AAIB Buletin No: 8/93 **Ref: EW/C93/4/1** **Category: 1c**

Aircraft Type and Registration:	Cessna 172 N Skyhawk, G-GRAY
No & Type of Engines:	One Lycoming 0-320-H2AD piston engine
Year of Manufacture:	1979
Date & Time (UTC):	2 April 1993 at 2355 hrs
Location:	In the Firth of Forth, near Mussleburgh
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Severe damage to engine and lower cowl, salt water damage to remainder of aircraft
Commander's Licence:	Commercial Pilot's Licence with Instrument Rating
Commander's Age:	33 years
Commander's Flying Experience:	1,125 hours (of which 146 were on type) Last 90 days - 90 hours Last 28 days - 70 hours
Information Source:	AAIB Field Investigation

History of the flight

The operating company of G-GRAY had arranged to transport a human liver from Birmingham to Edinburgh for use in a transplant operation. However, because the flight was at night and the Air Navigation Order prohibits single-engine aircraft operating on Public Transport at night, the pilot stated that it was a private flight and he was not re-imbursed.

The flight on 2 April was planned at FL80 via Gamston, Ottringham, Newcastle and St Abbs Head to Edinburgh. No problems were encountered during the flight north and the aircraft was transferred from Scottish radar to Edinburgh approach at 2327 hrs as it turned at St Abbs. Edinburgh offered a radar advisory service with radar vectors to runway 25, confirmed the heading as 275° and passed descent clearance to 4,000 feet on the QNH of 1010mb. Shortly afterwards, the following weather was passed to the pilot and acknowledged: surface wind light and variable, 20 km visibility in shallow fog, nil cloud, temperature 0°C/ dew point -1°C, QNH 1010 mb, QFE

1007 mb, ILS Runway 23 Cat 3 - low visibility procedures in force, touchdown RVR greater than 1,500 metres and mid-point visibility 1,200 metres.

At 2343 hrs the pilot reported level at 4,000 feet amsl and was advised that he had 26 track miles to touch-down. During the next seven minutes Edinburgh gave the pilot two heading changes and then a descent to 3,000 feet amsl. As he was being given this descent clearance at 2350 hrs, the pilot became aware of a change in the engine note; he activated the carburettor heat and checked the engine temperature and pressure gauges. The temperatures were normal, but the oil pressure indicated zero; the pilot reported this to Edinburgh and then stated that the engine was losing power. Shortly afterwards, at 13 miles to touchdown, he initiated a Mayday call and turned towards the coast. At 2351:54 hrs the engine lost all power and the pilot was aware of severe vibration; he pulled the mixture control to shut down the engine. By this time the aircraft was over the Firth of Forth, and ATC passed him a heading of 180° to steer for the coastline. Whilst looking for a suitable area in which to land the pilot became aware of a sea wall along the shore and, being unable to safely glide clear, elected to land in the water. After turning off the fuel and ignition, but leaving lights and electrical services on, full flap was selected. With the aircraft tracking approximately parallel to the sea wall, he landed the aircraft tail first onto the surface of the water with the stall warning sounding, following which the aircraft rapidly pitched nose down. The aircraft did not invert, but settled nose and left wing down in the water. At 2357:50 hrs the pilot reported to Edinburgh that he was in the water and by then ATC had activated the emergency services. The pilot was unable to open the left door and so opened his window to allow the aircraft to flood. However, his passenger had already opened the right door and so the pilot followed him out and they swam about 50 yards to the shore.

A short time later, the transplant liver was recovered from the aircraft by Royal Navy divers from Rosyth, still sealed within its sterile packaging, and taken to Edinburgh Infirmary for use in the operation.

Engineering examination

Later the following day, the essentially intact aircraft was recovered by crane, operating from the sea wall, and transported to the AAIB at Farnborough for detailed examination. Prior to transportation, it was given an initial examination. This revealed that there was sufficient fuel and oil remaining on board for flight, but that the engine oil dipstick was covered in metal debris. There were no signs of oil leakage in flight and, externally, the engine appeared intact. It was apparent that the pilot had shut down the engine, selected full flap and left the electrical services on.

After removal from the aircraft at the AAIB, the engine was strip examined. It was readily apparent that the number 3 connecting rod big-end cap bolts had failed due to excessive heating and seizure of the bearing. However, this was the worst symptom of general damage throughout the engine which indicated a lack of oil supply to the pistons, main and big end bearings. Large quantities of metal swarf were present in the sump, mostly generated from the bearing shells, and throughout all oil passageways. The suction (coarse) and pressure (fine) screen filters, both of the wire mesh type, were heavily contaminated with debris and the pressure filter had ruptured along a solder seam as a result of excessively high internal pressure, as shown in Figure 1. This had resulted in a small unfiltered flow path for oil. Debris was found partially jamming open the pressure relief valve and the oil cooler by-pass valve. With the exception of two of the big end drillways which were blocked by bearing shell material, all oil passageways were found to be unobstructed and the gear type oil pump was in a serviceable condition.

Of significance was a region of heavy wear and damage on the camshaft lobe and cam follower associated with the inlet valve for no 1 cylinder, as also shown at Figure 1. Metallurgical examination of these components indicated that 1) the quality and thickness of the surface hardening, on both the cam and follower, had been satisfactory as manufactured and, 2) that the degree and nature of the wear present on these components were such as to suggest that their degeneration had occurred over a significantly longer period than the duration of this flight. Additionally, extreme pitting and damage was present on the other cam follower faces for cylinders nos 1 and 2, with a lesser amount of wear present on the cam lobes for these same cylinders. Those associated with cylinders 3 and 4 showed little signs of abnormal wear.

Engine history

The Lycoming 0-320-H series engine was only fitted to the Cessna 172 aircraft type, and only during the period 1977 to 1981. It is a high compression engine with a nominal 2,000 hour life and was designed to be simpler than its predecessors, both to manufacture and to overhaul. In service it has been prone to problems however, particularly concerning premature failure of the camshaft and cam followers. The engine fitted to G-GRAY was an 0-320-H2AD model, serial No L-5954-76-T, and was originally built in 1979. After some 1,400 hours in service it was rebuilt in 1984 and zero-timed, by a UK overhaul agency, following excessive wear to the camshaft and cam followers. At this time the -T modification was incorporated, which installed a slightly redesigned crankcase able to accept a camshaft with wider lobes and larger diameter followers. After a further 500 hours in service, metal particles were again found during a filter inspection. This resulted in the camshaft and followers being replaced once more in 1987, but this time the engine was not zero-timed. The accident occurred after the engine had run a further 1,220 hours in service. The

FAA require to be notified if premature failure of the cam and followers occurs to a -T standard engine.

Engine maintenance requirements and records

The aircraft was certificated in the Transport Category (Passenger) and was maintained in accordance with the appropriate Light Aircraft Maintenance Schedule (CAA/LAMS/FW/1978, issue 2). The relevant section of this schedule requires, in the absensce of specific recommendations (page 3/3 para 2,2), that after 50 flying hours, or 62 days, the engine oil is changed and the oil filters are inspected and replaced/cleaned. The records also indicated that the last maintenance carried out on G-GRAY was an Annual check on 4 March 1993 (23 hours prior to the accident), when the filter was examined, but the oil and its additive were last changed on a 62 day check on 17 December 1992 (33 hours prior to the accident).

With the -H series engine, a CAA endorsed FAA Airworthiness Directive (AD), No 80-04-03, is applicable which requires that an anti-scuffing oil additive, reference Lycoming Pt No L-16702, is added to the oil at each oil change, but at periods not exceeding 50 hours. This AD also requires that at every oil change, but at periods not exceeding 100 hours, the lubrication system should be inspected for evidence of contamination. It specifically states the following:-

"Inspection consists of visual examination for minute particles of metal suspended in the oil, examination of the engine oil suction screen for presence of metal particles and the inspection of the external full flow oil filter for metal particles by cutting it open so that the pleated element can be unfolded and examined. If ferrous metal contaminants are detected during the above inspections, the camshaft lobes and all hydraulic lifters (followers) must be inspected for wear or loss of metal. Replace the camshaft and lifters found to have such indications."

The maintenance records showed that an additive had been added to this engine at approximately 50 hour intervals since the replacement camshaft and followers were fitted in 1987. The engine manufacturer states, however, that although scuffing was originally found to be one of the factors leading to camshaft/follower wear, more recent evidence suggests that corrosion which forms on the cam and/or followers during periods of inactivity may also be a factor. The oil additive is known to provide a measure of protection against this corrosion but will not prevent it, or scuffing, under all conditions. An analysis of an oil sample taken from the sump of G-GRAY revealed it to contain, apart from sea water, approximately 1% of solid material and that an oil additive was present in an acceptable concentration. The solids concentration, and quality of oil, were

considered by the agency which performed the analysis to be consistent with oil that had been in use for some 33 hours but the ferrous metal content was, however, abnormally high.

The engine manufacturer believes that benefits, such as reduced acid levels and lower levels of contaminants which may promote corrosion, lower wear rates and a reduced incidence of problems such as stuck valves, will be obtained from reduced oil change and filter service/change intervals on all their engines. To this effect they published Service Bulletin SB 480, dated 18 January 1988, which recommends a 50 hour period between oil changes/filter inspections for all direct drive engines with full flow type filters, a 25 hour period for all engines with pressure screen type filters, but with an overall calendar period of four months between oil changes/filter service, irrespective of filter type. The CAA regard this as a specific recommendation in accordance with which the LAMS schedule requires such engines to be maintained.

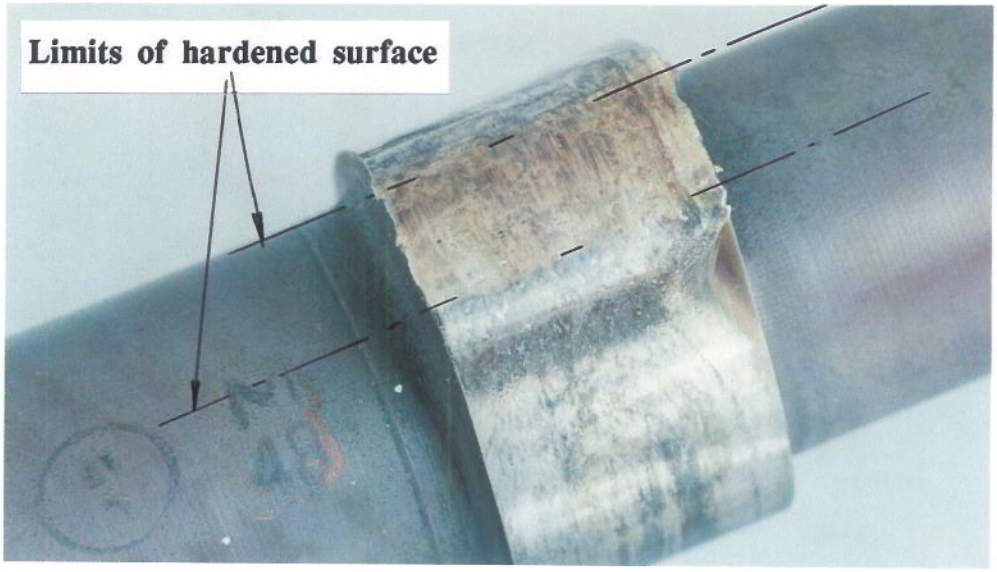
A manufacturer's modification is available which replaces the pressure screen filter with either a spin-on disposable, or replaceable cartridge, type filter.

Safety Recommendations

As a result of the findings of this investigation the following Safety Recommendation has been made to the CAA:-

93-44 In accordance with the manufacturer's recommendation (SB 480), and therefore the LAMS schedule, the CAA should emphasise to all relevant personnel that Cessna 172 aircraft, fitted with 0-320-H series engines which have pressure screen type filters, are subject to engine oil changes/filter inspection (together with oil additive renewal) at periods no greater than 25 hours, or four months, whichever occurs sooner, and that all direct drive engines are subject to a maximum period of four months between oil changes/filter inspection, irrespective of filter type.

Spalled exhaust and inlet valve cam followers for No 1 cylinder



Worn cam lobe, No 1 cylinder inlet valve, showing region where approximately 1 mm of material is missing from peak

Burst area in oil pressure screen filter

Debris found in oil filter

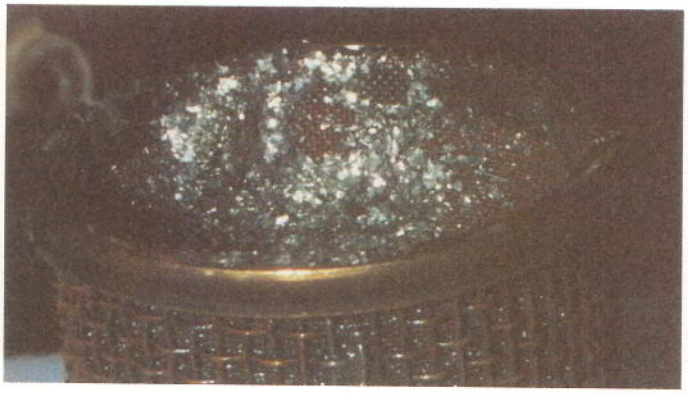


Figure 1