding to Theda Station, which was about 70 km to the north-north-east (Figure 1). On board the helicopter were the pilot and one passenger.

Figure 1: Area map.



The passenger advised that, about 5 to 10 minutes into the flight, he detected a rubber-like burning smell, combined with a hot metal smell that he associated with a damaged bearing. He reported that there were no cockpit indications of a problem with the helicopter. The passenger notified the pilot of the burning smell and the pilot immediately conducted a precautionary landing in a nearby clear area adjacent to a road (Figure 2). The passenger stated that the pilot elected to keep the engine and rotor system operating while conducting a visual inspection of the helicopter. The pilot was reported to have focussed his attention on the two rubber drive belts (V-belts) that transferred power from the engine to the helicopter’s rotor system.

Following the examination, the pilot remarked to the passenger that the rear V-belt appeared to be damaged, though he assessed that the helicopter was capable of conducting the short return flight to Doongan Station. The passenger also observed the V-belts and recalled that, other than the rear belt appearing slightly lighter in

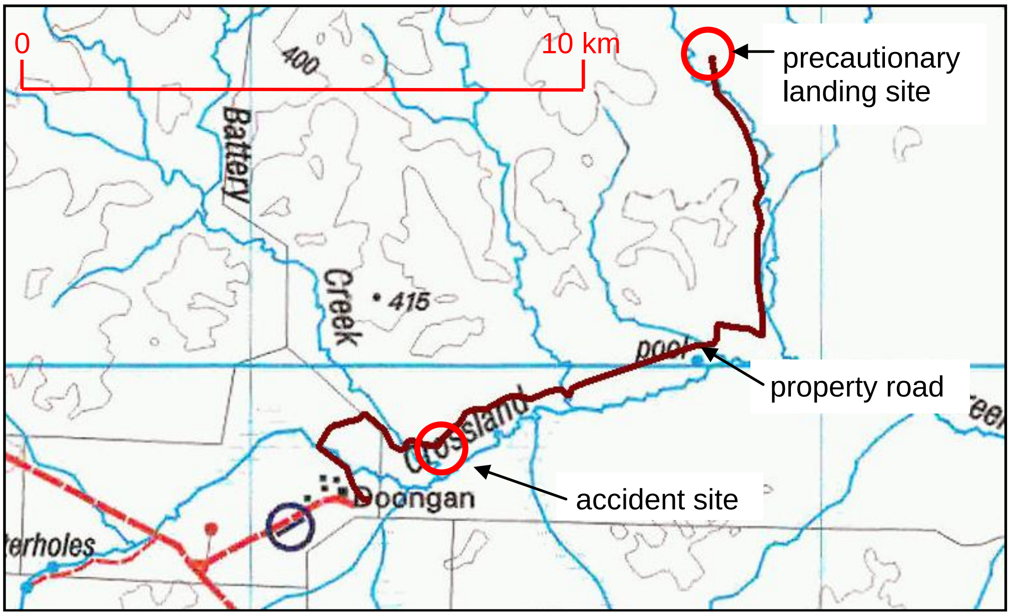
1 The 24-hour clock is used in this report to describe the local time of day, Western Standard Time (WST), as particular events occurred. Western Standard Time was Coordinated Universal Time (UTC) + 8 hours.

colour than the front belt,[2] they appeared to operate smoothly on the drive pulleys (sheaves). The passenger did not recall any burning smell when the helicopter was on the ground at the precautionary landing site.

Following the inspection and a discussion of the drive belt serviceability, the passenger suggested that the pilot should shut down the helicopter and arrange via satellite telephone for their return to Doongan Station by other means. The pilot advised that the satellite telephone was unserviceable and reiterated that, in his opinion, the helicopter was capable of continuing the return flight to the station. The passenger elected to remain at the precautionary landing site, whereas the pilot decided that he would return the helicopter to Doongan Station to facilitate maintenance and arrange a vehicle to recover the passenger.

The passenger watched the helicopter take off and climb to an estimated altitude of 600 to 1,000 ft above ground level (AGL) for the flight to the station. Visual contact was lost with the helicopter after several minutes due to the terrain; however, owing to the calm conditions, the passenger could still hear the engine noise of the helicopter for some time.

Figure 2: Accident site location



The passenger reported that, about 30 to 60 seconds after losing sight of the helicopter, he heard a change in engine noise, consistent with what he believed was a reduction in engine power. Subsequently, described by the passenger as being within 1 minute, the engine sound was heard to increase to the original level. The noise level then remained constant for about a further 30 to 60 seconds before ceasing abruptly. In response, the passenger began walking along the road in the direction of the station.

After walking about 11 km, the passenger saw smoke and flames and, upon reaching the source of the smoke, discovered the wreckage of the helicopter adjacent to the road. The helicopter had been destroyed by impact forces and fire and the pilot had been fatally injured.

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2 The V-belts were constructed of black rubber.

Pilot information

The pilot held a Commercial Pilot (Helicopter) Licence that was issued on 30 May 1997. He was endorsed to fly the R22 helicopter and held a Class 1 medical certificate without restriction. The pilot also held an approval to conduct aerial stock mustering operations[3].

According to entries in the pilot's flying log books and records held by the helicopter operator, the pilot's total aeronautical experience up to the week before the accident was 7,084 flying hours. That experience was almost entirely obtained in R22 helicopters.

The pilot had ferried the helicopter to Doongan Station from Katherine, NT 2 days before the accident, a total flight time of about 5 hours, and had been free from duty until the morning of the accident flight.

The pilot's most recent flight review was conducted on 15 February 2006 in a Robinson Helicopter Company R44. The investigation was unable to determine the specific sequences that were covered during that flight review; however, the instructor who conducted the review advised that a practice autorotation would probably have been conducted, although not from low level. The most recent flight review in an R22 was conducted about 3 years before the accident on 25 June 2004. The pilot had also undergone a company check flight in an R22 on 1 May 2007, comprising confined area approaches and general handling.

The pilot had previously held a maintenance authority that permitted the conduct of limited maintenance on R22 helicopter engines. That authority expired in December 2002.

The owner of the helicopter reported that the accident flight was conducted under a private contractual arrangement between the pilot and the passenger. The passenger advised that the helicopter and pilot were used for the conduct of ad hoc spotting and survey tasks.

Aircraft information

Aircraft specifications

The aircraft was manufactured in the US in 2004 and registered to the owner in January 2005. The helicopter had a maintenance release issued in the charter category that was valid until 21 September 2008 or 2,201.0 hours in service. Due to the fire damage, it was not possible to accurately determine the helicopter's total time in service; however, based on the known operation of the helicopter since the last maintenance, the helicopter had been operated for a total of about 2,106 hours at the time of the accident.

The R22 is a two-seat, single main-rotor helicopter equipped with skid-type landing gear. The helicopter was powered by a four-cylinder Textron Lycoming O-360-J2A engine that was capable of producing up to 180 brake horsepower (BHP). The maximum allowable continuous power was 124 BHP, with a 5-minute take-off

3 CAO 29.10 defined aerial stock mustering as '...the use of aircraft to locate, direct and concentrate livestock while the aircraft is flying below 500 ft AGL and for related training purposes.'

rating of 131 BHP to prevent damage to the drive system and increase engine reliability. In order to ensure those power limits were not exceeded, the pilot was required to determine their corresponding manifold pressure limits[4] using an installed placard in the cockpit. When operating the helicopter, the pilot was required to monitor the manifold pressure gauge to ensure that the calculated power limits were not exceeded, as there was no mechanical limitation on the amount of power that could be applied.

Recent maintenance history

The R22 last underwent scheduled maintenance 4 days prior to the accident at 2,101 hours in service. That maintenance included the replacement of the V-belts with new (Revision Y[5]) belts due to cracks that were found in the previous set of belts, and the regreasing of the upper and lower V-belt tensioning actuator bearings. The operator advised that all maintenance was conducted in accordance with the procedures specified by the helicopter manufacturer. That included the alignment of the drive sheaves as a result of the replacement of the V-belts.

The daily inspection of the helicopter, which was required to be carried out before the first flight of each day, included a requirement to check the condition of the V-belts and degree of belt movement with the clutch actuator disengaged. The investigation was unable to determine if this inspection was carried out on the day of the accident. Due to the fire, it was not possible to determine if any unserviceable items had been entered on the maintenance documentation in the days following the routine maintenance.[6]

The pilot did not express any concern with the helicopter's serviceability to the passenger on arrival at the station, or during the short flight prior to the passenger detecting the burning smell. While on the ground at the precautionary landing site, the pilot advised the passenger that the helicopter owner had experienced problems with the new V-belts on a number of R22 helicopters. A review of HCN's maintenance history indicated that the V-belts had been replaced a total of six times after an average time in service for each belt set of 323 hours.

Weight and balance

Flight with the pilot as the only occupant

Weight and balance calculations indicated that the helicopter was operating about 100 kg below its maximum allowable gross weight of 622 kg and within the centre of gravity limits at the time of the accident. The manufacturer's performance data indicated that the helicopter was capable of hovering out of ground effect[7] at that time.

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4 An installed manifold pressure gauge was the only measure of engine power available to the pilot.

5 V-belts were manufactured to a specification; however, minor changes were annotated with a different revision status. Revision Y was the latest belt status at the time of the accident.

6 The maintenance release was carried in the helicopter in accordance with the regulations.

7 Helicopters require less power to hover close to the ground due to a cushioning effect created by the main rotor downwash striking the ground. Under those conditions, the helicopter is operating 'in ground effect'. The US Federal Aviation Administration's *Rotorcraft Flying Handbook* stated

Flight with the pilot and passenger on board

Calculations of the weight and balance of the helicopter during the portion of the flight with the passenger on board indicated that the helicopter was about 40 kg above the maximum allowable gross weight. In addition, operation with the passenger onboard exceeded the allowable seat weight[8], and the longitudinal and lateral centre of gravity limits.

Performance data provided by the helicopter manufacturer indicated that with the passenger onboard the helicopter, it would have been capable of hovering in ground effect[9], but that to hover out of ground effect would not have been possible without exceeding engine power limits. Given the confined nature of the departure and landing areas during the flight with the passenger on board, the helicopter would have been required to operate out of ground effect to ensure obstacle clearance.

The manufacturer advised that the operation of the helicopter outside the centre of gravity limits increased the likelihood of controllability problems due to reaching the limit of the available cyclic travel.

R22 rotor drive system

On the R22 helicopter, engine power was transmitted to the rotor system through a drive-belt system that consisted of two rubber double V-belts, running on matching multi-grooved sheaves (Figure 3). Both the upper and lower sheaves were constructed of aluminium alloy; with a thermally–sprayed, metallised coating applied to improve wear resistance.

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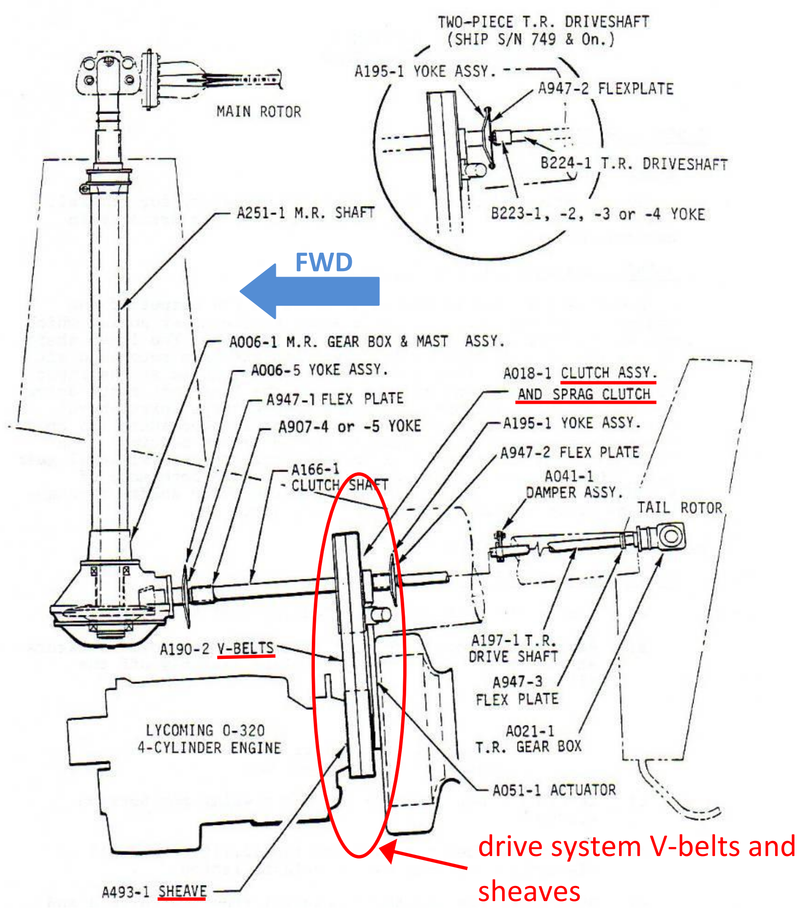
that flight in ground effect usually occurred at less than one rotor diameter above the surface (25 ft for an R22 helicopter). Operations above that height were defined as being conducted ‘out of ground effect’.

8 The maximum allowable weight per seat in the R22, including the stowage of any under-seat baggage, was 109 kg. Exceeding this limit increased the risk of the structural failure of the seat, particularly during an emergency landing sequence, with the resultant increased likelihood of severe injury to the seat occupant.

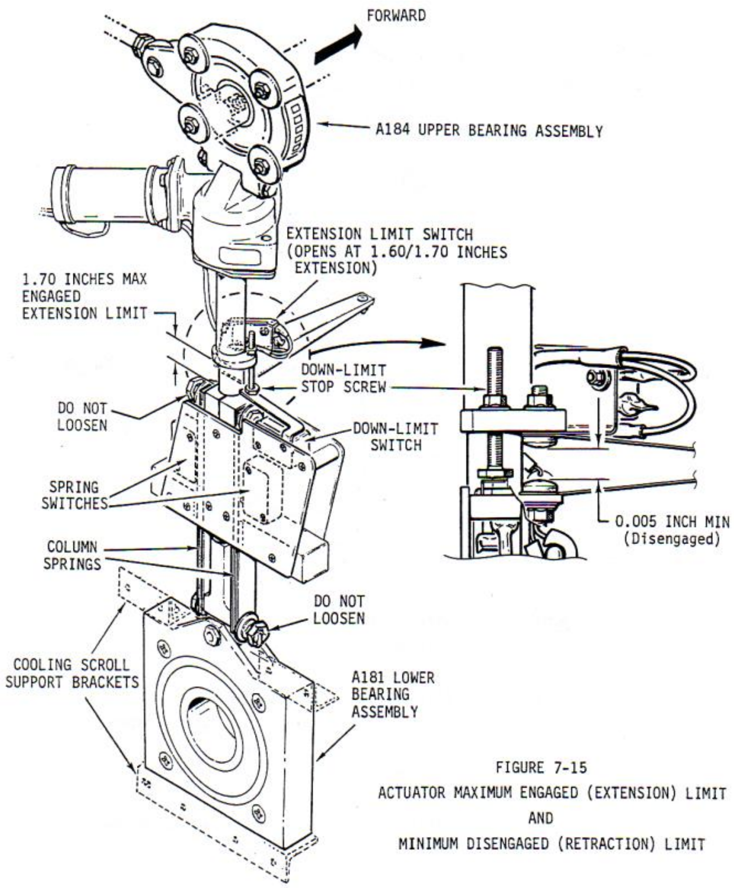
9 The manufacturer’s in ground effect performance data was based on the helicopter operating with a skid clearance of 2 ft above the ground.

Figure 3: R22 drive belt system



The upper drive sheave was mounted on the clutch shaft adjacent to a flexible coupling and could be moved relative to the engine-mounted drive sheave by means of an electric clutch actuator (Figure 4). That movement had the effect of varying the tension being applied to the belts.

Figure 4: Electric clutch actuator



During shutdown, the actuator was used to lower the top sheave to loosen the drive belts. During engine start, the belts were loose, allowing the engine to run without driving the rotor system. After engine start, the clutch switch located on the instrument console was selected by the pilot, powering the actuator to slowly move the top sheave up to the flight position and tighten the belts. The actuator was thereafter controlled by a load-sensing switch, which automatically maintained the correct belt tension during flight. Any movement of the electric actuator was indicated to the pilot by the illumination of a ‘clutch light’ that was positioned on the upper right side of the instrument panel.

The clutch shaft delivered power to the main rotor shaft through the main transmission and to the tail rotor via a separate drive shaft and gearbox. The upper sheave incorporated an over-running sprag clutch to allow the rotor system to continue rotating in the event of engine failure and to facilitate autorotation (see section on *Helicopter autorotation*).

Meteorological information

Observations of weather conditions were normally recorded at Doongan Station. However, due to activity associated with the accident, there were no recorded observations that day.

Observations at Mount Elizabeth Station (about 116 km south of Doongan Station) indicated fine, calm conditions at the approximate time of the accident. A Bureau of

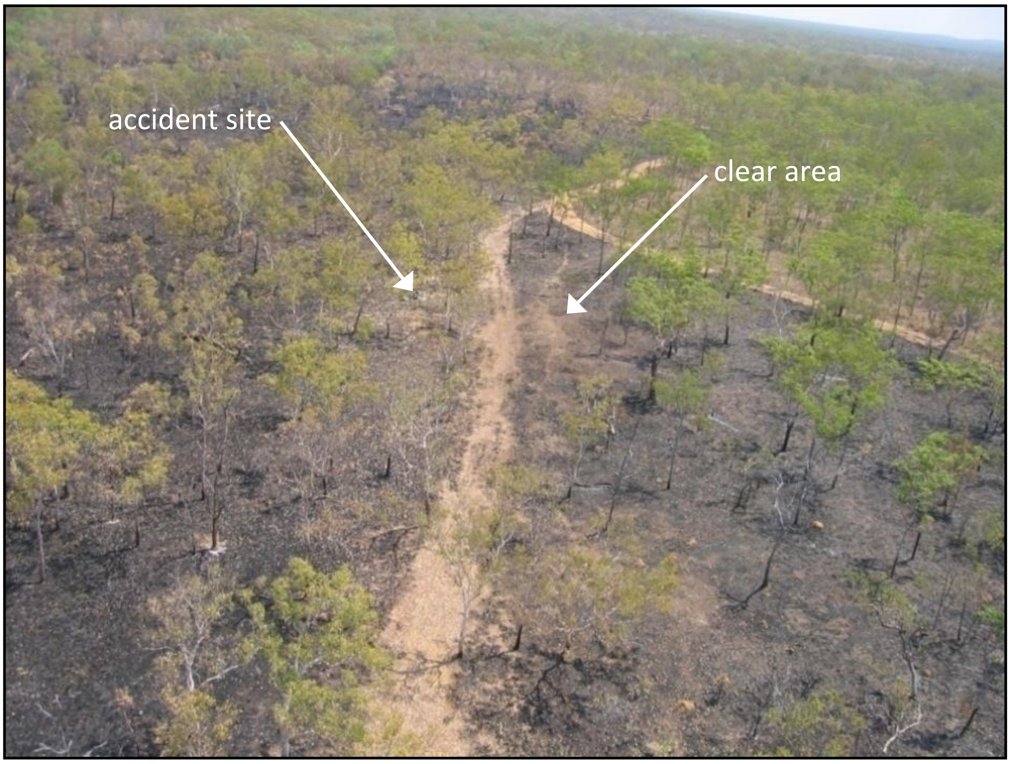
Meteorology (BoM) analysis stated that the weather conditions at Doongan Station were likely to have been similar to those at Mount Elizabeth Station, with the additional possibility of haze due to the high humidity and likelihood of smoke in the general area.

The passenger described the weather conditions on the morning as ‘still’.

Wreckage and impact information

The accident occurred over flat terrain with numerous small and medium eucalypt trees covering the site and surrounding area. The elevation of the accident site was about 1,200 ft above mean sea level (AMSL). Due to the surrounding trees, the accident site was not considered suitable to land an R22, although an adjacent clear area could have accommodated the helicopter (Figure 5).

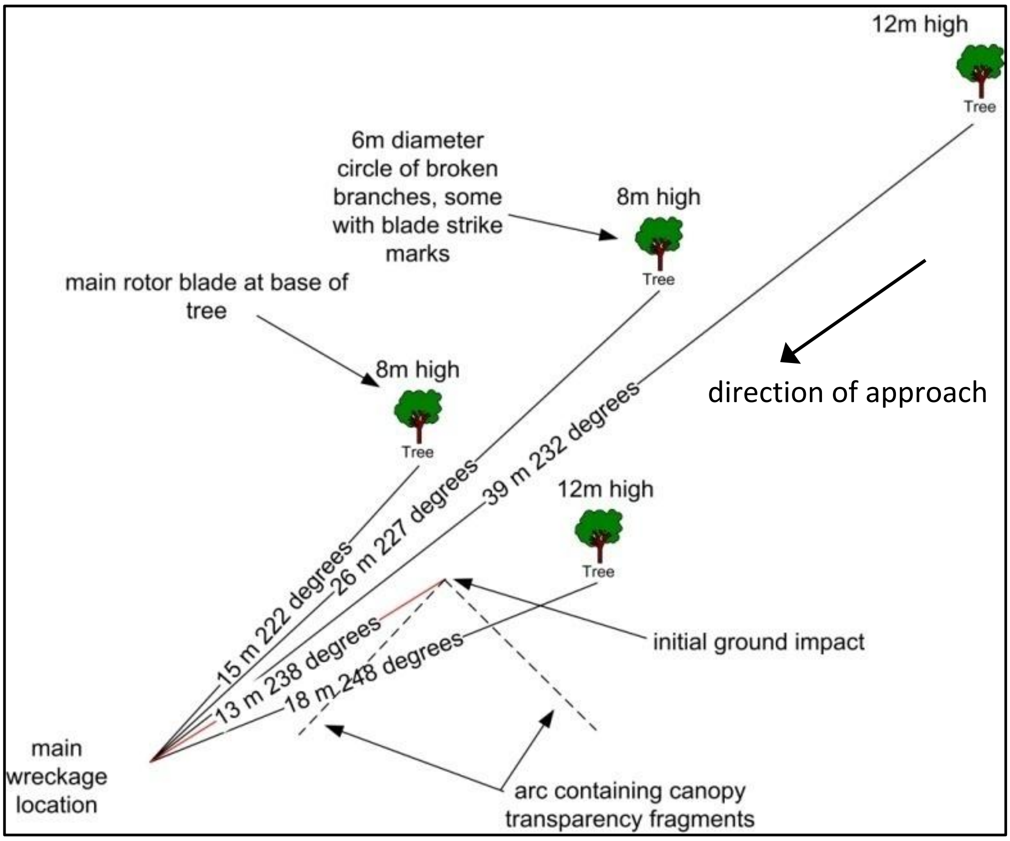
Figure 5: Accident site looking along the approximate flight path



The helicopter contacted four trees before impacting the ground in a steep nose-down, left skid-low attitude. The helicopter came to rest on its left side a further 13 m along the direction of approach (Figure 6). One of the main rotor blades had fractured and separated from the helicopter and was located about 15 m from the wreckage (Figures 6 and 7). A severe fire consumed the majority of the helicopter and ignited the surrounding vegetation.

Figure 6: Helicopter wreckage

Figure 7: Wreckage diagram



On-site examination of the wreckage accounted for all major parts of the helicopter. It was not possible to verify the integrity of the entire flight control system as sections of the aluminium control tubing were destroyed by fire. However, all steel components associated with the collective, cyclic and tail rotor pedal flight controls were found intact and secure. Examination of the main and tail rotor blades showed evidence of rotation at impact.

Both V-belts were destroyed by the fire, although charred remains of the V-belts were noted on the ground in the area of the engine and adjacent structure of the main wreckage. No evidence of the V-belts was found within the grooves of either the upper or lower sheaves.

A number of components were recovered for technical examination.

Examination of recovered components

The engine was examined at an approved engineering facility under the supervision of the Australian Transport Safety Bureau (ATSB). The remaining components were examined at the ATSB's facilities in Canberra.

Engine

The engine disassembly and inspection did not reveal any pre-impact defect or anomaly that would have prevented the engine from operating normally and, based on the evidence of rotation of the engine-driven alternator, the engine was rotating at the time of the collision. Furthermore, unlike a windmilling[10] propeller on a conventional aeroplane, the configuration of the helicopter drive system did not permit the engine to be turned by any external mechanism. Engine rotation was therefore indicative of engine operation. Due to the level of fire damage, it was not possible to verify the operation of the ignition system, including the magnetos.

Although there was evidence of engine operation, the specific power output of the engine at the time of the collision with terrain could not be determined.

Engine-driven alternator

The alternator was driven by the engine via a rubber drive belt. The rubber belt was destroyed by the fire; however, examination of the engine-driven alternator identified rotational scoring on the case and corresponding marks on the fan blade tips of the alternator. Given that a significant clearance is normally present between the fan and case, these marks were consistent with the alternator rotating at the time of the collision with terrain.

Main rotor blade

Inspection of the detached rotor blade indicated that the blade had contacted trees while rotating. The blade had fractured through the centre of a bolt hole in the blade's root fitting, and examination of that fracture surface indicated that the blade had been subject to overstress due to excessive bending loads consistent with the rotor blade striking the ground during the accident sequence.

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[10] The propeller of an inoperative engine could continue rotating due to the airflow that was produced by the forward speed of the aeroplane. That effect was known as 'windmilling'.

Drive sheaves

Examination of the upper drive sheave identified that the wear-resistant metallised coating was in a generally poor condition, with complete wear through to the aluminium alloy substrate in some areas.

Additionally, there was considerable variation in the primer wear pattern within the grooves of the upper sheave (Figure 8). The helicopter manufacturer advised that such variation in wear pattern was consistent with the front V-belt operating in a significantly damaged condition. The operator advised that the primer had been applied to the sheave as part of the recent replacement of the V-belts.

Figure 8: Upper sheave wear pattern

Sectioning of both sheaves indicated a variation in the thickness of the wear-resistant coating that was indicative of the helicopter's belt drive system operating out of alignment for some period of time. It was not possible to determine if the sheaves were misaligned at the time of the accident as the wear pattern could have been due to previous extended periods of misaligned operation. Examination of the sprag clutch and bearings (see section on *R22 rotor drive system*) did not reveal any damage, other than due to fire, which would have prevented normal operation.

Electric clutch actuator

Functional testing of the electric clutch actuator was not possible due to the degree of impact and fire damage, although the length of the actuator was found to be within the normal extension range for the type of V-belts fitted to the helicopter. Similarly, the dimension of the down-limit switch[11] was typical for a newly installed set of drive belts. Examination of the upper and lower actuator bearings did not reveal any damage, other than due to fire, which would have affected the operation of the bearings.

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[11] The down-limit switch determined the actuator retraction limit.

Medical and pathological information

A review of the pilot's aviation-related medical records and post-mortem examination found no evidence of any pre-existing medical disease, sudden illness, or incapacitation that may have affected his ability to operate the helicopter.

Toxicological analysis detected levels of carbon monoxide of less than 5% saturation. Ernsting et al (1999)[12] stated that this level was not sufficient to produce adverse affects, which can include nausea, headaches and drowsiness. Additionally, medical records indicated that the pilot was a smoker and, as such, that level of carbon monoxide was not considered significant.

Results of toxicological testing also detected the presence of cannabis compounds; the quantity and type of which the toxicologist reported were indicative of recent usage.

Additional information

Factors associated with V-belt failure

An investigation[13] of an R22 accident undertaken by the Transportation Safety Board of Canada (TSB) included the results of a review that was undertaken by the US Federal Aviation Administration (FAA) following a number of R22 drive belt failures or dislodgements. In discussing the FAA review, the TSB report stated:

> That [FAA] report noted that, in most cases, these problems have occurred with relatively new belts (less than 50 hours time-in-service) and have been associated with some combination of the following factors:
>
> • helicopter operation at high weight, or above gross weight conditions (sometimes compounded by turbulence);
>
> • improper sheave alignment at installation, or alignment shifts caused by initial belt wear-in;
>
> • sheave surface condition (new belts mounted on worn or corroded sheaves);
>
> • actuator tension being out of specification; or
>
> • excessive belt slack at initial engagement.

In addition to the V-belt failure or dislodgement events that were identified by the TSB and FAA, a number of similar Australian events were identified during the course of this investigation involving the failure of relatively new V-belts.

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12 John Ernsting, Anthony N Nicholson, David J Rainford (1999). *Aviation Medicine (Third Edition)* (pp 592-594). Hodder Arnold.

13 See http://www.tsb.gc.ca/eng/rapports-reports/aviation/2004/a04p0314/a04p0314.pdf

With regard to the effect on the V-belts of exceeding the helicopter's maximum gross weight, the helicopter manufacturer advised:

> Exceeding the maximum gross weight is an issue for the drive belts in that it is likely to lead to a condition where power limitations will be exceeded. The Lycoming O-360-J2A engine is capable of producing as much as 180 BHP compared to the maximum continuous rating of 124 BHP and 5 minute takeoff rating of 131 BHP for the helicopter. Torque is transmitted from the lower to upper sheave by a difference in belt tension between left and right sides. Exceeding manifold pressure limitations therefore leads to an excessive difference in tension. One half of the belt is subject to excessive slack in this condition and will be prone to vibrations and possible slippage that lead to belt damage and possibly causing one strand to move off the sheave, or splitting the strand from its backing to allow it to roll-over within the sheave groove. A misalignment of sheaves will exacerbate the tendency for one strand to move off the sheave.

Furthermore, in a notice to pilots relating to the conduct of ferry flights, the manufacturer stated:

> New V-belts are especially vulnerable at high power settings as they are still quite stiff and not yet broken in.

Concerning the smell of burning rubber experienced in-flight, the manufacturer's maintenance documentation stated:

> Advise all R22 pilots that the smell of burning rubber or a clutch light flickering or staying on for a longer than normal time may indicate an impending belt failure. Immediately pull the CLUTCH circuit breaker and land in the nearest open area where a safe normal landing can be made. Be prepared to enter full autorotation should a failure occur on the way down. Inspect the Vee Belts and actuator bearings for a possible impending failure.

The Emergency Procedures section of the *Robinson R22 Pilot's Operating Handbook* (POH) included the following symptoms of drive system failure:

> A drive system failure may be indicated by an unusual noise or vibration, nose right or left yaw, or decreasing rotor RPM while engine RPM is increasing.

Effects of overweight operation

In response to a request for information on the detrimental effect of operating overweight, the helicopter manufacturer stated:

> Exceeding the gross weight...is primarily detrimental to component fatigue lives and helicopter performance and handling, and may also cause immediate structural damage to the aircraft depending on how the aircraft is handled.
>
> ...Exceeding the gross weight will increase fatigue loads beyond those used in the calculation of fatigue life and therefore may cause a significant reduction in fatigue life. This is also addressed in Safety Notice SN-37.
>
> The certification requirements for helicopter performance and handling are only demonstrated up to aircraft weight and center [sic] of gravity limits, and therefore operations beyond these limits have the potential for increased pilot workload and insufficient performance for certain operations.

> There are no margins built into the weight limits defined for an aircraft. Although it may appear to the pilot that the aircraft is capable of normal operations at weights above the maximum, fatigue damage will accumulate at a rate higher than that anticipated, and loss of control is possible when encountering flight conditions associated with high pilot workload and/or requiring maximum engine power.

Helicopter autorotation

During the normal operation of a helicopter, the power required by the main rotor system to generate lift is provided by the engine. In the event of a loss of drive to the rotor system, due either to an engine or drive system failure, a helicopter is able to safely recover by entering autorotation. Autorotation is the condition where the main rotor blades are driven solely by airflow from beneath the rotor as the helicopter descends.

A necessary condition for autorotation is that the rotor blades must already be rotating. For this reason, it is essential that, on encountering a loss of drive to the rotor system, the collective is lowered to reduce the drag on the rotor and maintain the rotor revolutions per minute (RPM). In a low-inertia rotor system, such as found on the R22, the collective must be lowered immediately to prevent significant decay of the rotor RPM. The airspeed and rate of descent of a helicopter in autorotation, both of which are significantly higher than those of a normal landing, are reduced prior to ground contact using the kinetic energy stored in the rotor system.

All single-engined helicopters have a region of heights and airspeeds within which it is not possible to safely conduct an autorotative landing due to insufficient stored energy in the rotor system. This region is usually depicted on a Height-Velocity (HV) diagram (see Appendix A for the R22 HV diagram).

Effects of cannabis

The effect of cannabis usage on pilot performance was discussed in the ATSB research report, *Cannabis and its Effects on Pilot Performance and Flight Safety: A Review*[14]. In particular, the report stated:

> Cannabis causes impaired performance of complex tasks such as flying an aircraft. Flying skills deteriorate, and the number of minor and major errors committed by the pilot increase, while at the same time the pilot is often unaware of any performance problems.
>
> The more difficult the task required of the pilot, the more likely that carry-over effects of cannabis will result in impaired performance of the flying task. Thus a pilot may cope well with a routine flight in the 24 hours after a cannabis dose, provided nothing goes wrong. However, in-flight problems such as engine failure or deteriorating weather may overload the cognitive capacity of the pilot to a detrimental extent.
>
> On the basis of scientific research reviewed..., it would appear that a pilot should not fly an aircraft in the 24 hours following even a single dose of cannabis.

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14 Dr David G Newman (2004). *Cannabis and its Effects on Pilot Performance and Flight safety: A Review*, http://www.atsb.gov.au/media/36696/Cannabis_pilot_performance.pdf

On 22 September 2008, the Civil Aviation Safety Authority (CASA) introduced random testing of pilots, and other safety sensitive aviation personnel, for the presence of alcohol and other drugs (including cannabis). That testing regime is detailed in Civil Aviation Safety Regulations 1998 Part 99 *Drug and alcohol management plans and testing*.

ANALYSIS

The helicopter collided with terrain during the short flight from the precautionary landing site to Doongan Station. There were no direct witnesses to the accident and information obtained from the accident site was limited by fire and impact damage. Examination of the pilot's medical and post-mortem results found no evidence of any pre-existing medical condition or sudden illness that may have affected his ability to operate the helicopter. Similarly, the prevailing weather conditions on the morning of the accident were not considered to have been a factor. Therefore, the investigation considered the possible airworthiness and operational factors that could have contributed to the accident. The following analysis examines those factors.

Helicopter malfunction

The first indication of a potential problem with the helicopter prior to the accident was the burning smell that was detected by the passenger. The investigation considered a number of potential sources of the smell, specifically; the engine, the bearings associated with the clutch actuator and sprag clutch, and the rubber V-belts that provided drive to the alternator and to the helicopter's rotor system.

Due to the degree of fire damage, it was not possible to determine whether the engine may have been the source of the burning smell. However, detailed examination of the engine and the engine-driven alternator indicated that the engine was operating at the time of the collision with terrain. The possibility of a partial loss of engine power could not be discounted although, given the reduced operating weight of the helicopter at the time of the accident, a partial power loss would not necessarily have created an emergency situation. The evidence of alternator rotation also eliminated seizure of the alternator as a possible source of the burning smell.

The helicopter manufacturer's maintenance documentation advised that a burning rubber smell may be indicative of impending V-belt failure as a result of belt or actuator bearing damage. Examination of the clutch actuator and sprag clutch bearings found no evidence of damage that would account for the reported burning smell. Therefore, V-belt damage was isolated as the likely source of the burning smell. That was consistent with the findings from a number of other Australian V-belt failure or dislodgement events. V-belt failure or dislodgement was also identified as a factor in a number of US and Canadian R22 accidents. Fire damage prevented a direct assessment of the condition of the V-belts. However, technical examination of the upper sheave identified variation in the wear pattern that was indicative of a damaged front V-belt. Examination of the sheaves also identified poor surface condition of the upper sheave and evidence of wear on both sheaves, which was indicative of sheave misalignment. It was not possible to determine if the sheaves were misaligned at the time of the accident.

Although the helicopter was not operating at high gross weight at the time of the accident, the preceding flight exceeded the helicopter's maximum allowable gross weight and probably required its operation above the allowable manifold pressure limits. Advice from the helicopter manufacturer indicated that V-belts could be damaged by operation at excessively high power settings and that new belts, such as those installed on the helicopter, had an increased risk of damage.

The combination of overweight operation, poor sheave surface condition, sheave misalignment and relatively new V-belts were identified by the US Federal Aviation Administration (FAA) as factors that have contributed to the past failure or dislodgement of R22 V-belts.

The investigation considered the potential for factors such as engine power loss, flight control malfunction or other drive train failure to have influenced the development of the accident. None were supported by the available evidence. The pilot's observation following his examination of the V-belts after the precautionary landing, combined with the other available evidence, indicates that one or both of the belts were damaged prior to departure from the landing site on the accident flight. It is probable that the belts failed, or were dislodged from the drive sheaves during the return flight to the station, resulting in a loss of drive to the helicopter's rotor system.

Operational considerations

A loss of drive to the rotor system would have required the pilot to conduct an autorotative landing. The investigation considered a number of potential factors that may have contributed to the resulting accident.

The proximity of a suitable landing site adjacent to the accident location may have indicated that the pilot was attempting an autorotation to that site following the probable failure of the V-belts. In respect of the Height-Velocity diagram, since the operating height and airspeed of the helicopter were unknown, the extent of any alternate recovery options could not be verified.

The pilot's apparent lack of recency in the conduct of emergency procedures in the R22, and the potentially adverse effects of cannabis on the pilot's motor skills and cognitive capacity increased the risk of an unsuccessful autorotation. The investigation was unable to establish the degree of influence of these factors. The surrounding terrain was largely unsuitable for the conduct of an autorotative landing and, in this context, the effect of the initial contact with the surrounding trees may alone account for the severe outcome.

The investigation also considered the potential influence of the pilot's operational decisions on the development of the accident, and the factors which may have affected the pilot's decision making. Although the general effect of cannabis use included the impairment of cognitive function, particularly when under stress, the investigation was unable to quantify any influence that recent cannabis use may have had on the pilot's decision making.

The carriage of the passenger resulted in the operation of the helicopter beyond its allowable weight and centre of gravity limits. In addition to the detrimental effect on the V-belts, exceeding these limits also exposed the helicopter to potential controllability problems and an increased risk of structural failure. Although the pilot indicated an awareness of potential problems with new V-belts, the investigation could not determine if the pilot was aware of the implication of high power settings on new V-belts, as detailed in the helicopter manufacturer's ferry-flight notice.

The pilot's decision to assess the serviceability of the V-belts without shutting down the helicopter represented a missed opportunity to accurately determine the degree of any V-belt damage and the associated risk of continued operation. This decision may have been influenced by the pilot’s extensive experience operating R22 helicopters and his previously-held maintenance qualifications.

The decision to return the helicopter to the station after the precautionary landing, despite assessing that one of the V-belts was damaged, further subjected the drive belts to load and increased the risk of rotor drive failure. This decision, perhaps influenced by the; proximity of the station, the inoperative satellite telephone, and the pilot’s desire to facilitate maintenance access to the helicopter, probably contributed to the development of the accident.

FINDINGS

From the evidence available, the following findings are made with respect to the collision with terrain that occurred at Doongan Station, WA on 25 September 2007 and involved Robinson Helicopter Company R22 Beta II, registration VH-HCN. They should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing safety factors

- It is probable that the V-belts failed or were dislodged from the drive sheaves resulting in a loss of drive to the rotor system and necessitating an autorotative landing over inhospitable terrain.
- The pilot’s decision to return the helicopter to the station without shutting down to visually inspect the V-belts probably contributed to the development of the accident.

Other safety factors

- During the flight immediately preceding the accident flight, operation of the helicopter outside of the centre of gravity limits, and at a gross weight that exceeded the maximum allowable for the helicopter, increased the risk of controllability issues, component fatigue and V-belt damage.
- The recent use of cannabis by the pilot increased the risk of impaired motor skills and reduced cognitive capacity; in particular, in response to in-flight problems, such as an engine or rotor system drive failure.
- V-belt failure or dislodgement was identified as a factor in a number of overseas and Australian R22 accidents. *[Safety issue]*

SAFETY ACTION

The safety issues identified during this investigation are 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.

Depending on the level of risk of the safety issue, the extent of corrective action taken by the relevant organisation, or the desirability of directing a broad safety message to the aviation industry, the ATSB may issue safety recommendations or safety advisory notices as part of the final report.

Failure of R22 helicopter rotor drive system

Safety issue

V-belt failure or dislodgement was identified as a factor in a number of overseas and Australian R22 accidents.

Safety action taken by the Civil Aviation Safety Authority

In response to a number of R22 helicopter rotor drive system failures, on 14 August 2009, the Civil Aviation Safety Authority (CASA) issued airworthiness bulletin, AWB 63-006 *Issues related to the Robinson Helicopter Corporation (RHC) R22 main rotor drive system*. The purpose of the bulletin was to:

> **a.** Provide Operators and Maintainers' a consolidated summary of investigations carried out by CASA Airworthiness Specialists based on several information resources including CASA received SDRs,
>
> **b.** to remind maintainers and operators of the need to strictly adhere to the requirements of all current RHC approved data for the operation and maintenance of the R22, and
>
> **c.** provide a guide to the information available, including RHC data in relation to main rotor drive system with emphasis on the main rotor drive vee-belts (also known as the main drive belts).

CASA also advised that future relevant operational information regarding rotor drive systems failures would continue to be disseminated through advisory material and Directives.

ATSB assessment of action

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

Safety action taken by the ATSB

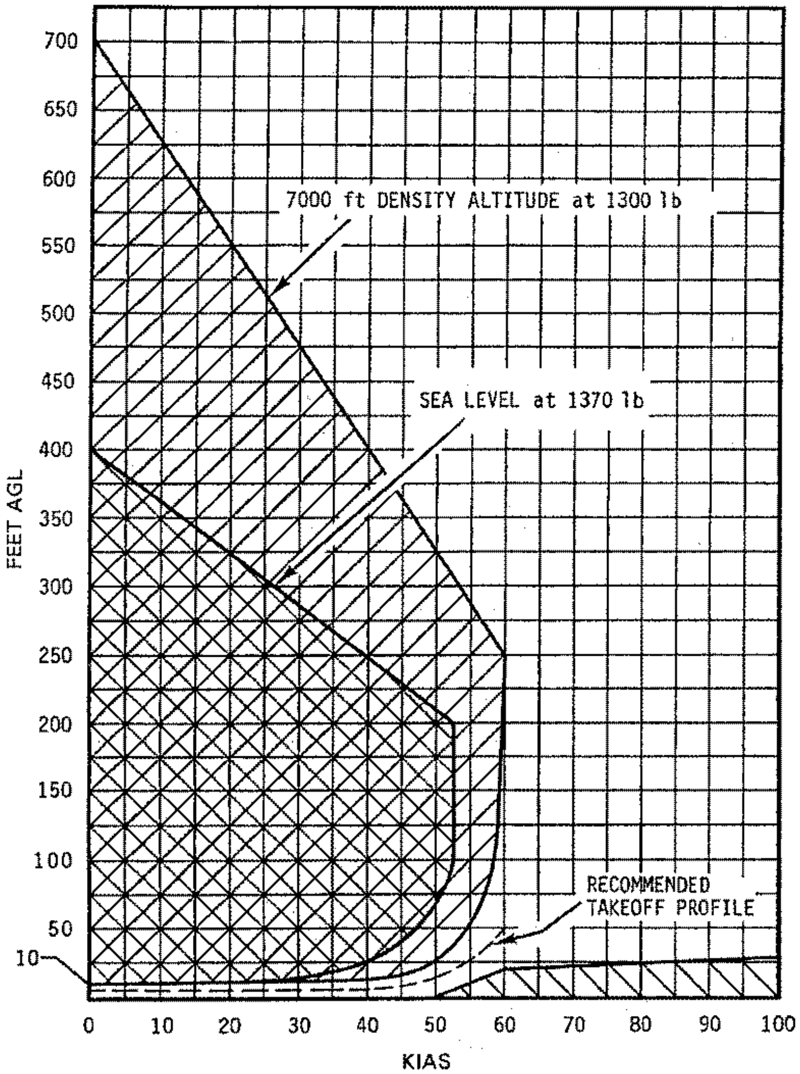
In response to this accident, and a number of other occurrences involving failure of R22 helicopter V-belts, the ATSB has commenced a safety issue investigation regarding the reliability of Robinson Helicopter Company model R22 drive belt systems. (ATSB investigation AI-2009-038). The results of that investigation will be published on the ATSB website www.atsb.gov.au

APPENDIX A: R22 HEIGHT-VELOCITY DIAGRAM

ROBINSON **SECTION 5**
MODEL R22 **PERFORMANCE**

DEMONSTRATED CONDITIONS:
SMOOTH HARD SURFACE
WIND CALM
103-104% RPM

AVOID OPERATION IN SHADED AREAS



HEIGHT - VELOCITY DIAGRAM

FAA APPROVED: 13 OCT 2000 **5-10**

APPENDIX B: SOURCES AND SUBMISSIONS

Sources of Information

The sources of information during the investigation included the:

- passenger onboard VH-HCN on the flight preceding the accident
- helicopter operator
- helicopter manufacturer
- Western Australia Police
- Civil Aviation Safety Authority (CASA)
- Bureau of Meteorology (BoM)
- Transportation Safety Board of Canada.

References

Dr David G Newman (2004). *Cannabis and its Effects on Pilot Performance and Flight safety: A Review*, ATSB research report.

Shawn Coyle (2002). *Cyclic and Collective – Further Art and Science of Flying Helicopters.* Helobooks, a Division of Mojave Books Limited.

Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the Transport Safety Investigation Act 2003, 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 passenger on the flight preceding the accident, the helicopter operator, CASA, the US National Transportation Safety Board and the helicopter manufacturer.

A submission was received from CASA. The submission was reviewed and, where considered appropriate, the text of the report was amended accordingly.

Collision with terrain Doongan Station, WA, 25 September 2007,
VH-HCN Robinson Helicopter Company R22 Beta II