HELICOPTER ACCIDENT REPORT AND EXECUTIVE SUMMARY

			Reference:	CA18/2/3/9688	
Helicopter registration	ZS-HKZ	**Date of accident**	28 February 2018	**Time of accident**	0945Z
Type of helicopter	Robinson R44 Raven II		**Type of operation**	Private (Part 91)	
Pilot-in-command licence type	Private Pilot	**Age**	57	**Licence valid**	Yes
Pilot-in-command flying experience	Total flying hours	157.9		Hours on type	157.9
Last point of departure	Farm Truter Boerdery near Ogies, Mpumalanga Province				
Next point of intended landing	Farm Truter Boerdery near Ogies, Mpumalanga Province				
Location of the accident site with reference to easily defined geographical points (GPS readings if possible)					
Farm Truter Boerdery (GPS position: 26°2'12.79" South 028°53'56.06" East) at an elevation of 4944 ft					
Meteorological information	Surface wind: 080°/6kt, Temperature: 25°C, Dew point: 12°C, QNH: 1023				
Number of people on board	1 + 1	**No. of people injured**	0	**No. of people killed**	2

Synopsis

On Wednesday 28 February 2018 a pilot, accompanied by a passenger on board the helicopter, took off from Truter Boerdery farm in Ogies (Mpumalanga Province) on a private flight with the intention to land at the same farm. Good weather conditions prevailed at the time leading to the accident. The flight was conducted under the provisions of Part 91 of CARs 2011 as amended.

A witness on the ground who is a worker in the farm saw the helicopter flying at a height of approximately 100m (328ft) above ground level (AGL) in the northerly direction when he heard a loud bang followed by an engine noise change. Shortly afterwards he observed the tail section separating from the helicopter as it spiralled out of control to the right in a nose-down attitude until it crashed and caught fire near a farm dam. A post-impact fire erupted and consumed the helicopter. The severed tail section was found approximately 350 m away South West from the main wreckage. The eyewitness ran inside the workshop to collect fire extinguisher before he rushed to the scene and used approximately eight dry powder fire extinguishers in order to contain the fire. The helicopter was destroyed and both occupants were fatally injured.

The investigation revealed that the main rotor blade severed the tail section in flight during a steep turn to the right. As a consequence, the helicopter spiralled to the right in a nose-down attitude, crashed and caught fire. The cause of the main rotor severing the tail cone was a result of an incorrect technique during the execution of the steep turn.

Probable cause

The main rotor severed the tail boom section during the execution of a steep turn at low RPM, which resulted in the helicopter spiralling in a nose down attitude to the ground.

SRP date	12 February 2019	Release date	21 February 2019

Name of Owner	**:** Truter Boerdery Trust
Type of Operation	**:** Private (Part 91)
Manufacturer	**:** Robinson Helicopter Company
Model	**:** R44 Raven II
Nationality	**:** South African
Registration Markings	**:** ZS-HKZ
Place	**:** Farm Truter Boerdery, Ogies, Mpumalanga Province
Date	**:** 28 February 2018
Time	**:** 0945Z

All times given in this report are Co-ordinated Universal Time (UTC) and will be denoted by (Z). South African Standard Time is UTC plus 2 hours.

Purpose of the Investigation:

In terms of Regulation 12.03.1 of the Civil Aviation Regulations (2011) this report was compiled in the interest of the promotion of aviation safety and the reduction of the risk of aviation accidents or incidents and ***not to apportion blame or liability.***

Disclaimer:

This report is produced without prejudice to the rights of the CAA, which are reserved.

1. FACTUAL INFORMATION

1.1 History of Flight

1.1.1 On Wednesday 28 February 2018 at 0945Z, a pilot, accompanied by a passenger, embarked on a private flight in the vicinity of the Truter Boerdery farm. The flight was conducted under visual flight rules (VFR). Fine weather conditions prevailed at the time leading to the accident.

1.1.2 According to an eyewitness who was standing at a distance of approximately 580m between the hangar and the wreckage, the helicopter flew for approximately 20 minutes in the vicinity of the farm while performing manoeuvres at a height of approximately 100 m (328 ft) above ground level (AGL). Some of the manoeuvres that the pilot was performing included out of ground effect (OGE) hover turns, as well as steep turns as demonstrated to the witness by the investigators using a helicopter model. The witness further stated that the helicopter was flying in the northerly direction when he heard a loud bang; this was followed by the engine noise change. He then saw what looked like the end of the tail section separating from the tail boom in-flight. The helicopter then spiralled uncontrollably, rotating nose right (clockwise when viewed from above) while descending nose down and crashed near the farm dam. A post-impact fire immediately erupted. He stated that the pilot was practising for his licence renewal which was scheduled to take place in the near future. The witness further stated that the pilot uplifted fuel before take-off.

1.1.3 The severed tail section was found 350 m away from the main wreckage. The main wreckage was destroyed by impact and post-impact fire. The main components of the helicopter were contained in the area of the crash site which was spanning approximately 350m in diameter. The wreckage was lying on its left side, facing in a northerly direction. Both occupants were fatally injured.

1.1.4 The eyewitness further stated that he rushed to the scene and used approximately eight dry powder fire extinguishers that were inside the workshop at the farm to contain the fire. The other workers plus the fire fighters from the farm also rushed to the scene and applied water to the burning wreckage. The police and emergency services were alerted and they arrived on the scene approximately 30 to 40 minutes later.

1.1.5 The accident occurred during day light conditions at a geographical position that was determined to be 26°2'12.79" South 028°53'56.06" East, at an elevation of 4944 ft above mean sea level (AMSL).

Figure 1: Google Earth overlay of the accident site

1.2 Injuries to Persons

Injuries	Pilot	Crew	Pass.	Other
Fatal	1	-	1	-
Serious	-	-	-	-
Minor	-	-	-	-
None	-	-	-	-

1.3 Damage to Helicopter

1.3.1 The helicopter was destroyed.

1.4 Other Damage

1.4.1 None.

1.5 Personnel information

1.5.1 Pilot-in-command (PIC)

Nationality	South African	Gender	Male	Age	57
Licence number	xxxxxxx	Licence type	Private		
Licence valid	Yes	Type endorsed	Yes		
Ratings	None				
Medical expiry date	31 January 2019				
Restrictions	Corrective lenses				
Previous accidents	On 24 February 2016 the pilot was involved in an accident with the same helicopter. CA18/2/3/9521				

(i) The pilot started his helicopter training in January 2016 and was issued with a student pilot licence. He then renewed his student pilot in Jan 2017 whereafter he applied for a private pilot licence (PPL) in March 2017 which was issued in April 2017.

(ii) The pilot was the holder of a PPL on a helicopter. He kept his pilot licences valid and owned a helicopter at the time of the accident.

(iii) According to the available information (pilot logbook), his first training flight on helicopters was on 05 January 2016, and on February 2016 he stopped flying for unknown reasons. He then did a recap with another aviation training school in September 2016. He continued with his training until he was signed for a PPL in 30 March 2017. The required paperwork was submitted on the same day to the regulating authority and he was issued with a PPL (helicopter) in April 2017. His last flight skills test (helicopter) was conducted on 30 March 2017. It was further noted that the majority of his helicopter flying hours entered in his logbook was conducted on the helicopter in question (ZS-HKZ), including his flying training. A copy of the pilot's helicopter flying logbook was made available in a photocopy format to the investigator. The last entry in his logbook was 09 February 2018, with his helicopter flying hours computed to be 157.9 hours.

NOTE: There was a six-month period where no documented evidence was available on the pilot's helicopter flying logbook. According to the copy of the pilot licence obtained from the SACAA licencing division, the pilot had a R22 type endorsed on his rating. However, there were no records found on his logbook for R22 flying.

Flying experience (helicopter):

Total hours	157.9
Total past 90 days	12.2
Total on type past 90 days	12.2
Total on type	157.9

1.6 Helicopter Information

1.6.1 The Robinson R44 Raven II Pilot Operating Handbook (POH) describes the helicopter systems as follows:

The Robinson R44 is a four-seater, single main rotor, single-engine helicopter constructed primarily of metal and equipped with skid-type landing gear. The primary fuselage structure is welded steel tubing and riveted aluminium sheets. The tail cone is a monocoque structure in which aluminium skins carry most primary loads. Fiberglass and thermoplastics are used in various other cabin structures, engine cooling shrouds and various other ducts and fairings.

The flight controls are dual flight controls as standard equipment, and all primary controls are actuated through push-pull tubes and bell cranks. Bearings used throughout the control system are either sealed ball bearings or have self-lubricated Teflon liners. Flight controls are conventional. The cyclic stick appears to be different, but the grip moves the same as in other helicopters due to the free hinge at the centre pivot. The cyclic grip is free to move vertically, allowing the pilot to rest his forearm on his knee if he chooses. The collective stick is also conventional, with a twist-grip throttle control. When the collective is raised, the throttle is opened by an interconnecting linkage. An electronic governor makes minor throttle adjustments required to maintain revolutions per minute (RPM).

Figure 2: Robinson R44 helicopter (photograph courtesy of Google)

Airframe:

Type	Robinson R44 Raven II	
Serial number	13253	
Manufacturer	Robinson Helicopter Company	
Year of manufacture	2012	
Total airframe hours (at time of accident)	346.0	
Last MPI (hours & date)	319.3	4 October 2017
Hours since last MPI	26.7	
C of A (issue date)	18 October 2017	
C of A (expiry date)	19 October 2018	
C of R (issue date) (Present owner)	05 October 2017	
Operating categories	Standard Part 127	
Previous accident	The helicopter was involved in an accident on 24 February 2016. It suffered major structural damage as a result of the accident sequence. SACAA accident reference number CA18/2/3/9521.	

Note: According to the airframe logbook, page 4, the helicopter was involved in a hard landing that occurred on 24 February 2016 at 213.5 airframe hours. Hard landing repairs were carried out in accordance with manufacturer specifications by an approved AMO. All work carried out was released under CRMA 3247 on page 89 of the airframe log book following the occurrence.

The flight folio was retrieved from the operator’s office. According to the flight folio serial no 008, the last entry was recorded on 09 February 2018, with a total of 108 lt of fuel on board. The hours that the helicopter flew that day was a total of 1 hour 45 min.

Engine:

Type	Lycoming IO-540-AE1A5
Serial number	L-34723-48E
Hours since new	346.0
Hours since overhaul	TBO not yet reached

Main rotor blades:

Part number	C016-7	
Serial numbers	6585	7116
Hours since new	127.83	
Hours since overhaul	TBO not yet reached	

Main gearbox:

Part number	C006-7
Serial number	8944
Hours since new	127.83
Hours since overhaul	TBO not yet reached

Main drive shaft:

Part number	C251-2 Rev Q
Serial number	R8291
Hours since new	127.83
Hours since overhaul	TBO not yet reached

Tail rotor blades:

Part number	C029-3	
Serial numbers	5590	5594
Hours since new	127.83	
Hours since overhaul	TBO not yet reached	

Tail gearbox:

Type	C021-1 Rev L
Serial number	5847
Hours since new	127.83
Hours since overhaul	TBO not yet reached

Weight and balance

According to the available information, 94 lt (24 US gallons) of fuel was uplifted prior to the flight. According to the available information on the flight folio, the helicopter was last flown on 9 February 2018. Prior to that flight, 108 lt (28 US gallons) of fuel were uplifted and the duration of the flight was approximately 1 hour and 45 min. According to the witness on the day of the accident, the pilot was airborne for approximately 20 min. The average fuel consumption for this helicopter type was 57 lt or 15 US gallons per hour. The helicopter consumed approximately 18 lt or 5 US gallons during the flight in question. The fuel that remained in the tanks would have been substantial. According to the weight and balance calculation, the centre of gravity was well within the limit as recommended by the manufacturer on this type of helicopter before the flight. For the purpose of calculations the weight of the occupants used on the weight and balance calculation form were obtained from the pathologist. The weight and balance calculation is attached on this report as appendix B.

1.7 Meteorological Information

1.7.1 An official weather report was obtained from the South African Weather Services (SAWS). The closest automatic weather station where data was recorded at the time of the accident was at Witbank in Mpumalanga Province, which was also the closest weather station to the accident site.

Wind direction	080°	Wind speed	6 kts	Visibility	Unknown
Temperature	25°C	Cloud cover	Unknown	Cloud base	Unknown
Dew point	12°C				

1.8 Aids to Navigation

1.8.1 The helicopter was equipped with standard navigational equipment as required by the manufacturer for this type helicopter. No defects that rendered the navigation system unserviceable were recorded prior to or during the flight.

1.9 Communication

1.9.1 The helicopter was equipped with standard communication equipment as required by the manufacturer for this helicopter type. No defects that rendered the communication system unserviceable were recorded prior to or during the flight.

1.10 Aerodrome Information

1.10.1 The accident did not occur at or close to an aerodrome.

1.11 Flight Recorders

1.11.1 The helicopter was not equipped with a flight data recorder (FDR) or a cockpit voice recorder (CVR), nor was either required by the regulations to be fitted to this helicopter type.

1.12 Wreckage and Impact Information

1.12.1 **Main wreckage:**

The helicopter was seen manoeuvring in the vicinity of the dam in the Truter Boerdery farm area in Ogies. Following the manoeuvres, the main rotor blade severed the tail section in-flight. Both the tail section and the main wreckage were located approximately 350 m apart. The wreckage layout indicated that the tail cone had broken away from the fuselage before the helicopter struck the ground in a spiral turn to the right. The distribution of the small parts of the cabin was consistent with the main rotor striking the cockpit area after impact with the ground. The main wreckage impacted the ground hard, while the nose spiralled to the right, which is consistent with the shift in the centre of gravity and main rotor RPM that is very low or possibly stalled. The main wreckage came to rest lying at an angle of 15°. The cabin was fragmented in small pieces, indicative of main rotor strike which was consistent with the facial injuries observed at the scene. The instrument panel was lying on its left with the major instruments still attached to it. Both skids had bowed outwards and the forward uprights had broken away from the skid attachment points. In addition, the heels of the skid broke off from the midsection. The main gearbox was lying on its left side and still coupled with the mast and the main rotor hub. The main wreckage was intact, with the major components still attached as seen in Figure 3 below. The auxiliary and the main fuel tank dislodged and were located at approximately 3 m and 1 m respectively from the wreckage. The tanks were deformed as a result of the impact. It could not be determined whether the tank had fuel inside although the area where the helicopter was resting had burnt out. The main wreckage was engulfed by fuel-fed fire, which subsequently burned some small vegetation around the wreckage. The grass vegetation at the accident site was green. The portion that burned was a result of fuel spillage caused by the ruptured fuel tank after impact, which led to the fuel-fed fire. The right-hand front cockpit door retainer with the vent door of the right cockpit door attached to it was lying on top of the main rotor blade. The impact on the retainer indicated that the leading edge of the main rotor blade had imprinted a dent on it as seen in Figure 4. The helicopter was consumed by fuel-fed fire which erupted after the crash. Only the last section of the tail boom, skid gear and half of the blade didn't catch fire.

Figure 3: The main wreckage destroyed by the post impact fire

1.12.2 **Rotor system:**

The main rotor blades were still attached to the main rotor hub. One of the blades was completely consumed by post-impact fire. The leading edge made of stainless steel had no impact marks while the other blade was consumed by fire from the root to the midsection only. The burnt blade didn't have signs of blade disintegration, as seen in Figure 6 below. The unburnt section of the main rotor blade didn't reveal any sign of disintegration or deformity, but it signifies a compression load on the top surface, and the trim tab was still attached to it; however, the blade was bent upwards in a curly position, indicative of damage caused by contact with the ground on the blade that was not rotating at full speed. The main rotor blade tip caps were still attached at the end of the blades. The balancing weights were still attached and secured to the blade ends. The inner part of the blade root was crushed, as seen in Figure 6, which is indicative of severe flapping. The main rotor hub was still intact, with the blade root attached to it. The pitch change links broke off in the middle, due to overload. The scissor link assembly broke off. All control tubes broke of ±70 mm near the clevis holes (eye end). It appears that one of the main rotor blades had rotated 135° (see Figure 6 of the main rotor head). The swash plate was still intact and had no signs of failure prior to impact. The mast was still intact, although it was bent slightly. The teeter stops were crushed and the plate was bent, which is indicative of hub assembly contact.

Figure 4: Shows burnt honeycomb core and composite material

Figure 5: The visible outer section of one of the main rotor blades

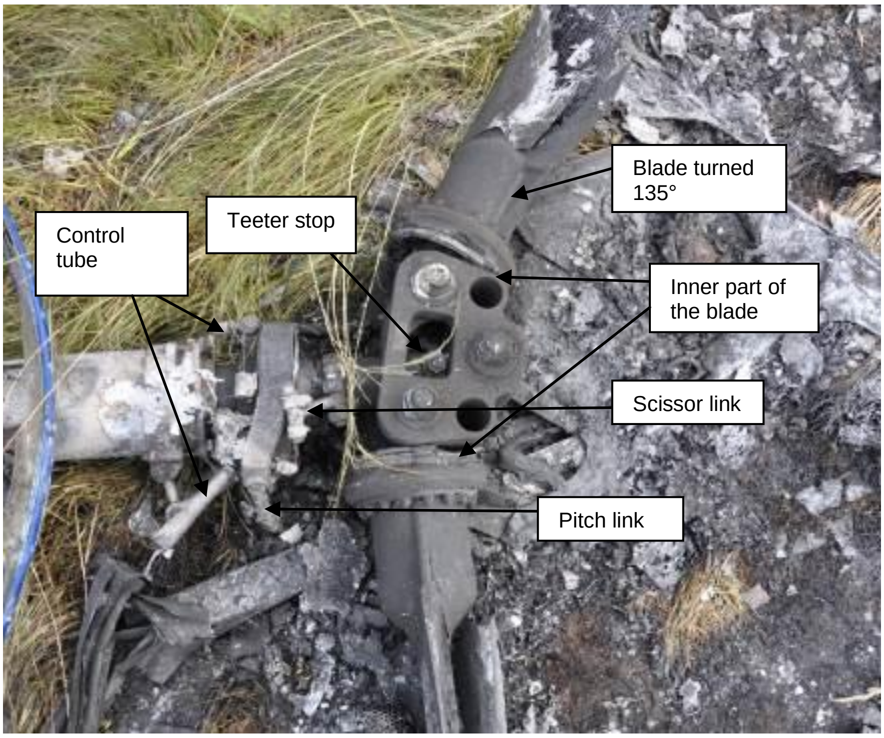


Figure 6: The main rotor hub assembly

1.12.3 **Transmission system:**

The main rotor gearbox was still intact with the mast attached to it. The gearbox was detached from the mounting and lying on its left side. The outside condition of the gearbox was good, except for damages caused by the impact and the post-impact fire. The upper sheath was lying between the cross tubes and had no visible score marks on the side that indicate rotation or not at impact. The flex plate was bent where it attaches to the driveshaft, which is indicative of sudden stoppage. The V-belts burned off completely. It could not be confirmed whether they were at tension or loose at impact. There was evidence of oil inside the transmission; however, the casing had cracked due to impact forces.

1.12.4 **Powerplant:**

The engine broke off from the mounts and the cooling fan was disrupted, which is indicative of damage caused when the engine was producing some power. The air pipes were observed to be burnt and the right-hand pipe sustained minor burns only. The exhaust mufflers were still attached to the engine but were squashed. The air intake pipes were detached as a result of the impact. The squirrel cage cooling fan was disrupted, displaying signs of rotational impact marks. The oil cooler housing had an imprint of the ring gear, similar to marks made by gear teeth when the engine is not operating at full RPM.

Figure 7: Yellow paint mark and blade imprint.

1.12.5 **Tail section:**

The tail section was located at a distance of approximately 350 m from the main wreckage, as seen in Figure 8 below. Observation of the impact point indicated that the main rotor blade severed the tail section in-flight. The yellow paint imprints on the impact point and the imprint were consistent with the yellow paint used on the main rotor blade tips. The tail drive shaft was severed at the same time as the tail section. The yellow paint imprints were visible on the tail drive shaft, as observed on the accident scene. The tail rotor control tube was located a distance of 5 m from the main wreckage. Observation revealed that it became dislodged when the helicopter impacted the ground. The tail rotor gearbox was turning freely, and no signs of oil leaks were observed around the housing. The temperature strip indicated 66°C, which was consistent with normal operation, as seen in Figure 11. The tail rotor blades were still intact with the output shaft. The damages observed on the tail rotor blades were as a result of the impact with the ground and they indicated damages caused by the impact on a stationary blade. The compression loads on the vertical stabiliser indicated that the tail cone impacted the ground with the vertical stabiliser first and then the tail rotor hub, as seen in Figure 9.

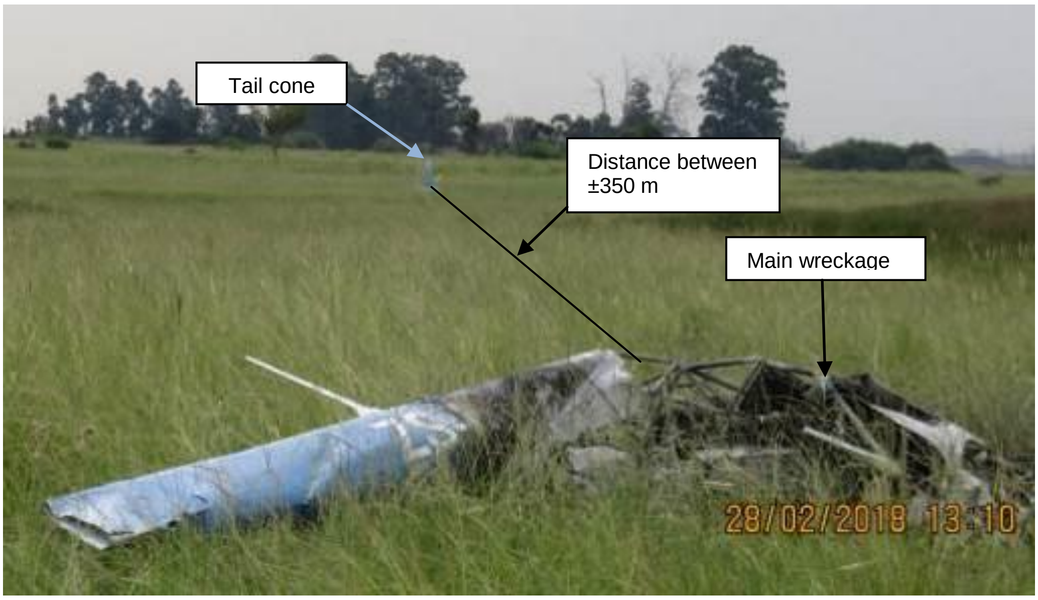


Figure 8: Shows the main wreckage and tail section

Figure 9: Shows a picture of the tail rotor blades assembly

Figure 10: Shows the picture of the severed tail cone by the main rotor blades

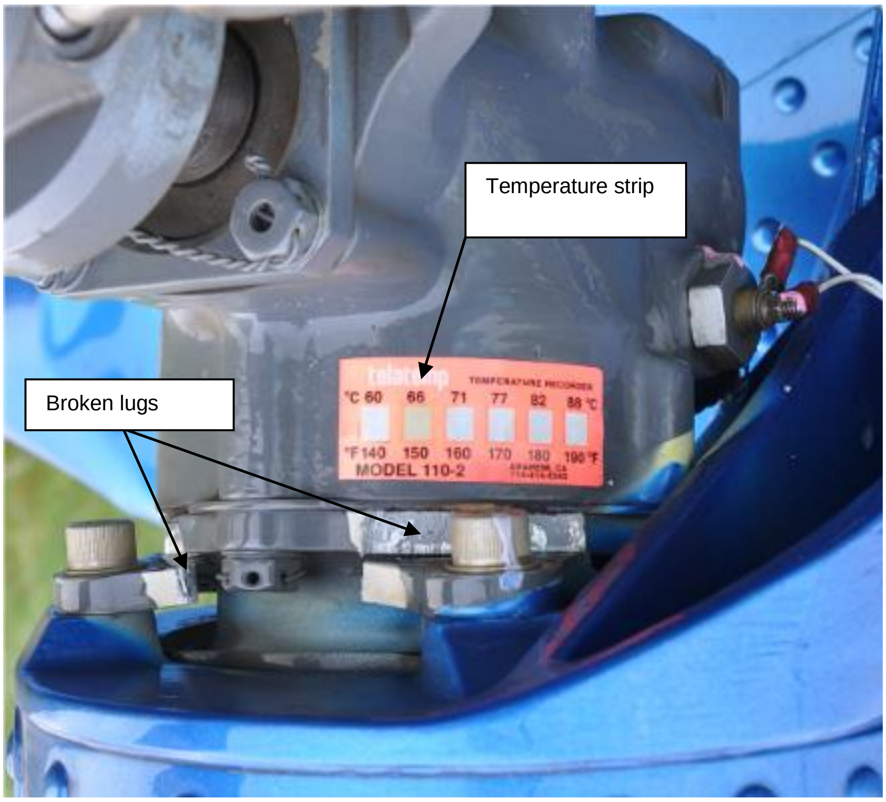


Figure 11: Shows the temperature strip on the tail rotor gearbox

1.13 Medical and Pathological Information

1.13.1 By the time this report was concluded the post-mortem reports had not yet been received from the Department of Health. Should there be anything in the reports that could change the probable cause of this investigation a revised report will be issued.

1.14 Fire

1.14.1 The main wreckage was consumed by the fuel-fed post-impact fire.

1.15 Survival Aspects

1.15.1 The accident was not considered to be survivable due to the cockpit structure of welded steel tubing and riveted aluminium sheeting, which was destroyed. The helicopter was equipped with safety harnesses, but due to the damage on the seats and fire that erupted, it could not be confirmed if the harnesses were used by the occupants.

1.15.2 The helicopter was engulfed by fuel-fed fire that erupted after the impact. The fire consumed most of the fuselage and started a small veld fire in the area of impact.

1.16 Tests and Research

1.16.1 The engine, a Lycoming IO-540-AE1A5, serial number L-34723-48E, was removed from the wreckage. Due to the impact damage it was not possible to subject the engine to a bench test procedure; therefore, a teardown inspection was conducted on Monday, 6 July 2018. Both magnetos were badly damaged and it was not possible to subject them to a bench test. According to the engine teardown inspection there were no anomalies found.

1.17 Organisational and Management Information

1.17.1 According to the available information this was a private flight. The pilot, who was also the owner of the helicopter, was preparing for his upcoming renewal of his private pilot licence.

1.17.2 The last maintenance inspection prior to the accident flight was certified on 4 October 2017 by an AMO that was in possession of a valid AMO approval certificate. No mechanical defect with the helicopter was recorded on the flight folio prior to the accident flight.

1.17.3 The maintenance records indicated that the helicopter was equipped and maintained in accordance with existing regulations and approved procedures.

1.17.4 The helicopter was in possession of a valid certificate of airworthiness.

1.18 Additional Information

1.18.1 The following information was sourced from the Robinson POH and Helicopter flight training manual TP 9982.

1.18.2 *STEEP TURNS (FAA 8083-21Helicopter flying handbook)*

Steep turns are a means of turning the helicopter in a relatively small area. The practice of these manoeuvres is excellent in developing the coordination of all three flight controls and the power control. It is important that you acquire the ability to *execute them accurately and smoothly. Your instructor will demonstrate them in different operational flying situations.*

Up to a limited angle of bank a steep turn may be executed without increasing power. However, in order to maintain a constant altitude, the airspeed must be sacrificed as a result of the increased aft cyclic pressure required to maintain that altitude. Remember that the greater is the angle of bank, the greater the amount of lift is required to maintain a constant altitude, therefore, additional lift is provided by an increase of power.

A steep turn is entered like any other turn but, as the angle of bank is increased beyond approximately 30°, you must increase collective in order to maintain height and airspeed.

It requires simultaneous co-ordination of all three controls. Because of the rapid change of direction, the lookout for other helicopter before doing a steep turn is even more important than for other turns.

To enter a steep turn, first look out, then apply lateral cyclic in the direction of the desired turn and:

- *as the bank increases, move the cyclic aft to maintain the correct fuselage attitude relative to the horizon. (By so doing you have increased the aft tilt of the disc which, unless compensated for, will cause the airspeed to decrease);*
- *to maintain the set airspeed, increase collective as necessary as the bank angle increases beyond 30°;*
- *once the desired bank angle has been achieved, keep it constant with lateral cyclic.*
- *maintain balanced flight (ball centred) throughout the manoeuvre with tail rotor pedals; and*
- *maintain a good lookout.*

To recover from a steep turn, proceed exactly as you would for any other turn, except that, as you roll off the bank, the collective should be reduced simultaneously with the return to straight and level flight. You must also relax cyclic backpressure to ensure that the helicopter does not climb as you roll out of the turn. Remember that these movements should be coordinated and smooth.

Should you find that the nose of the helicopter is tending to pitch down while in the steep turn, do not attempt to correct by applying cyclic backpressure alone since this will only serve to tighten the turn. Use lateral cyclic to reduce the angle of bank slightly, then correct the attitude with coordinated aft cyclic. Another frequent error is the application of too much aft cyclic before it is required when rolling into the steep turn, causing altitude control to be erratic

1.18.3 ***Low main rotor RPM*** *(FAA 8083-21Helicopter flying handbook)*

The coning angle of the disc is the result of the interaction between the lift being generated by the blades and the centrifugal force from their rotation. With the helicopter on the ground at normal operating RPM and with no collective pitch applied, the disc will be flat. In hover the blades will be coned upwards in response to the increase in lift being generated. Were the RPM to decrease while holding the same hover position, the blades would cone upwards because of the reduced centrifugal forces. A secondary effect of the reduced RPM is reduced lift. The *collective lever 40 would therefore need to be raised to maintain the same amount of lift. The resulting increase in blade pitch angle increases the drag on the rotor blades and, if not countered, will reduce rotor RPM even further.*

If the situation described above continues, the blades will stall – lift will suddenly reduce. The blades will then flap down. In forward flight the stall will not be symmetrical and the retreating blade will stall first. This situation will lead to main rotor divergence, with the stalled retreating blade potentially striking the mast and/or the airframe.

A Pilot's Operating Handbook safety tip stated: "Never allow rotor RPM to become dangerously low. Most hard landings will be survivable as long as the rotor is not allowed to stall". The Pilot's Operating Handbook also contained two safety notices; SN-10 and SN-24, relating to low rotor RPM and fatal accidents (see Appendix 5).

1.18.4 *Recovery from low rotor RPM (FAA 8083-21Helicopter flying handbook).*

Under certain conditions of high weight, high temperature or high density altitude, you might get into a situation where the RPM is low even though you are using maximum throttle. This is usually the result of the main rotor blades having an angle of attack that has created so much drag that engine power is not sufficient to maintain or attain normal operating r.p.m. If you are in a low r.p.m. situation, the lifting power of the main rotor blades can be greatly diminished. As soon as you detect a low r.p.m. condition, immediately apply additional throttle, if available, while slightly lowering the collective. This reduces main rotor pitch and drag. As the helicopter begins to settle, smoothly raise the collective to stop the descent. At hovering altitude you may have to repeat this technique several times to regain normal operating r.p.m. This technique is sometimes called "milking the collective." When operating at altitude, the collective may have to be lowered only once to regain rotor speed. The amount the collective can be lowered depends on altitude. When hovering near the surface, make sure the helicopter does not contact the ground as the collective is lowered. Since the tail rotor is geared to the main rotor, low main rotor r.p.m. may prevent the tail rotor from producing enough thrust to maintain directional control. If pedal control is lost and the altitude is low enough that a landing can be accomplished before the turning rate increases dangerously, slowly decrease collective pitch, maintain a level attitude with cyclic control, and land.

1.18.5 *Height velocity diagram (Robinson R44 pilot operating handbook)*

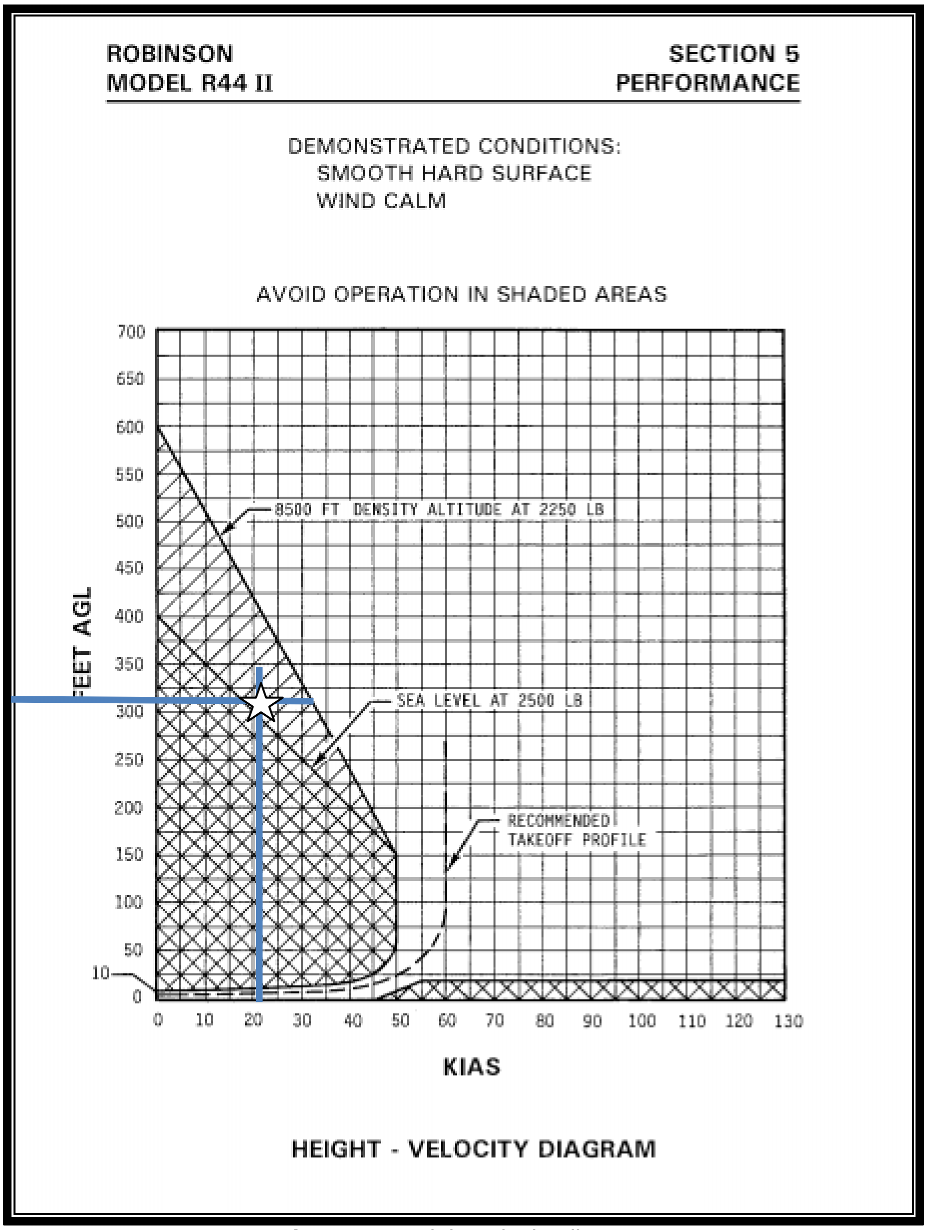


Figure 12: Height velocity diagram

1.18.6 Safety tips refer: Low RPM recovery – refer to Annexure A for more information.

1.19 Useful or Effective Investigation Techniques

1.19.1 None.

2. ANALYSIS

2.1 Man

2.1.1 The pilot was properly licenced in accordance with the regulatory requirements and had a valid medical certificate with restrictions to wear correction lenses when flying. The helicopter type was endorsed on his licence. According to the eyewitness, the pilot was observed performing manoeuvres in the vicinity of the dam at a height of approximately 380 ft. According to the available information, the pilot licence was due for renewal in the near future. The purpose of the flight was to practise manoeuvres in preparation for the licence renewal. Parts of the manoeuvres were steep turns and hover turns. The helicopter is fitted with servo actuators to assist the pilot with inputs on the controls. The feedback input is decreased and is dampened by the hydraulics. There is a small limited amount of inputs required by the pilot during the flying. The throttle on the collective is a twist grip action with the governor incorporated.

2.1.2 During the steep turn to either the left or right side, the rotor RPM tends to decrease. According to the witness statement, it is likely that the change in engine noise that was heard was the rotor RPM or engine RPM depleting. When the rotor RPM drops; the pilot must lower the collective immediately to regain the rotor RPM. With the pilot's relatively low experience, the response of lowering the collective may not yet have become a conditioned reflex. The pilot was subsequently unable to maintain rotor RPM, which allowed the rotor RPM to drop significantly, resulting in the blade to strike the tail boom as a result of diverge from the normal plain of rotation causing an in-flight break up due to abrupt inputs, with a subsequent loss of control and a high rate of descent to the ground. There could be several explanations for this. One is that he would have needed time to recognise the failure. In a practice engine failure, the instructor will give the student a prior warning, but in the event of a real failure it is likely to be sudden and without warning.

2.1.3 The height of 328 ft reported by the witness was sufficient for the pilot to execute an autorotation to regain rotor speed as explained by the POH. The height velocity diagram indicates that at 328 ft AGL, if the helicopter had airspeed of 50 knots or above, depending on the density altitude and the weight of 2113 lb, the pilot would have auto-rotated without damaging the helicopter. If the helicopter was outside these parameters, a correctly performed autorotation would have potentially resulted in some damage to the helicopter. It is most likely that if the pilot was operating the helicopter at a speed below 50 knots and the main rotor stalled, the helicopter would have been unrecoverable. The low rotor RPM can result in loss of tail rotor thrust. Due to loss of anti-torque, the resultant yaw to the right and subsequent spiral dive made it difficult for the pilot to gain control of the helicopter as it plummeted down. An incorrect recovery technique was used, which resulted in loss of control and destruction of the tail cone.

2.2 Machine

2.2.1 The helicopter was equipped and maintained in accordance with the manufacturer's requirements by a regulator-approved AMO. The last mandatory inspection was carried out on 04 October 2017. There were no defects recorded on the flight folio in any of the helicopter systems. The helicopter was in possession of a valid certificate of airworthiness as required by the regulatory requirements.

2.2.2 The damage to the helicopter and distribution of the wreckage indicate that the main rotor blades struck the tail cone in-flight, causing the tail section to break and subsequently striking the cabin area as well during ground impact. The witness stated that the helicopter was flying at approximately 328 ft; however, based on the evidence on the main wreckage position and the severed tail cone as found on the wreckage distribution, the height was most likely to be higher because of the distance between the two. The damage was typical of that seen in other R44 accidents where there has been a low rotor RPM, following a loss of engine power. A loss of engine power in the R44 helicopter requires immediate and correct action from the pilot to enable a successful autorotation to be made. If there is too much delay, or incorrect action, or if the pilot waits too long to lower the collective, the rotor RPM will decay to the point from which recovery is impossible. This is emphasised in the POH, dated 03 October 2002, as supplied by the manufacturer. The helicopter was involved in a hard landing incident on 24 February 2016. All major class 2 components were replaced by an approved AMO which did the repairs, whereby the helicopter was returned back to service on 04 October 2016 by a qualified maintenance engineer. The damages on the rotor head components were as a result of the impact sequence. The damages sustained by the major components were as a result of the impact sequence. The damage sustained by the no 2 main rotor blade was indicative of damage caused by the impact on a blade that was turning at low RPM. The rotor RPM was critically low, causing the blade to diverge from the normal plain of rotation, which resulted in an action reaction in that the tail cone subsequently became severed.

2.2.3 Other rotor head damage found included broken pitch change links, a broken scissor link and a bent mast shaft from excessive movement of the spindle tusks. The inner surface of the blade root was crushed, which is consistent with extreme teetering of the blade. The cabin area was struck by the main rotor blade during impact sequence. These damages were a typical signature of a low rotor RPM. A significant low rotor RPM often results in the main rotor blades striking the fuselage. In this case one of the main rotor blades struck the cabin area of the fuselage during impact and severed the tail cone twice in flight. The cabin strike was through the top right side of the cabin, which is consistent with the head injuries sustained by the pilot. The weight and balance calculations were considered to be within limits before take-off and prior to the accident, as prescribed by the manufacture specifications. The pilot uplifted fuel before take-off of approximately 24 US gallons (94 lt), which gave a total of 28 US gallons (108 lt) of fuel on board. The pilot was airborne for approximately 20 min and he consumed a total fuel amount of 5 US gallons (17.4 lt). The resultant fuel remaining on board at the time of impact was concluded as being 23 US gallons (90.6 lt). The helicopter was considered to have sufficient fuel on board before the crash. The grass vegetation at the accident site was green, and the portion that burned was indicative of fuel spillage after impact which ignited, causing the grass to burn and subsequently consuming the helicopter.

2.3 Environment

2.3.1 The prevailing weather conditions at the time had no influence on this accident. The surface wind was reported to be 080° at 06 kts by SAWS at Witbank, which is ±20 Nm from Ogies where the accident took place, and the wind was well within the operating limitations of this helicopter type. The terrain where the accident took place was flat and there was ample space available for an unscheduled or forced landing should that have been required.

2.4 Crash Survivability

The pilot incurred unnatural injuries of which one was a head injury; he was not wearing a flying helmet. Flying with an approved flying helmet could have provided him with the necessary protection to such a degree that his chances of surviving the accident could have been much better. The passenger that was sitting on the left front seat sustained injuries as a result of the destruction of the cabin structure.

2.5 Summary of the analysis

2.5.1 What was observed by the witness was the steep turn to the right followed by a change in engine noise and a loud bang. He saw the tail cone separating from the fuselage and the helicopter spiralling to the right with a nose-down attitude and crashing. The following potential causes of a loss of control in flight as a result of the in-flight breakup were considered during the investigation: Abrupt and excessive control inputs, loss of rotor RPM and low G pushover. The evidence suggests that only two of these were likely to have occurred. Abrupt and excessive control inputs during flight resulted in the main rotor blade severing the tail section. The second potential cause to likely have caused the in-flight breakup was low rotor RPM. Loss of rotor RPM resulted in the blades diverging from the normal plain of rotation, causing these blades to droop and impact the tail section. The damages found on the pitch change links were as a result of overload. The failed pitch link allowed the blade to twist beyond a 135° angle. In terms of Newton's Third Law of Motion there was an action-reaction on the main rotor blades, the advancing blade influenced the retreating blade to move down like in a seesaw action. The loss of the tail cone left the pilot with no chance to control the helicopter due to the loss of anti-torque system as well as a large change in CG due to the loss of the tail fins, tail rotor and tail rotor gearbox. The R44 Pilot's Operating Handbook Section 2 "low RPM horn and caution light" stated that the horn and illuminated caution light indicate that the rotor RPM may be below safe limits; to restore, immediately roll the throttle on, lower the collective, and in forward flight apply aft cyclic. These were actions that required immediate response from the pilot.

3. CONCLUSION

3.1 Findings

3.1.1 The pilot was the holder of a valid private pilot licence on helicopters and the helicopter type was endorsed on his licence.

3.1.2 The pilot was the holder of a valid aviation medical certificate that was issued by a designated medical examiner.

3.1.3 There was no recorded defect in the flight folio that could have hampered the airworthiness status of the helicopter prior to the flight. According to the weight and balance calculations, the helicopter was well within its maximum allowable weight as laid down by the manufacturer's specifications for this type of helicopter.

3.1.4 The helicopter suffered a low RPM condition, which resulted in the rotor blades to diverge from the normal plain of rotation and subsequently severing the tail cone and initiating an in-flight break-up and further impacting the cabin area on ground.

3.1.5 The helicopter was well within the weight and balance as required by the POH and was being operated within the centre of gravity limitation before take-off and prior to the accident. However the main rotor blades severed the tail cone the loss of tail fins, the tail rotor blades and the gearbox has caused a large change in the C of G.

3.1.6 The weather at the time of the accident was generally calm and suitable for the flight. Therefore, the weather was not considered a factor in this accident.

3.1.7 The teeter stops were crushed, the pitch change links broken in half and the inner part of the blade root was crushed. All these damages are associated with a low RPM event. The cause of the low RPM event that initiated the in-flight break-up could not be conclusively determined.

3.1.8 The engine, which was substantially scrapped due to the post-impact fire was recovered and subjected to a teardown inspection at an approved engine overhaul facility. The teardown inspection didn't reveal any mechanical evidence that could have contributed or have caused the engine to fail during flight. The damages on the squirrel cage cooling fan indicated that the engine was producing some power at impact. It could not be conclusively determined if the engine was turning at full power at impact, due to the fire damage.

3.2 Probable Cause

3.2.1 The main rotor severed the tail boom section during the execution of a steep turn at low RPM, which resulted in the helicopter spiralling in a nose down attitude to the ground.

4. SAFETY RECOMMENDATIONS

4.1 Safety message: The key lesson arising from this accident report is that helicopter pilots must be fully aware that a condition of main rotor stalling could result, the main rotor blades can diverge from a normal plain of rotation, causing the lift forces to overcome centrifugal forces, which can cause the blades to fold, break or droop down and resulting in the blades to impact part of the helicopter structure. Pilots need to have a conditioned reflex to roll the throttle on and lower the collective to recover from low rotor RPM as stipulated in the POH.

5. APPENDICES

5.1 Annexure A: Safety tips and Safety Notice 10

5.2 Annexure B: Weight and balance calculation

Safety tips and Safety Notice 10

SECTION 10

SAFETY TIPS

GENERAL

This section provides miscellaneous suggestions to help the pilot operate the helicopter more safely.

SAFETY TIPS

1. Never push the cyclic forward to descend or to terminate a pull-up (as you would in an airplane). This may produce a low-G (near weightless) condition which can result in a main rotor blade striking the cabin. Always use the collective to initiate a descent.
2. Never intentionally allow the fuel quantity to become so low in flight that the low fuel warning light comes on.
3. Never leave the helicopter unprotected where curious onlookers may inadvertently damage critical parts, such as the tail rotor blades.
4. Turn the strobe light on before engaging the drive system and leave it on until the rotors stop turning. The strobe light is located near the tail rotor and provides a warning to ground personnel. Leaving it on in flight is also advisable since the helicopter may be difficult for other aircraft to see.
5. Never carry an external load except when using an approved hook, nor attach anything to the outside of the helicopter. Also be sure no loose articles are in the cabin, particularly when flying with any of the doors removed. Even a small object or piece of cloth or paper could damage the tail rotor if it came loose in flight.
6. Avoid abrupt control inputs or accelerated maneuvers, particularly at high speed. These produce high fatigue loads in the dynamic components and could cause a premature and catastrophic failure of a critical component.

SAFETY TIPS (cont'd)

7. A change in the sound or vibration of the helicopter may indicate an impending failure of a critical component. Make a safe landing and thoroughly inspect aircraft before flight is resumed. A good practice would be to hover the helicopter close to the ground for a prolonged period and reinspect before resuming free flight.
8. Be sure ground personnel or onlookers don't walk into the tail rotor. The main blades can also be dangerous, particularly on a sloped surface where the bystander may be on higher ground than the helicopter.
9. Never allow rotor RPM to become dangerously low. Most hard landings will be survivable as long as the rotor keeps turning and is not allowed to stall.
10. Never make takeoffs or landings downwind, especially at high altitude. The resulting loss of translational lift can cause the aircraft to settle into ground obstacles.
11. A vertical descent or steep approach downwind can result in "settling with power." This happens when the rotor is settling in its own downwash and additional power won't stop the descent. Should this occur, reduce collective and lower the nose to increase airspeed. This can be very dangerous near the ground as the recovery results in a substantial loss of altitude.
12. The helicopter is stable on its landing gear as long as ground contact is made vertically or with the aircraft moving forward. Should ground contact be made with the helicopter moving rearward, tail damage and possibly a rollover could occur. Low time pilots and students should practice landings and hovering with the aircraft slowly moving forward.

SAFETY TIPS (cont'd)

13. When operating at higher altitudes (above 3000 or 4000 feet), the throttle is frequently wide open and the RPM must be controlled with the collective. The throttle/collective correlation is not effective under these conditions and the governor response rate is fairly slow, so extreme care must be taken to roll throttle off as the collective is lowered to prevent an overspeed.

14. Do not use collective pitch to slow the rotor during shut-down. Collective pitch produces lift on the blades which can disengage the teeter hinge friction and allow the blades to strike the tailcone. Also, do not slow or stop the rotors by grabbing the tail rotor. Stopping or turning the tail rotor by hand can damage the tail rotor drive.

15. Never land in tall dry grass. The exhaust is low to the ground and very hot; a grass fire may be ignited.

16. Always check an area for wires or other obstructions before practicing autorotations.

17. With hydraulic controls, use special caution to avoid abrupt control inputs or accelerated maneuvers. Since no feedback is felt in the flight controls, the pilot may be unaware of the high fatigue loads generated during such maneuvers. Frequent or prolonged high-load maneuvers could cause premature, catastrophic failure of a critical component.

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.

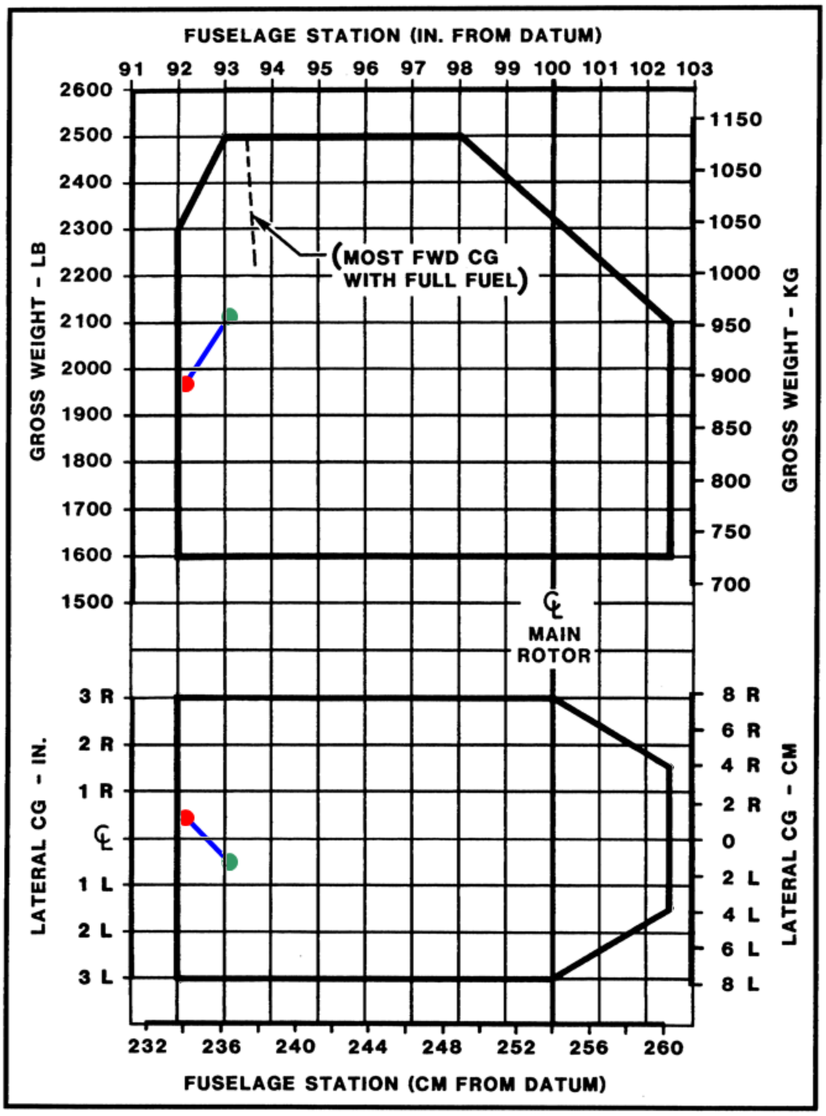
Power available from the engine is directly proportional to RPM. If the RPM drops 10%, there is 10% less power. With less power, the helicopter will start to settle, and if the collective is raised to stop it from settling, the RPM will be pulled down even lower, causing the ship to settle even faster. 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.

R44 II Weight and Balance

	WEIGHT	LONG. ARM	LONG. MOM.	LAT. ARM	LAT. MOM.
Empty Weight	**1552.00**	103.62	**160815.00**	0.00	**0.00**
Pilot	231	**49.5**	11434.50	**+12.2**	2818.20
Pilot Baggage	0	**44.0**	0.00	**+11.5**	0.00
Fore Passenger	187	**49.5**	9256.50	**-10.4**	-1944.80
Fore Passenger Baggage	0	**44.0**	0.00	**-11.5**	0.00
Right Aft Passenger	0	**79.5**	0.00	**+12.2**	0.00
Right Aft Baggage	0	**79.5**	0.00	**+12.2**	0.00
Left Aft Passenger	0	**79.5**	0.00	**-12.2**	0.00
Left Aft Baggage	0	**79.5**	0.00	**-12.2**	0.00
Total Weight & Balance w/Zero Usable Fuel	**No Fuel Weight**	**No Fuel Long. C.G.**	**Long. Empty Moment**	**No Fuel Lat. C.G.**	**Lat. Empty Moment**
	1970.00	**92.14**	181506.00	**0.44**	873.40
Main Tank	143.15	**106.0**	15173.688	**-13.5**	-1932.498
Aux Tank	0.00	**102.0**	0	**+13.0**	0
Total Weight & Balance w/Take Off Fuel	**Take Off Weight**	**Long. Full CG**	**Long. Full Moment**	**Lat. Full CG**	**Lat. Full Moment**
	2113.15	**93.07**	196679.69	**-0.50**	-1059.10

Weight and balance chart centre of gravity limits



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