**ACCIDENT**

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| **Aircraft Type and Registration:** | Robinson R22 Beta, G-TTHC | |
| **No & Type of Engines:** | 1 Lycoming O-320-B2C piston engine | |
| **Year of Manufacture:** | 1989 | |
| **Date & Time (UTC):** | 14 February 2009 at 1240 hrs | |
| **Location:** | Near Sandtoft Aerodrome, Humberside | |
| **Type of Flight:** | Training | |
| **Persons on Board:** | Crew - 1 | Passengers - None |
| **Injuries:** | Crew - 1 (Fatal) | Passengers - N/A |
| **Nature of Damage:** | Aircraft destroyed | |
| **Commander's Licence:** | Student pilot | |
| **Commander's Age:** | 54 years | |
| **Commander's Flying Experience:** | 75 hours (of which 75 were on type)<br>Last 90 days - 6 hours<br>Last 28 days - 6 hours | |
| **Information Source:** | AAIB Field Investigation | |

**Synopsis**

The helicopter was being flown by a student pilot in the circuit on a solo consolidation exercise. The weather conditions were good although conducive to carburettor icing. During the downwind leg, the main rotor blades struck and severed the tail cone and the helicopter fell vertically into a field fatally injuring the pilot. The investigation established that it is probable that following the pre-takeoff magneto checks, the ignition switch was set at the L (left) magneto position. The left magneto then failed causing the engine to stop. The rotor rpm decayed and the rotor disc tilted rearwards allowing the blades to strike the tail cone.

**History of flight**

The pilot was a student who was undergoing training at a flying school based at Leeds Bradford Airport. On the day of the accident he flew with his instructor from Leeds to Sandtoft Airfield, a distance of 33 nm, to conduct dual and solo circuit training.

The flight from Leeds to Sandtoft was uneventful and included some general handling practice, including autorotations. Contact was made with Sandtoft Radio at 1052 hrs. The helicopter joined the right-hand circuit pattern for Runway 23 and completed a number of circuits before landing and shutting down at 1134 hrs. It was then refuelled with 32 litres of Avgas and the pilot and his instructor took a half hour break from flying.

After the break the instructor walked back to the helicopter with his student to ensure that he strapped in correctly and was prepared to continue with the solo training. The student took off at 1208 hrs.

The instructor watched a number of the student's circuits from the ground and then moved to another position where he could see just the approach area. At approximately 1240 hrs two independent witnesses saw the helicopter crash into a field and called the emergency services.

*Search and rescue*

The first people to arrive at the scene were a local farmer and a pilot who telephoned Sandtoft Airfield to advise them there had been an accident. Later, at the request of the fire crew this pilot moved the fuel shutoff valve from the fully-open position to the fully-closed position. He stated that he did not move, or see anyone else move, any other controls or switches.

The airfield has a fire and rescue service category RFF 1. The two Airport Fire Crew were alerted by the A/G radio operator and deployed immediately off the airfield to search for the accident site. They arrived at the site within a few minutes and found several members of the public already there. There was no evidence of fire. Access with their vehicle was impossible so they carried some rescue equipment across the field to the helicopter. They recovered the pilot from the wreckage of the helicopter and spent 15 to 20 minutes attending to his injuries. They also took photographs of the scene including the positions of switches and the distribution of the wreckage.

The local area rescue services, including the air ambulance, arrived at the scene within 15 minutes. All attempts to resuscitate the pilot were, however, unsuccessful.

**Accident site details**

The helicopter came to rest in an upright position, on a heading of 044° in a waterlogged field just north of the M180 motorway. The tail cone had broken away from the main fuselage. The section aft of the strobe light was found approximately 30 m from the fuselage and the remainder of the tail cone was found next to the fuselage. Marks and indentations on the tail cone and tail rotor drive assembly were consistent with it having been struck at least twice by a main rotor blade. Items from the tail section of the helicopter, such as the rotor drive shaft and strobe light, were found on a heading of approximately 195°, between 30 m and 150 m from the fuselage. Both main rotor blades had creases along their lower surfaces and the pitch horn had broken off from one of the blades. The instrument panel was found lying, instruments facing up, on the ground just in front of the cockpit. The canopy had fragmented into a number of small pieces. Both fuel tanks had punctured and a fairly large quantity of fuel could be seen floating on the water in the field.

Both skids had bowed outwards and the forward uprights had broken away from the skid attachment points. In addition, the heels of both skids had bent upwards and broken away. Personal equipment and aircraft documentation was found in the baggage compartments beneath both seats; however it had not prevented the sides of the pilot's seat base crumpling during the crash. There was also compression damage to the structure underneath the cockpit floor. The pilot's three point inertia seat harness was intact.

Initial examination of the wreckage by the AAIB found the controls in the cockpit in the following positions: the mixture control was fully IN, (full rich), the carb heat had been pulled out by 11 mm, the fuel shut off valve was in the OFF position, the primer was locked IN, the governor switch on the end of the cyclic was in the ON position and the ignition switch was at the L position (See Figure 1). The key in the ignition switch was undamaged and there was relatively little damage in the area adjacent to the switch. Movement of the key during the impact is therefore considered unlikely.

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The ground impact marks indicated that the tail cone and tail assembly had broken away from the fuselage before the helicopter struck the ground in a slightly nose-high, upright attitude. There was no evidence of any rotation or horizontal movement of the fuselage section when it struck the ground. The distribution of the wreckage around the front of the helicopter was consistent with a main rotor blade striking the cockpit area after impact.


**Figure 1**
Position of ignition switch

**Pilot information**

The pilot started his flying training at a flying school based at Leeds Bradford Airport in August 2005. He made steady progress and in July 2007, having completed 55 hours of dual instruction, he flew on his first solo flight. There were several breaks in his training and on 24 January 2009 he resumed training again, after a six month gap. Since then he had completed a further six hours of dual instruction before this flight, his sixth solo flight. The pilot had flown at Sandtoft Airfield on two previous occasions. He had completed an independent R22/R44 Flight Safety Course in July 2008 and held a valid medical certificate which had been renewed two weeks before the accident.

**Pathology**

Post-mortem examination revealed that the pilot died of multiple injuries sustained on impact. There was no evidence of any pre-existing medical condition which could have caused or contributed to the accident.

**Radio communications**

There is an A/G communications service at Sandtoft, callsign Sandtoft Radio. The service included a facility for alerting emergency and rescue services. The communications were not recorded but the A/G operator recalled having received only routine calls from the helicopter prior to the accident.

Local Aerodrome regulations required transponder-equipped aircraft to squawk the VFR aerodrome traffic pattern conspicuity code (7010) when asked by the ATS unit in accordance with AIC 9/2007. However, no request was made by Sandtoft Radio and no primary or secondary recorded radar information for the helicopter was available.

**Witnesses**

Two aircraft were operating in the circuit at Sandtoft around the time of the accident. One, on final approach to Runway 23, carried out a go-around when he saw that a helicopter was occupying the runway. He climbed away on the dead side and then turned crosswind early to keep clear of the helicopter's departure lane. He saw the helicopter climbing on the crosswind leg, to the left and below his aircraft. Later, he heard the helicopter pilot report "HOTEL CHARLIE DOWNWIND". He did not hear or see anything further of the helicopter.

A second aircraft took off after the helicopter. The pilot of that aircraft when climbing away, reported having seen the helicopter ahead and below him, turning from crosswind to downwind in the circuit at around 500 to 600 ft. He noticed that the helicopter did an unusual wobble/yawing manoeuvre during its turn, after which it apparently recovered. He later heard its pilot give a "normal" downwind radio call.

There were two people who were able to give eyewitness accounts of the accident. The first witness was in a car travelling west on the M180 motorway. He saw the helicopter cross the motorway ahead of his car and then, after briefly looking away, he looked back and saw it in an unusual nose-high attitude. The plane of rotation of the main rotor blades appeared to be at an abnormal angle to the main helicopter fuselage. The helicopter recovered to an apparently normal attitude, briefly, and then started spinning round. He thought that it had turned clockwise (viewed from above) through several rotations, and then rolled onto its side with the blades towards the east. He saw it fall to the ground apparently out of control. As it fell he saw what he thought to be a main rotor blade detach.

The second witness saw the helicopter in an apparently normal circuit pattern but lower than usual. He then heard a metallic "crack" and looked up to see the helicopter descending rapidly, in a tail-low attitude, before going out of sight.

**Meteorological information**

The UK low level area forecast valid from 0800 hrs to 1700 hrs showed a warm front, lying approximately north to south across the UK, moving east to cross Sandtoft Airfield at around 1400 hrs. The area ahead of the front was forecast to be mainly clear with localised areas of haze and some scattered or broken low level cloud.

The closest airfields to Sandtoft for which METARs are issued are Doncaster, 7 nm south west, and Humberside 19 nm east. The 1220 hrs METAR for Doncaster was surface wind from 190 º at 6 kt, visibility greater than 10 km, few cloud at 4,800 ft, temperature 5ºC, dewpoint 1ºC and pressure 1029 hPa. The 1250 hrs report for Humberside was surface wind from 210º at 6 kt, visibility 6 km, scattered cloud at 3,000 ft, temperature 4ºC, dewpoint 2ºC and pressure 1029 hPa. A Sandtoft Airfield meteorological report obtained from an airfield website at 1400 hrs was: surface wind from 225ºat 5-8 kt, scattered cloud 1,200 ft, temperature 5.6ºC, dewpoint 2.8ºC, and pressure 1027 hPa.

The instructor in another R22 helicopter operating at Sandtoft about an hour before the accident, reported that he had noticed a significant accumulation of carburettor ice when carrying out pre-departure power checks.

**Aircraft information**

*General*

The R22 is a two-seat, single-engine helicopter powered by a four-cylinder Lycoming air-cooled engine. Filtered induction air is supplied to the carburettor via an airbox. Ambient air enters the airbox via a duct connected to the right hand side of the aircraft and hot air is ducted from around the exhaust pipes. A sliding control valve in the airbox, operated by the carb heat control in the cockpit, regulates the proportion of ambient and hot air entering the carburettor. The normal procedure is for the pilot to monitor the Carburettor Air Temperature Gauge and apply sufficient carb heat to prevent the temperature in the carburettor orifice, which is sensed upstream of the throttle butterfly valve, falling below 10ºC. In practice this is achieved by keeping the gauge needle in the yellow arc.

Engine speed is controlled either manually, by twist-grip controls, one located on each collective lever, or automatically by the governor system. The main components of the governor system are a toggle switch, correlator, control unit and actuator. The governor is switched on by the toggle switch mounted on the end of the right hand collective lever and operates between 80% and 115% engine rpm. Engine rpm is measured by mechanical points mounted in the right-hand magneto and the electrical output is sensed by the control unit, which sends a signal to the actuator causing the throttle connecting rod between the two collective levers to move. Movement of the throttle connecting rod causes the throttle twist grips to rotate and the butterfly valve in the carburettor to move. The pilot can override the clutch in the actuator by firmly gripping the throttle twist grip. A correlator is connected to the collective lever such that movement of the collective lever causes the carburettor butterfly valve to move without providing any feedback to the throttle twist grips.

The rotor system consists of a two-bladed teetering main rotor and a tail rotor driven by vee-belts connected between the output of the engine and a clutch assembly fitted between the tail rotor drive shaft and main rotor gearbox. The clutch assembly allows the rotor assembly to freewheel when the engine power is reduced. However, the clutch only freewheels in one direction and a reduction in the main rotor rpm will cause the engine rpm to decrease with the possibility of stalling the engine.

*Ignition system*

The engine is fitted with a dual ignition system equipped with two magnetos each of which supplies a high voltage to one of the two spark plugs in each of the four cylinders. Within the magnetos the high energy electrical power is fed from the coil via its outlet tab to the distributor by a rotating carbon brush. The magnetos are turned ON and OFF by a key-operated, five-position, rotary ignition switch mounted on the lower instrument panel. The five switch positions correspond to:

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| OFF | Both magnetos switched off. |
| R | Right magneto switched on, left magneto switched off. |
| L | Left magneto switched on, right magneto switched off. |
| BOTH | Both magnetos switched on. |
| START | Operates the starter motor, both magnetos switched on. |

The procedures in the R22 pilot's operating handbook require the magnetos to be checked after the engine has warmed up by setting the engine at 75% rpm and switching off each magneto in turn to check that the engine speed does not drop more that 7% rpm in two seconds.

A checklist, believed to have been used by the pilot, was found with the wreckage. The 'Start check' included a post-start test of the magnetos: 'Increase rpm to 75% -mag drop (7% max in 2 seconds)'. The instructor advised that the student had been taught to achieve this as follows:

- select one click of the ignition switch anticlockwise from both to the left magneto position

- watch that the drop of the needle is no more than 7% in 2 sec (ie. no less than 68% on the gauge
- click back to both
- two clicks anticlockwise to right magneto position same check and then turn the key back to both

There was no subsequent check of the switch position required before takeoff in either the pilot's checklist or the manufacturer's checklist.

*Loss of engine power*

A loss of engine power in the R22 helicopter will lead to a rapid decay in main rotor rpm if the corrective action of lowering the collective is not taken immediately. The Pilot's Operating Handbook (POH) contains a number of Safety Notices (SN) issued by the manufacturer in response to in-service experience of the R22 helicopter. SN-10, entitled '*Fatal accidents caused by failure to lower collective*' cites a failure to maintain rotor rpm as the primary cause of fatal accidents in light helicopters. The SN emphasises the importance of lowering the collective to maintain rpm as an instinctive response to any emergency and before any investigation of the problem takes place.

A loss of engine power in an R22 is evident by a nose-left yaw, change in engine noise and a rapid decay in main rotor rpm. If there is a delay in lowering the collective lever the rotor rpm might decrease to a level where the rotor blades stall. In forward flight the retreating blade will stall before the advancing blade. This will cause the rotor disc to tilt backwards, a phenomenon known as rotor blow back. With a reducing rotor rpm the helicopter would start to descend and the airflow impinging on the tail surface would cause the helicopter to pitch nose-down. If the pilot were to move the cyclic control rearwards to prevent the nose from dropping, then the combination of the rotor blow back and pilot input could cause the main rotor blades to strike the tail cone.

**Carburettor icing**

Carburettor icing is caused by the sudden drop in temperature of the air due to fuel vaporisation and pressure reduction at the carburettor venturi. The temperature can reduce by up to 30°C causing any moisture in the air to freeze, with a consequent build-up of ice in the carburettor throat adjacent to the butterfly valve. (The engine in the R22 is operated at a rated power so the butterfly valve does not open fully even at maximum power.) The subsequent reduction in cross-sectional area will gradually reduce the airflow and cause the engine rpm to decrease. Carburettor icing can occur when the ambient temperature is between -10°C and +30°C and the effect is most noticeable when the butterfly valve is closed.

If an engine, subjected to carburettor icing, is fitted with a governor, it will attempt to maintain the engine rpm by progressively opening the butterfly valve without the pilot being aware of what is happening. The POH for the R22 lists conditions when carburettor icing can be expected and warns the pilot that the governor system might mask the formation of carburettor icing. The limitations section of the POH, and a placard adjacent to the carburettor heat gauge, states "Caution below 18 in MP [manifold pressure] ignore gauge and apply full carb heat".

The student pilot had been trained to use the carburettor heat control routinely while flying in the circuit. Earlier in the day, while flying with his instructor, he had been applying full heat on the downwind leg before reducing power for descent, and then resetting to approximately half heat at 200 ft on final approach. Any further adjustments were made, if necessary, by reference to the gauge when above 500 ft on the climb out. The carburettor heat control is located to the left and below the pilot's knee, in a position where it would need to be operated by feel rather than physically looking at the control knob.

**Detailed examination of wreckage**

*General*

The helicopter was extensively damaged. There was no debris on the magnetic plugs in the main and tail rotor gearboxes and both gearboxes turned freely. The pitch horn had broken off from one of the main rotor blades, the eye end of its pitch link was missing and the push tube between the yoke assembly and swash plate had failed near the top of the cockpit. There was also minor damage to a number of the components in the main rotor head assembly. The main rotor gearbox frame was distorted and the tail rotor push tube was damaged. The governor actuator and the twist grip throttle were both at the fully open position. The vee drive belts were intact. Apart from the main rotor blade strike marks on the tail cone there was no other evidence of any pre-impact damage on any part of the helicopter.

*Engine*

The engine mounting frame had distorted in the crash and the engine had been badly damaged. Clean oil was found throughout the engine and in the oil filter, and all the spark plugs were light grey in colour indicating that the engine had been running with the correct mixture. The carburettor was examined in accordance with the maintenance manual and assessed as being serviceable. Clean fuel was found in the carburettor bowl, the acceleration pump operated normally and the jet was clean. The fan wheel slippage indicators were still aligned and there was no evidence to suggest that a mechanical failure had occurred prior to the accident.

*Magnetos*

Both magnetos were run on a test bench and whilst the right magneto operated satisfactory, there was no high voltage output from the left magneto. Both magnetos were dismantled and inspected in accordance with the maintenance manual. The right magneto was assessed as being serviceable. Whilst the coil and capacitor on the left magneto were found to be serviceable, the carbon brush in the distributor gear was found to be approximately 6.5 mm in length, which is 3 mm below the minimum permitted length quoted in the maintenance manual[1] of 9.53 mm (0.375 inch). The coil outlet tab, on which the brush runs, contained a depression, in the middle of which was a hole. The brush was replaced, the contact cleaned and the magneto was retested, but it still did not produce a high voltage at the distributor leads.

The brush and coil from the left magneto were examined by a metallurgist at the Royal Navy Material Integrity Group. They established that the wear pattern on the left and right magneto brushes was different and that material appeared to have been plucked out from the left brush. (See Figure 2)

Examination of the copper outlet tab on the left magneto coil revealed that it was covered in a layer of oxide and that the depression had formed due to a loss of material. The hole at the bottom of the depression had formed as a result of the copper melting and being pushed out of the depression. (See Figure 3).

**Footnote**

[1] Teledyne S20/200 Magneto Overhaul, Item 3.

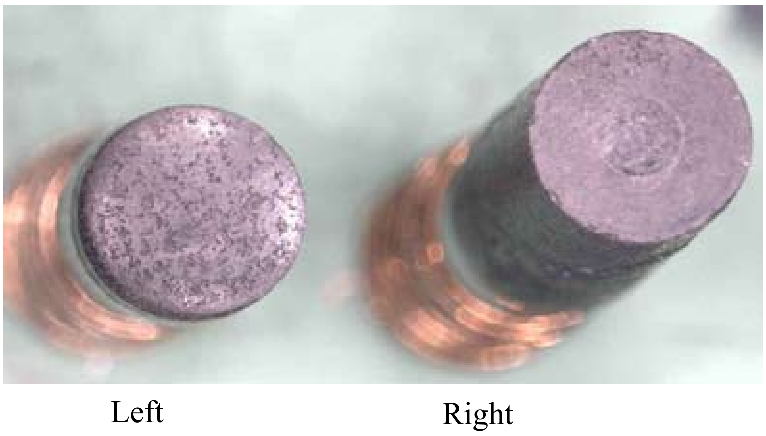


**Figure 2**

Wear pattern on carbon brushes

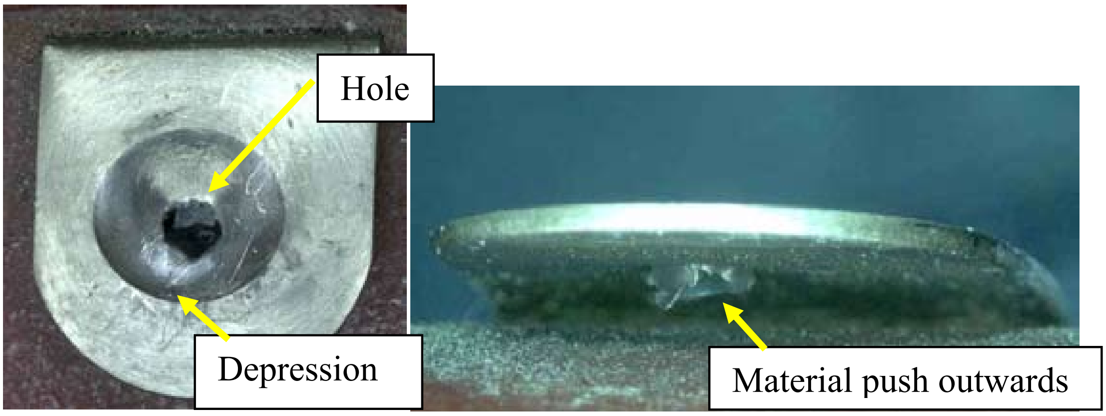


**Figure 3**

Copper outlet tab on left magneto coil

It is probable that the damage to the brush and outlet tab on the coil occurred over a period of time and started with a build up of oxides, which are abrasive and poor conductors. The presence of an oxide in the area between the rotating brush and outlet tab would have accelerated the wear in the brush and worn the depression in the outlet tab. This progressive build-up of oxides would eventually have resulted in arcing between the brush and tab which would have formed a carbon deposit. A metallurgist advised the AAIB that this particular type of carbon deposit would be abrasive with poor conductivity. Eventually the copper at the base of the depression would have reached a critical thickness such that the temperature rise from the arcing would be sufficient to melt the copper and force the remaining metal away from the tab. With the remainder of the outlet tab covered with oxides and a carbon (poor conducting) deposit there would no longer have been an electrical path between the coil and the distributor leads.

*Carb heat control*

The lock nut on the carb heat control cable end fitting was found to have unwound such that when the carb heat control was pulled ON the fitting would lift out of the instrument panel by approximately 6 mm (See Figure 4). The maintenance records show that this cable had last been disturbed during the rebuild about 462 hours earlier.

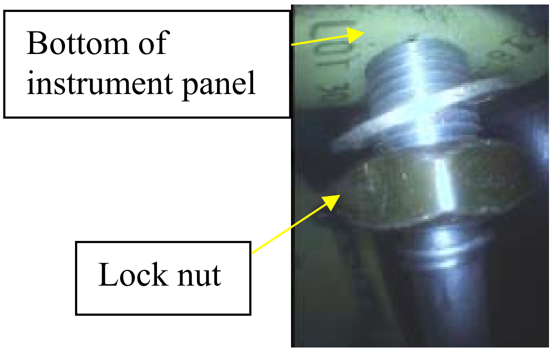


**Figure 4**

Carb heat cable end fitting

After the accident the carb heat control in the cockpit was found to have been pulled out by 11 mm, which corresponded to a 7% opening of the hot air port by cross section. However, the carb heat control valve, which is fitted to the air box, had detached from the bottom of the engine distorting the valve and causing the control cable to bend around the structure. It is, therefore, possible that it had been pulled out further than the 11 mm, but during the impact was pulled towards the cold position. From the damage to the air box it was established that the hot air port could not have been open by more than 60% of its cross-sectional area. Therefore it is assessed that at the time of the accident the hot air port had been open been between 7% and 60% of its cross-sectional area.

**Maintenance history**

The last 2,200 hour field overhaul was carried out in May 2007, approximately 462 hours prior to the accident, during which a 500 hr inspection was carried out on the left magneto. This inspection required the carbon brush to be checked for unusual wear and for the outlet tab on the coil to be checked for a visible depression. The maintenance organisation which undertook the work advised the AAIB that during this inspection the carbon brush was replaced and there was no evidence of excessive wear on the coil outlet tab.

The aircraft was maintained in accordance with the CAA Light Aircraft Maintenance Programme and the last maintenance activity on the helicopter was the 100 hr inspection that was completed the day before the accident flight. During this inspection the ignition switch functional test and the magneto timing were checked. An engine ground run was also carried out before the helicopter was returned to service during which the operation of both magnetos was checked. From the DATCOM fitted to the helicopter it was established that the accident occurred 2 hr and 36 minutes after these checks had been carried out.

The organisation who maintained the helicopter advised the AAIB that they were unaware of any recent engine or ignition faults.

**Analysis**

The damage to the helicopter and distribution of the wreckage indicates that the main rotor blades struck the tail cone with a force sufficient to cause the tail section to break away from the helicopter. The damage was typical of that seen in other R22 accidents where there has been a low rotor rpm following a loss of engine power.

A loss of engine power in the R22 helicopter requires immediate and correct action from the pilot to enable a successful autorotation to be made. If there is any delay, or incorrect action, the rotor rpm will decay to the point from which recovery is impossible. This is emphasised in the POH supplied by the manufacturer.

A number of potential causes of a loss of power were considered during the investigation. The evidence suggests that only two of these were likely to have occurred. The atmospheric conditions were conducive to serious carburettor icing at any power setting which was consistent with the report received from an instructor flying another R22 locally. A build-up of carburettor ice, which could ultimately lead to the engine stopping, had been masked by the governor gradually opening the butterfly valve in the carburettor. However, the pilot had been correctly applying carb heat when he flew with his instructor and there was physical evidence that some carb heat had been applied at the time of the accident. Although the carburettor heat control lock nut had unwound this would not have prevented the full operation of the carb heat. Therefore, whilst the possibility of carburettor icing can not be excluded, with the available evidence it seems unlikely that this was a causal factor.

The helicopter should have been flown with the ignition switch selected at BOTH so that the failure of one magneto would not result in the engine stopping. However, the evidence indicates that the magneto switch was inadvertently set to the L position during the pre-flight checks, and the selected left magneto had failed in flight. The left magneto passed the checks undertaken during the 100 hour servicing carried out 2 hours 36 minutes before the accident and would have been checked by the instructor and student at the start of each of the flights undertaken on the day of the accident. Nevertheless, from the available evidence, it appears that as a result of wear of the coil outlet tab the left magneto failed during the accident flight. With the right magneto turned off this would have resulted in the engine stopping.

The unusual 'wobbling' manoeuvre observed by another pilot in the circuit may have been the result of a yaw caused by an earlier, temporary, loss of engine power during the climb. The left magneto could have started to operate intermittently before failing altogether, causing engine power to be reduced and erratic. The downwind radio call made by the pilot, which was heard by several people, was described as routine, suggesting that he had not noticed any problem.

The pilot had practised autorotations earlier in the day with his instructor but, despite this, it seems he was not able to maintain rotor rpm and successfully enter autorotation when an actual loss of power occurred. 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. Another reason is that with the pilot's relatively low experience, the response of lowering the collective may not yet have become a conditioned reflex.

In summary it seems that there was an abrupt loss of engine power, as a result of the failure of the left magneto. The pilot was subsequently unable to maintain rotor rpm which allowed the rotor disk to strike the tail boom causing a loss of control and a high rate of descent into the ground.