DATA SUMMARY

LOCATION

Date and time	**Tuesday, 27 September 2011; 16:44 h[1]**
Site	**Vicinity of the Seville Airport (LEZL) (Spain)**

AIRCRAFT

Registration	**EC-CXP**
Type and model	**CESSNA 172 H "Reims"**
Operator	**Aeroclub de Sevilla**

Engines

Type and model	**TELEDYNE CONTINENTAL MOTORS TCM/RR O-300-D**
Number	**1**

CREW

Pilot in command

Age	**33 years old**
Licence	**CPL(A)**
Total flight hours	**425 h**
Flight hours on the type	**118 h**

INJURIES	Fatal	Serious	Minor/None
Crew			**2**
Passengers			**1**
Third persons			

DAMAGE

Aircraft	**None**
Third parties	**None**

FLIGHT DATA

Operation	**General aviation – Instruction – Dual control**
Phase of flight	**Takeoff – Initial climb**

REPORT

Date of approval	**27 January 2014**

[1] All times in this report are in UTC unless otherwise specified. To obtain local time, add 2 hours to UTC.

1. FACTUAL INFORMATION

1.1. History of the flight

The aircraft took off at 16:39 on a local instructional flight, departing from and arriving at the Seville Airport (LEZL). Onboard were the instructor, a student using dual controls and a third occupant. According to the instructor's account, once the aircraft was airborne and while over point Sierra (see Appendix A), at an altitude of about 1,000 ft, the engine started misfiring and losing RPMs. The instructor decided to return to the airport and informed the control tower (TWR) at LEZL. Since it was impossible to make it to the runway, the instructor decided to land at the old military base of San Pablo, in an area near the airport to the southwest (see Appendix A).

The occupants were not injured. The aircraft escaped serious damage, except for that confined to the engine.

When the engine was disassembled during an inspection conducted after the event, the number 2 cylinder rocker arm was found broken in two pieces.

Figure 1. View of the aircraft at the landing site

1.2. Personnel information

The instructor, a 33-year old Spanish national, had a JAR-FCL commercial pilot license (CPL(A)) and class 1 and 2 medical certificates, all valid and in force. He had single-engine, multi-engine and instructor ratings. He had a total experience of 425 h, 118 of them on the type.

The student, a 27-year old French national, had a student permit and a valid and in force medical certificate. He had a total of 40 flight hours, all on the type. The student was the pilot flying at the time of the incident, although the instructor took over the controls and the communications and eventually landed the airplane.

1.3. Aircraft information

1.3.1. *General information*

The Cessna F-172-H “Reims”, serial number (S/N) 172-0367, is a single-engine, fixed high-wing and fixed tricycle gear aircraft. This aircraft is outfitted with a Teledyne Continental-Rolls Royce TCM/RR O-300-D engine, S/N 30R870 and a dual-blade McCauley propeller, model 1c172EM7653 and S/N E5042. At the time of the incident, the aircraft had 2,864 h and the engine 490 h since overhaul[2]. According to the registration records, the aircraft had a Continental O-300-D on the date it was registered (22/11/1976).

The aircraft’s registration and airworthiness certificates and other administrative records were all valid and in force.

1.3.2. *Engine maintenance history*

The engine was installed by a maintenance center[3] (different from the one that regularly maintained the aircraft) with 2,388 h on the aircraft. The work order documented the removal of the old engine and the installation of the incident engine, which was of the same model and had been overhauled.

The engine had been overhauled at a JAR-145 authorized German maintenance center in 2004. This engine has a time between overhauls of 1,800 h or 12 years, whichever comes first. The return to service certificate after the engine’s overhaul was dated 30 June 2004, and referenced that the work had been completed in accordance with the TCM Engine Manual and that all of the service bulletins had been reviewed and/or

[2] Complete engine inspection that leaves it in an as-new condition.
[3] Authorized JAR-145 maintenance center.

implemented. No explicit entries were found indicating a replacement of the rocker arms or rocker arm bushings.

The first work order on record at the aircraft's current maintenance center[4] was for a 100-h (and/or annual) engine check conducted in October 2006, with 17 h on the engine (though when the hours were transferred the number 35 was mistakenly written on the order[5]). The aircraft had 2,405 h. Also during this inspection the oil was changed and the cylinder compressions were checked.

On 18 August 2011 (with 481 h), repair was performed on the engine due to low compression of the numbers 2 and 4 cylinders. The return to service certificate noted the following:

> *"Engine repaired (cylinders 2 and 4 due to low compression).*
> In accordance with maintenance program PM-C172-CXP Ed.1, Rev. 0 of 20/09/2009. Numbers 2 and 4 cylinders disassembled due to low compression (exhaust valves were seized open). Cleaned soot off cylinder head and valve guides, installed new exhaust valves P/N AEC655971 and two sets of seals P/N SA200T1. Ran functional test on the ground. Engine ready for return to service".

According to the information gathered during the information, after the low compression problem in cylinders 2 and 4, neither the rocker arms nor their associated bushings were replaced in the affected cylinders. The Maintenance Manual does not establish such task. According to the maintenance center, the rocker arms were inspected visually. No damage or abnormalities were noted.

At the time of the incident, nine hours following the repairs to cylinders 2 and 4, the engine had some 490 h.

1.4. Meteorological information

Based on the information gathered during the investigation, on the day of the incident the prevailing wind was from the south, varying from 40° to 160° at a speed of 5 to 8 kt. There was good visibility on the ground, in excess of 10 km, no clouds below 1,500 m, no cumulonimbus clouds or any significant weather events. The QNH was 1,019 hPa.

1.5. Communications

According to the record of communications between the aircraft and the control tower[6], at 16:33:06 the aircraft established contact with the control tower to report its intention

[4] Nationally authorized maintenance center.
[5] This 18-hour mismatch was carried until the last entry.
[6] All communications took place in English.

to make the flight. After several exchanges while taxiing to the holding point, at 16:38:44 the controller cleared the crew to take off on runway 09, reporting a wind from 190° at 10 kt, which the crew acknowledged.

At 16:39:50 the crew informed the tower that they were reaching point Sierra, and a minute later the tower informed the crew of their assigned transponder code.

At 16:43:39 the crew once again contacted the tower to report their intentions to return to the airport due to an engine failure. The controller authorized the return to the airfield and asked if the aircraft would require any assistance on the ground, to which the crew replied that they did not know at that time.

At 16:44:59 the controller requested the aircraft's position, as he did not have it in sight. The crew reported they were 4 or 5 miles out and losing altitude slowly.

At 16:46:02 the crew of the aircraft once again contacted the control tower to report they would not be able to reach the airport and that they were looking for a site nearby. Ten seconds later, the crew reported being at 300 ft and that they would try to reach the airfield, but immediately afterwards they decided to land nearby. The controller acknowledged the information, adding that he had the aircraft in sight.

At 16:47:08 the crew reported they had landed normally and that the three occupants were all right.

Subsequent communications were those involving the exact location of the aircraft, whether or not the crew needed help and coordination of the situation between firefighters and ACC Seville. No anomalies were observed that might be relevant to the investigation.

1.6. Aerodrome information

The Seville Airport (LEZL) is located 10 km northeast of the city of Seville. It is at an elevation of 111 ft and it has one asphalt runway measuring 3362 x 45 meters in a 09/27 orientation. Appendix A shows the visual approach chart for the airport and part of the flight path taken by the aircraft.

1.7. Additional information

1.7.1. *Information on the engine and description of the rocker arms*

The O-300-D model is a carburetor design with six air-cooled opposing cylinders. The valves are located on the cylinder heads (see Figure 2).

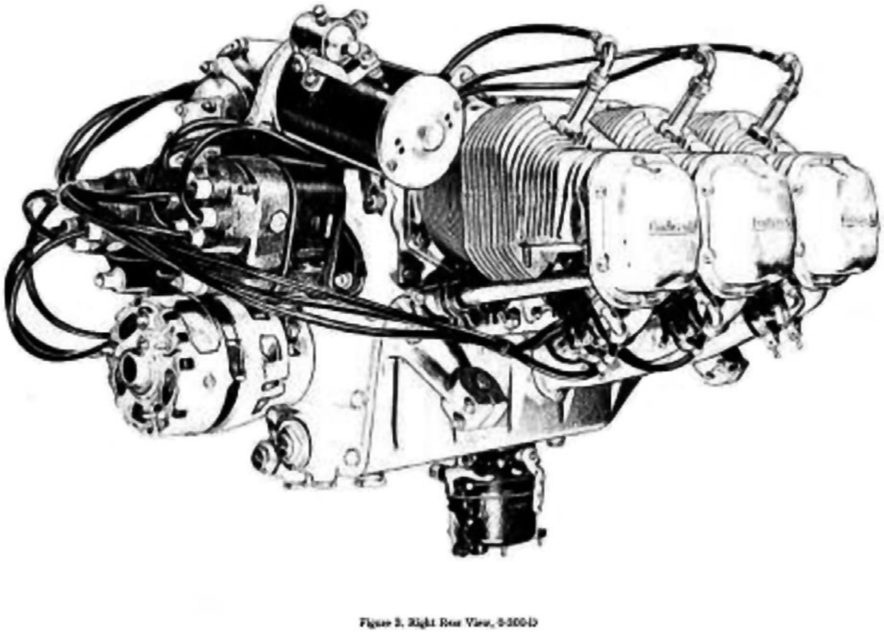


Figure 2. The O-300-D engine

The rocker arm is a mechanism atop the cylinder head that pivots on a fixed point supported by a shaft. The function of the rocker arm is to push the intake and exhaust valves downward (with a part called the "pad") to open them. This opening motion is synchronized with the engine strokes (intake, compression, power, exhaust).

The rocker arm is made to move toward the valves when a pushrod, moved by the camshaft, impacts against a part of the rocker arm called the "cup". This entire mechanism is lubricated with oil, which travels the length of the pushrod through an internal channel to the cup on the rocker arm, lubricating the bushing internally through two orifices, and then the rotating shaft. The intake and exhaust rocker on the same cylinder share the same shaft.

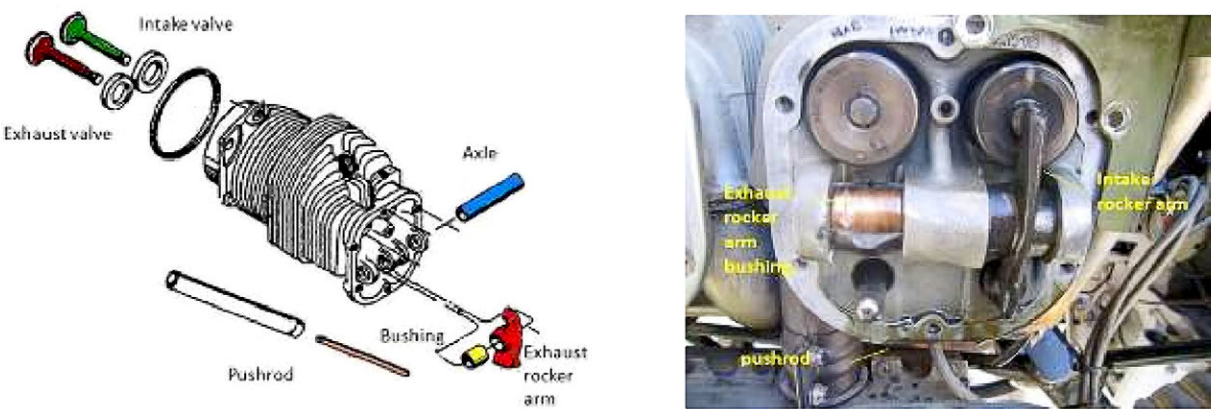


Figure 3. Simplified view of a cylinder with the rocker arm and head of the no. 2 cylinder

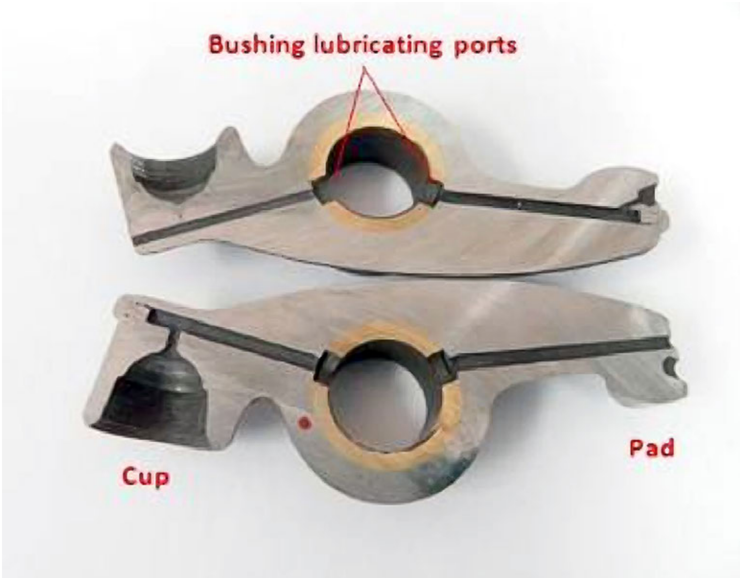


Figure 4. Cut-away view of a rocker arm showing the lubrication system

1.7.2. *Inspection of the aircraft*

After the incident, the aircraft was subjected to an inspection. The engine was started, revealing a loud banging noise at low RPMs. The condition of the spark plugs was checked, along with the ignition harness and the intake and exhaust ports. The engine was then disassembled. The cylinder head covers, where the valves are located, were removed and the rocker arm for the number 2 cylinder exhaust valve was found to be broken in two pieces (see Figure 5).

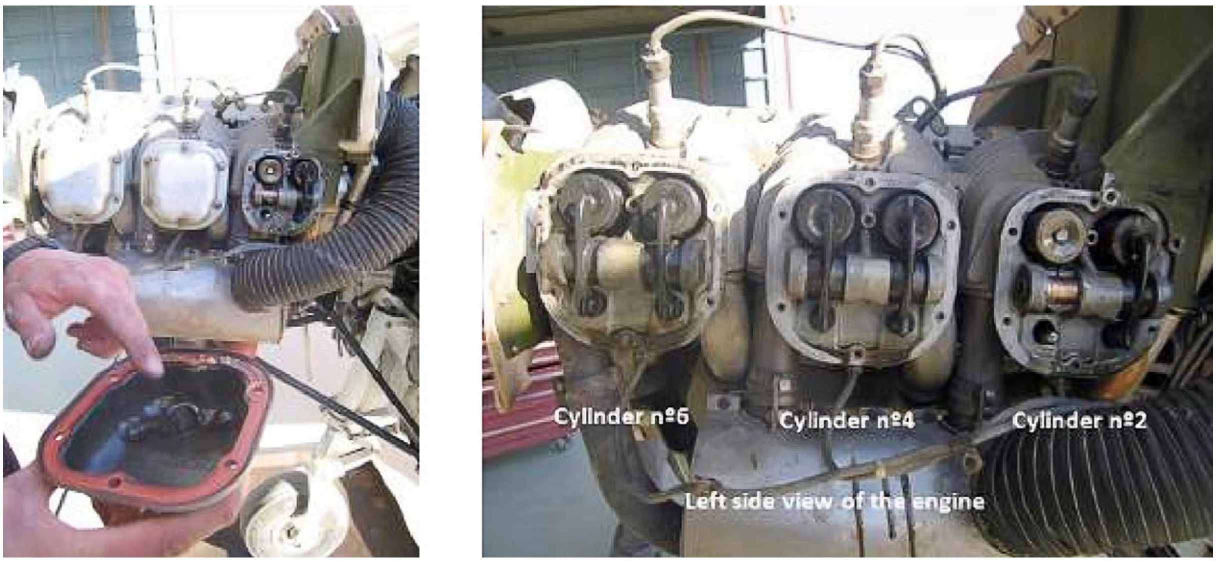


Figure 5. Disassembled covers on cylinders 2, 4 and 6 and condition of rocker arms

Figure 6. Rocker arms and axle from the no. 2 cylinder

Once the rocker arms on the remaining cylinders were verified to be undamaged, the inspection focused on the number 2 cylinder, which was fully disassembled. The condition of the valves, valve guides, rocker arm shaft, cylinder and piston were all checked, with no damage being noted aside from the broken rocker arm. There was oil residue and both the shafts and rocker arms seemed to be properly lubricated. The common exhaust and intake rocker arm shaft was not warped. All rocker arms had part number 35636/RR.

1.7.3. *Information from the engine manufacturer on the rocker arms*

The manufacturer's Illustrated Parts Catalog (IPC) lists the intake rocker arm as part number 639614 and the exhaust rocker arm as 639615. Based on the information provided during the investigation by the manufacturer, Continental (as the type certificate holder for Rolls Royce engines), the rocker arm with P/N 35636 was declared obsolete in 1971, replaced by P/N 639446. The drawing for this rocker arm listed the engines on which it was installed. The O-300-D was not on this list, the closest was the O-300-A. The IPC shows two different rocker arms, an intake and exhaust. The codes for each show their associated forging numbers, which are different. The exhaust arm had forging number 639446, the same as the part number that replaced the obsolete rocker arm.

The manufacturer was asked about the rocker arm's specifications and the reason for its replacement. It was also asked about the difference between the part and forging numbers, as well as how the affected parties were informed of the rocker arm replacement. The manufacturer replied that the engine was a Rolls Royce and not a Continental, meaning that Rolls Royce Limited in England was responsible for the RR O-300 type certificate[7]. The type certificate holder (TCH) on the date of the incident was

[7] **Type certificate (TC).** Document issued by a State that defines the design of an aircraft, engine or propeller type and certifies that the design satisfies the State's relevant airworthiness requirements.

verified to be Continental, and not Rolls Royce, and the questions were postulated once more, along with a request for additional information on the traceability of the rocker arm replacement. Its technical specifications were also requested so they could be compared against those of the rocker arms tested in the laboratory. The manufacturer did not reply.

The manufacturer's maintenance documentation (whether on maintenance program or overhaul inspections or information provided by service bulletins or airworthiness directives) has no information on replacing the rocker arms during inspections. In the inspection section, the Overhaul Manual specifies that the rocker arms are to be checked for cracks, particularly around the lubrication ports. It also states to check the rocker arm for nicks, as well as its straightness and condition of the bushing. The replacement of the rocker arm bushings is not expressly indicated. Service Bulletin SB97-6, issued by the manufacturer (replacing M-87-11 Rev. 2), provided, among others, a list for identifying the parts to be replaced on all engine models during maintenance, preventive maintenance and overhaul operations. Specifically, this bulletin listed a series of components to be replaced with new ones when the engine was overhauled. The list specifically included the rocker arm bushings. This bulletin did not have a revision date, only the initial issue date (1997). The current version of this bulletin is SB97-6B, with an issue date of 2009.

1.8. Tests and research

The intake and exhaust rocker arms, the bushings and shafts were disassembled on those cylinders that had experienced low compression (nos. 2 and 4) and where the seized exhaust valves were found.

A visual inspection of the rocker arm on the no. 2 cylinder revealed it was broken, with clear fatigue and fracture zones (see Figure 7).

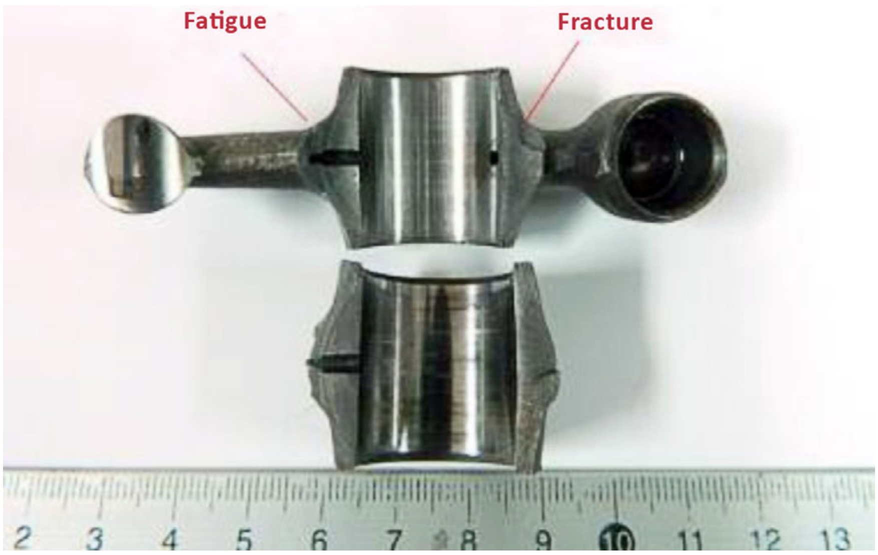


Figure 7. Fatigue and fracture zones on the damaged exhaust rocker arm

In addition, it was noted that the lubrication orifices on the bushing were not aligned with their associated channels in the rocker arm (see Figure 8).

The pad on the rocker arm had two flat spots caused by contact (see Figure 9).

Figure 8. Misalignment of the lubrication orifices

Figure 9. Flat spots on the pad of the damaged exhaust rocker arm

The rocker arm and bushing assembly on the exhaust valves of the numbers 2 and 4 cylinders of the Continental TCM-RR O-300-D engine were sent to a laboratory for analysis in order to:

- Characterize the fractures on the no. 2 cylinder exhaust rocker arm.
- Characterize the material, treatments and dimensions of these parts.
- Determine the operating conditions that could have resulted in the fractures exhibited in the two parts.
- Compare the corresponding parts on the nos. 2 and 4 cylinders, the latter of which experienced similar conditions as the former but whose rocker arm did not break.

The engine manufacturer did not supply the specifications for the parts, so the materials tested could not be compared against the manufacturer's requirements.

After analyzing and testing the parts, the laboratory concluded that:

1. Due to the chemical composition, microstructure and hardness, the samples analyzed could be made from:

    - Rocker arms: forged carbon steel, similar to ASTM A29/29M 8622 grade steel, with mixed martensitic, bainitic and ferritic structures and a hardness of approximately 300-325 HV. While these findings could not be compared against requirements or technical specifications[8], there were no significant differences among the rocker arms analyzed.

[8] Not supplied by the manufacturer.

- Shafts: 20NiCrMo2-2 (1.6523) s/EN 10084 carbon alloy steel, with a surface case hardening treatment present to a depth of approximately 0.43 in the sections analyzed (outer surfaces in contact with the bushing).
- Frictionless bushings: UNS C93200 tin-lead (Sn/Pb) bronze alloy with a hardness of around 95-100 HV. No significant differences or anomalies.

2. The macro- and micromorphological features exhibited by the rocker arm with the in-service fault were characteristic of a fatigue fracture that started on the outer surface on the cup side. There were no marks or signs of corrosion or wear or microstructural anomalies inherent to the material or to the manufacturing process that could have affected or initiated the in-service fracture of the piece. There was a second crack developing on the lubrication orifice on the opposite side, that of the pad. This crack was progressing from the inner surface on the rocker arm that was in contact with the bushing.
3. Save for some findings associated with the shafts[9], there were no significant differences in terms of the material, treatment, dimensions or surface finish on the four rocker arms analyzed, their associated bushings or the two shafts.

2. ANALYSIS

The aircraft had taken off at 16:39 for the purpose of conducting training, departing from and arriving at the Seville Airport. Onboard were the instructor, a student using dual controls and a third occupant. Four minutes after taking off, with the aircraft at a height of about 1,000 ft and nearing point Sierra, the engine started misfiring and losing RPMs. The instructor contacted the tower to report they were returning to the airport due to engine problems. The aircraft lost altitude gradually and the instructor eventually decided to land before reaching the airfield, on the old military base of San Pedro, south of the airport. Three minutes later the occupants reported to the tower that they had landed normally and that they were all in good condition.

The subsequent inspection of the engine revealed that the rocker arm on the no. 2 cylinder exhaust valve was broken in two. According to information from the maintenance center, almost a month and a half earlier a low compression problem had been detected in the nos. 2 and 4 cylinders, whose exhaust valves had seized, requiring their replacement. All other engine components were in good condition and no other rocker arms showed any anomalies like those present on the affected rocker arm. The two rocker arms on this cylinder, which shared a common shaft, were disassembled. There was no sign of deficient lubrication. The pushrods on both rocker arms showed no apparent damage. Given the similarity exhibited in the compression problem, the

[9] The hardness of the cores were different on the samples analyzed. There were also microstructural variations indicative of different heat treatments.

rocker arms on the no. 4 cylinder were disassembled. No evidence was found of damage to any component.

It was also noted that all the engine rocker arms had the same part number (P/N 35636/RR). According to the IPC, the P/N should be different depending on whether it is the intake rocker arm (639614) or the exhaust rocker arm (639615). Neither of these P/N matched the one in the incident aircraft. The manufacturer reported that rocker arms with P/N 35636/RR were obsolete and had been replaced by another with P/N 639446 in 1971. The usable on code for the obsolete rocker arm listed the engines on which they were installed. The O-300-D model was not on the list, the closest model being the O-300-A. The manufacturer (type certificate holder for the Rolls Royce engines) was asked about how owners were informed of the change in the rocker arms used and why the decision was made to change them. The manufacturer did not reply and no information was found detailing the replacement of the rocker arms. Since only the manufacturer has this information and can undertake a more in-depth study, a safety recommendation is issued in this regard, as detailed later.

When the airplane was registered in 1976, it had a Continental O-300-D engine, which was replaced with an overhauled Continental RR O-300-D engine in 2006. The time between overhauls for this engine should have been 1,800 h or 12 years, whichever came first. When the rocker arm broke, the engine had 490 h since this overhaul.

The engine had been overhauled at a German JAR-145 maintenance center in 2004. The rocker arms had not been replaced during the overhaul, nor was this required by the manual. The maintenance center logged that the overhaul had been conducted as per the TCM Maintenance Manual and that all the service bulletins had been reviewed and/or implemented.

Service Bulletin SB97-6 (which replaced M-87-11 Rev. 2), issued by the manufacturer, provided a list to be used to identify the parts to be replaced on all engine models during maintenance, preventive maintenance and overhaul operations. Specifically, this bulletin included a list of components to be replaced by new ones when the engine was overhauled. This list included the rocker arm bushings. The documentation for the overhaul done in Germany made no explicit reference to the bushings being replaced. The current version of the service bulletin dates from 2009 and it is the only available one. The previous version has no revision date, meaning investigators could not check whether it was valid at the time of the overhaul and thus whether the bushings were required to be replaced.

During the last task carried out on the engine which had suffered the seized valves in its no. 2 cylinder, neither the rocker arms nor the bushings were replaced. This is not mentioned in the Maintenance Manual. According to the maintenance center, the bushings were inspected visually and no evidence of defects was found. Investigators could not determine if the bushings were replaced during the overhaul and whether that could have contributed to altering the stress distribution on the rocker arm.

The rocker arms on two of the cylinders were sent to a laboratory for analysis and study of their individual characteristics and for a comparison among components affected by the same problem (seized exhaust valves). No determination could be made as to whether the materials and their characteristics complied with the manufacturer's specifications as these were not provided. A comparison of some of the pieces indicated that despite some differences in composition and treatment, these were irrelevant to the different performance of the escape rocker arms on the nos. 2 and 4 cylinders. The rocker arm on the no. 2 cylinder exhibited a fatigue fracture that had started on the outer surface on the cup end (impact from the pushrod on the camshaft). No structural anomalies, marks or signs of corrosion or wear were found that could account for the start of the fatigue process on the component.

3. CONCLUSION

3.1. Findings

- An analysis of the information gathered during the investigation yielded the following findings:
- The aircraft had valid and in force documentation and was airworthy.
- The instructor and student had their respective license and permit as well as valid and in force medical certificates.
- Weather conditions at the time of the incident were good, with daylight and no clouds. The wind was not gusting.
- The engine had been overhauled in 2004.
- The overhauled engine was installed on the aircraft in 2006 with 17 h.
- The time between overhauls should have been 1,800 h or 12 years.
- The engine had 490 hours at the time of the incident.
- During the inspection the exhaust rocker arm on the no. 2 cylinder was found broken in two pieces.
- This cylinder had experienced low compression and its exhaust valve had seized, same as on the no. 4 cylinder.
- The rocker arms on both cylinders were disassembled. No evidence of a lack of lubrication was found.
- The remaining engine components were in good condition.
- All of the rocker arms had the same part number.
- In its IPC, the manufacturer shows the intake and exhaust rocker arms as being different, with different part numbers.
- The manufacturer reported that the incident rocker arms had been obsolete since 1971.
- The drawing of the rocker arm did not list the O-300-D engine as one that used this rocker arm.
- The manufacturer did not provide information on the reason for changing the rocker arm, on how this was communicated to owners so they could make the change or on the specifications for the parts for comparison purposes.

- The investigation has been unable to determine if the rocker arm bushings had been replaced during the overhaul or whether this could have initiated the fatigue process that developed in the rocker arm.
- The findings from the laboratory analysis concluded that there were no significant structural or compositional anomalies in either the rocker arm or the shaft that could have triggered the fatigue.

3.2. Causes

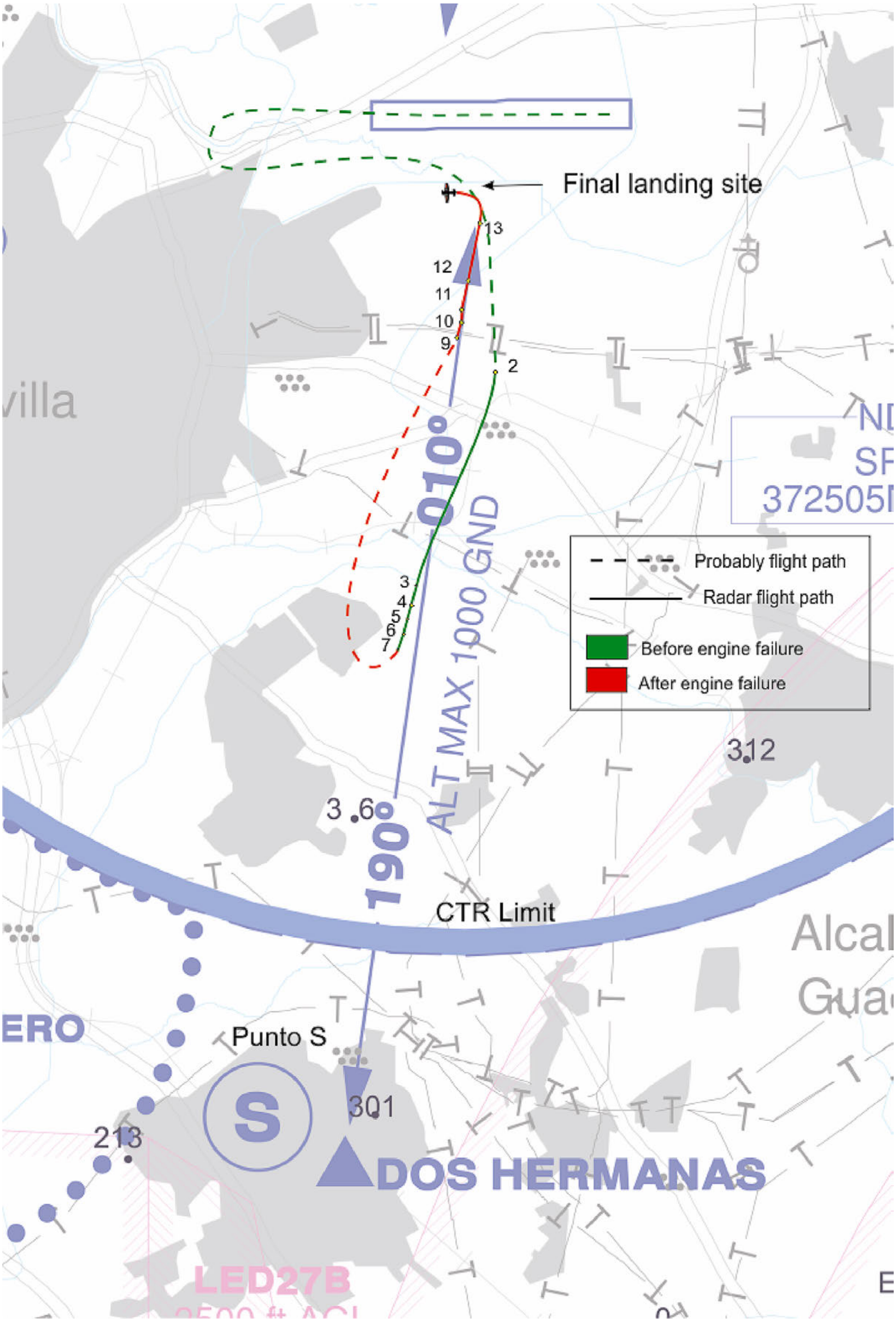
The incident took place because the rocker arm that actuates the no. 2 cylinder exhaust valve fractured, which stopped opening this valve, thus preventing the exhaust gas in the cylinder from escaping. This caused the engine to function abnormally. The crew decided to return to the airport but since they were losing altitude, they decided to make an off-field landing.

4. SAFETY RECOMMENDATIONS

As a result of the investigation, it was noted that the rocker arms still installed in the engine had been replaced in the manufacturer's documentation by another model in 1971. Neither the reasons for this substitution nor the differences between the models (in case this could have influenced the in-service failure of the rocker arm) could be determined due to a lack of information that, in this case, only the manufacturer can provide. As a result, the following safety recommendation is issued:

REC 06/14. It is recommended that Continental (type certificate holder for Rolls Royce engines) undertake a study of this case to determine the type of in-service failure that occurred and assess the need to inform the owners that could have obsolete rocker arms installed in their engines to replace them.

APPENDIX A
Visual approach chart for the Seville Airport with the flight path taken by the aircraft


Final landing site
13
12
11
10
9
2
3
4
5
6
7
010°
ALT MAX 1000 GND
190°
3 .6
CTR Limit
Punto S
301
213
312
DOS HERMANAS
LED27B
Probably flight path
Radar flight path
Before engine failure
After engine failure
villa
ERO
Alcal
Gua
372505