Aircraft Type and Registration:	Piper PA-28-161 Cherokee Warrior II, G-BRDF
No & Type of Engines:	1 Avco Lycoming O-320-D3G piston engine
Year of Manufacture:	1977
Date & Time (UTC):	18 October 1993 at 0909 hrs
Location:	5 miles west of White Waltham Airfield, Berkshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Engine crankshaft fractured, crankcase, propeller, accessories and cowling damaged
Commander's Licence:	Private Pilot's Licence
Commander's Age:	24 years
Commander's Flying Experience:	110 hours (of which 22 were on type) Last 90 days - 14 hours Last 28 days - 3 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and AAIB examination and enquiries

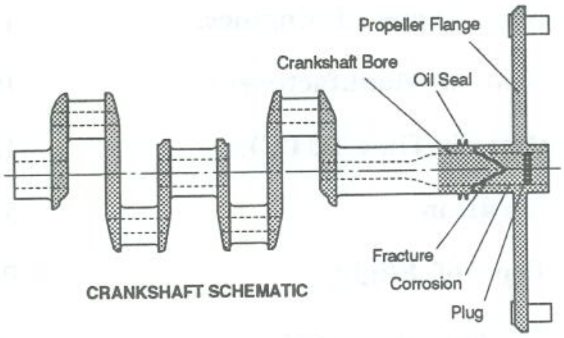
Flight History

The aircraft was being positioned from Popham Airfield to White Waltham Airfield. While overhead Junction 10 of the M4 Motorway at 1,500 feet amsl (around 1,350 feet agl), with the destination in sight, the pilot heard the engine speed increase and then saw the starter ring gear, alternator belt and parts of the nose portion of the engine cowling fly up in front of the windscreen and depart over the top of the fuselage. Realising that he had lost the propeller, the pilot chose a field adjacent to the north side of the M4, made a 'MAYDAY' RT call and carried out a forced landing in the field with no further damage resulting, in spite of the ground being quite soft.

The propeller was recovered and examination showed that the engine crankshaft had fractured just behind the integral propeller mounting flange, near the position of the forward oil seal (Figs 1 and 2).

Crankshaft Description

The crankshaft is manufactured from hot-forged AMS 6415 steel, heat treated to a hardness of Rockwell C 32-37. The crankshaft surfaces are case hardened (0.018 to 0.026 inch thick) by nitriding, with the exception of the propeller flange and the adjacent outer diameter surfaces. In the area of the failure the crankshaft has a nominal outer diameter of 2.375 inches and a radial thickness of 0.25 inch. The crankshaft journals are hollow, and are filled with the oil mist permeating the crankcase when the engine is running. When the engine is to drive a fixed pitch propeller, the bore passing through the forward section of the crankshaft is sealed by a plug fitted in its forward end. This bore reduces in diameter towards the rear, where it opens into the crankcase interior.



CRANKSHAFT SCHEMATIC

Engine Examination

The engine was bulk stripped and the components examined, with no abnormalities found except for those concerning the crankshaft, described below. Detailed specialist examination of the crankshaft fracture showed that the fracture surfaces had been damaged by rubbing and corrosion but concluded that the separation had resulted from a high cycle reverse torsional fatigue mechanism that had initiated from a number of corrosion pits in the crankshaft bore. After the cracks had progressed through a substantial proportion of the crankshaft section the rate of advance had increased until the remaining unseparated portion had failed as a result of overload. It was clear that much of the cracking had occurred in high cycle fatigue and that it had progressed over an extended period of service.

The bore through the forward section of the crankshaft was found to be coated in a thick layer of solid oil sludge-like deposit, in the order of ¼ inch thick, consistent with the centrifuging effect that would be present in this area with the crankshaft turning. In an area immediately behind the plug, heavy corrosion was present on the surface of the crankshaft bore (Fig 3). It was noted that the reduced diameter portion of the bore effectively constituted a weir, making the larger diameter forward part of the bore a sump into which debris or water entering the bore would be centrifugally separated from the oil while the engine was operating and where it would remain trapped when the engine stopped. It also appeared possible that the forward portion of the crankshaft could be a relatively cool area with the engine running and thereby particularly conducive to condensation. The bore also exhibited heavy machining scores and extensive brittle cracking across these scores. Microsection examination and hardness measurements showed that the bore had a hardened layer, typical of that produced by carbo-nitriding, with deep corrosion pitting and cracking present, and parts of the outer surface of the forward portion of the crankshaft had a less complete hardened layer.

Engine History

Records indicated that the engine, Serial No L7595-39A, had been built in 1977 and owned by Georgia, USA, based operators until being imported to the UK in 1989, since when it had been based at White Waltham. Prior to importation it had been overhauled, in the USA, after 2,479 hours operation since new. At the time of the accident it had operated for 1,950 hours since the overhaul. The engine had thus accumulated 4,429 hours since new, over a period of 16 years. The records did not indicate any particular events or abnormalities that were likely to have affected the crankshaft.

Previous Similar Cases

The CAA Safety Data and Analysis Unit (SDAU) Database contained a single previous occurrence with similarities to G-BRDF's failure, on a Piper PA-28-161 on 13 March 1992. On a test flight following rectification work, severe engine vibration and power loss was experienced and the engine failed completely after landing. Signs of a large oil leak from the propeller flange area was found, together with significant lateral propeller play. A 4 to 5 inch, 370° spiral crack in the crankshaft was found. A record of a second similar case was found in CAA General Aviation Safety Information Leaflet (GASIL) 8/89; in May 1989, an Avco Lycoming O-360-A3A returned to the overhaul shop for rectification of an oil leak from the crankshaft propeller flange area was found to have a spiral crack in the crankshaft extending 400° from a propeller flange lightening hole to the first crankpin throw. Laboratory examination reportedly revealed that the crack originated in a corrosion pit in the crankshaft bore and may have been associated with water retention at the edge of a partial layer of grease on the surface. The GASIL stated that '. . . water repellent greases or sprays should be used and that it is strongly suggested to look very carefully at the crankshaft nose if an oil leak is present'.

A major UK repair and overhaul organisation dealing with Avco Lycoming engines has conducted crankshaft bore inspection for corrosion since 1968 as a standard procedure for every engine that is fully stripped. In almost all cases a magnaflux crack detection procedure is conducted on the forward section of the crankshaft. Their experience is that severe corrosion in this area is seen occasionally and three cases of extensive spiral cracking in crankshafts have been encountered. Basic details available on two of these cases [an AEIO-3600B1F (believed to drive a variable pitch propeller) in May 1991 and an O-320-D3G in May 1993] indicated that they were additional to the two cases noted above; no information on the third case was available.

The crankshafts of Avco Lycoming and Teledyne Continental Motors (TCM) direct drive engine types are reportedly quite similar, except for the few types with solid crankshafts, and may be affected by this type of corrosion. A Rolls-Royce Motors Ltd Service Bulletin (SB T-416/1) issued in 1960 applicable to TCM O-240 engines, with status 'declared mandatory by CAA' notes, 'it is possible that in service conditions could exist which are conducive to the creation of pitting on the inside bore of the crankshaft. In extreme cases this pitting has developed and formed significant stress raisers which finally lead to cracks propagating through the crankshaft section. If this crack remains undetected, it could propagate to a point where the propeller could become detached'. The Bulletin required a crankshaft external dye penetrant crack detection procedure, followed by inspection of the bore for corrosion pitting after cleaning and limited honing. Only chlorine-free solvents were permitted for cleaning and, after inspection, the bore was to be coated by aerosol with a water displacing penetrating oil with inhibitors such as WD-40. With corrosion pitting evident, continuation in service was only permitted if the crack detection check was repeated at 10 hour intervals until a replacement crankshaft was fitted.

G-BRDF's engine manufacturer was aware of several similar cases of crankshaft cracking in various engine models, in all cases affecting engines that had been overhauled and that were equipped with a fixed pitch propeller. In all cases the cracks had originated at corrosion pits. It was likely that these cases included at least two of those noted above; it was not known if they included the other cases mentioned above. Corrosion in the crankshaft bore was characterised as an occasional problem, thought to be influenced by oil sludge accumulation, water accumulation and time. The degree of accumulation of sludge and water was considered to be a function of oil quality, oil change frequency and oil operating temperature, among other possible factors. The manufacturer is reportedly considering various means of reducing or preventing crankshaft bore corrosion and intends to develop a service publication requiring inspection of the bore at overhaul and defining limits on corrosion pitting aimed at preventing this type of failure.

The indication that engines driving fixed pitch propellers were more prone to corrosion of the bore of the forward section of the crankshaft was possibly due to the fact that with the propeller removed the bore remained hidden from view by the blanking plug. With a variable pitch propeller installation no plug is fitted and, given the usual requirement to remove the propeller for maintenance on a regular basis, it would be expected that the crankshaft bore would be available for inspection more frequently than with a fixed pitch propeller installation.

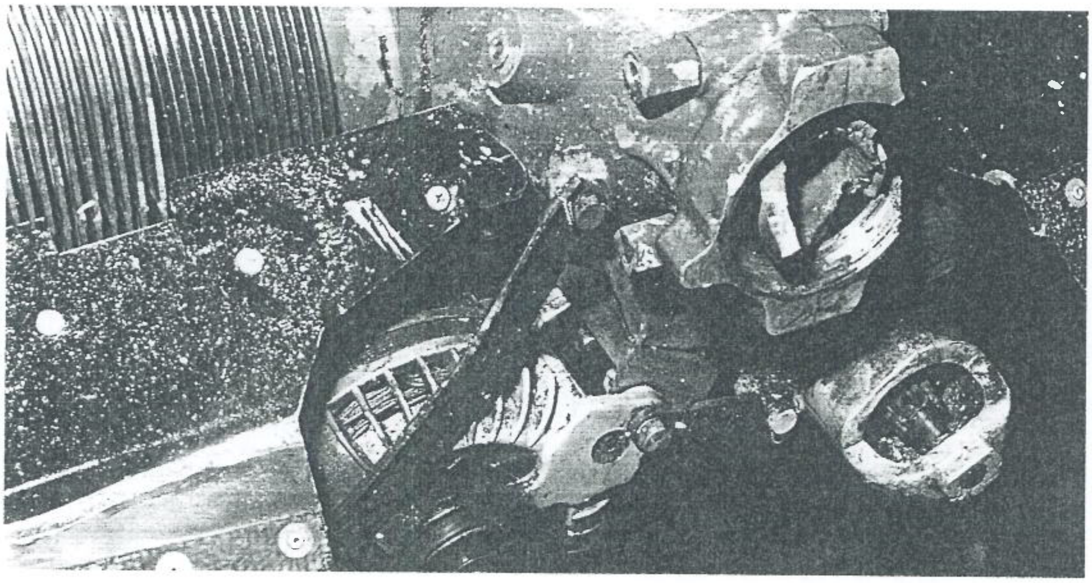
Summary

The evidence showed that the loss of G-BRDF's propeller was at least the fifth recorded case to have occurred in recent years of gross cracking of Lycoming crankshaft forward sections. While few background details on the previous cases were available, it was clear that corrosion of the bore was responsible in at least one of them and the manufacturer considered that this was the cause of the problems. Corrosion was clearly the cause in the case of G-BRDF's failure. The Service Bulletin described, issued 34 years ago, applied to the engine of a different manufacturer but concerned an apparently similar type of crankshaft and indicates that the potential hazard from cracking as a result of corrosion is not a new problem. In view of the evidence and the potentially catastrophic consequences of failure, the following safety recommendation has been made.

Safety Recommendation 94-7

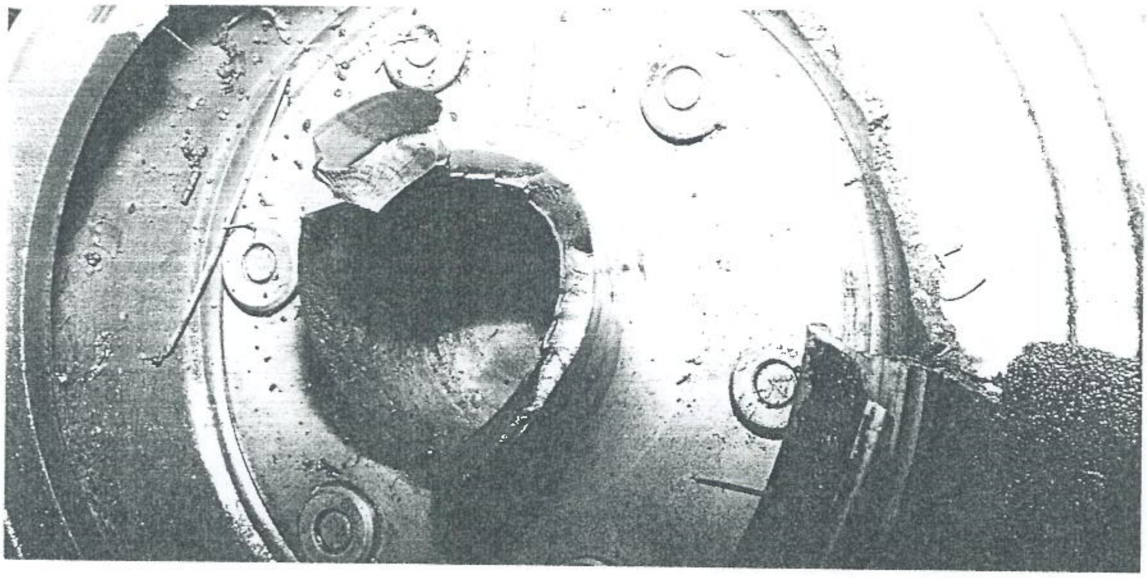
It is recommended that the CAA liaise with the FAA and require procedures to be issued, for UK registered aircraft powered by the Avco Lycoming O-320-D3G and for other engines with similar crankshaft design features, for the mandatory inspection of the forward portion of the crankshaft bore aimed at detecting existing significant corrosion and/or cracking before any such effects progress to the point of crankshaft fracture. In parallel, mandatory procedures should be developed aimed at preventing subsequent corrosion.

G-BRDF CRANKSHAFT FAILURE



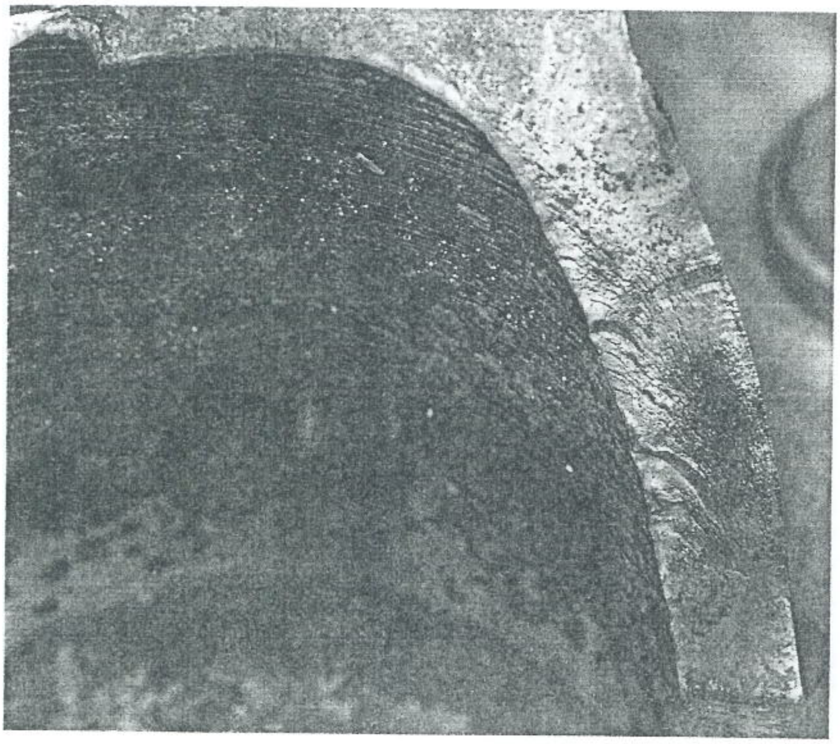
Fractured Crankshaft

Fig 1



Propeller Flange

Fig 2



Corrosion in Crankshaft Bore

Fig 3