Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT A11O0222

COLLISION WITH TERRAIN

GREAT LAKES HELICOPTER CORP.
ROBINSON R22 BETA (HELICOPTER) C-GVAR
REGION OF WATERLOO INTERNATIONAL AIRPORT, ONTARIO
28 NOVEMBER 2011

Canada

Aviation Investigation Report

Collision with Terrain

Great Lakes Helicopter Corp.
Robinson R22 Beta (Helicopter) C-GVAR
Region of Waterloo International Airport, Ontario
28 November 2011

Report Number A11O0222

Synopsis

The Robinson R22 helicopter (registration C-GVAR, serial number 2110) was departing the Region of Waterloo International Airport, Ontario, for a local training flight with a student and instructor on board. At 1131 Eastern Standard Time, approximately 1 minute after take-off, the helicopter crashed in a drainage swamp on airport property fatally injuring the instructor and seriously injuring the student. The helicopter was destroyed by impact forces; there was no post-impact fire. The emergency locator transmitter did transmit a signal.

Ce rapport est également disponible en français.

Factual Information

History of Flight

The occurrence flight was to be a basic navigation training exercise in an area extending approximately 28 miles to the southwest of the Region of Waterloo International Airport, Ontario (CYKF). The pre-flight inspection, start-up and engine run-up were completed near the company's hangar located to the west of the air traffic control tower at CYKF. Buildings obstruct the view from the control tower to the hangar area, so company procedure is to reposition (air taxi) after run-up to a departure area south of the approach path to Runway 08.

After C-GVAR repositioned to the grassy departure area there was a short delay due to tower frequency congestion. During this 5-minute time period the crew decided to practice touchdowns and lift-offs from the hover. At 1130, the air traffic controller instructed C-GVAR to lift off at the crew's discretion and make a turn around the control tower for a southbound departure (Figure 1).

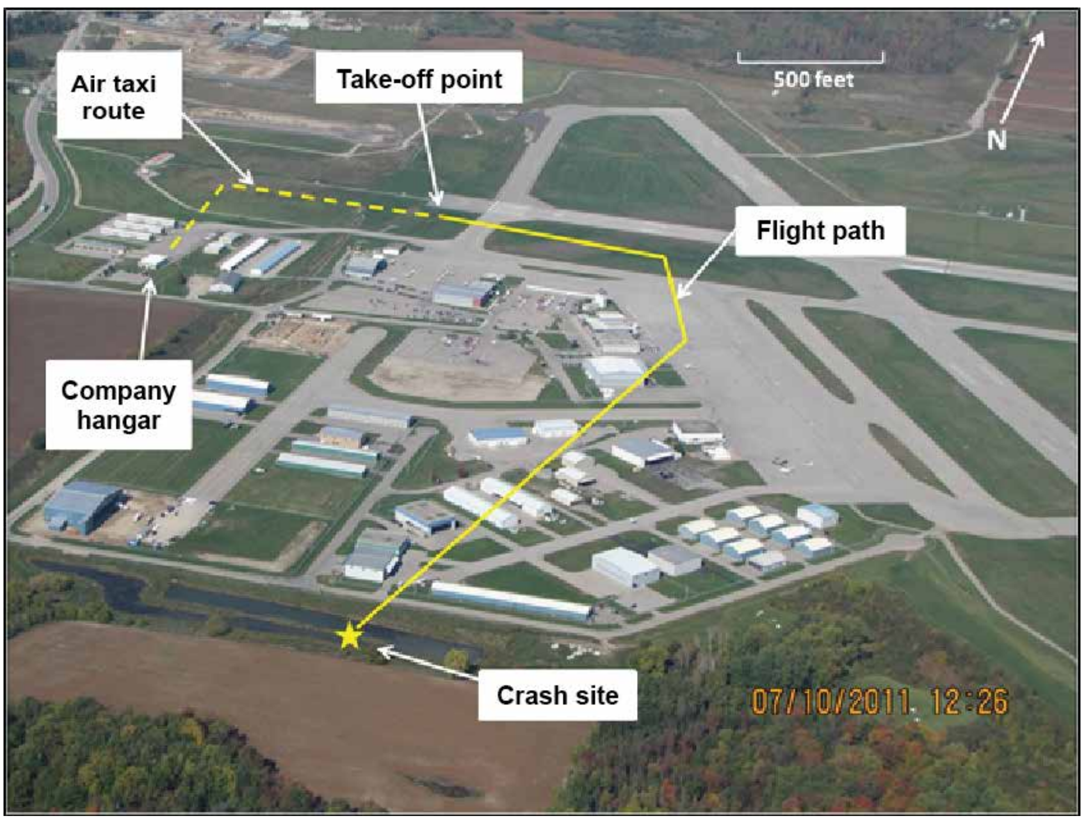

Figure 1. Flight path

C-GVAR lifted off from the grassy area with the student pilot in control and proceeded as instructed by the air traffic controller. After reaching approximately 200 feet above ground level (agl), at a typical departure speed, southbound over an area of multiple hangars and overhead wires, the instructor instructed the student to apply carburetor heat. It is not clear whether this instruction was actioned; however, shortly thereafter the engine shuddered, the engine rpm (revolutions per minute) decreased, and the instructor assumed control. The helicopter yawed first to the left then back to the right and began to descend. At 1131, C-GVAR impacted the ground in a level pitch attitude with little forward velocity.

The crash site was a 4-foot deep drainage swamp on the airport's southern perimeter, approximately 60 feet short of an open field. The helicopter was destroyed. The instructor was fatally injured by the vertical impact force and the student was seriously injured.

Weather Information

The weather at CYKF was appropriate for visual flight rules (VFR) flight. The wind was light and variable, visibility was greater than 9 statute miles, ceiling was overcast at 1300 feet agl, temperature was 4°C and the dew point was 1°C. It had rained most of the previous day and at the time of the occurrence the ground, including the grassy area, was very wet.

Flight Crew Information

Records indicate that the instructor was licensed and qualified in accordance with existing regulations. In addition to the required training, a Robinson Helicopter Company Pilot Safety Course was completed in December 2008, which focused on emergency procedures including autorotation. At the time of the occurrence the instructor had approximately 1040 total flight hours, mostly on Robinson helicopters. The instructor was off duty the preceding 2 days and the occurrence flight was the second flight of the day.

The student pilot had approximately 18 total flight hours, the most recent flight being 1 week earlier.

Helicopter Information

Records indicate that C-GVAR was equipped and maintained in accordance with existing regulations. The helicopter had accumulated a total of 5448.5 hours since new. The last inspection was a scheduled 50-hour inspection performed on 01 November 2011 when the helicopter had 5441.6 hours. There were no recorded current or deferred defects at the time of the occurrence. The helicopter was being operated within published weight and balance limitations.

The helicopter was equipped with a Lycoming O320-B2C engine, a 4-cylinder, carbureted, normally aspirated engine producing 160 horsepower. The engine controls include a twist grip throttle, fuel mixture control, carburetor heat control, and an rpm governor. The following gauges are installed to monitor engine performance: engine and rotor dual tachometer, manifold pressure gauge, ammeter, oil pressure and temperature, and a carburetor air temperature gauge.

The fuel mixture and carburetor heat controls are located on the centre pedestal in close proximity to each other. To aid in identification, the control knobs are shaped differently. Furthermore, the fuel mixture control knob is red while the carburetor heat control knob is black (Photo 1). To prevent the inadvertent deployment in flight, the manufacturer's checklist directs the pilot to place a removable cylindrical plastic guard over the mixture control knob before starting the engine (Photo 2). This guard is not to be removed until engine shutdown when the mixture control knob is pulled to the idle cut-off position (Photo 3). This plastic guard is not permanently attached to the control panel.

C-GVAR was not equipped with on-board recorders nor were these required by regulation.

Photo 1. Mixture control top right and carburetor heat control bottom right

Photo 2. Mixture control with guard installed

Photo 3. Mixture control in idle cut-off position

Wreckage Examination

The crash site was a drainage swamp on the airport perimeter which had thin wires strung across it in a checkerboard fashion to prevent birds from occupying it. The helicopter's position amongst the wires indicated a near vertical descent. Most of the damage and deformation to the helicopter was on the bottom surface, consistent with a near vertical impact with little forward velocity. One of the main rotor blades was bent in a fashion consistent with coning, which may have resulted from low rotor rpm in flight or from impact with the water. There was no evidence of rotor mast bumping or main rotor blade contact with the tail boom.

There were no pre-impact mechanical failures or system malfunctions that would have contributed to this accident. A teardown of the engine and accessory gearbox revealed that although they were serviceable, they were not turning at impact. The plastic mixture guard was not found at the crash site. The fuel mixture control was found in the full rich position. The carburetor heat control knob was found in the cold position. Examination of the cable-operated guillotine valve in the carburetor air box confirmed that the carburetor heat was selected to cold prior to impact.

The helicopter was equipped with a Pointer Sentry 4000-10 emergency locator transmitter (serial number 342606), which activated on impact.

Carburetor Icing

Carburetor icing is a phenomenon where the temperature of air entering the carburetor is reduced by the effect of fuel vaporization and by the decrease in air pressure caused by the Venturi effect. If water vapor in the air condenses when the carburetor temperature is at or below freezing, ice may form on internal surfaces of the carburetor, including the throttle valve. As ice forms, this increases the Venturi cooling effect due to narrowing of the carburetor throat and this narrowing reduces power output. Unchecked, the ice can quickly lead to a complete engine failure. To overcome carburetor icing aircraft manufacturers provide a system to heat the incoming air and prevent ice accumulation.

Unlike piston-powered aeroplanes, which normally take off at full throttle, helicopters take off using only as much power as required. This partial throttle position makes them more vulnerable to carburetor ice, especially when the engine and induction system are still cold. The Robinson R22 is equipped with a throttle governor which can easily mask carburetor icing by automatically increasing the throttle to maintain engine rpm, which will also result in a constant manifold pressure (Appendix A). To alert pilots to the possibility of carburetor ice, the helicopter is also equipped with a carburetor air temperature (CAT) gauge which displays a yellow arc outlining the range of temperatures to be avoided during possible icing conditions. Robinson R22 pilots are instructed to apply carburetor heat as required to keep the CAT out of the yellow arc during power settings above 18 inches manifold pressure and to apply full carburetor heat at settings below 18 inches (Appendices A and B).

If significant ice is allowed to develop within the carburetor and full heat is applied to melt it, the resultant water flow through the engine causes the engine to run rough temporarily and to lose further power. [1]

To help determine whether flight conditions are more or less susceptible to carburetor ice, charts based on a knowledge of dry (ambient) air and wet (dew point) air temperatures have been produced (Appendix C). The temperature and dew point at the time of the occurrence when referenced against these charts describe the conditions as the most severe or "Serious Icing – Any Power". In addition, the likelihood of accumulating ice can be exacerbated by operations in cloud, fog, rain, areas of high humidity, or in this case, ground operations over wet surfaces, especially wet grass. [2]

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[1] Transport Canada, *Helicopter Flight Training Manual*, Second Edition – TP9982E, page 15

[2] Civil Aviation Authority – General Aviation Safety Information Letter, The CAA Accident Prevention Leaflet, issue 2 of 2003, page 7

Low RPM Rotor Stall

The manufactuer notes that rotor stall due to low rpm causes a very high percentage of light helicopter accidents (appendices D and E). This risk is greatest in small helicopters such as the R22 with low main rotor blade inertia. When engine power is lost, the collective must be lowered immediately which induces a rate of descent. If this rate of descent is reduced by raising the collective, the rotor rpm will reduce. If the rpm reduces too much the rotor will stall and no longer provide the lift required to support the helicopter.

Robinson Helicopter Company Safety Notices

Following a series of accidents and incidents the Robinson Helicopter Company issued safety notices (SN) to its operators to reduce the likelihood of similar accidents. These are published on its website and at the back of the pilot's operating handbook (POH). Of particular relevance are the following SNs (see appendices):

- SN-01 – Inadvertent Actuation of Mixture Control in Flight
- SN-10 – Fatal Accidents Caused by Low rpm Rotor Stall
- SN-24 - Low rpm Rotor Stall Can Be Fatal
- SN-25 – Carburetor Ice
- SN-31 – Governor Can Mask Carb Ice

Analysis

The helicopter's engine was not running at impact although there were no mechanical anomalies which would have prevented its operation.

The weather conditions at CYKF were highly conducive to carburetor icing. In addition to the temperature / dew point spread, the operation conducted over the wet grass would have intensified the rate of ice accumulation.

The investigation could not determine whether the carburetor heat control was adjusted as required to keep the CAT out of the yellow arc during the period the helicopter was hovering over the wet grass or during the take-off; however, when the helicopter struck the ground, the carburetor heat was selected to cold. This cold selection may have been the result of not applying carburetor heat, or if it was applied after ice had formed in the carburetor and the immediate result was a rough running engine, the carburetor heat may have been de-selected. In either case the engine likely stopped due to ice blocking the airflow through the carburetor.

An instructor flying with a relatively new student would likely be carefully monitoring the student's actions, particularly during the critical take-off phase. The possibility that the mixture control was inadvertently selected to idle cut-off was considered to be unlikely as the student would have had to remove the mixture guard, pull the mixture control to idle cut-off and return it to full rich without the instructor's intervention. In addition, the fact that the carburetor heat, which would have been required given the conditions, was found in the cold position would further suggest that this scenario is unlikely.

At the time the engine failed, the position of the helicopter would have made a successful autorotation very difficult; it was at low altitude over a group of hangars with multiple overhead wires strung between numerous poles. The closest spot which was free of obstacles was the field 60 feet beyond the crash location.

The quick yawing following the engine failure most likely resulted from torque changes due to the power loss. This yawing would have decreased forward velocity, and increased the angle of descent. In an attempt to decrease the angle of descent and reach the field, the pilot likely raised the collective causing the rotor rpm to decrease to a point which could no longer sustain flight. The helicopter subsequently fell almost vertically into the swamp area short of the field.

Findings as to Causes and Contributing Factors

1. Environmental conditions were conducive to serious carburetor icing. It could not be determined if carburetor heat was applied.

2. The helicopter's engine failed during departure most likely due to ice accumulation in the carburetor.

3. The departure path took the helicopter over an area of buildings and obstacles which would have made a successful autorotation difficult.

4. The pilot likely raised the collective in an attempt to reach a suitable field causing the rotor rpm to decay to a point which could no longer sustain flight. The helicopter subsequently fell, almost vertically, into the swamp.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 07 August 2012. It was officially released on 05 September 2012.

Appendix A – Safety Notice SN-31

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Safety Notice SN-31

Issued: Dec 96

GOVERNOR CAN MASK CARB ICE

With throttle governor on, carb ice will not become apparent as a loss of either RPM or manifold pressure. The governor will automatically adjust throttle to maintain constant RPM which will also result in constant manifold pressure. When in doubt, apply carb heat as required to keep CAT out of yellow arc during hover, climb, or cruise, and apply full carb heat when manifold pressure is below 18 inches.

Also remember, if carb heat assist is used it will reduce carb heat when you lift off to a hover and the control may require readjustment in flight.

Appendix B – Safety Notice SN-25

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Safety Notice SN-25

Issued: Dec 86 Rev: Nov 99

CARBURETOR ICE

Carburetor ice can cause engine stoppage and is most likely to occur when there is high humidity or visible moisture and air temperature is below 70°F (21°C). When these conditions exist, the following precautions must be taken:

During Takeoff - Unlike airplanes, which take off at wide open throttle, helicopters take off using only power as required, making them vulnerable to carb ice, especially when engine and induction system are still cold. Use full carb heat (it is filtered) during engine warm-up to preheat induction system and then apply carb heat as required during hover and takeoff to keep CAT gage out of yellow arc.

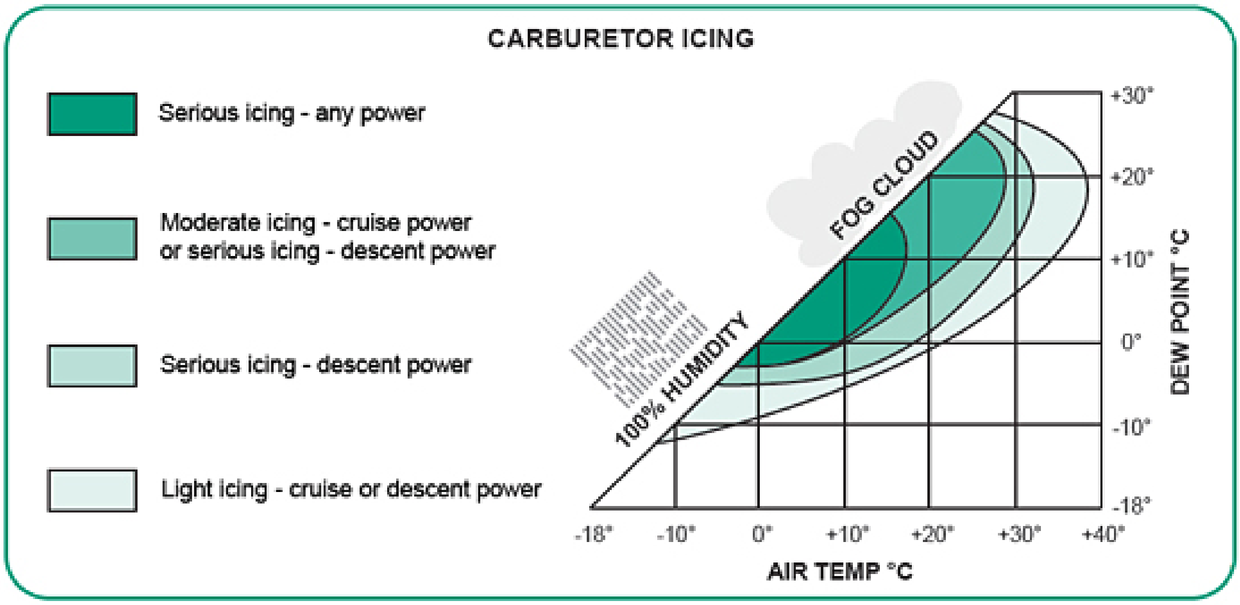
During Climb or Cruise - Apply carb heat as required to keep CAT gage out of yellow arc.

During Descent or Autorotation -

R22 - Below 18 inches manifold pressure, ignore CAT gage and apply full carb heat.

R44 - Apply carb heat as required to keep CAT gage out of yellow arc and full carb heat when there is visible moisture.

Appendix C – Carburetor Icing Probability Chart



Source: Transport Canada, *Helicopter Flight Training Manual*, Second Edition – TP9982E, page 15

Appendix D – Safety Notice SN-10

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Safety Notice SN-10

Issued: Oct 82 Rev: Feb 89; Jun 94

<u>FATAL ACCIDENTS CAUSED BY LOW RPM ROTOR STALL</u>

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 **<u>before</u>** 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.

Appendix E – Safety Notice SN-24

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Safety Notice SN-24

Issued: Sep 86 Rev: Jun 94

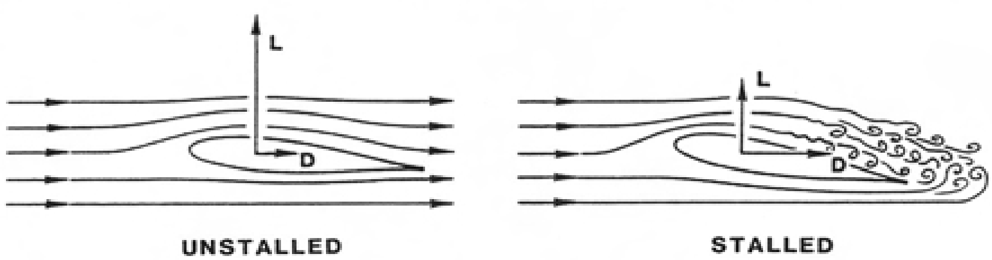
LOW RPM ROTOR STALL CAN BE FATAL

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

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

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

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



Wing or rotor blade unstalled and stalled.

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Safety Notice SN-24 (continued)

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

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

Appendix F – Safety Notice SN-01

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Safety Notice SN-1

Issued: Jan 81 Rev: Feb 89; Jun 94

INADVERTENT ACTUATION OF MIXTURE CONTROL IN FLIGHT

Cases have been reported where a pilot inadvertently pulled the mixture control instead of the carb heat or other control, resulting in sudden and complete engine stoppage. The knobs are shaped differently and the mixture control has a guard which must be removed and a push-button lock which must be depressed before actuating. These differences should be stressed when checking out new pilots. Also, in the R22, it is a good practice to always reach around the left side of the cyclic control when actuating the lateral trim. This will lessen the chance of pulling the mixture control by mistake. Always use the small plastic guard which is placed on the mixture control prior to starting the engine and is not removed until the end of the flight when the idle cut-off is pulled. Replace the guard on the mixture control so it will be in place for the next flight.

If the mixture control is inadvertently pulled, lower the collective and enter autorotation. If there is sufficient altitude, push the mixture control in and restart the engine using the left hand. DO NOT disengage the clutch.