Aircraft Type and Registration:	Hiller 12 OH-23B, N33514	
No & Type of Engines:	1 Franklin 6V335B piston engine	
Year of Manufacture:	1954	
Date & Time (UTC):	18 November 2004 at 1258 hrs	
Location:	Northampton (Sywell) Aerodrome, Northamptonshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Tail boom severed, damage to main rotor blades, one skid bent and engine crankcase fractured	
Commander's Licence:	FAA Private Pilot's Licence	
Commander's Age:	58 years	
Commander's Flying Experience:	7,152 hours (of which 16 were on type) Last 90 days - 28 hours Last 28 days - 19 hours	
Information Source:	AAIB Field Investigation	

Synopsis

The aircraft ran out of fuel transitioning to the hover during an approach to land. The fuel gauge was reading approximately 25% full at the time. Investigations revealed that the fuel gauge fitted was not approved for use on aircraft.

History of the flight

The pilot had agreed to take two associates of the owner for short flights, and the aircraft owner's representative was present to assist in the activities. The pilot arrived at Sywell at about 0900 hrs and carried out a full daily pre-flight check of the helicopter whilst it was still in the hangar. The weather was poor with a cloudbase of approximately 600 feet, light and variable winds and a visibility around 3,000 metres in light drizzle. The pilot assessed that the weather would be suitable for hovering manoeuvres on the aerodrome and low level circuits.

At midday, the two passengers arrived and, having been joined by the pilot, all three boarded the helicopter. The engine start and warm-up proceeded normally and the helicopter lifted off into the hover. However, when the pilot attempted to transition into forward flight he found that, even with full throttle, the helicopter did not perform adequately so he therefore set it down again. One passenger disembarked and the aircraft subsequently lifted off and performed acceptably. The pilot recalls that the time of this lift-off was about 1215 hrs. The aerodrome movement record, kept by the Aerodrome Flight Information Service Officer (AFISO), showed the aircraft's departure time as 1204 hrs, although it is not clear whether this relates to the first attempt at takeoff or the subsequent successful departure. The sortie then consisted of a hover-taxi to an area of the aerodrome set aside for helicopter manoeuvres, a few spot turns, takeoffs and landings, and a brief circuit. The pilot then hover-taxied the helicopter to the dispersal and, with the engine running, the passengers swapped over. The pilot then flew another similar sortie.

Returning to the dispersal following the second flight, the pilot indicated to the owner's representative that he intended to shut down. However, the owner's representative indicated that another passenger wished to fly. Again, the passengers swapped over, and the aircraft departed for a third detail similar to the previous two.

On approach to land from this third detail, at approximately 60 feet agl, with the speed close to 40 kt, the pilot began a gentle transition into the hover. The engine then, very suddenly, lost power. The pilot described the loss of power as being "instant" and "as though the magnetos had been turned off".

The pilot lowered the collective lever immediately, assessed that there was insufficient speed and height for full auto-rotation and therefore concentrated his efforts on maintaining a level attitude before attempting to cushion the touchdown with an upward application of collective control. He is of the opinion that the rotor RPM had only decayed slightly by the time the collective was lowered in response to the engine failure.

The helicopter touched down without significant yaw and with some forward speed. The touchdown was firm enough to cause the helicopter to bounce several feet into the air. The pilot reported that he lost tail rotor authority at this stage and the helicopter touched down a second time slightly right skid low. Ground marks left by the helicopter's skids were consistent with this recollection. The pilot reported that the rotor disc then toppled causing the main rotor blades to strike and sever the tail boom. The accident occurred at approximately 1258 hrs; between 43 and 54 minutes after the first lift-off.

Both the pilot and passenger, who had been wearing four point harnesses, vacated the aircraft without injury. The helicopter sustained considerable damage to the main rotor blades, the tail boom was severed, the lower part of the engine case fractured and the right hand skid was slightly deformed. There was no fire.

The avoid curve

The Hiller Flight Manual includes a depiction of the *'Height-Velocity Chart for Safe Autorotation Landings'*. Examination of the chart showed that at 60 feet and 40 kt, the helicopter is just outside the cross-hatched ('avoid') area.

The pilot

The pilot was a self-employed helicopter instructor with UK CAA instructor qualifications and an FAA Private Pilot's Licence. He had received type conversion training on the Hiller UH-12 from an FAA examiner.

The helicopter

The Hiller UH-12B, first flown in the late 1940s, is a conventional three-seat light helicopter, designed for military training and utility use. It has a two-blade main rotor and a conventional tail rotor. It is powered by a vertically-mounted, six cylinder, horizontally-opposed, Franklin piston engine (another engine option may be fitted). Fuel is stored in a bladder tank, housed in an enclosed space under the engine mounting structure. The tank is fitted with a float type fuel quantity sensor/sender, which is connected to a fuel gauge mounted on the right hand side of the instrument panel.

The Hiller Flight Manual states that total fuel capacity is 28 USG, of which 1.5 USG is unusable. It does not give fuel consumption information, although early editions of the manual state that fuel endurance is 1 hour 20 minutes at V_{NE} and 1 hour 50 minutes at 70 mph.

The aircraft had been placed into storage in the USA following a heavy landing in 1984, and then 're-manufactured' by a corporation whose main business was the re-manufacture of Hiller helicopters. It had flown approximately 12 hours since being 'zero-timed' in the summer of 2004. The Helicopter Log showed that parts from several other helicopters had been used in its construction. The Engine Log Book showed that the engine had been disassembled, repaired, and overhauled prior to installation in the helicopter on 16 June 2004. The Engine Log Book stated that the engine had *'zero time since overhaul'* but gave no detail of the total engine hours. The Helicopter Log Book included an unsigned entry detailing work carried out in the re-manufacture of the helicopter, dated 18 June 2004 and, in different hand-writing, sequentially after this entry, certification of an annual inspection dated 10 June 2004.

The aircraft owner, who had no previous experience of trading in aircraft and was not a qualified pilot or engineer, had established a business with the intention of marketing Hiller helicopters in the UK. He had made arrangements for the importation of the helicopter, which was to be offered for sale and used to demonstrate the type to potential buyers.

When inspected after the accident, the helicopter was found to be fitted with a 'Datcon' fuel gauge. No record of approval of fitment of this type of gauge to the helicopter could be found in the Log Book. Investigation revealed that the fuel gauge was of a type not approved for use in aircraft.

Enquiries revealed, that according to FAA Unapproved Parts Notification No 2003-00043, the FAA had withdrawn the Mechanic Certificate held by the President of the corporation concerned. He had also been found to have '*approved aircraft and engines for return to service, contrary to Federal Aviation Regulations*'. The Notification advised that '*all products approved for return to service by* (this individual) *should be considered suspect'.* The owner stated that, prior to the accident, he was not aware of FAA Unapproved Parts Notification No 2003-00043. Further investigation revealed other action taken by the FAA in respect of the individual.

Fuel management

The owner had developed a policy of always filling the helicopter with the maximum fuel load prior to flight and it appears that this policy had been adhered to by those concerned with the operation, until the day of the accident.

The owner did not keep a Technical Log for the aircraft, and thus reference to fuel loaded and consumed was not possible.

Prior to the series of flights, the pilot made an assessment of the quantity of fuel on board. Although on previous occasions he had used a calibrated dipstick to measure the level of fuel in the tank, on this occasion he was not able to locate the dipstick. Instead, he made a visual assessment, looking down the fuel filler neck into the tank and using a small torch. He had not received training in assessing fuel quantity in this manner. He estimated the tank contents to be between half and three-quarters full and equated this to roughly 16 USG. The fuel gauge in the cockpit showed just over half a tank remaining, which the pilot believed equated to roughly 15 USG.

The pilot stated that during his type conversion training he was told that the helicopter consumes between 12 USG to 14 USG per hour. During cross-country flying in the USA, in a similar helicopter, the pilot had assessed the fuel consumption as being about 13 USG or 14 USG per hour. Another experienced Hiller pilot stated that he believed fuel consumption to be 14 USG per hour in typical cruise, and about 16 USG per hour during hovering flight, although he added that these figures were not conservative.

The pilot anticipated flying only two flights, lasting about 15 minutes each, and calculated that, using a fuel burn of 14 USG per hour with 20 minutes reserve, he required a total fuel quantity of 11 or 12 USG. Therefore, he assessed the fuel quantity to be adequate for the planned flying.

The pilot reported that the fuel gauge was reading slightly over ¼ full prior to the last circuit and that it was his usual practice to consult the fuel gauge as part of his 'FREDA' checks when downwind in a circuit, although he does not recall clearly whether he did this on the final circuit. The pilot had not previously flown the helicopter with a fuel quantity below ½ full and stated that he had no specific reason to disbelieve the gauge, although he shared the commonly-held opinion that fuel gauges in light aircraft and helicopters tend to be unreliable.

FREDA checks

FREDA checks are very widely taught in both fixed and rotary wing flying, as routine checks to be carried out in flight. The mnemonic represents Fuel, Radios, Engine(s), Direction, and Altimeter. The 'Fuel' element is commonly taught to involve a check of the fuel remaining in the tanks, that the correct tank is selected (if more than one is fitted), and that the fuel indicated is sufficient for the continuation of the flight. It is also usual for other in-flight checklists, such as those carried out prior to descent, approach, or landing, to include an action relating to fuel quantity assessment by reference to the fuel gauge(s).

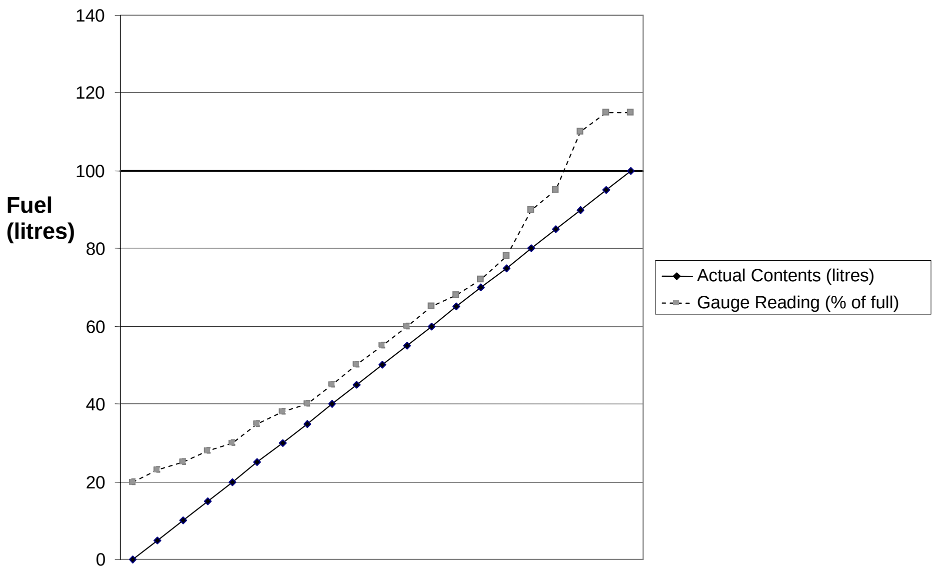
Flight records

There is no requirement, under Federal Aviation Requirements, for aircraft not used for commercial flight operations for an accurate record of flying hours to be kept contemporaneously. The Aerodrome Flight Information Service recorded flying operations, but ground running and brief hovering flight at the owner's hangar were not recorded in this manner. The owner kept approximate records of flight time. Federal Aviation Requirements do, however, require owners to make accurate entries of aggregate flight times in the Helicopter and Engine Logs.

Fuel remaining after the accident

The AAIB investigation began with an assessment of the fuel remaining in the helicopter. The helicopter had been moved from the accident site to the owner's hangar and was standing on its skids in a normal level attitude. The fuel feed to the carburettor was disconnected at the carburettor end and a suitable container was positioned to collect fuel. The electric fuel pump was switched on.

Fuel flowed readily from the tank and no cavitation of the electric fuel pump was apparent. The helicopter's tail was then weighted down, to simulate a nose-high attitude, as might be encountered when transitioning into the hover. In this attitude, the pump was again selected on, and fuel began to flow. Very soon, the flow became less steady and the pump was heard cavitating. Some 700 mls of fuel were collected before flow ceased. The helicopter was again returned to the level attitude and the test re-commenced, with a further one litre being collected before flow stopped. The tank was then drained into a measured container. The total fuel taken from the tank was determined to be 4.8 litres, or 1.3 USG.



The fuel tank was gradually re-filled with measured quantities of Avgas, the gauge readings being taken at various fuel states. The chart above compares fuel in the tank with fuel contents indicated on the gauge.

Airworthiness requirements

The aircraft type was certificated in October 1948, according to US Civil Air Regulations (CARs), the precursors of the current Federal Aviation Regulations (FARs). These regulations made provision for civil certification of aircraft by proof of conformity with the CARs and also made provision for certification of aircraft which had been certificated to a US Army or Navy standard, without proof of conformity with the CARs, on the grounds that these standards provided similar levels of safety to the CARs then extant.

Those Regulations in force in 1956, included CAR6.613, which states: *'Fuel quantity indicators shall be calibrated to read zero during level flight when the quantity of fuel remaining in the tank is equal to the unusuable fuel supply…'*. The current (2004) FARs, and others, include similar requirements regarding fuel gauge accuracy. The passing of time made it very difficult to establish that CAR6.613 was in place when the Hiller UH-12B was first certificated and whether the aircraft was certificated on the basis of military certification (the fact that the aircraft was built in substantial numbers for the armed forces makes this likely). The investigation did not attempt to establish what requirements were in place within the US Army and Navy standards.

Analysis

In the absence of the dipstick, the pilot was able to assess the fuel quantity before flight only by visual inspection of the tank contents and from the reading on the fuel gauge. He was not familiar with assessing fuel quantity at low levels in this fashion and training on the type had not covered this. Indeed, given the arrangement of the filler neck and fuel tank, an accurate visual assessment would certainly have been difficult.

However, it appears that the pilot's initial assessment of fuel quantity was reasonably accurate, as evidenced by the subsequent calibration tests of the gauge system. His initial assessment of the fuel requirement for the proposed operation also appears reasonable, given the absence of meaningful consumption data in the aircraft Flight Manual. However, his knowledge of expected fuel consumption related more to cruise flight than operations such as continuous hovering and hover-taxiing, which by their nature, are times at which high power is required, with consequently high fuel consumption.

The difficulty that the pilot experienced in transitioning into forward flight with three persons on board, on his first attempt, may indicate that the engine was not delivering full power. Given this, its fuel consumption may have been higher than usual in the ensuing manoeuvres. The engine suffered significant damage in the accident, to the degree that post-flight tests to assess performance and fuel consumption were not feasible.

However, the first two flights proceeded without incident, and it is apparent that the pilot was assessing fuel consumption during these flights, by reference to the fuel gauge. This was in accordance with his training and the training that pilots normally receive. During this time the gauge indicated a gradually decreasing fuel quantity and this over time would have given a strong indication as to the rate of fuel consumption. When requested to fly the additional flight, the pilot understood the fuel contents to be around ¼ (equivalent to some 7 USG). This quantity of fuel would have been sufficient to carry out a brief circuit, albeit with little more than a minimal reserve.

Tests after the accident showed that at fuel quantities close to the minimum usable, the fuel flow ceased when the aircraft nose was pitched up, as would be the case when transitioning into the hover, and this accounts for the sudden power loss.

The power loss occurred at a speed and height very close to the 'avoid curve', a time when a very high degree of pilot skill and familiarity with the type would be required to ensure a 'normal' touchdown. Although the pilot was very experienced in helicopter flying, he lacked substantial experience on the Hiller helicopter. His decision to maintain a level attitude and cushion the touchdown as much as possible was a good one, and ensured the safety of the helicopter's occupants.

The practise of advising pilots to distrust fuel gauges is necessarily contradictory to that of instilling reference to the fuel gauge readings, such as during a FREDA check, in flight. The availability of 'real-time' information about fuel states may cause a pilot to re-assess his fuel plan, where he is not certain of the fuel consumption of the aircraft (for example, because he has little knowledge of predicted fuel burn or because the manoeuvres being executed may result in fuel burn which is erratic or unpredictable). A pilot, once airborne, may be expected to place some reliance upon the fuel gauge unless he has specific reason to doubt its accuracy and this is reflected in regulatory requirements. Reason to doubt a gauge might be that it appears not to move, or shows a clearly erroneous reading. However, a gauge which, at first inspection appears to indicate the tank contents (as assessed by other means) accurately, and then continues to show sensible changes (a decreasing fuel quantity over time, at a reasonable rate), will not give the pilot cause for doubt. It is probable that the pilot believed the gauge reading was accurate for this reason and there was nothing about the gauge's performance which would have given him reason to distrust it.

The possibility that the fuel gauge sender unit was disrupted during the impact sequence was considered. If this had occurred, the subsequent evaluation of the gauging system would have been invalid. However, the minor damage to the helicopter's skids indicates that the impact was not extreme. The float is of low mass and would have been cushioned by the fuel beneath it in the tank in any downward deflection. Other significant damage to the helicopter appears to have resulted from the toppling of the rotor disc, destruction of the blades and subsequent extreme vibration of the rotor, rotor head, engine and mountings. The fuel gauging system, as tested after the accident, performed in a manner which reflected the pilot's recollection of gauge indications. For these reasons, it is considered unlikely that the sender unit was disrupted in the accident sequence.

The owner's policy of refuelling prior to every flight appears, at first, to have considerable merit. However, this policy, together with the duration of flights conducted, meant that the aircraft had never previously been operated at a low fuel level. Had the aircraft been refuelled from a low level to full, the disparity between the gauge reading and the actual contents might have been discovered, through comparison of fuel quantity uplifted and tank capacity. However, as technical records were not kept, this discovery would have relied upon the expertise and insight of those conducting the refuelling.

With regard to the absence of a Technical Log, it is apparent that in order for aggregate flight times to be entered correctly in the aircraft log books, there must be a source of accurate data on individual flights. The absence of this requirement may cast doubt on the accuracy of log book records on aircraft not used for Public Transport or Aerial Work. If an accurate record of flight times and of fuel uplifted and consumed had been kept, the owner could have determined fuel consumption accurately and have kept track of fuel on board. The fuel gauge error could therefore have been identified.

The FAA had previously investigated the activities of the President of the Corporation re-manufacturing the helicopter, with particular regard to the use of unapproved parts on aircraft and had deprived him of his professional qualifications. It appears that, despite this, his corporation was still involved in re-manufacturing helicopters with unapproved parts.

The accident helicopter was one which the owner had acquired from the US with a view to establishing a business marketing similar 're-manufactured' helicopters of the same type. However, the fact that the helicopter was certificated under an airworthiness code (possibly a military one), which was derived more than fifty years ago, calls into question the issue of 're-manufacture' of old aircraft, as a helicopter offered 'as new' for sale today, may in fact meet very different standards of airworthiness to those currently in force. In particular, an aircraft certificated to a very old Standard, may not incorporate safety features which have been developed through the ongoing process of safety improvement in the intervening time.

Conclusions

The accident occurred as a result of sudden loss of power caused by fuel starvation and at a time when the height and speed of the helicopter made a successful auto-rotation to a normal power-off landing difficult. The power loss was sudden, as the pitch attitude of the aircraft is critical to the fuel supply from the tank when the tank is very nearly empty. The pilot's handling of the helicopter minimised the damage and ensured a safe outcome for its occupants. Furthermore, the inherently strong design of the helicopter and its wide skids contributed to their safety.

The pilot relied upon the quantity indications displayed on the fuel gauge and had no specific cause to doubt the readings. The fuel gauge fitted to the helicopter was inaccurate, indicating significantly more fuel on board than was present in the tank. The fuel gauge was not approved for use on the helicopter. The pilot or owner however, could have established a better knowledge of the helicopter's fuel consumption, had records of flying times and fuel consumed been kept.

Safety action

The FAA has been notified of this accident and is undertaking an investigation into the installation of the unapproved fuel gauge.