**No: 10/86** **Ref: 1b**

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| **Aircraft type and registration:** | Cessna F177RG (Reims Cardinal) G-OADE |
| **No & Type of engines:** | 1 Lycoming 10-360-A1 B6 piston engine |
| **Year of Manufacture:** | 1972 |
| **Date and time (UTC):** | 27 April 1986 at 1620 hrs |
| **Location:** | Arborfield, near Reading, Berks |
| **Type of flight:** | Private (pleasure) |
| **Persons on board:** | Crew — 1 Passengers — 1 |
| **Injuries:** | Crew — None Passengers — None |
| **Nature of damage:** | Left and nose landing gear collapse, propeller damage, damage to hull caused by wire fence |
| **Commander's Licence:** | Private Pilot's Licence |
| **Commander's Age:** | 50 years |
| **Commander's Total Flying Experience:** | 517 hours (of which 61 were on type) |
| **Information Source:** | AIB Field Investigation |

**Circumstances**

Whilst passing Reading en-route from Chichester (Goodwood) to Coventry, engine oil suddenly started to stream from the front of the engine cowl and spray back onto the windscreen. The spray rapidly increased and within seconds had completely obscured forward vision.

The aircraft was turned south towards Blackbushe Aerodrome, but within less than a minute the engine started to run roughly and fumes entered the cockpit. A decision was made to effect an immediate emergency landing and, shortly afterwards, the engine stopped — apparently due to lack of oil.

Following a curved approach to the left, with full flap selected, the aircraft successfully touched down in a field of new crop, narrowly missing high tension pylons and cables which were on the right side of the aircraft and hence out of the pilot's area of clear vision. Shortly after touchdown the nose and left main landing gears collapsed and the aircraft slid for a further 50 metres before colliding with a wire fence and coming to rest. The hull was substantially intact and both occupants evacuated the aircraft successfully.

**Examination of wreckage**

The oil leak was caused by a failure of the aluminium alloy elbow-fitting at the forward end of the high pressure oil pipe, which connects the constant speed unit (CSU) at the rear of the engine to the propeller oil transfer gallery at the front of the crankcase. The union was fractured through the threaded section, flush with the crankcase, where it screwed into the crankcase casting. Laboratory examination of the fracture surfaces indicated that the failure resulted from fatigue.

The fracture surface was bright and unoxidised.

The oil pipe assembly comprised a rigid stainless steel pipe approximately 80 cm long, with conventional flared ends fitted with steel collars and nuts. The pipe was rigidly connected at its aft end to a union on the CSU, and to the (failed) elbow union at its forward end. It had been pre-shaped at manufacture to enable it to be routed through a somewhat restricted and inaccessible area beneath the right hand cylinders, and should have been supported by pipe clips in the area where it passed beneath the cylinder barrels. No clips or other forms of support were fitted to G-OADE, although there was one waxed string tie-wrap attaching some electrical cabling to the pipe.

In its post-fracture condition, there was noticeable misalignment between the elbow portion of the union (attached to the pipe) and the remaining piece of union in the crankcase. In order to bring the fracture surfaces back into alignment it was necessary to spring the pipe into position, which involved both bending and twisting of the pipe. The forces involved in re-aligning the fracture surfaces were measured in order to determine the static pre-load imposed upon the union prior to failure. It was found that, although the shear force on the union was insignificant, the bending moment pre-load was approximately 72 Newton-Metres (Nm), which would produce a static bending stress of the order of 53 Mega-Pascals (MPa) at the failure cross section.

X-ray analysis of the union indicated that it was an aluminium alloy of the 2014 type, and hardness measurements confirmed that its strength was within the expected range.

**Previous history**

Five days before the accident, the aircraft had been en-route passing Elstree Aerodrome when there had been an oil leak from the same area of the cowl, which also resulted in some windscreen contamination. A precautionary landing was made at Elstree, where it was checked by a maintenance organisation based on the airfield and the leak traced to the (same) forward union on the CSU oil pipe. On that occasion however, the leak was caused by a split in the nut securing the pipe to the union, and the union itself appeared undamaged. The pipe was removed and a new pipe assembly obtained from an approved supplier. This new pipe had steel nuts, compared with the original pipe which had anodised aluminium alloy nuts. The new pipe was fitted, the nuts tightened (by hand initially), and the engine was run to confirm that there were no leaks. The union was not removed during pipe replacement, and was not disturbed — other than by the attachment of the new pipe. The next day the aircraft was collected by its owner and flown back to its home base at Coventry. The aircraft appeared quite normal during this flight, and also during the next flight, which was from Coventry to Goodwood. However, during the return journey to Coventry the union fractured, resulting in the accident.

**Examination of original pipe assembly**

Laboratory examination of the original pipe assembly revealed that the failure of the pipe nut had been caused by a stress corrosion mechanism leading to multiple longitudinal cracks, one of which had traversed the whole length of the nut, allowing it to spring apart slightly with consequent loss of pipe joint integrity. X-ray analysis indicated the material composition was consistent with that of a 2024 aluminium alloy and the microstructure showed unidirectional grain characteristics typical of components manufactured from wrought or extruded bar stock. Such material is very susceptible to end-grain corrosion attack of the kind which had occurred. There were no indications of fatigue, and the nut failure was clearly separate from, and entirely unconnected with, the subsequent union failure.

There was no direct evidence to indicate whether the union had been partially fractured by fatigue before the replacement pipe was fitted. There was considerable fretting damage on the original pipe where it passed in front of the cooling air baffle on the forward cylinder, and the baffle itself was also worn. (This damage was not caused by the new pipe, which sat against the baffle in a slightly different position.) The fretted area was at the forward end of the pipe, close to the union, and was almost certainly caused by vibration of the baffle rather than of the pipe itself. Several bands of slight fretting, typical of marks produced by pipe clips or ties, were evident on the pipe in the area where supporting clips would normally be positioned. However, these marks could have been caused by electrical cable-ties rather than pipe support clips. Because the original pipe was no longer in place, the accuracy of its alignment with the union, and hence the mean operating stress in the union with the original pipe fitted, could not be estimated.

**Fatigue failure**

Fatigue cracking only arises when a component operates in an environment of cyclicly varying (alternating) stress. Failure occurs as a result of the progressive advance of a crack through the material, cycle by cycle, until the component is weakened to the extent that it fails in overload. The distance which the crack front advances with each stress reversal, and hence the number of cycles to failure, is governed by:

1) the magnitude of the stress reversals (alternating stress component), and
2) the level of the mean (static) operating stress (about which the alternating stress component varies).

The time taken for the damage cycles to accumulate to the point of failure will depend on the frequency of the alternating stress. However, if the stress environment (static/alternating stress combination) is below a threshold value for the material known as the fatigue limit, no damage occurs and the component has, in theory, an infinite life.

On G-OADE the pipe union was a fixed component operating in a nominally static stress environment, arising from the pressure of the oil and the weight of the pipe assembly itself. However, pipe assemblies of this type — involving rigid pipes with limited support between end-fittings — are prone to resonance, with consequent high frequency cyclic loading of the end-fittings and their attachments. If these stresses cause fatigue damage, component failure is likely to occur rapidly because of the high frequency of the alternating stress. The potential for this condition to occur is reduced if the pipe is correctly supported, but it must be correctly aligned to ensure minimal static stresses in the unions, otherwise the operating stresses may still be above the fatigue limit and even small alternating stress levels will produce fatigue damage.

On the Cessna 177RG installation, the pipe assembly is difficult to replace without removing additional engine components, which impede access and make it difficult to manoeuvre the pipe into position beneath the cylinders without distorting it. Because the pipe is a stainless steel component of considerable stiffness, any misalignment of the pipe relative to the unions will produce high static stresses in the end-fittings compared with the corresponding situation involving a more flexible pipe material. Fatigue data for the type of aluminium alloy used in the pipe union indicates that for a notched area, such as the threaded (failed) section of the union, the static stress component of 53 MPa caused by the pipe misalignment would be sufficient to lift any superimposed cyclic stress, such as that arising from pipe resonance, into the regime where cumulative fatigue damage would be likely to occur, leading ultimately to complete fracture across the threaded section.

The log books indicated that the original pipe had been fitted to the aircraft for a period in excess of 750 hours without disturbance. The new pipe assembly had been fitted for less than ten hours when failure occurred.