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Aircraft Type and Registration:	Robinson R22 B; EI-TKI
No. and Type of Engines:	One Lycoming 0-320-B2C
Aircraft Serial Number:	1195
Year of Manufacture:	1989
Date and Time (UTC):	1st. August 1997; 1550 hrs
Location:	Hazelwood, Co. Sligo
Type of Flight:	Private
Persons on Board:	2
Injuries:	Nil
Nature of Damage:	Undercarriage distorted
Commanders Licence:	Private Pilots Licence (Helicopters)
Commanders Age:	38 years
Commanders Flying Experience:	Total 261.2 hrs Last 90 days 31.0 hrs Last 30 days 1.9 hrs Last 24 hours 1.9 hrs
Information Source:	AAIU Field Investigation

History of the Flight

The aircraft had just completed its Annual Inspection at a helicopter maintenance facility at Dublin Airport. The owner arrived there on the day of the incident with the intention of flying the aircraft to his home base, which is located to the rear of his private residence in Co. Sligo. Following discussions with the maintenance personnel he performed a pre-flight inspection in preparation for the flight to Sligo. As part of this inspection he noted the fuel contents as displayed on the cockpit gauges.

The main tank gauge indicated approximately 7/8 full and the auxiliary tank gauge indicated approximately ½ full. He removed both fuel tank caps and physically inspected the fuel levels.

He was satisfied that the visual inspection corresponded with the indicated contents, and he calculated that there was at least 2½ hours of fuel in the aircraft.

He took off for Sligo at 13:55 hrs, accompanied by his young daughter, routing initially to Athlone. ATC routed him via Dunshaughlin due to other traffic, and he then routed directly to Athlone. On departing Athlone, he made a diversion to show the town of Longford to his daughter, and then routed to the Sligo base. At this point the pilot noted that the main tank indicated ½ full and the auxiliary tank was indicating zero. Half main tank indicated 9 gallons remaining, which equated to a duration of a little over one hour. An onboard portable GPS unit indicated 33 minutes flight time to base, at this point.

As the aircraft approached its home base, it crossed Lough Gill, a large lake. The pilot then descended to the hover over a large field to the rear of his landing area. In the hover he performed final pre-landing checks. The pilot stated that at this time the main tank was indicating slightly under ¼ and the low fuel contents warning light was not illuminated. He then proceeded to hover-taxy the aircraft over a fence into his landing area. As he passed over the fence, he became aware of a significant loss of power, and the low rotor speed alarm activated. He flew the aircraft sideways to clear the fence and landed heavily. At touch-down the engine was already stopped. The undercarriage cross tubes were distorted as a result of the heavy landing. The pilot reported that the approximate time of landing was 15:50 hrs. The pilot and his daughter exited the aircraft unhurt.

Investigation

Investigation showed that both fuel tanks were empty and the carburettor bowl was almost dry. When power was turned on the low fuel warning flight illuminated correctly. The main fuel tank indicated approximately 1/8 fuel, even though the tank was empty. The aircraft was then refuelled and the engine performed normally. The low fuel light extinguished normally when sufficient fuel was added. The main tank fuel gauge over-read during these tests, by approximately 1/8 of full indication or 2¼ US Gallons. However, it was noted that the reading was not consistent, and that the indicator needle varied upwards by approximately 1/16 of fuel indication, from time to time, without any change of the physical contents. Further examination revealed a slightly loose nut on a connector at the rear of the fuel gauge cluster. When this connector was removed, i.e. open circuit, the main fuel tank gauge indicated full, with zero contents in the tank.

The connectors on the back of the fuel gauges are marked with a red line. All the other connectors were tight, and the red line indicator was intact. The loose nut on the connector in question was moved before the state of the red line was positively ascertained.

No evidence of fuel leaks were found on the aircraft.

Fuel Management

The owner maintained a fuel log book, where he recorded fuel added, and the flying time available on the tank contents. This system appeared to work well when he flew and operated the aircraft. However, during the Annual Inspection, new transmission drive belts were fitted, and the aircraft had to be ground run for a number of hours, in order to bed-in the new belts. Some fuel was added for these grounds runs, but the quantity was not recorded. The owner was not present for these ground runs and consequently neither this running time not the added fuel were recorded in his fuel log.

The fuel tanks on this aircraft are quite deep, and dark, thereby making visual estimation of the tank contents difficult, when viewed through the filler opening. This is particularly so when the inspection is made in bright sunlight, as on the day of the incident, due to the reflected glare from the area surrounding the filler opening, and also because of the high position of the filler opening.

The fuel tank design on the R22 is a simple gravity feed system. The feeds from the auxiliary tank and main tank are permanently interconnected. The auxiliary tank, which holds approximately 9 US Gallons, is exhausted when the main tank contents is reduced to 4.5 US gallons or approx. ¼ full. 4.5 US Gallons equates to approx. 35 minutes flying, at cruise power setting.

The R22 flight manual, in both the Emergency Section and Section 10, *"Safety Tips"*, specifically warns against the use of the low fuel contents warning light as a working indication of fuel contents. Furthermore, Robinson Safety Notice SN 15, which was contained in the Flight Manual of EI-TKI, warns on the dangers of fuel exhaustion, and cautions the pilot:

"Never to rely solely on the fuel contents gauge or the low fuel warning light".

The same notice further cautions the pilot:

"Always land to refuel before the main tank fuel gage reads less than ¼ full full."

and

"NEVER allow the fuel quantity to become so low in flight that the low fuel warning light comes on."

Engineering Information

The aircraft is equipped with a low fuel contents warning light that is set to come on when the fuel contents in the main tank reduces to approx. 1.5 US gallons, which equates to approximately 10 minutes flying. This light is activated by a float switch which is separate from the fuel contents gauge. The function of this light was checked on the Annual Inspection by manually depressing the float, while the fuel contents exceeding the level required to activate the light, and was found to function satisfactorily.

It was also found to function satisfactorily when checked by varying the tank contents, after the incident. It was later calibrated and was found to come on when the remaining usable fuel reduced to 10 lbs weight. The R22 maintenance manual states that the light should activate when the remaining fuel reduces to a minimum of 8 lbs. No reason was found as to why it did not function on the flight in question.

Apart from the check of the low fuel switch, no other checks on the fuel indicating system were required on the Annual Inspection, nor were any performed.

Because the main and auxiliary tanks on this aircraft are permanently interconnected, there is a direct correlation-relation between the contents of the two tanks, as follows

Auxiliary Tank Contents	Main Tank Contents
Full	Full
Empty	4.5 US gallons (¼ full)

This data was determined by experiment. It is not contained in the flight manual.

A linear relationship exits between the contents of the two fuel tanks. When the auxiliary tanks is ½ full, the main tank would be slightly less than ¾ full. Therefore, when the pilot inspected the gauges prior to departure from Dublin, and the main tank indicated approximately 7/8 full and the auxiliary tank indicated ½ full, an indication discrepancy existed, indicating that one of the gauges was misreading at that time. During the flight, when the auxiliary tank read zero and the main tank indicated ½ full, a further indication discrepancy existed.

In common with most helicopters, the hover attitude of the R22 is more tail down than the cruising attitude. Because the fuel tank outlet is at the front end on the tank, the fuel outlet is more likely to uncover in the hover rather than in the cruise, in a low fuel situation. This aircraft was in the hover when the engine stoppage occurred.

Background Information

The owner stated he twice experienced problems with fuel tank contents indications on the main tank, after the previous Annual Inspection, in August 1996, and that he returned the aircraft to the maintenance organisation for rectification. This is disputed by the maintenance organisation, who stated that the aircraft was returned only once, when an earthing fault in the fuel contents sender (transmitter) was found and rectified. The aircraft log book contains only one entry pertaining rectification work on the fuel indication system in or around this time.

The owner did not have, nor ever used, a calibrated dip stick to check fuel contents.

Other Information

The Robinson Helicopter Company issued a Service Bulletin, SB 83, on 04 March 1997. Accomplishment of this bulletin was required by 31 May 1997 or within 100 flying hours, whichever occurred first.

This service bulletin related to a modification to ensure the security of the fuel tank vent lines inside the main rotor mast fairing. Inspection of EI-TKI, after the incident, revealed that the modification, as required by the service bulletin, had not been accomplished.

The vent pipe flexible line attachment to the top of the auxiliary tank was found to be disconnected after the incident. It is considered possible, but unlikely, that this line had become detached during the heavy landing. No evidence of fuel loss, through the disconnected vent, was found.

There is no evidence that either of these deficiencies contributed to the engine stoppage.

Robinson Helicopters do not manufacture or supply a fuel tank dip-stick for the R22.

UK Public Transport Requirements

In the UK, the CAA have introduced a requirement for R22 helicopters, which are registered as public transport aircraft, which reflects on this incident. Each aircraft is required to carry dip-sticks for checking fuel tank contents. Because dip sticks are not produced by Robinson, the local Robinson agent in the UK, Helitech of Luton, supplies light-weight metal dip-sticks which are approved to meet the CAA minor modification requirement for the R22.

Conclusions

This incident was caused by the in-flight exhaustion of the aircraft's fuel. The stipulation in the aircraft's flight manual that the aircraft should land for refuelling when the fuel contents indication reduces to less than ¼ full was not observed. The pilot was misled-led by an over-reading contents gauge.

His pre-flight inspection did not detect a discrepancy between the main tank gauge indication and the physical contents of the main fuel tank. Reliance on a difficult visual observation, rather than a simple dip stick, increased the difficulty of detecting such a discrepancy. The cause of the over-reading gauge was a slightly loose electrical connection to the fuel indicator gauge.

SB 83, while not related to this incident, should have been accomplished, according to the manufacturer's recommendation, by 31 May 1997, on this aircraft. The responsibility for the accomplishment of this bulletin lay with the operator.

The fuel indicating system in the R22 is not fail safe, in that any increased resistance in the indicating circuit causes the fuel quantity to over-read.

The use of a fuel contents dip stick would have given the pilot accurate information as to the true contents of the fuel tanks, before take-off.

Safety Recommendations

1. The fuel indicating system should be reviewed by the manufacturer, with a view to making the fuel indication decrease in the event of increased circuit resistance or an open circuit situation. **(SR 17 of 1999)**

2. Operators and pilots of R22 helicopters should consider the use of simple calibrated dip stick to verify fuel contents, due to the difficulty of visually checking the tank contents of this aircraft. **(SR 18 of 1999)**

3. The manufacturer of the R22 should consider the provision of a fuel contents dip-stick for the R22, or alternatively should adopt the use of the tool used in the UK. **(SR 19 of 1999)**