FINAL REPORT

AAIU Report No.2002/004
AAIU File No. 1999/0054
Date Published:

Name of Owner:	McAuliffe Trucking Ltd
Name of Operator:	Eirecopter Helicopters
Aircraft Type and Registration:	R22 Beta, EI-MAC
No. and Type of Engines:	One Avco Lycoming 0-320-B2C
Aircraft Serial Number:	1433
Year of Manufacture:	1990
Date and Time, Coordinated Universal Time (UTC):	27 August 1999, 10:11 hours
Location:	Cornakelly, Ballinamuck, Co. Longford
Type of Flight:	Private
Persons on Board:	Crew-one Passenger - one
Injuries:	Crew- Fatal Passenger - Fatal
Nature of Damage:	Aircraft Destroyed
Commander's Licence:	Private Pilot's Licence (Rotorcraft)
Commander's Age:	42 Years
Commander's Flying Experience:	Total Fixed Wing - 271 hours Total Helicopter (R22) - 50 hours
Information Source	Air Traffic Control (ATC) Watch Manager, Dublin Airport. Air Accident Investigation Unit (AAIU) Field Investigation.

<u>INTRODUCTION</u>

The Final Report of the above accident followed two earlier Draft Reports. This Report is a further elaboration of the Final Report issued to six interested parties on the 7 February 2001. The first Draft Report had been issued to the same interested parties on the 16 May 2000. Factual comments in writing on this Draft Report were invited to be submitted within a period of 28 days, as laid down in SI 205 of 1997. The Investigator-in-Charge (IIC) subsequently allowed a longer period in which to reply to those interested parties who requested it.

While awaiting these replies, a High Court action was initiated by one interested party under Section 24 (*Disclosure of Records*) of the Air Navigation (Notification and Investigation of Accidents and Incidents) Regulations, 1997. Mr Justice Peter Kelly delivered his Judgement on the 3 July 2000. In his conclusion he stated that the application had failed and was therefore dismissed. Replies were then received from four interested parties, which were responded to by the AAIU. The AAIU amended the first Draft Report where matters raised in these replies were accepted. The fifth interested party had no comment to make. Finally, on the 24 August 2000, a belated reply was received from the sixth interested party, which introduced previously unknown information to the investigation. This information was included in the second draft. Also, in a further response by the AAIU to points raised in the various replies, further clarification and explanation of matters which were already written about in the first draft, were made in the Analysis section of the second Draft.

The second Draft Report was issued to six interested parties on the 5 December 2000.

SYNOPSIS

The accident was notified to AAIU of the Department of Public Enterprise by the duty Watch Manager, Dublin ATC. The accident investigation was carried out under S.I. No. 205 of 1997, Air Navigation (Notification and Investigation of Accident and Incidents) Regulations, 1997. Under the provisions of the International Civil Aviation Organization (ICAO) Annex 13, Aircraft Accident and Incident Investigation, the USA, as the State of Manufacturer, was invited to participate in the investigation. Mr Ron Price, National Transportation Safety Board (NTSB) was the accredited representative. Mr Richard Sanford, the UK representative of the Robinson Helicopter Company, supplied additional technical information.

The pilot was availing of a partially free flight offered by the Operator on the successful completion of his Private Pilot's Licence (PPL) - (Rotorcraft) in June 1999. He had undergone his R22 flight training with the Operator, who presented the pilot with his completed Flight Exercise Report at the end of his course. He planned to fly from Weston Aerodrome, Co. Kildare to Sligo Airport. While overflying Co. Longford, between the villages of Moyne and Ballinamuck, several eyewitnesses subsequently stated that they saw the helicopter at a relatively low altitude, 200-300 feet, with pieces falling from it. Almost immediately after the last reported sighting the helicopter crashed into the middle of an open field. The aircraft was destroyed. There was post-impact fire. There were no survivors.

1. FACTUAL INFORMATION

1.1 History of the Flight

On the morning of the 27 August 1999 an operations assistant carried out the daily 'A' check on two R22 helicopters, EI-CPO and EI-MAC, respectively, in preparation for the day's flying activities. EI-CPO was designated by the Operator for use by the pilot that day. The pilot was so informed by the operations assistant. This aircraft did not have dual controls fitted. However, the pilot elected to use EI-MAC which did have the dual controls fitted.

The operations assistant, who is also a qualified R22 pilot, said that the pilot carried out a meticulous pre-flight check on EI-MAC. He asked the pilot if he would remove the dual controls. This would normally take less than one minute. The pilot declined this offer and said that he would take care of that matter himself. In the event, the pilot did not remove the dual controls. The operations assistant did not press the matter of the dual controls as he concluded that the pilot was in charge of the flight and that such matters were his responsibility.

The pilot flight-planned to route from Weston Aerodrome via Newtown-mountkennedy to Sligo Airport. EI-MAC took off at 08:50 hours from Weston on a private flight under Visual Flight Rules (VFR) conditions. At Sligo the pilot intended carrying out some local aerial photography by prior arrangement with a professional photographer, who had travelled by road from Dublin for that purpose. The pilot was to be remunerated for this service by a Dublin based company. Initially the pilot flew southeastwards to the Newtownmountkennedy area, Co. Wicklow, to a field adjoining the house of a business colleague who he picked up, and together they routed for Sligo **(Appendix A).** On exiting the Dublin Control Zone, at 09:40 hours approximately, EI-MAC was requested to contact Shannon Control on frequency 124.7 MHz when it was in range. Shannon Surveillance Radar interrogated EI-MAC's transponder signal intermittently thereafter. From 09:53 hours onwards Shannon Control made numerous attempts to contact EI-MAC. Up to 10:03 hours there were four responses to the ATC communications checks, all frequency activated but no voice transmission was audible. Finally, at 10:04.17 hours, the pilot made clear contact with Shannon Control. He advised that he was just fourteen miles to the north of Abbeyshrule and he asked for a copy of the Sligo weather. Shannon relayed this weather information which the pilot acknowledged. At 6½ minutes before impact and a distance of approximately 8 miles from the crash site, Shannon asked EI-MAC to report when he had two-way communications with Sligo Airport. The pilot again acknowledged this call at 10.04.56 hours. This was the last transmission between EI-MAC and Shannon Control.

A witness furthest from the crash site at a distance of 2 miles to the east said that she saw the helicopter passing over her house and *"it didn't appear to be travelling low and there was no abnormal noise level from it".*

At a distance of 1.5 miles from the crash site another witness reported that she observed a helicopter low in the sky *"with heavy engine noise"*. She said that *"the noise was unusual in that it appeared to be a battering noise" and that the helicopter was travelling unusually fast for a helicopter.*

At a distance of approximately 0.5 miles from the crash site a witness stated, *"that the helicopter passed in front of her house at a distance of three to four fields away. It was so low that she could see the colour of the occupants' clothes".* She said, *"There was a loud noise like a grinding noise coming from the helicopter".* She saw what she thought was a piece of blade, about two feet in length, falling from the helicopter. As the piece fell she *"noticed the helicopter tilt to the right quite sharply".* She realised that the helicopter was in difficulty and ran inside the house to pick up the phone. She rang 999. The operator transferred the call to Dublin ATC.

The time recorded for the 999 call was 10:10.48. The helicopter disappeared from her sight behind tall bushy trees whilst she was on the telephone and impacted the ground an estimated 40 seconds later. This would put the time of the crash at 10:11.28.

From 10:13 hours onwards Shannon Control continued to try to make direct radio checks with EI-MAC or, indirectly, through contacting overflying aircraft with a request to relay their communications checks. These calls continued to 10:42 hours but there was no further response.

As far as can be ascertained from various eyewitness sources the accident occurred at approximately 10:11 hours, in the townland of Cornakelly, Ballinamuck, Co. Longford, in daylight hours **(Appendix A).**

1.1. Injuries to Persons

Injuries	Crew	Passengers	Others
Fatal	One	One	-
Serious	-	-	-
Minor/None	-	-	-

1.3 Damage to Aircraft

On site inspection by the AAIU showed that the aircraft was destroyed following a heavy ground impact with a large vertical component. There was no indication of significant forward speed at impact. There was post-impact fire.

1.4 Other Damage

There was minor damage to grass in the impact area, caused by burning aviation fuel.

1.5 Personnel Information

The pilot possessed a valid PPL (Rotorcraft) and a PPL (Aeroplanes), issued by the Irish Aviation Authority. He previously held a Commercial Pilot's Licence (CPL) - (Aeroplanes). His PPL (Aeroplanes) was first issued in 1984 and since then he had accumulated approximately 270 hours flying experience on fixed wing aircraft, mostly on Rallye and Cessna aircraft. In 1997 he commenced helicopter conversion training on the Robinson R22 and qualified for the issue of a PPL (Rotorcraft) on 17 June 1999, with approximately 39 hours helicopter experience accumulated. The pilot had applied to the IAA for a reduction in the total number of hours required for the granting of a PPL (Rotorcraft) because he already held a PPL (Aeroplanes).

The IAA granted him a reduction of 6 hours from the 45 hours normally required for a PPL (Rotorcraft) licence. Subsequently, he flew approximately 10 hours on the R22 up to the day of the accident.

The passenger was not the holder of a pilot's licence. He was known to have a keen interest in flying and, through his business, would have used helicopters for transporting film "rushes" from remote location areas back to the studios. He was scheduled to undergo an R22 course in the USA in October 1999.

1.6. Aircraft Information

1.6.1 General

The Robinson R22 Beta is a light two seat reciprocating engine-powered helicopter with a two-blade teetering rotor system. It is manufactured in the USA, with over 3000 units in operation worldwide, including 7 units registered in Ireland, with a small number of UK registered helicopters operating here also. It is frequently used as a low-cost initial student training aircraft. The two seats are side by side in an enclosed cabin with a curved two-panel windscreen. The flying controls are all mechanical. The cyclic control stick, known as a 'T' bar cyclic, is mounted between both pilots with handgrips on a swing arm, which gives access from either seat for instructional purposes. The pilot sits in the right seat; the left cyclic pitch control and left collective control can be easily removed for solo flight.

1.6.2 Maintenance

The total flying time of the helicopter recorded in the airframe and engine logbooks was 1739 hours.

An annual inspection had been carried out earlier in the year and the helicopter released to service on the 3 July 1999. The following work was included at that time.

(i) Exhaust Guide Valve Inspection to No. 2 and No. 4 cylinders in accordance with Service Bulletin 88B

(ii) Compression checks satisfactory.

(iii) Magneto 500-hour inspection completed.

(iv) Oil change carried out.

(v) Pitot Static Leak Check carried out.

(vi) Radio checks completed.

(vii) FAA Airworthiness Directives checked and found satisfactory.

A 50-hour inspection was carried out on the 23 August 1999, (four days before the accident) in accordance with the Light Aircraft Maintenance Schedule (LAMS-H-1978) and the helicopter was released for service.

1.7 Meteorological Information

1.7.1 General

Met Éireann, The Irish Meteorological Service, supplied an aftercast for the Moyne area of Co. Longford, on the morning of the 27 August 1999 as follows:

Area lay in a moist southwesterly airstream. A weak frontal system, west of Co. Longford, was moving eastwards at a speed of 15-18 kts.

1.7.2 Estimate of Weather Conditions in the area.

Surface Wind	200/10-12 kts
Wind 1000 ft	220/18 kts
Wind 2000 ft	230/20 kts
Visibility	8-10 Km becoming 3-5 Km in/near front
Cloud	Bkn St, Cu, Sc 1000-2000 ft. Becoming Bkn/Ovc St 400-700 ft in near/front.
Weather	Mist – light rain/drizzle in/near front.
Temperature	16° C
Dewpoint	15° C
Mean Sea level pressure	1016 hPa
Freezing level	10,500 ft

1.7.3 Witness Weather Observations

Many witnesses recalled that it was a fine summer morning in the area, with high patches of broken cloud and sunlight conditions. The grass in the impact field and the surrounding farmland was dry. The fine weather continued throughout the day and into the evening in the area.

One particular witness, who was working with his father on their farm about one mile from the accident site, gave his opinion of the prevailing weather that morning as follows *"……….. it was the same as it is now, it was dry, it was bright, there was no wind of any account, if anything there was a slight haze but it certainly wasn't cloudy, visibility would have been near perfect, the sky was clear, there was no wind of any account, there was no rain, it was bright and fairly sunny at the time………"*

1.7.4 Turbulence

In further response to an interested party who wrote that a "combination of wind and terrain resulted in sudden uplifting turbulence, inducing low-G, low RPM condition…………" The term "uplifting turbulence" is not a recognised or understood meteorological phenomenon. However, turbulence can arise from a variety of sources. The severity of the turbulence is a function of the strength of the wind and the degree of "roughness" of the surface. Annex 3 to the Convention on International Civil Aviation states that only severe turbulence shall be forecast by way of SIGMET. Conditions at the time and place of the accident did not warrant the issue of a SIGMET due to mechanical turbulence.

Turbulence can also arise because of orographical effects, normally only associated with mountains. Mountain waves can be generated provided the stability/instability and wind conditions are favourable. Annex 3 states that a mountain wave SIGMET will only be issued, if the mountain waves are forecast to be severe. Conditions at the time and place of the accident did not warrant the issue of a SIGMET due to mountain waves.

Turbulence can also be caused by convective currents in cumulonimbus (Cb) or towering cumulus (TCU) clouds. On significant weather charts, severe turbulence is always implied in CB and TCU clouds. Convective activity at the place and time of the accident was not sufficient to generate severe turbulence.

1.7.5 Wind

Reference was also made by the same interested party to "orographic wind", a term that is not a recognised or understood meteorological phenomenon. However, local winds can be generated by orographic effects. For example, the Föhn wind arises when an air mass is forced to rise adiabatically over a mountain obstruction. The precipitation on the windward side of the mountain means that the descending air on the lee side of the mountain will descend primarily at the dry, rather than the saturated, adiabatic lapse rate. This generates a relatively warm down-slope flow called the Föhn wind. There was no significant Föhn effect at the place and time of the accident.

Orographic effects can also lead to local winds known as katabatic and anabatic winds. These winds are generated by differences in density between the air at the top and bottom of a mountain and are often associated with snow-covered mountains. The conditions or topography at the place and time of the accident did not lead to any significant anabatic or katabatic wind effect.

1.8 Aids to Navigation

The pilot was originally scheduled to fly an R22 helicopter, EI-CPO, which had the dual controls removed. He requested to fly EI-MAC, which had better navigation equipment on board including a Transponder, VHF Omni-directional Range (VOR) receiver, and a Global Positioning System (GPS), which included a moving map display. He said that he needed to practise his navigation techniques.

1.9 Communications

The pilot maintained normal VHF communications with both Dublin and Shannon Air Traffic Control areas. He did not make any emergency call to Shannon ATC.

In April 1999 the Robinson Helicopter Company (RHC) issued a Safety Notice, SN No 35, about R22 electrical system malfunctions when flying near broadcast towers. This Notice stated, inter alia, *"early indications of a high power radio field include strong interference in the intercom system and aircraft radio receivers. Increasing field strength may cause random illumination of warning lights and erratic governor and tachometer operation. If the pilot has removed his hand from the collective lever to adjust the radio due the interference, initial erratic operation of the governor may go unnoticed. Under these conditions the governor may roll the throttle to idle or open it rapidly overspeeding the engine and rotor"*

There is a large transmitter mast at a height of 1375 ft at Corn Hill, Co. Longford, in the vicinity of the helicopter's track. This mast houses TV and VHF radio transmitters to serve the hinterland of Co. Longford and its environs.

The helicopter's track would have been about 4 miles north east of this mast. The power outputs of the transmitters and frequencies are as follows:

4 TV Channels	20 kW	600-700 MHZ,
Mobile Phone	250 w	870-960 MHZ,
VHF	25 w	70-80 MHZ.

1.10 Aerodrome Information

Not applicable

1.11 Flight Recorders

There was neither a Cockpit Voice Recorder (CVR) nor a Flight Data Recorder (FDR) installed in the helicopter. There is no regulatory requirement to do so.

1.12 Wreckage and Impact Information

1.12.1 On-site Investigation

1.12.1.1 Airframe

The entire helicopter wreckage found was within a concentrated area of 210 metres from the final impact site and along a track consistent with the path of the helicopter, as observed by numerous eyewitnesses. The final crash site was in the middle of a small field and the wreckage was spread over the adjacent three fields, along the helicopter track, to the east and south of that site.

Most of the wreckage outside of the impact field consisted mainly of pieces of Perspex from the helicopter canopy and doors. The exception to this was a piece of a tail rotor blade found 140 metres from the impact site in the field to the east and the helicopter LH door which was found 110 metres from the impact site in the field to the south.

There was evidence of black paint on pieces of the windscreen and cabin Perspex found along the helicopter flight path. Also, traces of blue paint were found on the underside of one of the main rotor blades, which came from the helicopter canopy. This indicated that the cabin suffered from a main rotor blade strike in flight prior to the ground impact.

At the impact site itself all parts were found within an area of 10 metres from the main airframe and engine wreckage, which had caught fire on impact with the ground. The main rotor blades and head were intact and found less than 4 metres from the airframe.

The main rotor head and blades had separated from the aircraft in one piece due to the failure of the main rotor shaft just underneath the head.

All elements of the transmission system were recovered at the impact site. The transmission system bore evidence of impact damage, with the tail rotor drive shaft failures indicating the presence of both torsion and bending failure.

The outer two sections of the tail boom had been cut off and found with the tail rotor assembly and one tail rotor blade 5 metres from the airframe. The tip of the other tail rotor blade was found 4 metres from the airframe. The tail stabiliser was found 8 metres away at the perimeter of the immediate impact site.

The ring of rivets that attach the boom to the fuselage had failed completely.

The helicopter hit the ground upright with an attitude of approximately 10° nose down and approximately 40° roll to the left.

There was no evidence to indicate that the helicopter had suffered a bird strike.

The wreckage was removed that night to the AAIU facility at Gormanston, Co. Meath for detailed inspection.

1.12.2 AAIU Facility Inspection

1.12.2.1 Engine

The inspection showed that the engine had suffered a heavy vertical impact, with no indication of significant forward speed at impact. The left side of the engine showed heavy impact damage, whereas the right side was relatively free of impact damage. This indicates that the helicopter struck the ground left side low, with little forward speed. The free-wheel assembly was examined and found to function in the correct sense. The engine mixture control knob was pushed fully "in" (Rich).

The carburettor, located underneath the engine, was destroyed, making it impossible to determine if any fault lay therein. The carburettor heat airbox valve indicated that "Carb heat" was applied at time of impact. The control knob was found pushed "in" (i.e. Carb Heat "off") but this anomaly was attributed to cable damage at time of impact. The oil sump, also located under the engine, was cracked open, and all the oil had escaped. The alternator, located on the left rear of the engine, had been forced into the flywheel. The resultant damage to the flywheel indicated that it was rotating at the time of impact. The starter ring gear was also separated from the flywheel, again indicating rotation at impact. The engine cooling fan had suffered damage which also indicated rotation at impact. The inlet manifolds on the left side had broken open, and were filled with soil. The spark plugs were removed and all were in good condition. However, the two lower plugs on the left side were contaminated with soil, and some oil. The soil had entered the left cylinders through the broken manifolds, and this also indicated rotation of the engine at impact.

The engine was subsequently removed from the airframe, and stripped. With the engine out of the airframe, the spark plugs removed, and the damaged alternator assembly removed, the engine was easily rotated by hand. All inlet and exhaust valves were found to function correctly when the engine was rotated. All four cylinders were then removed, and inspected.

All cylinders, pistons and rings were found to be in good condition. Internal inspection of the engine showed a clear condition, with no signs of metal chips or other contaminants.

The oil filter assembly had been cracked at impact and was subjected to considerable heat. The filter element was found to be clean and in particular was clear of metal contamination.

1.12.2.2 Transmission System & Rotors

The flex plate assemblies that take the engine drive to the main rotor gearbox and tail rotor gearbox were found distorted but intact. The main gearbox was cracked open at the base of the mast support casting, with the crack largest on the right hand side, indicating an initial impact on the left side of the aircraft. The transmission belts were totally destroyed in the post crash fire. Small fragments of the belts were found in the V groves of the drive pulley.

The main rotor shaft fracture was a combination of low speed torsion and bending. The stops in the head showed indications of moderately heavy contact, indicating that mast bumping had occurred. Both spindle tusks had failed and broken off.

One main rotor blade was relatively straight but had a blue paint mark on its lower surface at a distance from the root consistent with a blade strike on the top of the cabin. The other blade was considerably bent, in a vertical plane, towards the tip. This blade also was substantially damaged in its trailing edge. Examination of this damage clearly indicated that it was caused by contact with the tail rotor gearbox. Both blades exhibited skin wrinkles at about 5 feet from the blade pitch link.

The tailboom showed clear indications that the rear left side of the boom had been struck by a main blade, forward of the tail rotor gearbox. This impact caused the end section of the boom, complete with gearbox to hinge to the left by 180º, causing the gearbox to impact with the trailing edge of the main rotor blade.

No evidence of any pre-existing defects was found in any of these components.

1.12.2.3 Flight Controls

The flight controls components were recovered in the main impact area. There was considerable fire damage, including melting of some of these components, in the under-floor area. The pieces were laid out and examined. All failures and breakages were determined to be caused by ground impact, with the exception of the damage to the tail rotor pitch control rod, which was caused by the main rotor blade striking the tail boom just prior to impact.

It was noted that full dual controls were fitted to the aircraft. The rudder and cyclic controls were found to be connected and fitted on both sides, the right collective lever was in position, and the pattern of fire damage on the left collective indicated that it was fitted at the time of impact.

1.12.2.4 Fuselage

Although neither door had evidence of the correct split pins having been inserted in their top hinges, both doors were found in the locked condition. The left hand door was located back along the flight path, 110 metres from the crash site, in an adjacent field to the crash field. There were pieces of door-frame found, again along the flight path, in the farm yard 160 metres from the crash site. The right hand door was found at the crash site, 4 metres forward and right of the cockpit.

Due to the extent of the fire, which followed the crash, it was not possible to positively identify all panels and cowlings of this helicopter. All the helicopter blades were, however, found and identified at the crash site.

1.12.3 Technical Analysis of Wreckage

1.12.3.1 Warning Lights

The following engine associated warning-light bulbs were removed for analysis:

a. Low Rotor, Revolutions Per Minute (RPM) warning light.

b. Governor off warning light.

c. Low oil pressure warning light.

d. Alternator warning light.

e. Starter "On" warning light.

f. Clutch engagement.

Evidence of bulb filament stretching may indicate that the bulb was lit at time of impact. Indications from light bulb analysis showed that:

(a) The Low Rotor RPM warning light was "On", indicating low main rotor RPM at time of impact.

(b) The Governor "Off" bulb had an insignificant amount of stretching indicating that the light was "<u>Off"</u> at time of impact.

(c) The Engine Low Oil Pressure warning light was "On" indicating reduced engine oil pressure at the time of impact. Reduced engine oil pressure could be due to low RPM or loss of oil. No oil was found on the skids, tail boom or tail rotor, indicating the absence of a serious pre-impact oil leak. Some oil was found in quantities of clay embedded in the engine.

(d) The filament of the alternator warning bulb was broken with no signs of stretching indicating that the light was "off".

(e) The starter "On" warning bulb was broken with no sign of stretching.

1.12.3.2 Engine

The engine was found to be in good condition, and no defects apart from impact and fire damage were found. The indications, from the cooling fan, the flywheel, ring gear and the soil in the left cylinders, all indicate that the engine was rotating at the time of impact. No indications of an engine malfunction were found. No evidence of oil starvation prior to impact was found.

1.12.3.3 Transmission and Rotors

The marks and damage to the main rotor clearly indicate that mast bumping did occur, one blade struck the top of the cabin and the other blade had struck the side of the tail boom. These impacts are further clear indications of mast bumping. The nature of the fracture to the main rotor shaft indicates that the rotor was rotating at the time of ground impact. The departure of a mid section of the tail rotor blade is consistent with rupture of that blade while rotating at speed or during ground impact. There is no evidence of in-flight failure of the transmission system, main or tail rotor blades.

1.12.3.4 Flight Control System

The available evidence indicates that the flight control system was fully serviceable until the point where the main rotor blade struck the tail boom. All damage to the flight control system was the result of ground impact and fire.

The wreckage clearly indicates that full dual controls were fitted to the aircraft for this flight.

As the debris of the tail boom was all found in the main wreckage area, with the exception of a middle portion of the tail rotor blade, the evidence is that the strike of the tail boom by the main rotor occurred just before or during ground impact, and not in the cruise phase of the flight. The departure of the section of the tail rotor blade segment was as a consequence of this strike.

The discovery of debris from the top left of the cabin area a short distance along the flight path, just prior to impact, and the clear indication that the main rotor blade struck the cabin structure indicated a low energy strike situation and mast bumping.

1.13 <u>Medical and Pathological Information</u>

The post mortem examination of the pilot by the State Pathologist revealed no pathological evidence of any medical or physical condition that may have caused or contributed to the accident.

1.14 <u>Fire</u>

The aircraft suffered extensive fire damage. No evidence of pre-impact fire was found. In particular, the lack of fire damage to the tail boom indicates that there was no in-flight fire. Inspection of the wreckage indicated that the fire was caused by the rupture of the fuel tanks, following impact with the ground. Local people, who arrived quickly at the scene, used buckets of water from a nearby animal trough to extinguish the fire.

1.15 Survival Aspects

The accident was unsurvivable. The harness assemblies were damaged by fire at the site. One fixed buckle half was found with the male half attached. The fixed part of one harness assembly was found still attached to a piece of the helicopter fuselage. The male half of the other buckle was found charred and lying in the wreckage. Its corresponding buckle half was not found. None of the strap lengths were recovered except for a small piece of fabric wrapped around the roller of the port inertia reel. The remainder of the straps were consumed in the fire.

1.16 Tests and Research

The manufacturers of the GPS navigation system were contacted with a view to attempting to retrieve stored back track information from the system.

They informed the investigation that the model installed on this helicopter did not have the ability to store such information.

The hand-held GPS was forwarded to the manufacturer for analysis. They informed the investigation that due to the damaged condition of the set, the memory back-up power was no longer being applied to the memory circuit in the unit, and consequently all data stored in the unit had been erased.

1.17 Organisational and Management Information

The pilot intended to carry out local aerial photography over Sligo. The Operator understood that the purpose of the flight was a cross-country exercise, Weston – Sligo Airport – Weston. The Operator only became aware of the intended photographic element of the flight from the AAIU after the accident.

In March 1999, the manufacturers of the helicopter, RHC, issued Safety Notice No. 34 **(Appendix B)** warning that photographic flights should only be conducted by well trained and experienced pilots having at least 500 hours as helicopter pilot-in-command, at least 100 hours of which should be as pilot-in-command of an R22.

Relevant Safety Notices are issued by the manufacturers, RHC, to R22 helicopter owners on a regular basis on foot of a subscription service. When a new helicopter is sold on, the next owner must then apply to RHC to be put on the subscription list for Safety Notices. Unless a new owner makes alternative arrangements to procure these notices, these notices will not be issued to him because the manufacturer would be unaware of the new owner's details. The manufacturer said that the Operator purchased a full set of Safety Notices in December 1999 and followed this with the purchase of a subscription service for the year 2000. The manufacturer also said that the owner of the helicopter was not receiving Safety Notices in 1999. He had purchased the helicopter in 1998 and the previous operator told the investigation that these notices would not have been transferable on the sale of the aircraft.

It is not known whether the pilot of EI-MAC was aware of the most recent issue, March 1999 viz "SN No 34 Photo Flights - Very High Risk" **(Appendix B)**. It is normal to insert such notices in the helicopter Flight Manual. However, no such notice was found in the burnt remains of the Flight Manual amongst the wreckage.

1.18 Additional Information

1.18.1 Robinson R22 General Background

The R22 is the smallest helicopter in its class and incorporates a unique cyclic control and rotor system. Certain aerodynamic and design features of the helicopter cause specific flight characteristics that require particular pilot awareness and responsiveness. The R22 has a three hinged rotor hub assembly incorporating a teetering rotor system, which is common to two bladed rotor systems **(Appendix C)**. However, the main rotor system of the R22 has very low inertia and has, therefore, a reduced capability of storing energy in flight. The maintenance, by the pilot, of recommended engine speed (RPM) is consequently very important in preventing rotor blade stall. The automatic throttle governor also helps to maintain engine speed but this can be over-ridden by the pilot at any time.

The low inertia of the main rotor system also makes the R22 very sensitive as a consequence of reduced damping in all three axes of roll, pitch and yaw. The NTSB has investigated means of increasing R22 main rotor inertia. However, the NTSB state that added inertia would adversely affect rotor blade transient response, overshoots and blade flapping. Advantages gained through reducing RPM decay rates as described above, must be assessed with respect to degraded rotor transient response.

According to the manufacturers, a strike to the cabin in flight by a main rotor blade is indicative of a low-G mast bumping manoeuvre. In such a manoeuvre, the rotor system is not aerodynamically "loaded" and is not capable of generating the forces necessary to effect changes in the attitude of the helicopter. As a result, the helicopter rolls to the right under low G, driven by tail rotor thrust. During this roll the main rotor disc tilt angle lags the attitude of the airframe and the blade flapping safety margin is reduced. Left cyclic movement by the pilot to correct for the right roll may further reduce the flapping margin to the point that the rotor hub contacts the rotor mast and/or the blade then strikes the cabin roof. Consequently the manufacturers state that rotor/airframe contact accidents result from:

(a) Low Rotor RPM stall
(b) Low-G manoeuvre resulting in mast bumping

However, these findings by the manufacturer have not been completely substantiated by the FAA or NTSB.

In 1982, after several accidents involving the R22, the manufacturers along with a representative from the FAA carried out a "Main Rotor Hub Teeter Angle and RPM Decay Survey". The result of this survey, following test flights with specialist equipment on board, was that the R22 rotor system "will not stall, exceed its teeter clearance nor contact the tailcone, when the helicopter is flown within its approved limitations."

Pilots should be aware of the effects of reduced 'G' operations on light helicopters such as the R22 in light of the particular characteristics of the teetering rotor system and high tail rotor system. When a low 'G' situation is encountered, such as an abrupt 'pitch-over' induced by abrupt forward cyclic motion, or by turbulence, the main rotor disc may become unloaded. A rolling tendency will be encountered which would only be aggravated by the application of controls in any direction other than that which would 'load' the disc.

The pilot's natural tendency to fly the aircraft back to level flight, by application of lateral cyclic or anti-torque pedal, can lead to mast bumping and subsequent rotor separation, without the pilot having adequate knowledge of the cause of the roll and proper recovery actions necessary for safe continuation of flight. If the helicopter rolls to the right in a low 'G' condition the pilot must immediately apply gentle aft cyclic to restore positive 'G' and rotor thrust.

Following pressure from the NTSB, the Federal Aviation Administration (FAA) convened a Technical Panel (TP) tasked with researching solutions to main rotor blade/airframe contact accidents. The FAA's TP proposed specific action concerning the R22 and R44 helicopters in the areas of pilot training, type design changes and operating limitations, one of which included removal of the left cyclic control stick when the left seat is not occupied by a rated helicopter pilot. This limitation was to prevent inadvertent or improper control input by a passenger or pilot involved in impromptu flight instruction. These recommended solutions arose from the fact that the R22 had a higher number of fatal accidents up to 1995, due to main rotor/airframe contact when compared to other piston powered helicopters. Many of these accidents in the USA have been attributed to pilot performance or inexperience, leading to low rotor RPM or low 'G' limitations that resulted in mast bumping or main rotor-airframe accidents.

The FAA Technical Panel Final Report (17 March 1995) proposed the following:

<u>Design Changes</u>

- An improved engine RPM governor
- An increased low rotor RPM warning threshold.
- Provide low rotor RPM warning horn through the intercom system.

<u>Operating Limitations</u>

The panel also proposed the following:

- AD95-02-03. Viz; Flight in turbulent weather.
- Increase of the minimum power-on rotor RPM limit.
- Removal of the left cyclic control stick for flights not conducted with a rated helicopter pilot in the left seat.
- Prohibit flight with the governor selected off.

<u>Notices</u>

The FAA also followed with the issue of:

- Special Airworthiness Alert ASW-94-2

- Special Airworthiness Information Letter ASW-95-01 (10 Jan 1995)
- Airworthiness Directive 95-02-03 (Jan 12 1995)
- *Special Federal Aviation Regulation (SFAR) No 73 (27 Feb 1995)*

The FAA state that "the onset of rotor/airframe contact is insidious, occurs with little prior warning to the pilot, and usually results in catastrophic damage to the helicopter". At the same time, it states that "the R22 helicopter meets type certification requirements".

Among follow up actions by the FAA was the emergency issuing of *Special Federal Aviation Regulation (SFAR) No. 73* in February 1995. This SFAR specifies pilot experience, training, currency and checking requirements for the operation of the R22 and the R44. SFAR No. 73 recommends, inter alia, an Awareness Training Requirement that includes:

- Energy management
- Mast bumping
- Low rotor RPM (blade stall)
- Low G hazards; and
- Rotor RPM decay

and minimum hours Aeronautical Experience to act as pilot-in-command of a Robinson R22.

This emergency Regulation expired on 31 December 1997 and has since been extended to the 31 December 2002, because of the dramatic decrease in the number of R22 accidents/incidents in the USA.

The FAA Flight Standardisation Board Report (15 Feb 1995) states:

"Where normal reaction time available to the pilot would meet minimum certification requirements under normal power settings, operating with high angle of attack of the main rotor blades may leave less time available for recovery and correction of a low rotor RPM condition. Such available time may be of sufficiently short duration as to exceed the pilot's capability to respond." The Board also recommended the revision of FAR Part 27 *"to consider main rotor system inertia in single engine helicopters".*

At the same time the manufacturers said that they would continue to pursue their product improvements viz:

- Automatic carburettor heat system to prevent engine failure due to pilot inattention and subsequent carburettor icing.
- Stainless steel main rotor blade skin to increase rotor inertia and decrease the rotor RPM decay rate.

The first of these improvements was incorporated in the R22 Beta II helicopter, which is an R22 Beta with an up-rated O-360 Lycoming engine installed. The “carb heat assist” system correlates application of carburettor heat with changes in collective setting in order to reduce pilot work-load. Manufacturer’s research is still continuing on the second proposal i.e. the stainless steel main rotor blade skin.

Note:

(a) The Aircraft Flight Manual (AFM) of EI-MAC, which is approved by the IAA, incorporates a reference to the above SFAR No.73 in the Limitations Section **(Appendix D).**

(b) The AFM, Section 4, Normal Procedures, states:- “Removable controls should be removed if person in left seat is not a rated helicopter pilot”

In April 1996 the NTSB issued a Special Investigation Report (SIR) following a number of R22 accidents since 1981 involving main rotor blades contacting the helicopters fuselage. All of these accidents resulted in fatalities. Limited pilot experience in rotorcraft was identified in a considerable number of these accidents. Airspeed and low main-rotor RPM were two of the parameters that could influence the onset of main rotor stall or mast bumping. The SIR required revisions to the Limitations Section, the Normal Procedures Section and the Emergency Procedures Section of the R22 Flight Manual by the Robinson Helicopter Company (RHC). These were issued in 1996.

There is a clear relationship between pilot inexperience in the R22 and main rotor/airframe contact accidents. An analysis of this type of accident, indicated that in 23 of 30 fatal accidents, the pilot manipulating the controls had less than 200 flight hours in helicopters or less than 50 flight hours in the R22. This fact provoked the “awareness training” programme required by SFAR 73 issued by the FAA.

Between 1981 and 1995 there were 31 in-flight break up accidents reported on Robinson R22 helicopters. Most, but not all, occurred in the USA. These were caused by tailboom, cockpit, or tailboom and cockpit strikes. Since the last recorded accident of the above SIR in Australia on the 17 July 1995, to end of December 2000, there have been 19 other fatal accidents involving the Robinson R22 helicopter. The investigations into 12 of these have been completed. The remainder are ongoing. The conclusions are as follows:

No.	Details	Country
8	Pilot Error.	USA
1	Fuel Contamination, due to use of barrels and hand pump.	USA
1	Carburettor ice suspected. Student solo. UK report.	UK
1	Power failure, followed by pilot handling error. UK report.	UK
1	Power failure, use of automotive fuel, handling error.	USA

On-going investigations include the following:

1	First solo cross-country. Accident on base leg for landing.	USA
1	In flight separation of MR blades in cruise flight.	USA

1	Engine cylinder exhaust valve found broken.	USA
1	In flight separation of MR blades during photography.	Denmark
1	In flight break- up following reported engine problem.	UK
1	In flight separation of tail section.	Argentina
1	Mid-air collision with fixed wing aircraft.	Germany

1.18.2 Engine Icing

Carburettor icing is the subject of R22 pilot's Safety Notice SN-25 (revised in 1999). This Notice instructs on the application of controls to prevent or limit the onset of carburettor icing as follows:-

> ***"During climb or cruise, apply carb heat as required to keep carburettor air temperature (CAT) gauge out of yellow arc"(i.e. -15° to +5°).***

Carburettor icing can occur on relatively warm days particularly if conditions are sufficiently humid. Carburettor icing is prevented by heating the intake air in an exhaust heat exchanger. This type of icing is likely at any power setting such as that used during cruise power or descent power. In cruise, the ice tends to form in the carburettor venturi or upstream side of the throttle butterfly where, on this helicopter, the temperature probe is located. In descent, however, the ice may also form on the downstream side of the butterfly.

On this helicopter the carburettor heat control knob is on the centre control. The pull "ON" position should be selected in time to prevent the formation of ice, because if the selection is delayed the use of hot air might be too late to melt the ice before the engine stops. A slight drop in RPM would be the first sign of carburettor icing and this may not be associated with any apparent rough running of the engine. Partial heating can induce carburettor icing as it may melt ice particles, which would otherwise pass into the engine without causing trouble, but not prevent the resultant mixture from freezing as it passes through the induction system. Alternatively, partial heat may raise the temperature of the air into the critical range.

Furthermore, in the R22, if the RPM should drop slightly due to carburettor icing, the engine governor system will automatically open the throttle a little further in order to bring the RPM back up. This will allow further ice to build up at the throttle valve and the process starts all over again. The first sign the pilot might get will be when the engine starts to run rough, which could mean that it is close to stopping. Therefore, when flying in conditions conducive to carburettor icing, the pilot should closely observe the carburettor temperature gauge and be attentive to any automatic rotation of the throttle twist grip. The manufacturer's SN-31 states as follows:-

> *"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."*

The chart at **(Appendix E)** shows the wide range of ambient conditions conducive to the formation of induction system icing for a typical light piston engine.

2. ANALYSIS

2.1 General

The flight from Weston to Sligo, via the Newtownmountkennedy area, was uneventful and routine up to 10:10 hours. Very shortly after this time an in-flight catastrophic event occurred resulting in the disintegration of the Perspex windscreen, as it was struck by the main rotor blades. The shattered pieces of Perspex fell to earth in fields adjacent to the crash site, as did some loose cockpit items, including an aeronautical chart, an aviation information book, mobile phone and the left-hand door. There was evidence of black paint (similar to that found on the rotor blades) on pieces of the windscreen and cabin Perspex found along the helicopter flight path. Also, traces of blue paint were found on the underside of one of the main rotor blades, which came from the helicopter canopy. This indicated that the cabin suffered from a main rotor blade strike in flight prior to the ground impact.

This event would have caused a critical loss of rotor RPM and very severe airframe vibration and loss of control, leading to the final impact. Pilot aided recovery would have been impossible after such airframe strikes. Finally, just before or during ground impact the main rotor struck the tail boom. An examination of the wreckage determined that there was no indication of any aircraft technical malfunction prior to this rotor strike.

The effect of the electric field from the Corn Hill transmitter on the helicopter's electrical system was considered. However, at a range of 4 miles the estimated electric field strength would be of the order of 100 mV/metre. This strength would be unlikely to cause interference in the helicopter's electrical or electronic systems, in particular, the engine speed governor.

A witness, approximately 0.5 miles from the final crash site said she saw a two-foot object fall from the helicopter between her house and the main road. Following the accident, the area between and north of the road were searched and nothing was found. The manufacturers stated that they have never known of a piece of cowling or panel departing on R22 helicopters in flight. They do state that on occasions, doors have either come open or been opened by crew members in flight, causing objects to be lost out of the cabin.

The main rotor blades and hub assembly complete were found in close proximity to the wreckage site.

The technical investigation determined that the main rotor blades came in contact with the helicopter cabin. As a result of this the canopy shattered and particles of Perspex fell to the ground. The net effect of blade contact with the canopy would be a reduction in Rotor RPM, severe vibration and loss of flight control. Possible reasons as to why such an event did occur include:

- Technical
- Environmental

- Helicopter mishandling
- Incapacitation

2.1.1 Technical

An examination of the helicopter and engine on-site and at the AAIU facility at Gormanston determined that no pre-existing mechanical defect existed prior to impact.

2.1.2 Environmental

Analysis of the weather forecast and eyewitness observations concluded that the weather on the day of the accident was dry, bright, with light winds and good visibility.

Further meteorological and topographical analysis of references by an interested party to various types of turbulence and wind concluded that these phenomena were not a factor in this particular accident.

The reported temperature and dew point conditions at the time of the accident were conducive to the likelihood of engine carburettor icing occurring.

The investigation found that “Carb Heat” was applied at the time of impact. While it cannot be determined when “Carb Heat” was actually applied, it can be deduced that if the pilot cycled the “Carb Heat” during the flight, the likelihood is that engine icing was not a factor. Alternatively, if the pilot did not cycle the “Carb Heat” during the flight, it is possible that the engine icing, with its subsequent power loss and resultant loss of engine and rotor RPM could have occurred. Application of “Carb Heat” following the on-set of carburettor icing could actually deteriorate the condition further, or be too late to affect a recovery back to full RPM.

2.1.3 Helicopter Mishandling

Conditions which can lead to helicopter mishandling include:

- An evasive manoeuvre (such as to avoid other aircraft, birds, obstructions, weather etc).
- In response to an onboard technical malfunction.
- An abrupt, inadvertent or inappropriate control input.

2.1.3.1 Evasive manoeuvre

The investigation found no evidence to suggest that the helicopter was engaged in any evasive manoeuvre. In particular no other aircraft were recorded by Shannon Radar to be in close proximity of EI-MAC prior to impact or no indication of bird-strike damage was found on or near the helicopter wreckage.

2.1.3.2 Response to Technical malfunction

No pre-existing technical defect was found in the wreckage examination. Furthermore, the investigation could not establish conclusively as to whether the engine suffered from “Carb Icing”, which could lead to a critical reduction of engine and/or rotor RPM.

2.1.3.3 Abrupt, inadvertent or inappropriate control input

The flight characteristics, sensitivity to flight control inputs and high rotor RPM decay rate are inherent to the R22 because of its low gross weight. As a result the helicopter must be treated gently by its pilot and flown within the approved limitations.

An abrupt control input by either the pilot or a passenger could develop a situation whereby there is a divergence of the main rotor from its normal plane of rotation. If the helicopter is flown inadvertently out of its approved limitations or outside its normal safe operating envelope, it is possible that rotor RPM could decay to such a degree that the main rotor blade would strike the helicopter fuselage. Similarly, if the handling pilot makes an inappropriate control input in response to a technical problem (engine failure, power loss etc.), a perceived technical problem, or to a low G situation, it is likely that this condition would deteriorate further and to such a degree that a blade strike would occur.

2.1.4 Incapacitation

Medical incapacitation by the handling pilot can cause loss of aircraft control leading to an accident. However, in this particular case, post mortems carried out on both the pilot and the passenger by the State Pathologist found no pathological evidence of any medical or physical condition that could have contributed to this accident.

2.2. Discussion

The erratic behaviour of EI-MAC prior to its final impact with the ground could be due to (a) an engine problem or (b) a flight control input problem. It could also have been due to a combination of both. On the R22, (a) and (b) are very much interlinked as for instance when a rotor blade is near the stall condition it can act as a brake and almost stop the engine. This is attributed to the low inertia of the rotor disc.

(a) Engine problem

The examination of the engine revealed no evidence of abnormalities or deficiencies.

The aftercast figures for temperature and dew point at the time of the accident indicate that there was a risk of serious icing. It cannot be concluded from the evidence found as to when the carburettor heat was selected “ON” during the flight. It may have been cycled by the pilot during flight or it may have been put on if or when engine icing became apparent. It is therefore appropriate to consider the possibility of loss of power due to carburettor icing.

Witness reports use the words loud, cracking, battering, crackling and grinding to describe the noise emanating from EI-MAC from about 1.5 miles from the crash site. If the pilot had an engine problem at that stage, the instructions are clear viz:- *“lower the collective, pull on the cyclic control to convert forward energy to rotor rotational energy (ie. maintain RPM) and then sort out the problem.. If no solution to the problem can be obtained, auto-rotate and land immediately”.* The pilot has in the region of 1 second to lower the collective in the event of an engine problem leading to a loss of RPM. The low rotor warning horn and light will alert the pilot.

If the helicopter is at 500 ft, a steady glide at 65 kts should be established giving a maximum glide range of about 0.37 nm. If the altitude is less, as in this case, then there is less time and less distance in which to glide and less time to sort out the problem. This is one of the reasons to maintain an altitude of not less than 500 ft during cruise.

It is clear from SN 31, that if the pilot is inattentive to the CAT gauge or the engine throttle, the onset of low rotor RPM could occur without warning. It could then be too late for the engine to respond to raise the rotor RPM in time. The throttle must be opened and the collective lever lowered immediately to increase rotor RPM.

If, in the event of an engine problem, the pilot inadvertently maintains forward cyclic and/or up collective, the rotor RPM will reduce further. This would lead eventually to a drop in both airspeed and altitude. Rapidly, there would be less and less kinetic (forward speed) and potential (height) energy to convert into rotational energy. At this stage, with less power available, there will be an onset of blade stall causing fuselage vibrations, the helicopter would start shaking and it would be difficult to control. The blade stall will increase the drag, causing further reduction in rotor RPM. From the ground this would be seen as a “rocking” motion and if blade contact is made with the canopy, pieces of Perspex will be seen falling from the helicopter. The low rotor warning horn would be sounding continuously and the low rotor RPM warning light would be illuminated.

In previous cases involving the R22 and carburettor icing problems the symptoms as described by witnesses to this accident are similar. Engine noises were described as *"crackling and popping", "banging noises" and "spluttering and misfiring".* The helicopter movement would be *"wobbling back and forth" "swaying from left to right"* followed by*" fuselage rotating slowly in a clockwise direction" and an "instant nose dive".* In some cases, where recovery was achieved, the pilot was unaware of the engine sounds as heard by witnesses at the time and some reported no mechanical deficiencies prior to the low RPM warning. There was evidence in this case that the Low Rotor RPM warning light was on and that the Engine Low Oil Pressure warning light was also on at the time of impact.

(b) Flight Control Problem.

A problem in this area could have been initiated by an abrupt and/or inadvertent and/or inappropriate control movement originating in the cockpit. As previously indicated this could have originated in a corrective manoeuvre following a low “G” condition. Low “G” could be caused by:-

Excessive forward cyclic input in forward flight
Rapid lateral cyclic movement
Abrupt lowering of the collective in high-speed forward flight

It must be assumed in this case that the sound heard by the witnesses, particularly early on, was the sound of blade flapping. Blade flapping of 2º or 3° is normal, but uncontrolled blade flapping such as experienced if the rotor disc is allowed to become unloaded (as in a low “G” situation) will allow the blades to strike the fuselage. It will also occur anytime the cockpit control movements are abrupt and/or beyond full range.

Blade flapping increases rapidly from acceptable to excessive angles in only one or two rotor revolutions, leaving little, if any, reaction time for the pilot to correct the situation. Excessive flapping will lead to mast bumping. Evidence of mast bumping was apparent on examination of the wreckage in this case. Aggressive manoeuvring may also result in eventual rotor stall.

Another problem can be caused by an inexperienced pilot attempting to manoeuvre the helicopter at low forward speeds. He may become distracted in the cockpit, fail to give due attention to airspeed, and the helicopter can rapidly lose lift and begin to descend. An inexperienced pilot may raise the collective to stop the descent. This can reduce RPM thereby reducing power available and causing an even greater descent rate and a further loss of RPM. The reduced tail rotor thrust then allows the helicopter to rotate to the right. The main rotor blades then stall and the helicopter falls rapidly whilst continuing to rotate. The situation is then unrecoverable.

3. CONCLUSIONS

3.1 Findings

3.1.1 The pilot held a valid Private Pilot's Licence (Rotorcraft) issued by the Irish Aviation Authority. The privileges of the Private Pilot's Licence in the Air Navigation (Personnel Licensing) (Amendment) Order, 1996, do not permit flight for remuneration purposes. He had approximately 50 hours experience on the R22. The pilot did not hold a Flight Instructor's Rating.

3.1.2 It was the pilot's intention to engage in aerial photography for commercial purposes in the Sligo area.

3.1.3 The investigation was unable to discover the original copy or any copy of the pilot's Flight Exercise Report, which would normally carry the Flying Instructor's comments on the pupil, on a flight by flight basis. The Operator stated that the completed Report was given to the pilot at the end of his flying course. It would have been helpful to the investigation if the Operator retained the original copy on file.

3.1.4 The subscription service, for the supply of Robinson R22 Safety Notices, was not being availed of by either the owner or Operator of EI-MAC at the time of the accident.

3.1.5 Robinson Helicopter Company Safety Notice, SN-34, Photo Flights-Very High Risk, is both unambiguous and clear in its intent. It is normally carried in Section 10 of the Aircraft Flight Manual (AFM). It was not found in the charred remains of the AFM.

3.1.6 The pilot was medically fit to carry out the flight on 27 August 1999. No pathological evidence of any medical or physical condition was subsequently found that may have caused or contributed to the accident.

3.1.7 The general weather conditions in the Longford area were sunny and mild, with moderate winds. Visibility was good. The conditions and topography were not conducive to in-flight turbulence

3.1.8 A witness 2 miles from the crash site, and an estimated 1 min 38 seconds before impact, reported that the helicopter passing over her head did not appear to be in difficulty. One half mile later another witness reported a battering noise coming from the helicopter.

3.1.9 A third eye-witness living near the crash area saw EI-MAC flying to the front of her house from right to left direction, at relatively low altitude. She recalled that she could distinguish the colours of the two occupants shirts or jackets through the cockpit Perspex. She recalled seeing the helicopter obviously in trouble, "*a piece of blade falling from it and the helicopter dipping off to the side*" some three to four fields away from her house, near the main road. She immediately dialled 999. Some 40 seconds later the helicopter crashed. The witness then saw a column of smoke rising. A subsequent extensive ground search by the Investigators and the local Gardai did not locate this piece. Later technical investigation at the AAIU facility at Gormanston, Co. Meath, accounted for all parts of the main rotor and tail rotor blades.

3.1.10 The aircraft was maintained in accordance with an approved maintenance schedule. Witnesses heard the engine running right up to its silence resulting from the ground impact.

3.1.11 The investigation did not reveal any evidence of a technical malfunction to any component of EI-MAC.

3.1.12 Full dual controls were fitted to EI-MAC. They were not removed by the pilot, contrary to Section 4, Normal Procedures of the R22 Pilot's Operating Hand Book.

3.1.13 VHF communications between the pilot and ATC were normal. No Mayday or emergency call was made after the pilots last routine transmission at 10:04.56 hours to Shannon ATC.

3.1.14 The flight path of EI-MAC was recorded by Shannon Surveillance Radar, on exiting the Dublin Control Zone, to loss of contact near Castlepollard, Co. Westmeath. This loss of radar contact is not unusual in the context of this relatively low level cross-country VFR flight.

3.1.15 VHF communications with Shannon were also intermittent, probably due to the helicopter's relatively low altitude and intervening high ground between the helicopter and Shannon.

3.1.16 The pilot's last position report to Shannon, that he was 14 miles north of Abbeyshrule, was probably derived from the onboard GPS navigation system.

3.1.17 In this latter part of the flight the aircraft descended from an altitude where it had good radio communications with Shannon ATC to an altitude of some 200 to 300 feet above ground level, shortly before the accident. The reason for this descent from cruise altitude to near ground level is not known. It is normal and prudent practice for pilots of single-engined helicopters to maintain at least 500 feet altitude above ground level, in case of the need for an autorotative landing.

3.1.18 The main rotor blades contacted the fuselage during flight, causing failure of the main rotor system and subsequent loss of control of the helicopter.

3.1.19 There is no indication of any aircraft malfunction prior to this rotor strike.

3.1.20 Just prior to or during the ground impact a main rotor blade made contact with the tail boom and was struck on its trailing edge by the tail rotor gearbox. The tail rotor gearbox turned through 180° during the ground impact.

3.1.21 Moderate, severe or extreme air turbulence, which can also cause mast bumping, are considered not to have been factors in this accident.

3.2 Causal Factors

The main rotor blades struck the fuselage during flight, causing failure of the main rotor system and subsequent loss of control of the helicopter.
Possible factors contributing to this strike include:

- An abrupt and/or inadvertent and/or inappropriate control movement outside the helicopter's approved limitations leading to excessive flapping of the main rotor blades, rotor mast bumping and a strike of the blades on the fuselage.

- A main rotor blade stall resulting from an inappropriate response to a lowering of rotor RPM due either to engine carburettor icing or to a flight control action originating in the cockpit.

4. Safety Recommendations

It is recommended that:

4.1 The Irish Aviation Authority (IAA) should issue an urgent Notice to all Operators of Robinson R.22 and R44 helicopters in Ireland requiring the removal of the left cyclic control stick for flights, apart from instructional flights, conducted with a person other than a helicopter rated pilot in the left seat**. (SR 7 of 2001)**

The IAA issued AIC No 27/00, dated 1 August 2000, entitled 'Light Helicopter Operations', which, inter alia, addressed the above requirements.

4.2 The Irish Aviation Authority (IAA) should issue a NOTAM on Robinson R-22/R-24 training, emphasising the subjects contained in the Awareness Training programme as laid down in SFAR No. 73, which is a proven successful model**. (SR 8 of 2001)**

4.3 The Irish Aviation Authority (IAA) should consider discontinuing the practice of granting pilots with fixed wing experience a reduction towards the amount of hours required for the award of a Private Pilot's Licence (Rotorcraft), specifically in regards to R22 and R44 helicopters. **(SR 9 of 2001)**

The IAA stated that reduction in flight time experience (rotorcraft) is in conformity with JAR-FCL Part 2 (Helicopters) if the pilot is the holder of a fixed wing licence.

APPENDIX A


ACCIDENT SITE
14 NM NORTH OF ABBEYSHRULE
LONGFORD
PROBABLE FLIGHT PATH
LAST RADAR CONTACT
ABBEYSHRULE
RADAR PLOTTED FLIGHT PATH
WESTON
PICKUP POINT
Scale 1 : 500,000

APPENDIX B

ROBINSON
HELICOPTER COMPANY

Safety Notice SN-34

Issued: Mar 99

PHOTO FLIGHTS - VERY HIGH RISK

There is a misconception that photo flights can be flown safely by low time pilots. Not true. There have been numerous fatal accidents during photo flights, including several involving R22 helicopters.

Often, to please the photographer, an inexperienced pilot will slow the helicopter to less than 30 KIAS and then attempt to maneuver for the best picture angle. While maneuvering, the pilot may lose track of airspeed and wind conditions. The helicopter can rapidly lose translational lift and begin to settle. An inexperienced pilot may raise the collective to stop the descent. This can reduce RPM thereby reducing power available and causing an even greater descent rate and further loss of RPM. Rolling on throttle will increase rotor torque but not power available due to the low RPM. Because tail rotor thrust is proportional to the square of RPM, if the RPM drops below 80% nearly one-half of the tail rotor thrust is lost and the helicopter will rotate nose right. Suddenly the decreasing RPM also causes the main rotor to stall and the helicopter falls rapidly while continuing to rotate. The resulting impact is usually fatal.

Photo flights should only be conducted by well trained, experienced pilots who:

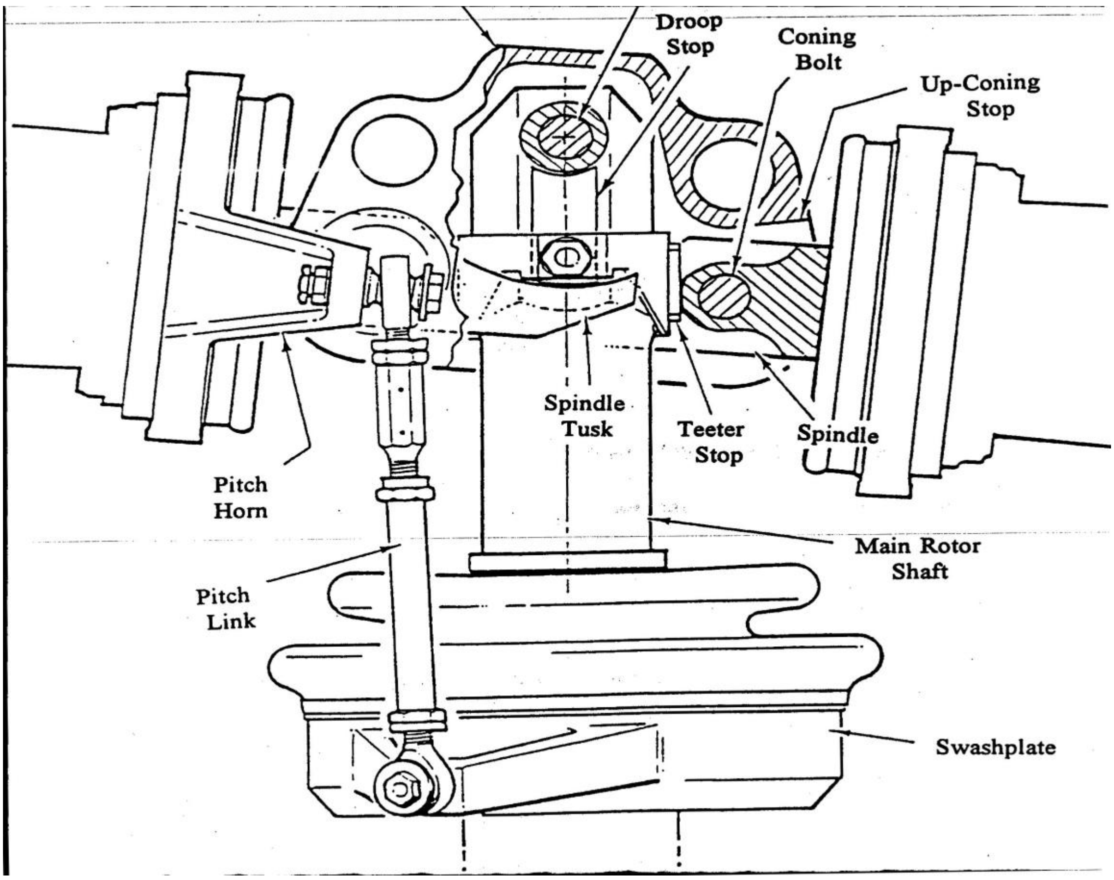
1) Have at least 500 hours pilot-in-command in helicopters and over 100 hours in the model flown;

2) Have extensive training in both low RPM and settling-with-power recovery techniques;

3) Are willing to say no to the photographer and only fly the aircraft at speeds, altitudes, and wind angles that are safe and allow good escape routes.

Please reread Safety Notice SN-24

APPENDIX C


Droop
Stop
Coning
Bolt
Up-Coning
Stop
Spindle
Tusk
Teeter
Stop
Spindle
Pitch
Horn
Main Rotor
Shaft
Pitch
Link
Swashplate

APPENDIX D (Page 1)

Special Federal Aviation Regulation 73

Robinson R–22/R–44 Special Training and Experience Requirements

1. *Applicability.* Under the procedures prescribed herein, this SFAR applies to all persons who seek to manipulate the controls or act as pilot in command of a Robinson model R–22 or R–44 helicopter. The requirements stated in this SFAR are in addition to the current requirements of part 61.

2. *Required training, aeronautical experience, endorsements, and flight review.*

(a) Awareness Training:

(1) Except as provided in paragraph (a)(2) of this section, no person may manipulate the controls of a Robinson model R–22 or R–44 helicopter after March 27, 1995, for the purpose of flight unless the awareness training specified in paragraph (a)(3) of this section is completed and the person's logbook has been endorsed by a certified flight instructor authorized under paragraph (b)(5) of this section.

(2) A person who holds a rotorcraft category and helicopter class rating on that person's pilot certificate and meets the experience requirements of paragraph (b)(1) or paragraph (b)(2) of this section may not manipulate the controls of a Robinson model R–22 or R–44 helicopter for the purpose of flight after April 26, 1995, unless the awareness training specified in paragraph (a)(3) of this section is completed and the person's logbook has been endorsed by a certified flight instructor authorized under paragraph (b)(5) of this section.

(3) Awareness training must be conducted by a certified flight instructor who has been endorsed under paragraph (b)(5) of this section and consists of instruction in the following general subject areas:

(i) Energy management;

(ii) Mast bumping;

(iii) Low rotor RPM (blade stall);

(iv) Low G hazards; and

(v) Rotor RPM decay.

(4) A person who can show satisfactory completion of the manufacturer's safety course after January 1, 1994, may obtain an endorsement from an FAA aviation safety inspector in lieu of completing the awareness training required in paragraphs (a)(1) and (a)(2) of this section.

(b) Aeronautical Experience:

(1) No person may act as pilot in command of a Robinson model R–22 unless that person:

(i) Has had at least 200 flight hours in helicopters, at least 50 flight hours of which were in the Robinson R–22; or

(ii) Has had at least 10 hours dual instruction in the Robinson R–22 and has received an endorsement from a certified flight instructor authorized under paragraph (b)(5) of this section that the individual has been given the training required by this paragraph and is proficient to act as pilot in command of an R–22. Beginning 12 calendar months after the date of the endorsement, the individual may not act as pilot in command unless the individual has completed a flight review in an R–22 within the preceding 12 calendar months and obtained an endorsement for that flight review. The dual instruction must include at least the following abnormal and emergency procedures flight training:

(A) Enhanced training in autorotation procedures,

(B) Engine rotor RPM control without the use of the governor,

(C) Low rotor RPM recognition and recovery, and

Ch. 2

APPENDIX D (Page 2)

(D) Effects of low G maneuvers and proper recovery procedures.

(2) [No person may act as pilot in command of a Robinson model R–44 unless that person—

(i) [Has had at least 200 flight hours in helicopters, at least 50 flight hours of which were in the Robinson R–44. The pilot in command may credit up to 25 flight hours in the Robinson R–22 toward the 50 hour requirement in the Robinson R–44; or

(ii) [Has had at least 10 hours dual instruction in a Robinson helicopter, at least 5 hours of which must have been accomplished in the Robinson R–44 helicopter and has received an endorsement from a certified flight instructor authorized under paragraph (b)(5) of this section that the individual has been given the training required by this paragraph and is proficient to act as pilot in command of an R–44. Beginning 12 calendar months after the date of the endorsement, the individual may not act as pilot in command unless the individual has completed a flight review in a Robinson R–44 within the preceding 12 calendar months and obtained an endorsement for that flight review. The dual instruction must include at least the following abnormal and emergency procedures flight training—

(A) Enhanced training in autorotation procedures;

(B) Engine rotor RPM control without the use of the governor;

(C) Low rotor RPM recognition and recovery; and

(D) Effects of low G maneuvers and proper recovery procedures.]

✗ (3) A person who does not hold a rotorcraft category and helicopter class rating must have had at least 20 hours of dual instruction in a Robinson R–22 helicopter prior to operating it in solo flight. In addition, the person must obtain an endorsement from a certified flight instructor authorized under paragraph (b)(5) of this section that instruction has been given in those maneuvers and procedures, and the instructor has found the applicant proficient to solo a Robinson R–22. This endorsement is valid for a period of 90 days. The dual instruction must include at least the following abnormal and emergency procedures flight training:

(i) Enhanced training in autorotation procedures,

(ii) Engine rotor RPM control without the use of the governor,

(iii) Low rotor RPM recognition and recovery, and

(iv) Effects of low G maneuvers and proper recovery procedures.

(4) A person who does not hold a rotorcraft category and helicopter class rating must have had at least 20 hours of dual instruction in a Robinson R–44 helicopter prior to operating it in solo flight. In addition, the person must obtain an endorsement from a certified flight instructor authorized under paragraph (b)(5) of this section that instruction has been given in those maneuvers and procedures, and the instructor has found the applicant proficient to solo a Robinson R–44. This endorsement is valid for a period of 90 days. The dual instruction must include at least the following abnormal and emergency procedures flight training:

(i) Enhanced training in autorotation procedures,

(ii) Engine rotor RPM control without the use of the governor,

(iii) Low rotor RPM recognition and recovery, and

(iv) Effects of low G maneuvers and proper recovery procedures.

(5) [No certificated flight instructor may provide instruction or conduct a flight review in a Robinson R–22 or R–44 unless that instructor—

(i) [Completes the awareness training in paragraph 2(a) of this SFAR.

(ii) [For the Robinson R–22, has had at least 200 flight hours in helicopters, at least 50 flight hours of which were in the Robinson R–22, or for the Robinson R–44, has had at least 200 flight hours in helicopters, 50 flight hours of which were in Robinson helicopters.

APPENDIX D (Page 3)

Up to 25 flight hours of Robinson R–22 flight time may be credited toward the 50 hour requirement.

(iii) [Has completed flight training in a Robinson R–22, R–44, or both, on the following abnormal and emergency procedures—

(A) Enhanced training in autorotation procedures;

(B) Engine rotor RPM control without the use of the governor;

(C) Low rotor RPM recognition and recovery; and

(D) Effects of low G maneuvers and proper recovery procedures.

(iv) [Has been authorized by endorsement from an FAA aviation safety inspector or authorized designated examiner that the instructor has completed the appropriate training, meets the experience requirements and has satisfactorily demonstrated an ability to provide instruction on the general subject areas of paragraph 2(a)(3) of this SFAR, and the flight training identified in paragraph 2(b)(5)(iii) of this SFAR.]

(c) Flight Review:

(1) No flight review completed to satisfy §61.56 by an individual after becoming eligible to function as pilot in command in a Robinson R–22 helicopter shall be valid for the operation of R–22 helicopter unless that flight review was taken in an R–22.

(2) No flight review completed to satisfy §61.56 by individual after becoming eligible to function as pilot in command in a Robinson R–44 helicopter shall be valid for the operation of R–44 helicopter unless that flight review was taken in the R–44.

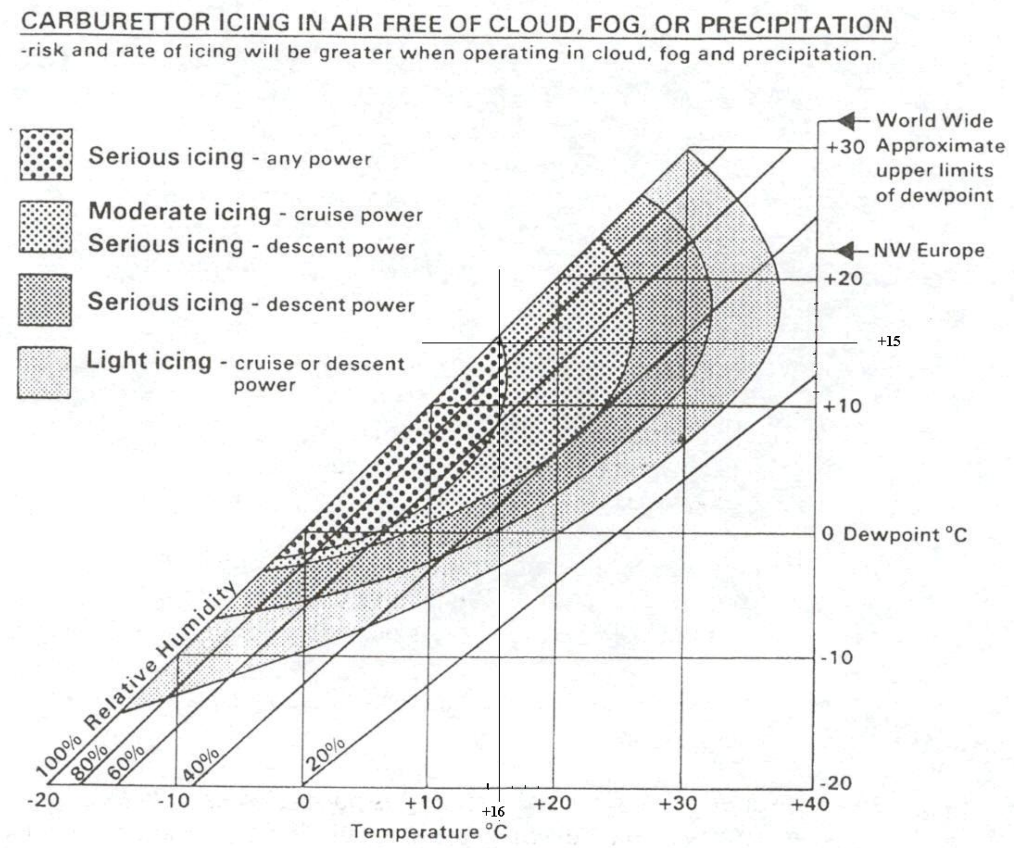
(3) The flight review will include a review of the awareness training subject areas of paragraph 2(a)(3) of this SFAR and the flight training identified in paragraph 2(b) of this SFAR.

(d) Currency Requirements: No person may act as pilot in command of a Robinson model R–22 or R–44 helicopter carrying passengers unless the pilot in command has met the recency of flight experience requirements of §61.57 in an R–22 or R–44, as appropriate.

3. *Expiration date.* This SFAR expires December 31, [2002], unless sooner superceded or rescinded.

*U.S. Government Printing Office: 1998 - 432-359/80006

APPENDIX E



The graph shown above is reproduced from the Irish Aviation Authority (IAA) Aeronautical Information Circular (AIC) NR 11/97, titled “Induction system icing on piston engines as fitted to aeroplanes, helicopters and airships”

A Temp/Dew point of 16°/15°C (forecast for the area) corresponds to conditions where serious icing could occur at any power setting but particularly at a low power setting such as during descent. Cruise power could also produce moderate carburettor icing.