## ACCIDENT

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|---|---|
| **Aircraft Type and Registration:** | Piper PA-28RT-201 Cherokee Arrow IV, G-BHAY |
| **No & Type of Engines:** | 1 Lycoming IO-360-C1C6 piston engine |
| **Year of Manufacture:** | 1979 (Serial no: 28R-7918213) |
| **Date & Time (UTC):** | 11 September 2017 at 0956 hrs |
| **Location:** | Wolferton, Norfolk |
| **Type of Flight:** | Private |
| **Persons on Board:** | Crew - 1 Passengers - 1 |
| **Injuries:** | Crew - 1 (Fatal) Passengers - 1 (Fatal) |
| **Nature of Damage:** | Engine front fuselage, wings and landing gear severely disrupted |
| **Commander's Licence:** | Private Pilot's Licence |
| **Commander's Age:** | 58 years |
| **Commander's Flying Experience:** | 1,129 hours (of which 406 were on type)<br>Last 90 days - 15 hours<br>Last 28 days - 10 hours |
| **Information Source:** | AAIB Field Investigation |

## Synopsis

The aircraft was en route from London Southend Airport to Newcastle International Airport. Over the Wash, the pilot reported that the aircraft's engine was rough running and he turned towards the coast, during which time the engine failed. During the forced landing it is likely that the aircraft stalled and then struck a berm (the old sea wall) with a high rate of descent. The pilot and his passenger were fatally injured.

Whilst it could not be positively determined why the aircraft stalled, the investigation revealed that the aircraft's engine had not been maintained according to the manufacturer's instructions whilst it was not used for long periods and parked outside.

## History of the flight

*Background information*

The aircraft had been based at Newcastle International Airport and the pilot flew it via France to Menorca, Spain, in July 2017.

In September 2017, the pilot and passenger flew the aircraft back from Menorca, through France, bound for Newcastle. On 10 September they landed at London Southend Airport after the pilot decided to divert, due to inclement weather, en route to Newcastle and elected to stay overnight.

*Accident flight*

On 11 September 2017 the pilot planned to continue from Southend to Newcastle. Prior to departure the occupants were seen to take about an hour preparing the aircraft. The aircraft took off at 0908 hrs.

At 0953 hrs, when the aircraft was over the Wash after crossing the Norfolk coast, the pilot transmitted a MAYDAY to the Distress and Diversion Cell (D&D) on 121.5 MHz, stating he had a "VERY ROUGH RUNNING ENGINE," that the aircraft was at 3,300 ft amsl, descending, and he would turn south towards RAF Marham. A short time later he transmitted "THAT'S SMOKE NOW I THINK WE'VE GOT AN ELECTRICAL FIRE…". About one minute later he transmitted "ENGINE HAS FAILED". At this point the aircraft was at about 1,400 ft amsl and D&D informed the pilot the aircraft was 13.5 nm from RAF Marham, to which the pilot replied he would not make it. The controller suggested Great Massingham 9 nm away but the pilot replied he would not make that either and, as the aircraft was passing 1,200 ft amsl, he added "IT'S GONNA BE A FIELD". This was the last transmission received from the aircraft and was 30 seconds before the last radar contact. Figure 1 shows some of the radio transmissions relative to the radar track.

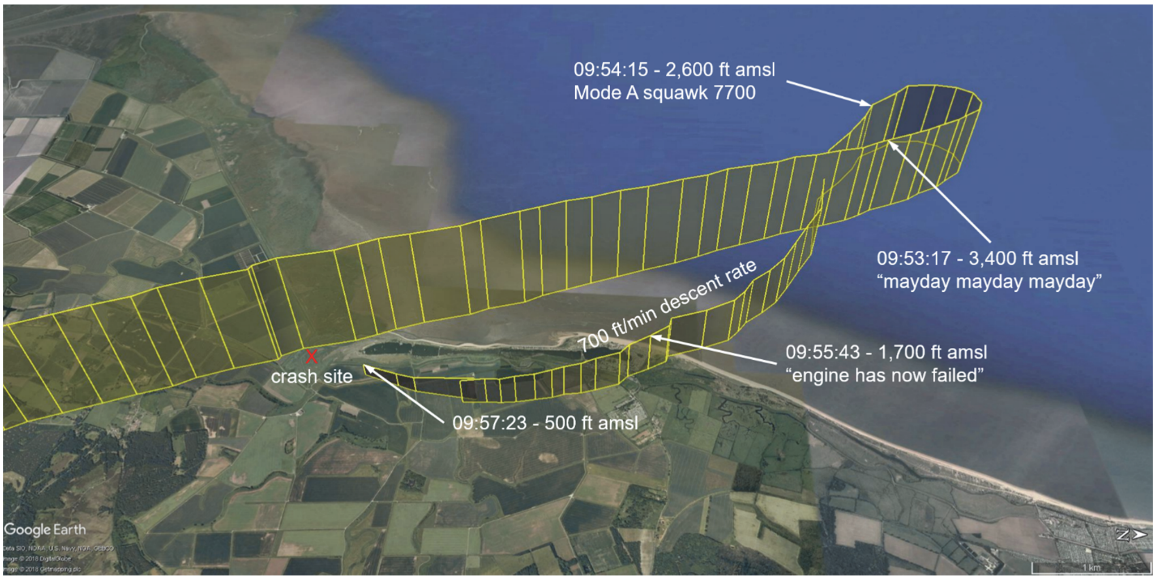


**Figure 1**

View looking to the west of last seven minutes of the radar track
(altitudes are Mode C ±50 ft, corrected to the QNH 988 hPa)

The aircraft was witnessed at low level just prior to the accident. One witness, about 0.3 nm north-north-west of the accident site, stated that he saw the aircraft flying at about 300 ft agl in a southerly direction over farmland. At the time, he was not aware of any engine noise. When the aircraft was close to the berm (the old sea wall), at about 40 ft agl, he saw it "drop vertically" and disappear from his view.

Another witness, who was working in a field about 0.25 nm south-west of the accident site, stated that he first saw the accident aircraft at a low altitude, flying in about a southerly direction towards the old sea wall. The aircraft had its landing gear down and the propeller was not turning as one blade was stationary, pointing vertically up. When it was about twice the height of the trees on the old sea wall, the aircraft "turned right and stalled". The nose dropped quickly and the aircraft struck the berm.

All the witnesses commented that the weather was fine, with the wind strong, from the west.

The accident site was about 2.5 m south-west of Snettisham, Norfolk. Two of the witnesses were at the scene quickly and administered first aid to the occupants. Police and paramedics arrived soon after, as did an air ambulance helicopter and a Coastguard helicopter. However, the occupants were declared deceased at the scene.

**Meteorology**

An aftercast produced by the Met Office stated that there was a deep area of low pressure centred over the northern North Sea with strong winds on its southern and southwestern flanks. The forecast low-level winds valid for 1200 hrs across East Anglia and the Wash were expected to be from 260° at 30 kt at 1,000 ft amsl and from 260° at 35 kt at 2,000 ft amsl.

Observations from RAF Marham at 0950 hrs and Norwich Airport at 1020 hrs recorded wind from 230° at 14 to 23 kt with some gusts higher. Marham recorded FEW clouds at 1,900 ft aal, SCATTERED clouds at 2,700 ft aal and BROKEN clouds at 3,500 ft aal. At both airfields the visibility was greater than 10 km and the QNH was 988 hPa.

The aircraft was on approximately a southerly track as it flew back towards the coast. A surface wind from 230° at 15 kt, would give an airspeed about 12 kt greater than the ground speed calculated from the radar returns.

**Medical information**

Post-mortem examinations were carried out on the pilot and passenger by a consultant histopathologist who concluded that both died as a result of multiple injuries sustained in the accident. Toxicology test for drugs and alcohol for the pilot were negative and a level of 1.9% of carboxyhaemoglobin was recorded.

A review of the reports at the RAF Centre of Aviation Medicine concurred that the injuries sustained by the pilot and passenger were consistent with decelerations sustained by the aircraft impacting the ground and, given the level of carboxyhaemoglobin recorded, it was unlikely that they had been exposed to excess carbon monoxide prior to their deaths.

**Aircraft's information manual**

The '*Piper Arrow IV Information Manual*' states in the '*ENGINE POWER LOSS IN FLIGHT*' checklist '*trim for 79 KIAS*'. It also states in the section titled '*STALLS*':

> *'An approaching stall is indicated by a stall warning horn which is activated between five and ten knots above the stall speed [58 to 63 KIAS]…*
>
> *The gross weight stalling speed of the Arrow IV with power off and full flaps is 53 KIAS. With flaps up this speed is increased 6 KTS...'*

**Recorded information**

Radar returns from the aircraft were recorded for the flight starting shortly after takeoff from Southend and stopping when the aircraft was about 0.25 nm from the accident site. The returns included height information (rounded to the nearest 100 ft) and indicated that the cruise altitude for the flight was about 4,300 ft amsl. A composite radar track of the last 17 minutes of flight from the Cromer and Debden radar heads is shown in Figure 2 and an expanded plot of the final phase is shown in Figure 1.


**Figure 2**

Portion of radar track of G-BHAY – final 17 minutes

The aircraft crossed the coastline at 0951:30 hrs and started to descend 30 seconds later. After a further 1 minute 17 seconds (about 3 nm from the coastline crossing) the pilot made the MAYDAY radio transmission (RTF) to D&D (Figure 1).

The pilot then commenced a 180° turn to the left[1] during which he passed his MAYDAY message and reported the aircraft's altitude as 3,300 ft. He completed the message about halfway through the turn, as the sound from the engine (recorded on the RTF) became distinctively rough sounding. The aircraft had descended about 600 ft since the initial MAYDAY call.

At 0954 hrs, with the aircraft now on a reciprocal heading, the pilot changed the radar transponder Mode A squawk to 7700[2]. He then turned the aircraft further to the left towards the nearest point on the coastline, which he crossed 90 seconds later, at about 1,800 ft amsl. At this point he reported the "ENGINE HAS FAILED", before turning onto a southerly track parallel to the coastline. This was just over five minutes since the aircraft started descending over the Wash and about 2.5 minutes after the initial MAYDAY call.

The aircraft continued to descend with the pilot making a RTF transmission at 0956:45 hrs stating that he was "PASSING ONE THOUSAND TWO HUNDRED FEET NOW" and that "IT'S GONNA BE A FIELD". The last radar return was at 0957:23 hrs with the aircraft at about 500 ft amsl, 0.25 nm to the north of the eventual accident site. The average descent rate during the descent from 4,300 ft was about 700 ft/min and groundspeed averaged over the last minute was 60 kt.

**Aircraft description**

The Piper PA-28RT Cherokee Arrow IV is a four-seat, all-metal, low-wing, single-engine aeroplane fitted with a 'T' tailplane and retractable tricycle landing gear.

The aircraft has conventional flying controls, mechanical trim in the elevator and rudder systems and three-position trailing edge flaps, operated mechanically by a floor-mounted lever in the cockpit. The stall warning system consists of a small pivoted tab, on the leading edge of the left wing, which moves upwards with the onset of stall and sets off an electrical warning buzzer in the cockpit.

The landing gear is retracted by an electrohydraulic system, with hydraulic pressure supplied by an electric pump in the rear fuselage. The landing gear is operated by a two-position toggle lever in the cockpit, next to the engine and propeller controls, and below are three landing gear status indicators. There was a landing gear automatic extension system originally included on the PA-28RT models but in G-BHAY this feature had been removed.

**Footnote**

1 At this point, the coastline closest to the aircraft was behind and to its right at less than 2 nm.
2 7700 is the code to indicate to ATC that the aircraft is in distress. It shows ATC and other radar listening stations that an aircraft is in difficulties and enables position and altitude information to be seen.

The aircraft is fitted with a Lycoming IO-360-C1C6 four-cylinder piston engine, normally aspirated with mechanical fuel injection and driving a two-blade constant speed propeller. The cylinders are numbered one to four[3] and the lubricating oil pump is driven directly from the end of the crankshaft. There are two overhead valves per cylinder, opened by rockers and push rods and closed by dual concentric springs. There is a single camshaft driven by the crankshaft through the first stage of the accessory gear train and hydraulic tappets and followers lift the push rods. The crankshaft is a single piece forging, carried on three main white metal bearings and oilways through the crankshaft enable the delivery of oil to the big-end bearings. There is a centrifugal bobweight damper between the No 3 and No 4 big-end bearings.

Engine lubrication is by a wet-sump system with a capacity of up to eight quarts of engine oil, six quarts being considered the normal level shown on a calibrated dip stick. Oil pressure is generated by the single-stage gear pump and oil is drawn from the bottom of the sump and delivered by the pump through a cartridge filter into the galleries and drillings within the crankcase to distribute it around the engine. Oil to lubricate the main and big-end bearings is delivered through the main bearing webs in the crankcase and the pistons and cylinders are spray-lubricated from jets beneath each cylinder. Oil from the camshaft lifters passes along the pushrod tubes into the rocker boxes to lubricate the rockers valves and springs and used oil from the rocker boxes drains through external tubes into the sump. Used oil from the crankshaft, pistons and cylinders drains directly back into the sump.

The engine has aluminium alloy pistons, each fitted with two piston rings and an oil control ring. The oil control ring consists of a dual-rail bevelled edge ring, backed by a continuous coil spring. There are four oil drain holes, spaced around the oil control ring grove through the piston skirt.

The engine drives a two-blade variable pitch constant speed propeller. The pitch control of the blades is by a piston and spring assembly which uses engine oil metered through a mechanical governor driven by the accessory gearbox on the rear of the engine. Propeller rpm is set by a lever next to the throttle in the cockpit.

The ignition system consists of two engine-driven magnetos and two spark plugs per cylinder. Ignition and the magnetos are controlled by a four-position key switch in the cockpit.

## Maintenance history

The aircraft had a comprehensive set of maintenance records and journey log and had a valid Airworthiness Review Certificate scheduled to expire on 18 March 2018 following its annual inspection on 14 March 2017. The last entry in the journey log was on 13 August 2017 and showed 31 hours remaining to its 50-hour check.

The aircraft had been owned by a syndicate since 1987 and was usually kept in a hangar at Newcastle International Airport, maintained on behalf of the syndicate by an aircraft

**Footnote**

[3] The No 1 and No 2 cylinders are on the front right and left side of the engine and the No 3 and No 4 cylinders are on the rear right and left side of the engine.

maintenance company based at Carlisle. The aircraft log book shows that it had been flown by only two different people, with most of the flying by the accident pilot.

Only one flight (in October 2015) was recorded in the journey log between January 2015 and October 2016. The aircraft had been parked outside at Newcastle, some 9 nm from the sea, from November 2015 to July 2016, including a prolonged period of inclement weather during December 2015. It is not known whether measures were taken to prevent deterioration to the aircraft or its engine during the long period of parking.

The annual maintenance requirements during the period of inactivity of October 2015 to October 2016 had not been carried out. On 10 October 2016, the aircraft was authorised for a single ferry flight from Newcastle to Carlisle for the now-overdue annual maintenance inspection, this flight was recorded in the journey log as 20 minutes. The aircraft was then stored in a hangar at Carlisle and eventually underwent its most recent annual maintenance inspection, during March 2017.

### Annual inspection

The March 2017 annual inspection was carried out in accordance with CAP 766 *Light Aircraft Maintenance Programme.* This included an engine oil and filter change and the engine was recorded as running on Aero Castrol 80+. An engine compression check was carried out and all the four cylinders were found to be satisfactory (‘*73 or 74 over 80*’), within the limits laid down by the engine manufacturer. There were no defects recorded in the documentation during the annual inspection. When the aircraft was released to service it was recorded as having accumulated 4,881:30 airframe hours, 1,065:45 engine hours and the propeller overhaul had zeroed its flying hours. The engine was last overhauled on 26 May 2004[4] and had thus consumed just over 50% of its 2,000-hour overhaul life at the time of the accident.

### Aircraft usage since the annual inspection

After the March 2017 annual inspection, all the flying recorded in the log was by the accident pilot and included flights over several days through France, arriving in Menorca on 12 July 2017. The journey from Newcastle to Menorca was via Le Touquet, Fleres, La Roche-sur-Yon and Carcassonne and totalled a flying time of 10 hours and 45 minutes.

Whilst flying to Carcassonne, the pilot encountered a landing gear problem whereby it did not satisfactorily indicate locked down. After visual confirmation with ATC he landed safely and then flew on to Menorca with the gear down. In Menorca, he had three replacement landing gear microswitch assemblies shipped and a local aircraft mechanic replaced the microswitches on the left and right main landing gears.

Three 45-minute flights were recorded whilst the aircraft was in Menorca, between 17 July and 13 August 2017.

**Footnote**

[4] The time between overhauls may be carried out on a calendar 12 year or 2,000 flying hours basis. The operator/owner can decide to apply either. The majority of engines are overhauled on a flying hours basis but require regular inspections and checks to ensure serviceability as they often take more than 12 years to accrue 2,000 flying hours.

**Engine anti-deterioration measures**

The engine contains ferrous and non-ferrous alloys; the external surfaces have anti-corrosion treatments such as paint or metallic plating, the internal surfaces in general rely on the properties of the lubricating oil for protection. However, many of the internal surfaces are subjected to heat and corrosive products during the combustion process which are kept at bay by additives within the oil. When the engine stops running the internal surfaces and components are left with a coating of oil but if the engine is not run for a period this coating becomes less effective, especially if an engine is subjected to a moisture-laden environment. Ferrous components such as the cylinder liners, crankshaft and connecting rods can develop surface corrosion in the form of rust. In areas where there may be more reactive deposits from the combustion process, such as the cylinder liners, surface corrosion may develop into pitting corrosion.

There are methods to prevent deterioration by a process known as 'inhibiting' and the engine manufacturer, Lycoming, issued specific guidance on this in Service Letter Number L180B, dated 13 November 2001.

**Accident site**

The accident site was on private agricultural land towards the top of a berm (the old sea wall) which formed part of the secondary inland sea defences on the north Norfolk coast. There was a line of coniferous trees to the west of the accident site, visible in Figure 3; these were about 25 ft high.


**Figure 3**
Accident site

The pilot was found in the left front seat and his passenger in the right front seat and the aircraft was upright on a northerly heading, complete except for the upper engine cowling which had detached during the impact and landed nearby. The windscreen had fragmented and the fuselage distorted in the severe vertical deceleration, so that the door frames and roof section were cut and folded back by the emergency services to release the pilot and passenger. The landing gear had been in the down position but the nose gear had been forced back up into its bay by the impact. The right main landing gear had been forced rearwards and detached from the wing whilst the left had remained attached but was also distorted rearwards.

One of the propeller blades was intact and the other blade had bent backwards under the nose of the aircraft. The propeller showed no signs of rotating when the aircraft hit the ground. There were no ground marks behind the aircraft and the only ground marks apparent were within the 'footprint' of the aircraft which were only visible after the aircraft was lifted during recovery.

Both wing tanks contained fuel and approximately 40 imp gal (48 US gal) were drained from the fuel tanks at the accident site. The top of the engine was exposed and the crankcase had a large hole near the base of the No 4 cylinder, exposing the remains of the No 4 piston connecting rod. Figure 4 shows the damage to the crankcase.

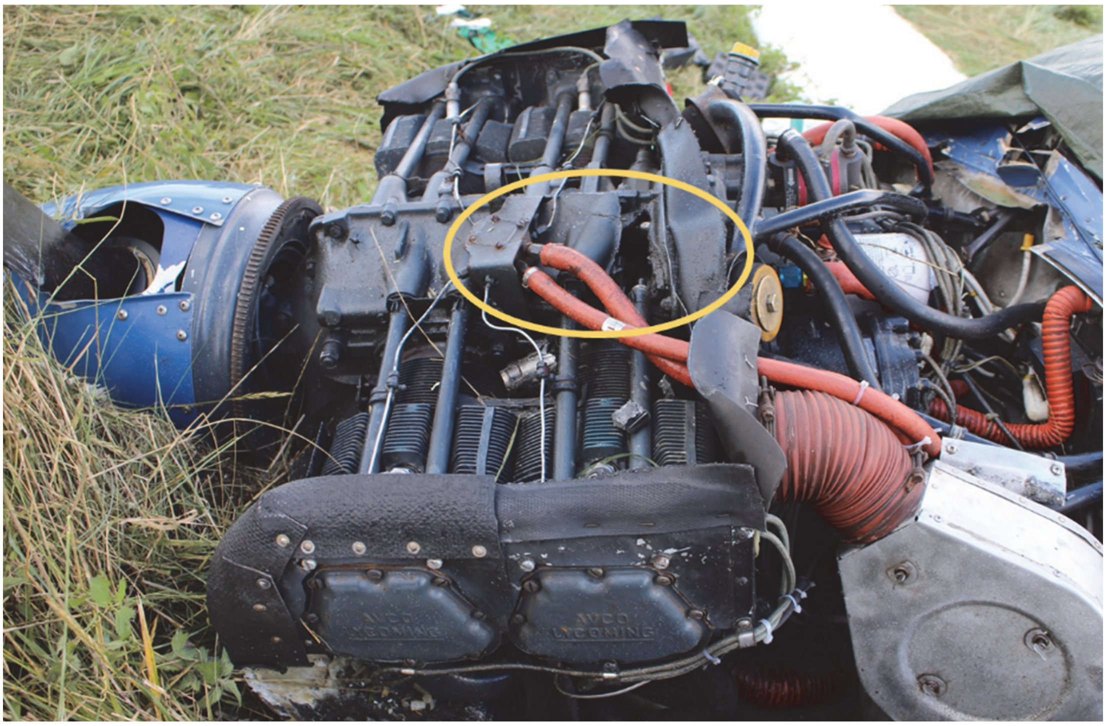

**Figure 4**

Crankcase damage

The battery was damaged and was disconnected and made safe at the accident site. The ignition master key had bent and was found on the cockpit floor; the key switch was damaged but appeared to be in the BOTH position.

The pilot and passenger were wearing three-point safety harnesses which had been cut by the emergency services during the rescue operation. The safety harness webbing, attachment points and buckles were intact and in good condition.

The luggage bay included items used in the care and maintenance of the aircraft, with a plastic storage box carrying nine 1-litre plastic engine oil containers. Four were labelled *Total Aero DM 15W50* and five were labelled *AeroShell W15W-50*, all labelled in French. The four *Total* containers were empty. Three microswitch assemblies were found in one of the flight bags with associated paperwork, two in a used condition and one still in its manufacturer's packaging.

After the initial examination the wings were removed to enable recovery to the AAIB headquarters for more detailed examination.

**Aircraft examination**

*Structure*

Detailed examination showed that the rudder, tailplane and elevator were attached correctly and relatively undamaged but that the area beneath the engine and cockpit around the fire wall was crushed and severely buckled upwards and rearwards by the vertical deceleration when the aircraft struck the berm. The entire underside of the fuselage was covered in engine oil and oil was still seeping from fuselage skin joints and seams. Figure 5 shows the condition of the forward underside of the fuselage and Figure 6 shows oil seeping from the fuselage skin joints.

**Figure 5**

Forward underside of the fuselage

**Figure 6**
Oil seeping from the fuselage skin joints

*Flying controls*

There was continuity of the pitch and yaw flying controls up to the instrument panel although the elevator controls had detached from the yoke shaft linkages due to the disruption of the firewall and cockpit floor. The elevator trim wheel position indicator showed a down (DN) trim setting. There was no evidence of any disconnection or restriction of the controls in flight and marks between the flaps and wings made during the impact, and the linkage and lever positions, showed that two stages of flap had been set.

*Cockpit and instruments*

The nature of the impact meant that little extra useful information could be extracted from the cockpit instruments, except for the barometric altimeter setting of 987 hPa.

None of the circuit breakers had tripped. The aircraft systems master switches were consistent with an interrupted engine-out forced landing: battery master switches ON, fuel pump OFF, landing and anti-collision lights ON and the pitot heat OFF. The transponder 'squawk' was set at 7700.

The stall circuit breaker was correctly set and there was electrical continuity to the warning buzzer. The stall tab fitted to the left wing leading edge was undamaged and correctly opened and closed the circuit when tested. The buzzer was removed and bench tested and was found to operate correctly.

There was no evidence of fire within the aircraft or in any of its components and systems.

*Survivability*

The lack of ground marks behind the aircraft at the accident site and relatively flat impact with the ground suggest the aircraft was rapidly brought to a stop by the berm. Although the pilot and passenger were wearing their harnesses they received fatal injuries due to the rapid vertical deceleration as the aircraft hit the ground and the structural deformation of the cockpit area and the proximity of solid objects, such as the control yoke and instrument panel.

**Propeller and engine examination**

The propeller examined showed that, apart from the bent blade, the propeller was in an 'as new' condition which reflected its low usage since its recent overhaul and there was no indication of pre-impact damage.

The engine was examined externally prior to strip down. The equipment fitted to the rear of the engine and accessory gearbox, and the fuel system components, were in good condition except some impact damage when the aircraft struck the ground.

The spark plugs were removed and examined. The No 1 and No 2 cylinder pairs of spark plugs were heavily carbon-contaminated, with thick granular carbon. The No 2 cylinder pair of spark plugs had no visible gap between the electrodes. In contrast, the No 3 and No 4 cylinder pairs of spark plugs were clean, with insulators and electrodes light grey-brown in appearance, indicative of a normal ignition process.

The oil dip stick was not in contact with any oil and was dry. The underside of the sump was covered in a film of engine oil, although there were no obvious signs of leakage or weeping joints around the engine. However, as observed at the accident site, the crankcase had a large hole in its upper surface through which could be seen the remains of the No 4 connecting rod big-end. There was also sign of a partial rupture near the camshaft forward end where a piece of debris had become trapped between one of the cam lobes and the crankcase. The internal crankcase web above the sump had also been holed by debris impact.

The crankshaft was in one piece and but showed signs of rubbing and discolouration due to excessive heat on the rear main journal, the No 4 crankpin and the No 2 crankpin. There were also debris impact marks on the surfaces of the No 3 and No 4 crankpin surfaces. Figure 7 shows the overheated condition of the No 4 crankpin.

The camshaft, pushrods and valve gear were undamaged. However, the hydraulic lifters and followers near the crankcase hole had been ejected and were found loose in the engine bay. In addition, several of the other cam followers were damaged because of debris impact.

When the engine was disassembled approximately one quart of lubricating oil was found within the engine lubrication system, heavily contaminated with ferrous and non-ferrous metallic debris. The oil pump was undamaged, free to rotate and could produce an oil flow. The filter was intact and the element not blocked, although it contained fine debris. The oil pick-up strainer gauze tube within the sump was completely blocked with metallic debris along its length.

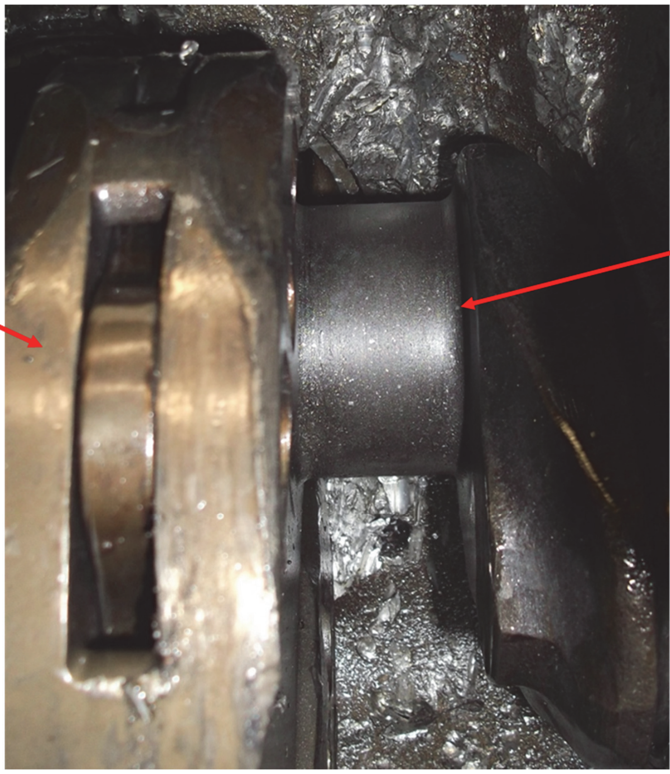


**Figure 7**
No 4 crankpin condition

*Cylinder, piston and connecting rod examination*

The No 1 and No 2 cylinder liners had linear scoring within the piston-swept area. There was heavier localised scoring where debris had been picked up on the piston skirt and small areas of pitting corrosion were present in both cylinders, were smoothed by the action of the piston and oil control rings. The pitting corrosion was more prevalent in the No 2 cylinder and heavier pitting corrosion was present at the top of both cylinders, outside the piston-swept area. Figure 8 shows the corrosion in the No 2 cylinder.

The piston skirts were heavily scored on their lower surfaces[5] due to debris entrapment. All the piston rings were in place but were jammed in their grooves by distortion from the scoring and the No 2 oil control ring was clogged with oily sludge and was slightly distorted.

Significant evidence of 'blow-by' was present on both the No1 and No 2 piston skirts, with associated carbon build-up around the piston crowns. The connecting rods were still attached to the crankshaft but were dry of oil and showed evidence of excessive heat, with the big-end bearings starting to disintegrate.

**Footnote**

[5] In a horizontally opposed engine such as in the case the pistons are considered to present an upper and lower surface to the cylinders.


**Figure 8**
An example of the pitting corrosion in the No 2 cylinder

By contrast the No 3 and No 4 pistons were in better condition and had stopped in their respective cylinders when their big ends detached from the crankshaft. There was no evidence of blow-by and no scoring of the piston skirts. However, the underside of the pistons was covered in multiple debris strike marks and the No 3 connecting rod was bent and twisted and its half-cap, end bolts and bearing shells pulverised. The No 4 connecting rod and associated parts had similar damage and fragments of the No 3 and No 4 bearings had evidence of excessive heating and swaging whilst under load. Figure 9 shows the condition of the pistons and damage to the connecting rods.


**Figure 9**
Pistons and connecting rods

## Analysis

*Operational aspects*

The aircraft approached the coastline west of Snettisham, Norfolk, about 2 nm north of the accident site, at about 1,800 ft amsl. The last radar return was at about 500 ft amsl and 0.25 nm to the north of the accident site.

The aircraft's ground speed during the last few radar returns was about 60 kt. The wind recorded at Marham and Norwich was from 230° at 14 to 23 kt with some higher gusts. As the aircraft flew on a southerly track, the airspeed would have been about 12 kt greater than the ground speed; around 72 kt. Whilst this was less than the published recommended glide speed of 79 kt, it was 13 kt above the 'clean stall' speed of 59 kt and 19 kt above the '*full flaps*' stall speed. The witness evidence, that the aircraft was subsequently seen to stall before impacting the ground, was consistent with the ground impact, with high vertical deceleration and low forward speed. It could not be determined when or why the aircraft's airspeed reduced further, towards the stall speed, but as the wind recorded was also gusting by up to an additional 10 kt, the aircraft could have stalled partly due to a decrease in its airspeed due to the windshear caused by the gusty wind conditions.

As the master switches were ON, the aircraft's stall warning buzzer should have sounded. Given the stressful situation the pilot was in it is possible that he did not hear it or did not hear it in time to respond correctly. Additionally, given the low height at which the aircraft was seen to stall, the pilot may have been reluctant to attempt a recovery, by pitching the aircraft down, as he may have been conscious of the vicinity of trees to the west along the berm and wanted to attempt to clear them before lowering the nose.

Witnesses stated that they saw the aircraft with the landing gear lowered before the accident. Examination of the aircraft after the accident found that 'Flaps 2' was selected, and appeared to be trimmed for this configuration, the battery master switches were ON and the fuel pump was OFF. Given these facts, it is reasonable to believe that the pilot had secured the aircraft for a forced landing and chosen a field in which to complete it before the accident. However, it could not be determined which field he intended to land in. Had he turned the shorter distance back towards land, right rather than left, this would have given him more height and time over land with which to make his field choice. He may have turned left as he was sitting in the left seat; this was the more instinctive direction from the left seat and the land was easier to see from this seat.

Carboxyhaemoglobin levels and lack of evidence in the aircraft indicate that, despite the pilot's report to ATC, there was no fire. The pilot may have thought this due to fumes entering the cabin through the aircraft's ventilation system when the engine was failing.

*Engineering*

It is clear from the evidence that the engine suffered a catastrophic failure which led to its eventual stoppage.

The No 1 and No 2 pistons show significant exhaust 'blow-by' and contamination of the oil control rings and this led to the severe fouling of the No 2 cylinder spark plugs. This was probably the point where the pilot detected the engine rough running and prompted his MAYDAY call. It is known that blow-by can cause pressurisation of the crankcase which in turn causes oil to be ejected from the breather. The breather exit tube is situated behind the nose landing gear bay on the underside of the aircraft and excessive oil loss through the breather tends to cover the area behind the breather and be carried by the airflow rearwards, consistent with the oil-soaked fuselage underside in this case.

As the oil was lost, the temperature of the remaining oil started to rise and this, along with the reduced quantity, meant that lubrication of the main and big-end bearings degraded. It is possible the oil pressure drop had an additional effect on the propeller, causing its pitch to 'hunt' against the main spring in the blade pitch mechanism; this would have manifested itself as an engine pulsation exacerbating the roughness of the engine running experienced by the pilot.

From the rough running report to engine stop was about 2.5 minutes, heard in the background of the ATC recordings. At some point the big-end bearings started liberating wear debris and the evidence indicates that this was happening whilst the oil pump was attempting to draw oil from the sump, explaining the almost total clogging of the oil pick-up strainer with bearing material. This would cause a worsening effect on the bearings as the oil pump struggled to maintain pressure and flow.

In general, big-end bearings are the first to suffer as a lubricating system starts to fail. In this case, the No 4 big-end loosened as its bearing overheated, disintegrated and induced stresses in the half-cap bolts, which failed, allowing the connecting rod to detach from the crankshaft. This allowed the connecting rod free to flail as the engine continued to run for its last few seconds, with the No 4 big-end half-cap, bolts and bearing remains becoming caught up in the bobweight damper sweeping them around between it and the No 3 big-end and connecting rod, causing it to disintegrate. The No 4 connecting rod eventually forced its way out of the crankcase and the engine stopped.

It is noted that in similar engine failure cases in the past, AAIB experience suggests that the No 4 piston, cylinder and associated components are usually the first to degrade and suffer damage.

*Initiating conditions*

Between November 2015 and July 2016 the aircraft was parked outside at Newcastle International Airport, nine miles from the sea and in inclement weather conditions. There is no evidence that the engine had been inhibited during the aircraft's period of inactivity and it is likely that corrosion took hold during this period. This was evident in the No 1 and No 2 cylinder walls, with localised pitting corrosion at the top of the cylinder and within the piston-swept area. The engine manufacturer's Service Letter (Number L180B, dated 13 November 2001) is clear on the actions to be taken to prevent engine deterioration and notes that active corrosion can occur in a short period of time.

The subsequent annual check, in March 2017, included a compression check, within acceptable limits. Although this is considered a good indication of cylinder, piston ring and valve interaction, it does not necessarily show how well the oil control ring is performing or whether the piston and oil control rings, or the cylinder walls, are starting to deteriorate. There is no requirement to visually check the internal surfaces of the cylinders and pistons at an annual check, so the corrosion would remain undetected and the compression test result would not give cause for concern.

The journey log shows that from October 2015 to March 2017, only 20 minutes were recorded as having been flown. From March 2017, the journey log showed 18 hours and 40 minutes up to 13 August 2017. If the pilot flew a similar route back through France as he had flown outbound, it is possible that an additional 10 hours was accrued, taking the total hours since the annual inspection to approximately 29 hours. Taking this usage pattern into account, it is likely that most of the deterioration around the No 1 and No 2 pistons and cylinders occurred since the annual inspection in March 2017.

*Oil consumption*

Discussions with the maintenance organisation suggest that it was usual for this pilot to be well prepared and to carry extra tools, spares, fluids and personal equipment in the aircraft. Four empty oil containers were found in the aircraft but there was no record as to when the oil was replenished and, based on 4 litres over 29 hours, an oil consumption rate of about 0.13 litres per hour is reasonable over that period. However, engine oil consumption tends to increase as an engine deteriorates and it is likely that this was the case in this engine.

Staff at the maintenance organisation also suggested that the pilot was particular in his preparations for flight and that it is unlikely that the pilot would have taken off from Southend without the oil dip stick showing at least the recommended level of six quarts in the sump. It is not known whether the pilot had to replenish the oil at Southend to achieve that level but it means that five quarts were lost during the 40 minute flight from Southend to the point where the engine stopped. This suggests a rapidly increasing degradation of the engine during this flight and this degradation may have started before he landed at Southend, without having yet become apparent to the pilot.

*Reported smoke in the cockpit*

Despite the report of smoke in the cockpit made during the radio transmission, no evidence of fire could be found in the aircraft. It is therefore likely the smoke was due to overheated oil fumes or smoke exiting the engine through the crankcase breach, filling the engine bay and then surrounding the nose of the aircraft before being drawn into the cabin ventilation and heating system.

## Conclusion

The accident was likely the result of the aircraft stalling at a low height from which there was insufficient height to recover, during an attempted forced landing following a catastrophic engine failure.

The engine failure was due to oil loss caused by damage and premature wear to the oil control rings. The engine had been inactive for several months, and probably had not been inhibited in accordance with the manufacturers guidance, leading to the formation of corrosion within the engine.