Technical report

A-011/2021

Accident occurring on 19 April 2021 involving the DIAMOND DA20-C1 aircraft, registration EC-LAO, at Sant Jaume dels Domenys (Tarragona)

Please note that this report is not presented in its final layout and therefore it could include minor errors or need type corrections, but not related to its content. The final layout with its NIPO included (Identification Number for Official Publications) will substitute the present report when available.

GOBIERNO DE ESPAÑA
MINISTERIO DE TRANSPORTES, MOVILIDAD Y AGENDA URBANA
SUBSECRETARÍA
COMISIÓN DE INVESTIGACIÓN DE ACCIDENTES E INCIDENTES DE AVIACIÓN CIVIL

Notice

This report is a technical document that reflects the point of view of the Civil Aviation Accident and Incident Investigation Commission (CIAIAC) regarding the circumstances of the accident and its causes and consequences.

In accordance with the provisions in Article 5.4.1 of Annex 13 of the International Civil Aviation Convention; and with articles 5.6 of Regulation (UE) nº 996/2010, of the European Parliament and the Council, of 20 October 2010; Article 15 of Law 21/2003 on Air Safety and articles 1 and 21.2 of Regulation 389/1998, this investigation is exclusively of a technical nature, and its objective is the prevention of future civil aviation accidents and incidents by issuing, if necessary, safety recommendations to prevent from their reoccurrence. The investigation is not pointed to establish blame or liability whatsoever, and it's not prejudging the possible decision taken by the judicial authorities. Therefore, and according to above norms and regulations, the investigation was carried out using procedures not necessarily subject to the guarantees and rights usually used for the evidences in a judicial process.

Consequently, any use of this report for purposes other than that of preventing future accidents may lead to erroneous conclusions or interpretations.

This report was originally issued in Spanish. This English translation is provided for information purposes only.

CONTENTS

ABBREVIATIONS

° ‘ “	Sexagesimal degrees, minutes and seconds
°C	Degrees Celsius
%	Per cent
AESA	National Aviation Safety Agency
AMSL	Above mean sea level
APP	Approach Control Service
ATO	Approved Training Organisation
CAMO	Continuing Airworthiness Management Organisation
CESDA	Centre for Advanced Aviation Studies
cm	Centimetres
CTR	Control zone
E	East
EGT	Exhaust gas temperature
FL	Flight level
fpm	Feet per minute
ft	Feet
ft/min	Feet per minute
GPS	Global Positioning System
h	Hours
hPa	Hectopascals
HR	High Ring
IAT	Initial Aiming Point
kg	Kilograms
kgm	Kilograms per metre
KIAS	Knots of indicated airspeed
km	Kilometres
km/h	Kilometres per hour
kt	Knots
l	Litres
L	Left
lb	Pounds
LECB	Barcelona FIC/ACC
LR	Low Ring
m	Metres
m^2	Square metres
METAR	Aviation routine weather report (in aeronautical meteorological code)
MHz	Megahertz
min	Minutes

NM	Nautical miles
No.	Number
psi	Pounds per square inch
QNH	Altimeter subscale setting that indicates elevation while on the ground
R	Right
RoD	Rate of descent
s	Seconds
s/n	Serial number
SMS	Safety Management System
SOP	Standard operating procedures
TAF	Terminal aerodrome forecast
TCM	Teledyne Continental Motors
TWR	Control tower
UTC	Coordinated universal time
VFR	Visual flight rules
VORD/DME	Omni-directional VHF radio beacon / distance measuring equipment

Synopsis

Owner and Operator:	REGO Foundation
Aircraft:	Diamond DA20-C1, registration number EC-LAO
Date and time of the incident:	Monday, 19 April 2021, 17:40[1]
Site of the accident:	Sant Jaume dels Domenys (Tarragona)
Persons on board:	1 student pilot, unharmed
Type of flight:	General aviation - Instruction - Solo
Phase of flight:	On route
Flight rules:	VFR
Date of approval:	6 June 2022

Summary of the incident:

The aircraft took off from Reus Airport with a student pilot as the sole occupant. The pilot's aim was to carry out a training activity (specifically, a cross-country flight) as part of the Bepilot programme, which is a non-university integrated ATP course.

After taking off, the aircraft headed towards exit point E of Reus Airport CTR. Shortly after passing this point, the pilot radioed Air Traffic Control to declare an emergency due to an engine failure.

The pilot made an emergency landing in a vineyard located in the municipality of Sant Jaume dels Domenys (Tarragona).

The aircraft sustained significant damage during the landing roll-out, predominantly to its landing gear, propeller and front part of the fuselage.

The pilot was unharmed.

The investigation has concluded that the accident was probably caused by the emergency landing, which itself was the result of engine failure during the flight.

We have also identified a number of other factors (specified below) that we believe contributed to the accident:

[1]All times in this report are expressed in local time. UTC can be calculated by subtracting two units from the local time.

- Incorrect identification of the fault with the engine, which led the pilot to assume that the engine had stopped entirely.
- Late detection of the power line located very near to the site chosen for the landing. This prevented the landing from taking place in the chosen location and with the intended heading.

The report contains a safety recommendation addressed to the REGO Foundation ATO, recommending that it bolster the training given to its students so that they can perfect their skills with regard to identifying emergencies correctly, assessing and selecting sites for emergency landings, and managing risks when manoeuvring at low altitudes.

1. FACTUAL INFORMATION

1.1. History of the flight

The aircraft involved in the accident was a Diamond DA20-C1 bearing the registration number EC-LAO. On the day of the accident, it was scheduled to be used for four flights.

During one of these flights, which took place mid-morning, the crew reported that they had received warnings of high fuel pressure outside of the normal range. Additionally, they had noticed a little more vibration than normal coming from the front part of the aircraft.

After they completed the flight, the crew reported their observations to the maintenance service.

The next flight scheduled for the aircraft in question was to involve a solo student pilot.

After assessing the situation, the persons in charge at the ATO and CAMO decided to change the plan, and the student undertaking the solo flight was assigned another aircraft. The next flight involving the aircraft in question was carried out by a crew consisting of an instructor and student pilot. According to their report, they did not notice any anomalies during the flight.

Consequently, the decision was made to continue with the aircraft's initial schedule. The next flight scheduled was a solo flight, which was carried out by the student pilot who had the accident.

This student pilot knew of the high fuel pressure warnings before he began the flight.

The flight began at 17:20 local time. The aircraft took off from Reus Airport with the student pilot as the sole occupant, and planned to carry out a local flight under visual flight rules.

It was a navigation flight with an estimated duration of 1.5 hours; the aim was to fly to the town of Palamós (Girona) and return to the airfield of origin.

After taking off, the aircraft headed east and exited Reus Airport CTR via point E.

Shortly afterwards, the pilot changed direction in order to head towards the town of Vilafranca del Penedés (Barcelona), the next point on the route. He then adjusted the engine's fuel mixture. The established height for the flight was 2,000 ft.

The aircraft's EGT gauge was non-functional, meaning that the student pilot was unable to use it to adjust the fuel mixture. In the absence of the EGT gauge, the pilot gently moved the mixture lever back so that it was in line with the "M" on the "Mixture" sign, as he remembered that this was the position the lever usually remained in when he adjusted the fuel mixture using the EGT gauge. After moving the lever, he checked that the engine was working correctly and left the lever in the aforementioned position.

Around 17:35, the student pilot radioed to declare an emergency (Mayday) due to engine failure, stating that he was in the Vilafranca area and would attempt to perform an emergency landing.

Shortly after 17:40, the aircraft landed in a vineyard located around 1.5 km from the town of Sant Jaume dels Domenys.

The aircraft sustained significant damage during the landing roll-out, predominantly to its landing gear, propeller and front part of the fuselage.

The student pilot was unharmed.

1.2. Injuries to persons

Injuries	Crew	Passengers	Total in the aircraft	Others
Fatal				
Serious				
Minor				
Unharmed	1		1	
TOTAL	1		1	

The student pilot was taken to a hospital, as he was experiencing pain in his back. Following an examination and diagnostic checks, he was released.

1.3. Damage to the aircraft

The damage suffered by the aircraft mostly affected its landing gear (the front landing gear collapsed), and to a lesser extent the wings and the front and lower part of the fuselage.

1.4. Other damage

A number of vines were damaged in the vineyard in which the aircraft landed, along with several posts and wires that formed part of the espalier structure.

1.5. Information about the personnel

1.5.1. Student pilot

The 30-year-old student pilot was studying for an ATP integrated course, within the Bepilot program of the E-ATO-247 Rego Foundation, which is located at Reus Airport (Tarragona).

He had a total of 66 h and 50 min of flight experience, of which 21 h and 30 min were in the same type of aircraft as the one involved in the accident (Diamond DA20-C1).

He had accumulated more than 35 h of flight time as pilot flying (PF) on cross-country solo flights.

His Class 1 medical certificate was valid until 20 July 2021.

1.6. Information about the aircraft

1.6.1. General information

The aircraft involved in the accident was a Diamond DA20-C1, a low-wing aircraft equipped with tricycle-type fixed landing gear. It was built in 2008 and bore the serial number C0537.

Its general characteristics are as follows:

- Wingspan: 10.89 m
- Length: 7.24 m
- Height: 2.16 m
- Wing area: 11.60 m^2
- Empty weight: 553.0 kg
- Maximum take-off weight: 800 kg
- Track width: 1.86 m
- Wheelbase: 1.67 m
- Engine: Continental IO-240-B, s/n: 1036308
- Propeller: wooden two-blade fixed pitch
- Fuel capacity: 93 l, consisting of a single tank located beneath the baggage compartment.

1.6.2. Airworthiness and maintenance of the aircraft

The aircraft had an airworthiness certificate in the Very Light Aircraft category, issued by AESA on 4 May 2011.

Its airworthiness review certificate had been issued on 10 June 2020 and was valid until 15 June 2021.

1.6.3. Information about the engine

The aircraft's engine was installed in March 2019. At the time of installation, it had accrued 0 h of operation, while the aircraft itself had accrued a total of 4,378 h of operation.

The engine had been rebuilt in November 2018 at the facilities of the manufacturer, Teledyne Continental Motors (TCM), located in Mobile (Alabama, USA). (TCM 8130-3, Track no. 537278.)

At the time of the accident, the engine had accrued 893 h of operation.

The last maintenance check had taken place on 16 April 2021, i.e. three days before the accident, and consisted of a 100 h inspection. At that time, the engine had accrued 886 h of operation.

1.6.4. Exhaust gas temperature (EGT) gauge

Paragraph 2.13 of the aircraft's flight manual lists the minimum equipment and flight and navigation instruments that are required to operate the aircraft, depending on the type of operation.

The EGT gauge is not listed in the minimum requirements for any of the operations.

1.6.5. Fuel pressure gauge

Section 2.5 ("Engine Instrument Markings") in the aircraft's flight manual contains a note in the paragraph providing information on the upper limit of the red zone of the fuel pressure gauge.

This note indicates that the allowable pressure range for the fuel system is greater than 32.5 psi, and that operation to the upper limit of the red zone is permitted. However, the note also states that this situation is temporary, pending installation of a modified fuel pressure gauge.

After the high fuel pressure warnings were issued by one of the crews that flew the aircraft, the plane was inspected by maintenance personnel, who found that although the fuel pressure markers were inside the red zone, they had not reached the upper limit; therefore, according to the flight manual, the fuel pressure was within the operational limits.

Nonetheless, the decision was taken to reschedule the next flight, so that it could be supervised by an instructor. The instructor reported that they did not notice any anomalies during the flight.

Figure 1. Fuel pressure gauge

1.6.6. Weight and balance

The student pilot calculated the weight and balance of the aircraft on the basis of the following information:

	Arm (m)	Mass (kg)	Moment (kg-m)
Empty weight	0.234	558.00	130.41
Pilot and passenger	0.143	60.00	8.58
Baggage	0.824	5.00	4.12
Combined baggage	-	-	-
Total moment and weight		625.00	143.11
Usable fuel	0.824	65.50	53.98
Total moment and mass		**688.52**	**197.09**

According to this calculation, the aircraft's weight at take-off was lower than its maximum take-off weight of 800 kg.

The centre of gravity was within the operational limits specified by the flight manual.

1.6.7. Flight manual – emergency procedures

Engine failure during flight (engine running roughly)

1)	Mixture:	Rich
2)	Alternate air:	Open
3)	Fuel shut-off	Open
4)	Electric fuel pump:	On
5)	Ignition switch:	Cycle L – BOTH – R – BOTH
6)	Throttle	Maintain at present position
7)	No improvement	Reduce throttle to minimum required power, land as soon as possible

Restarting the engine during flight (with propeller spinning)

The procedure states that the propeller will continue to spin as long as the aircraft's speed is at least 60 KIAS.

The procedure to apply is as follows:

- Airspeed (KIAS) 73 kt
- Mixture Rich
- Fuel shut-off valve Open
- Ignition switch Both
- Electric fuel pump On
- Fuel prime On
- Throttle ¾ inch (2 cm) forward

ONCE THE ENGINE STARTS

- Oil pressure Check
- Oil temperature Check
- Fuel prime Off
- Electrically powered equipment On (if required)

Gliding

- Flaps Cruise
- Airspeed at 1,764 lb (800 kg) 73 KIAS
- Glide ratio 11:1
  Example: for every 1,000 feet of altitude the aircraft can move forward 11,000 feet or 1.8 NM (3.4 km).

1.7. Meteorological information

To plan the flight, the student pilot consulted the METAR and TAF for the departure/arrival airport and the alternative airports, along with the significant weather charts, wind charts and temperature charts.

The METAR for Reus Airport for 16:00 (14:00 UTC) indicated wind intensity of 9 kt with an average direction of 110º, albeit with variations ranging from 070º to 170º. Visibility was in excess of 10 km, there was little cloud at 2,500 ft, the temperature was 17ºC, the dew point was 8ºC and the QNH was 1,016 hPa.

The TAF, which was valid from 09:00 UTC on 19 April 2021 to 09:00 UTC on 20 April 2021, forecast variable wind direction with a speed of 3 kt; visibility in excess of 10 km; little cloud at 2,500 ft; a maximum temperature of 20ºC at 12:00 UTC on 19 April 2021; and a minimum temperature of 8ºC at 05:00 UTC on 20 April 2021. Change between 09:00 and 11:00 UTC on 19 April 2021: wind direction of 120º and wind speed of 8 kt. Change between 18:00 and 21:00 UTC on 19 April 2021: variable wind direction and wind speed of 3 kt.

The significant weather chart for 18:00, which was valid from 15:00 to 21:00 UTC, forecast no significant weather phenomena in the area in which the flight was to take place.

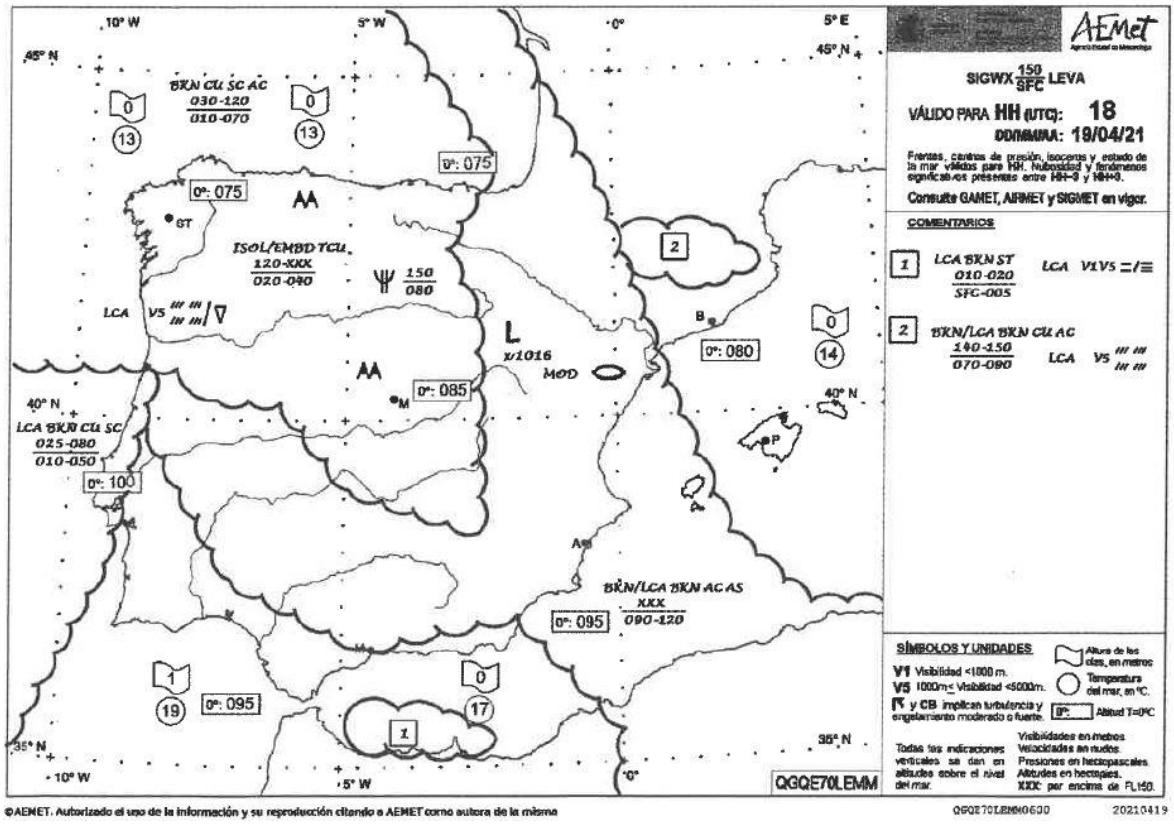

Figure 2. Low-level significant weather chart valid for 18:00 UTC on 19 April 2021

1.8. Aids to navigation

A radar trace was available for nearly all of the flight: specifically, from take-off through to 17:39:22 (15:39:22 UTC), when the signal was lost.

The radar trace virtually coincides with the aircraft's trajectory as determined from the data recorded by the GPS carried by the student pilot. As the data recorded by the latter are more precise than those of the radar, particularly with regard to altitude, the investigation decided to use the GPS data to obtain the values for speed, rates of descent and heading.

However, the radar data did provide another type of information that is relevant to the analysis of the incident.

The data shows that at 17:36:47, the student pilot changed the code of the transponder to 7700, i.e. the emergency code.

Moreover, the data also shows that at 17:38:02, when the aircraft was at 1,300 ft, the transponder's Mode C was lost. The signal was recovered some 45 s later, when the aircraft was at 1,100 ft.

The radar trace is reproduced in Figure 3, in order to show the aircraft's position at the time the relevant communications were made.

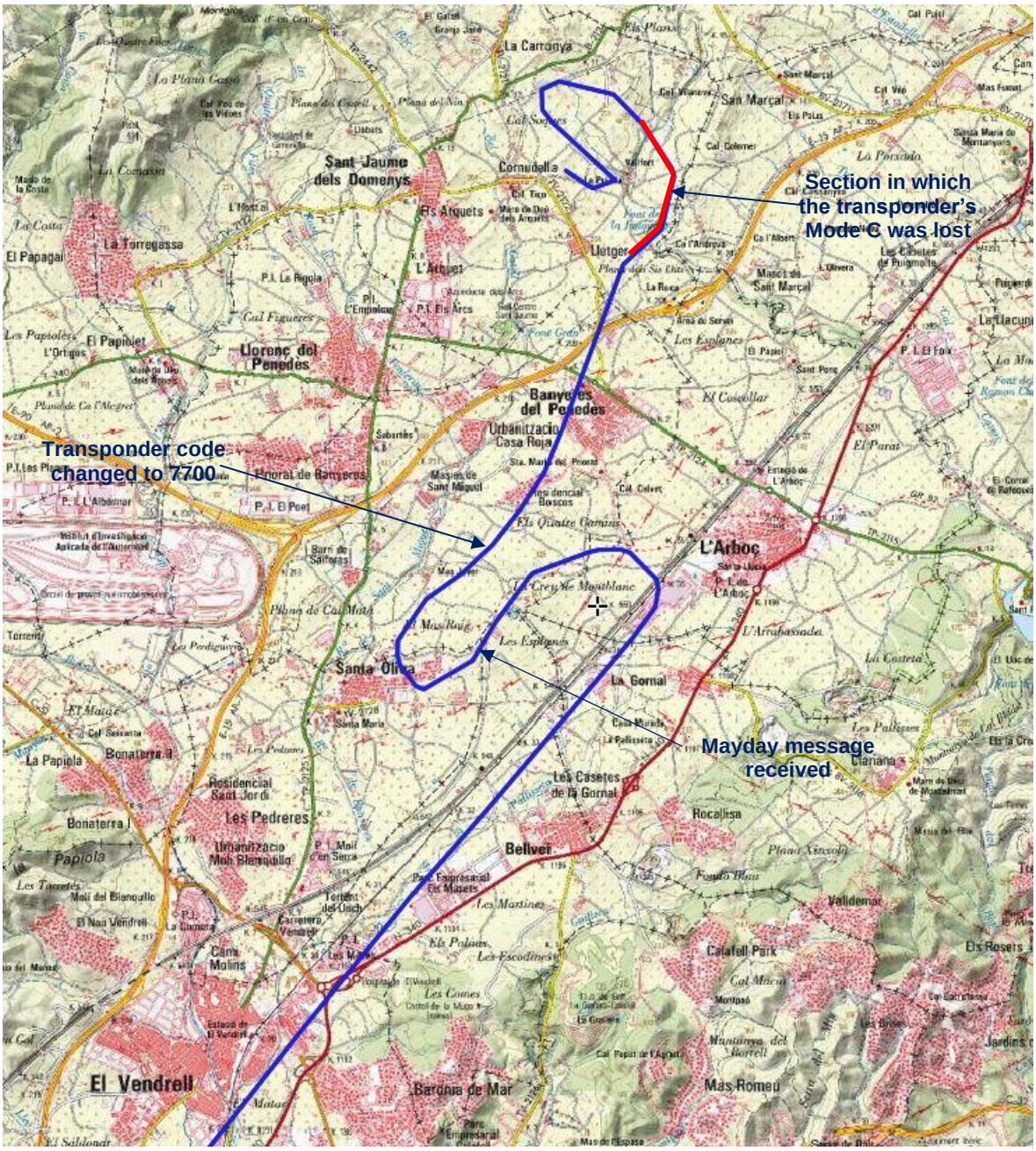

Figure 3. Radar trace of the final part of the flight, superimposed onto a topographical map

1.9. Communications

After analysing the recordings of the radio communications for the control tower at Reus Airport and the LECB sector to which the aircraft was transferred, it was ascertained that the student pilot only maintained radio contact with the control tower at Reus Airport.

Although the content of these communications is entirely standard, below are details of those that are most relevant to the flight, in order to provide a timeline.

The controller at Reus Airport authorised the take-off at 17:20:35, and also provided wind information.

At 17:30:15, the student pilot called the Reus Airport control tower to inform them that he was approaching point E at 2,000 ft.

The controller replied that for air traffic information, he should contact Barcelona on 127.7 MHz. This message was received correctly by the student pilot.

The engine failure occurred shortly afterwards. The student pilot reported the emergency on the frequency 127.7 MHz; however, this message was not heard by the corresponding sector of Barcelona ATC, perhaps because of the aircraft's low altitude.

The student pilot's "Mayday" message was heard by the pilot of another aircraft who was flying in the area; the latter then retransmitted the message after realising that ATC had not received it.

This message was received at 17:35:47 by the controller at Barcelona APP. In said message, the crew of the other aircraft informed ATC that they had heard another aircraft, in the Vilafranca area, declare an emergency due to engine failure, and that said aircraft was going to attempt an emergency landing. The crew of the other aircraft also provided part of the call sign of the aircraft that had made the Mayday transmission.

At 17:36:38, after dealing with a number of communications from other aircraft, the controller asked the aircraft to confirm the message. The pilot repeated the information, adding for clarification that his aircraft was not the one that had declared an emergency.

At 17:36:58 the controller confirmed receipt of the information, stating that he had already seen it and that he had not been contacted.

He then spoke to the control tower at Reus Airport to ask whether the student pilot had contacted the tower; the tower responded that the student pilot had not.

At 17:39:17 the controller at Barcelona APP called another aircraft (ROG4FFZ) that belonged to the same operator as the one involved in the incident and was flying in the same area. The controller asked the other aircraft whether they could see the student pilot, who was descending at around 5 NM, 11 o'clock relative to the other aircraft's position.

At 17:42:43 the crew of the aircraft ROG4FFZ informed Barcelona APP that they had located the aircraft that had reported the emergency, and that it was located just below their position. Shortly afterwards, they gave the name of the area closest to where the events were taking place.

Lastly, at 17:55:45 the crew of another aircraft belonging to the same operator informed Barcelona APP that the student pilot of the aircraft in question had contacted the operations department and informed them that his condition was fine.

1.10. Information about the aerodrome

Reus Airport is home to the ATO that operated the aircraft. Its elevation is 71 m (233 ft) and it has a runway designated 07-25 measuring 2,459 m long by 45 m wide.

Reus CTR comprises a circle with a radius of 12 NM, centred on VOR/DME RES. Vertically, it extends from the ground up to FL75. It is classified as Class D airspace, while the transition altitude is set at 1,850 m (6,000 ft). There are four entry/exit points to Reus CTR:

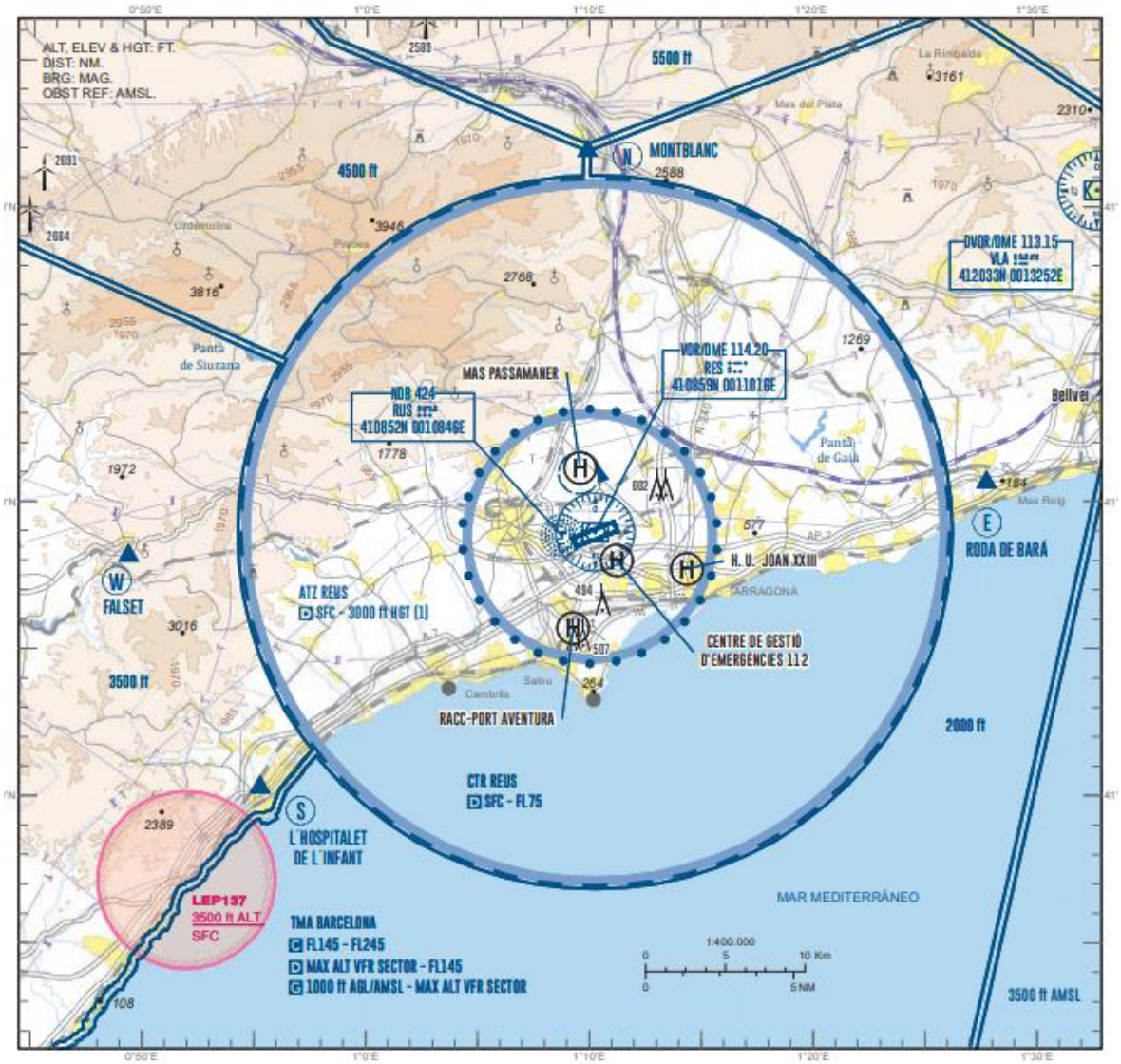

Figure 4. Extract from the visual approach chart / VAC – ICAO for Reus Airport, published in the AIP for Spain

- N, located at Montblanc.
- E, located at Roda de Bará.
- S, located at L'Hospitalet de L'Infant.
- W, located at Falset.

The aircraft involved in the incident exited the CTR via point E.

1.11. Flight recorders

The aircraft was not equipped with a flight data recorder or a cockpit voice recorder, as the aeronautical regulations in force do not require the fitting of these recorders on these types of aircraft.

During the flight, the student pilot used the “Safesky” app, which - among other functions - stores flight information. The student pilot made the flight data available to the investigation team.

The student pilot stated that he slightly altered the heading (from 045 to 041) of the part of the trajectory that was planned for the section between the coast and Vilafranca del Penedés, as he wanted to reconnoitre the area in case there was an engine problem and he had to make an emergency landing.

The aircraft’s trajectory is consistent with the statement made by the student pilot.

He also stated that he cut the mixture shortly after passing over point E. As the EGT gauge was non-functional and he was unable to use it to adjust the mixture, he decided to gently pull back the mixture lever so that it was in line with the “M” on the “Mixture” sign, as he remembered that this was where he had positioned it on other occasions when he *had* used the EGT gauge.

The flight data for the period between 17:33:47 and 17:39:59 (when the recording ended) has been analysed. Figure 5 presents an image of the aircraft’s trajectory based on the flight data.

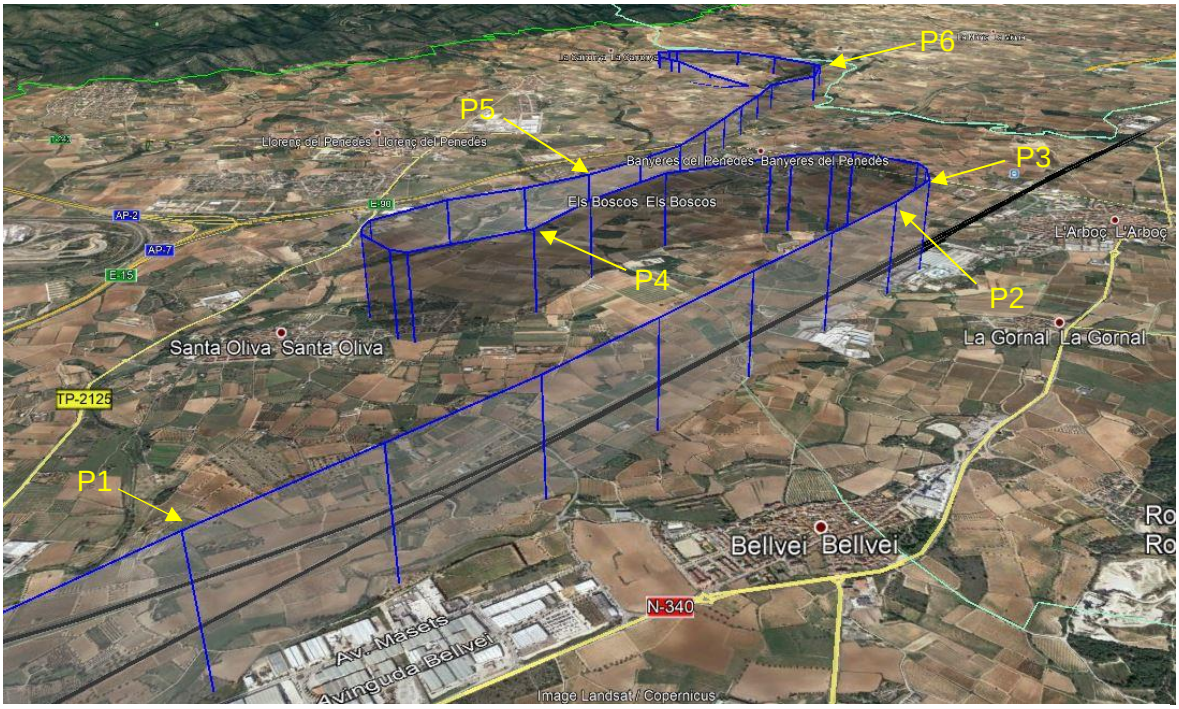

Figure 5. Image of the final part of the aircraft’s trajectory, obtained using the data from the “Safesky” app

At the start of this period (marked P1 in Figure 5), the aircraft was around 2 km north-east of the town of El Vendrell, flying on a heading of 041º at an altitude of 1,847 ft and with a ground speed of 209 km/h.

The data shows that at 17:34:47 (P2) the aircraft's speed had slowed from 212 km/h (recorded at the previous point) to 194 km/h. However, there was no significant change in altitude or heading, which remained at 041º.

The next record (P3) corresponds to 17:34:55. By this stage, the aircraft's heading had changed to 013º. Its speed had continued to decrease, reaching just 166 km/h at this point.

The aircraft continued to veer to the left, until reaching a heading of 212º (P4). During this manoeuvre, the aircraft's heading altered by more than 180º. Its speed was 162 km/h and its altitude was 1,729 ft.

At P4, the aircraft started to veer to the right, reaching 049º at P5.

Between P5 and P6 its speed remained stable, in excess of 157 km/h throughout the section.

The table below shows the following information for each of these sections: the duration (in s), the speed range, the initial and final altitude, and the variation therein.

Section	Duration (s)	Speed range Min/max (km/h)	Initial altitude (ft)	Final altitude (ft)	Variation in altitude (ft)	Rate of descent (ft/min)
P3-P4	47	162/205	1910	1729	-181	-231
P4-P5	48	155/176	1729	1506	-223	-278
P5-P6	90	158/169	1506	1198	-308	-205

The flight through this section lasted for 3 min and 5 s, during which time the aircraft covered a distance of 8 km and descended 712 ft (217 m). Its average speed was 155 km/h (84 kt).

The table below shows the data for the final part of the flight (from P6 to the end), so that it can be studied in more detail. This section covers the period from 17:38:00, corresponding to point P6, to 17:39:50 (P19).

Time	Altitude (ft)	Ground speed (km/h)	Heading (º)	Time between points (s)	Difference[2] in altitude between points (ft)	Rate of descent (RoD)[3] (ft/min)
P6	1198	158	021			
				13	-4	-18.5
P7	1194	148	049			
				13	-29	-133.8
P8	1165	169	354			
				2	-13	-390.0
P9	1152	169	341			
				11	-40	-218.2
P10	1112	176	323			
				9	-26	-173.3
P11	1086	173	311			
				13	-26	-120.0
P12	1060	158	250			
				2	0	0.0
P13	1060	148	243			
				3	-7	-140.0
P14	1053	144	219			
				4	-13	-195.0
P15	1040	144	172			
				4	-23	-345.0
P16	1017	140	144			
				2	-13	-390.0

[2] A negative value indicates that the aircraft descended in relation to the previous point.

[3] A "-" sign in front of a value indicates a descent.

P17	1004	144	134			
				9	-233	-1553.3
P18	771	151	134			
				11	-125	-681.8
P19	646	104	147			
				2	-6	-180.0
P20	640	108	175			
				10	-10	-60.0
P21	630	122	275			
				2	3	90.0
P22	633	122	287			
				9	23	153.3
P23	656	40	212			

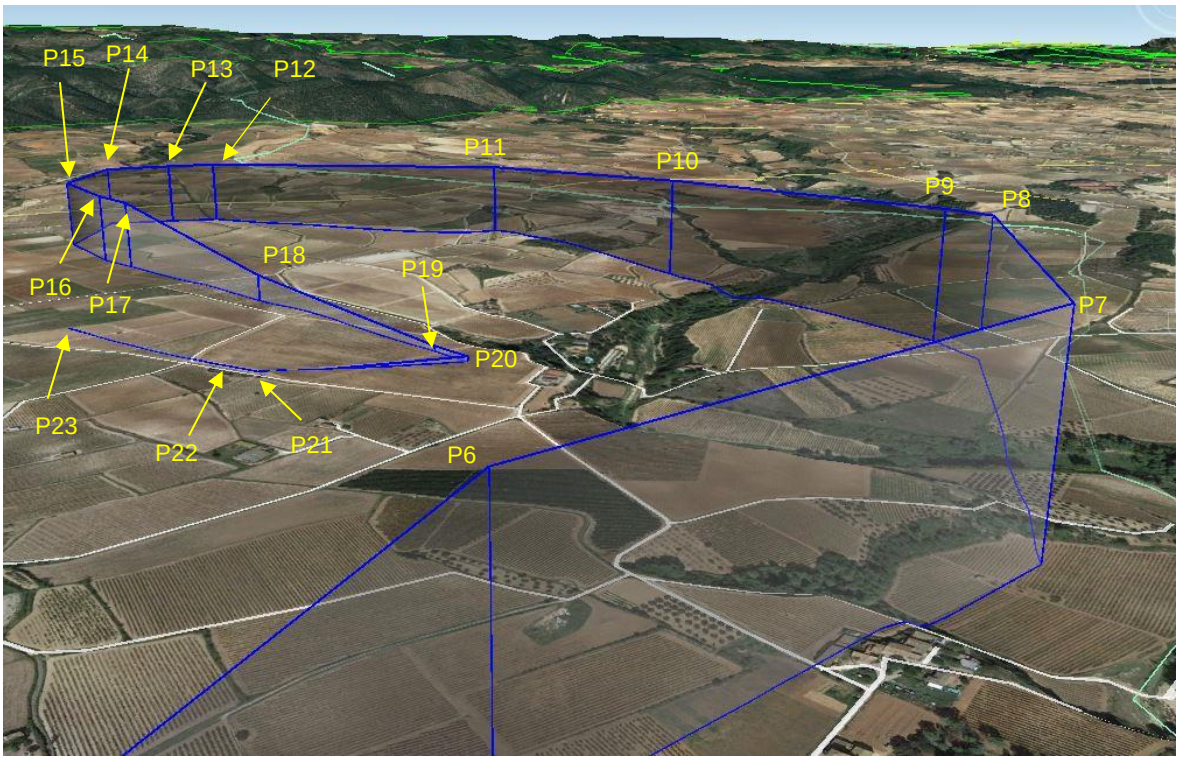

Figure 6. Image of the final part of the aircraft's trajectory, obtained using the data from the "Safesky" app

1.12. Aircraft wreckage and impact information

The aircraft landed in a vineyard.

The aircraft landed on a north-west heading, while the rows of the vineyard's espalier structure were laid out south-west to north-east; in other words, virtually perpendicular to the direction of landing.

As soon as the aircraft made contact with the ground, it began to strike the lines formed by the espalier structure. The propeller and each of the three sections of the aircraft's landing gear became caught in the wires of the vineyard's espalier structure, resulting in abrupt deceleration.

Figure 7. Photographs of the aircraft at the site where it landed

The striking of these wires also resulted in the collapse of the front landing gear.

As a result of this collapse, the front of the aircraft dropped down, coming to a rest on the ground. One of the propeller blades was broken off at the bottom, and fell to the ground next to the propeller. The other blade was bent backwards approximately halfway along its length. Neither of the two blades had impact marks or scrapes consistent with spinning.

The aircraft came to a stop after travelling for around 25 m, during which time it crashed through seven rows of the espalier structure.

1.13. Medical and pathological information

N/A

1.14. Fire

There was no fire.

1.15. Survival aspects

Despite the rapid deceleration that the aircraft underwent after becoming caught in the wires of the espalier structure, it retained its shape and did not suffer any appreciable deformation. The safety belt adequately restrained the occupant and the seat maintained its shape and location.

This forceful braking action may have caused the injuries suffered by the student pilot.

The wires of the espalier structure did not snag on any part of the airframe, which did not suffer any appreciable damage.

Nor was the cockpit damaged; it remained operational and the student pilot was able to open it and get out without any difficulty.

1.16. Tests and research

1.16.1. Aircraft inspection

After the accident, the aircraft was taken to a hangar at Reus Airport, where it was inspected.

The inspection focused on the aircraft's engine and the following observations were made:

- The fuel tank contained around 21 gallons (78 litres) of petrol. The fuel looked to be in good condition. No water or other substances or pollutants were observed.
- The engine had sufficient oil.
- The fuel system was in good condition. The fuel pump and filter were clean. The electric pump was inspected and found to be working.
- All of the spark plugs were removed and checked to make sure they were in normal condition. The ignition switches were checked. The ignition timing was adequate.
- The induction system was correct.
- The engine was rotated by hand and found to rotate normally. No unusual noises were heard.

The decision was taken to perform a functional test on the engine, for which it was necessary to remove the remains of the old propeller and fit a new one.

The engine started up as normal.

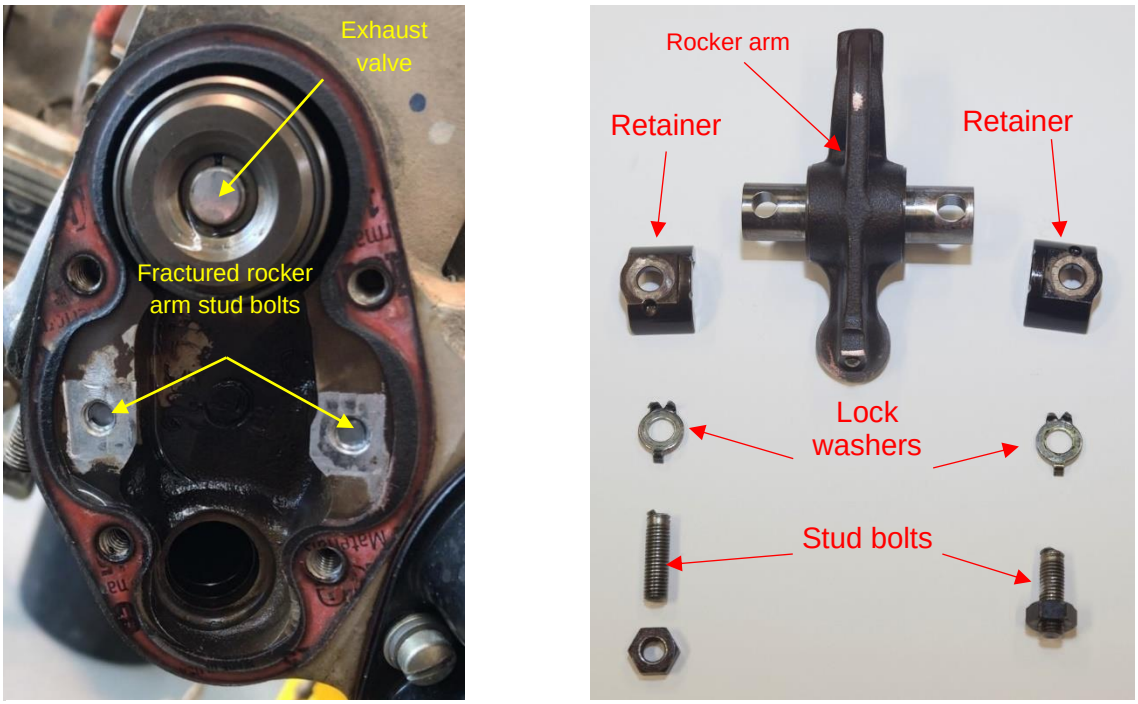

Figure 8. Photographs of the exhaust valve area on cylinder no. 4 (left) and the components that were found to be loose (right)

Once it reached a suitable temperature, the throttle was opened to full power. The RPM increased, albeit not to the expected level. The engine produced an unusual noise and vibrated forcefully.

After the engine was turned off, the rocker covers were removed, and it was observed that the rocker arm of the exhaust valve on cylinder no. 4 had become loose and detached.

All of the components comprising the rocker arm assembly were examined after the rocker cover was removed. The following observations were made:

- The shaft remained assembled in the rocker arm housing. The two washers on either side of the rocker arm were also in position.
- The retainers were loose but showed no signs of significant damage.
- The two stud bolts that hold the retainers had fractured at the point where they enter the cylinder head (Figure 8, left-hand photograph).
    - One of the bolts still had its threaded nut, while the other did not.
    - The threads on the stud bolt that was missing its threaded nut showed no significant damage. The nut on this bolt was loose, and there was no apparent damage to its threads.
- The two lock washers were also found to be loose, intact, and with no appreciable damage.

1.16.2. Inspection of another engine of the same type

Given that the operator of the aircraft involved in the accident had another aircraft of the same model, equipped with the same type of engine (IO-240-B32, s/n: 1035257), which had also been rebuilt in 2019 (TCM 8130-3, Track no. 530317) by Continental Motors, Inc. at its facilities in Mobile, Alabama, the decision was taken to inspect the condition of its rocker arms.

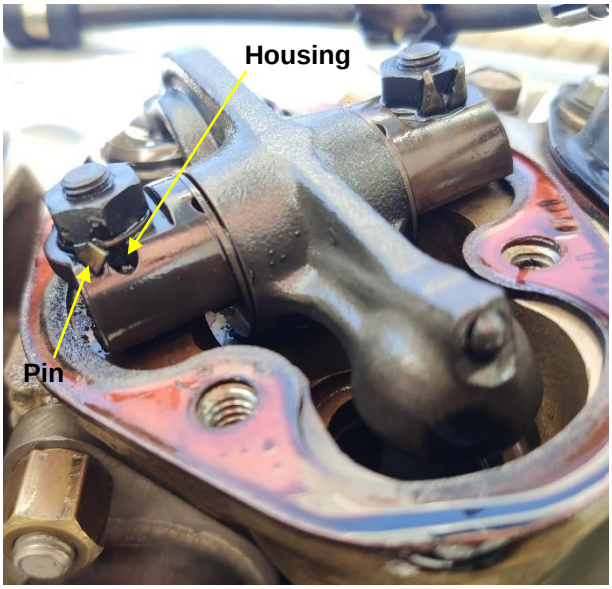

Figure 9. Photograph of exhaust valve rocker arm cylinder no. 3, engine IO-240-B32, s/n: 1035257.

One of the lock washers for the nut securing the shaft retainer in the exhaust valve of cylinder no. 3 was found to be defective, as the pin had not been inserted into the retainer housing (see Figure 9).

Under such conditions, the washer would not perform a sufficient braking action on the nut, which could therefore become loose.

1.17. Organisational and management information

The Rego Foundation (the ATO that operated the aircraft) is a Part-ORA certified training organisation that is qualified to provide training courses for Part-FCL, including the use of FSTD. It is authorised by AESA under no. E-ATO-247.

1.17.1. The ATO's Safety Management System (SMS)

The accident was analysed by the ATO's Safety Department, which reached a number of preliminary conclusions that should be adopted immediately.

One of those conclusions, concerning adjustment of the mixture, consisted of the issuance of an internal SOP limiting adjustment of the mixture during flight, as follows:

- Adjusting the mixture is prohibited for all solo student flights for normal operations in Diamond DA20-C1 aircraft.
- In an emergency, or for exceptional operations, the mixture lever can be used in accordance with the procedure specified in the flight manual.
- All solo cross-country flights by student pilots must take place below 5,000 ft AMSL.

The Safety Department also concluded that meetings should be held with the students in order to tell them about what had happened, answer any queries, and extract positive lessons.

As a result of the Safety Department's thorough study and analysis of this event, an action plan was drawn up (see section 1.17.3).

1.17.2. Operating manual

Engine failure procedure

The figure below shows the procedure followed for teaching and practice on how to deal with an engine failure during flight, with specific regard to the Diamond DA20-C1 aircraft.

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ENGINE FAILURE

Aim: To learn how to fly safely in the event of complete or partial engine failure in flight.

SIMULATED ENGINE FAILURE	
0. FI ITEMS	
Throttle Mixture	IDLE Full FWD
1. FLY	
Speed Flaps Trim	**73 KIAS** **CRUISE** SET
2. NAVIGATE	
Field Wind	Select, keep in sight Check (smoke), select **IAP**
3. RE-START (if enough time and height)	
Fuel shut-off valve Mixture Fuel pump Ignition	OPEN Full FWD ON BOTH
With PROPELLER FULL STOP	
Throttle Ignition	IDLE say: "START"
With PROPELLER WINDMILLING	
Height Speed	3000 ft AGL (minimum) 137 KIAS (expect 1000 ft loss)
4. COMMUNICATE (if enough time and height)	
Transponder Call ATC (**NO PTT**)	say: "7700" "MAYDAY (x3), ATC, Callsign, Position, Intentions"
5. SECURE	
At any time if RE-START has no success	
Mixture Fuel pump Fuel shut-off valve Throttle Ignition	say: "CUT-OFF" say: "OFF" say: "CLOSED" say: "IDLE" say: "OFF"
6. PROCEDURE	
Proceed to **HIGH RING** or **LOW RING** according to your altitude, without losing visual with **IAP**, to join the pattern detailed in the picture	
7. ON FINAL	
Flaps Speed CASH Master Switch	LDG 65 KIAS Perform say: "OFF"

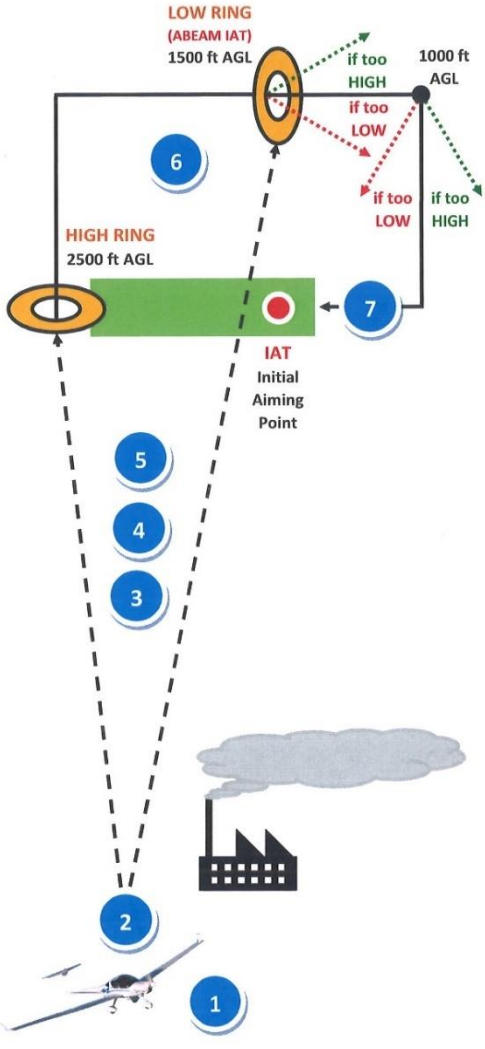


Figure 10. Procedure for teaching and practice on how to deal with an engine failure during flight, with specific regard to the Diamond DA20-C1 aircraft

The procedure addresses the majority of likely scenarios: complete or partial lack of power, propeller windmilling or stopped, etc. It also specifies the actions to take in each instance to restore normal operation. Additionally, it provides instructions for performing a forced landing if the attempts to restart the engine are unsuccessful.

In fact, one of the first actions to be taken after an engine failure, even prior to attempting to restart it, is to choose a landing site.

According to the procedure, the landing manoeuvre effectively follows a kind of airfield traffic pattern. The aim of this procedure is to provide students with guidelines and teach them to identify references on the ground that will allow them to execute a forced landing as safely as possible.

1.17.3. Measures adopted by the operator

The Rego Foundation has adopted a series of short-term measures designed to improve the skills of its instructors and the training given to its students, in order to enhance the safety of solo student flights.

With regard to the instructors, the Foundation will run two refresher courses that are to include training in various areas (safety, ATO, maintenance, etc.), a theory exam and a flight test or simulator test.

The students will also be given refresher courses - both theory and practical - before returning to solo flight.

Additionally, the Foundation has drawn up an internal action plan that includes the adoption of measures focused chiefly on the medium and long term. This plan is based on four key concepts: training, operational safety, compliance and airworthiness. In relation to said plan, the following should be highlighted:

<u>Training</u>

- Bolster the structure of the training department through the recruitment of additional staff.
- Standardise procedures.
- Bolster solo flight operations.
- Bolster the human factors.
- 80% of students' training flights will be with the same instructor (junior) until their first solo flight, while the remainder will be with a senior instructor for the checks.
- Efforts will be made to ensure that the times between flights for each student are as short as possible, to prevent situations in which a student has to fly solo after a long period without flying.
- Review the DA20 course. Includes the extension of the students' safety course from 2 hours to 6 hours. The aim of this measure is to improve the students' capacity to identify emergencies.
- Impose the requirement to carry out all landings while gliding (i.e. with the engine idling) once the approach is assured, in order to improve students' awareness of how an aircraft behaves during an engine failure.

<u>Operational safety</u>

- Increase the size of the Safety Department.
- Plan a new safety course as part of the course for the DA20 aircraft. The aim of this measure is to improve the students' capacity to identify emergencies.
- Implement a new SMS.

Compliance

- Recruit a pilot with experience and knowledge of the regulations that apply to the ATO.
- Draw up an annual audit plan so that all of the organisation's departments can be audited on an annual basis.
- Draw up plans for corrective and preventive actions based on the information arising from the audits.

1.18. Additional information

1.18.1. Urgent safety recommendations

As a result of the evidence found with regard to the condition of some of the lock washers on the screws securing the rocker arms, which points to incorrect assembly during the process of rebuilding these engines (which was carried out at the facilities of Continental Motors, Inc. in Mobile, Alabama), the following four urgent safety recommendations were issued:

REC 12/21: It is recommended that Continental Motors, Inc. should carry out the necessary actions and investigations to determine the cause and nature (isolated, organisational, etc.) of the circumstances that led to the faulty installation of some of the rocker shaft lock washers at its facility in Mobile (Alabama).

REC 13/21: It is recommended that Continental Motors, Inc. should take action to ensure the correct installation of the lock washers.

REC 14/21: It is recommended that Continental Motors, Inc. should determine which engine units have potentially left its factory in Mobile (Alabama) with incorrectly installed lock washers.

REC 15/21: It is recommended that Continental Motors, Inc. should contact all operators of aircraft equipped with engines potentially affected by this problem in order to verify the extent of the problem and, where necessary, replace the defective washers.

1.19. Useful or effective investigation techniques

N/A

2. ANALYSIS

2.1. General aspects

The flight was not affected by any type of limiting meteorological phenomena at any point on the planned route.

The student pilot had calculated the weight and balance of the aircraft, which were within the operational limits.

The student had prepared the operational flight plan correctly.

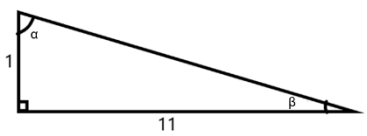
In conclusion, the student's planning and preparation for the flight, and the assessment of its feasibility, are considered complete and correct.

2.2. Analysis of the aircraft's behaviour after the engine failure

As can be seen from the trajectory (section 1.11), up until point P3 the aircraft was flying stably on a north-eastern heading. After point P3, the aircraft's trajectory made a sharp turn to the left. According to the information provided by the pilot, after realising that the engine had failed he then turned in order to find a place to land. It can therefore be deduced that the engine failure occurred around point P3.

After point P3, the aircraft's trajectory incorporated a number of turns. Between P3 and P6, the aircraft covered a distance of 8 km in 3 min and 5 s, during which time it descended 217 m. Its average speed during this section was 155 km/h (83 kt).

The aircraft's best glide ratio is 11:1. In other words, for each metre of altitude lost, the aircraft can advance a maximum of 11 metres. This ratio is expressed graphically in the following right triangle.



Between P3 and P6, the aircraft descended by 217 m. With a maximum glide ratio of 11:1, it would have advanced around 2,400 metres.

In reality, however, the distance between these two points is a little over 8,000 metres: more than triple the maximum possible distance for gliding.

The aircraft's flight manual specifies that for a glide ratio of 11:1, a speed of 73 kt is required.

At 73 kt and with a glide ratio of 11:1, the rate of descent can be calculated at around 670 fpm.

According to the GPS trajectory shown in the tables in section 1.11, the loss of altitude from the point where the engine failed to where the aircraft landed was 1,237 ft (377 m). The average rate of descent during this section was 255 fpm.

It can therefore be deduced that in the best-case scenario, the aircraft would have taken a little under 2 minutes to reach the ground.

The fact that the aircraft travelled for 8 km after the engine failed and remained flying for around 5 min clearly indicates that the engine did not stop; on the contrary, it was supplying a reasonable amount of power.

2.3. Analysis of the engine failure

During the instruction flight that took place several hours before the flight in which the accident occurred, the crew (consisting of an instructor and a student) reported that they had received high fuel pressure warnings and had noticed vibrations coming from the front of the aircraft.

Although the fuel pressure was close to the red zone at the top of the pressure gauge (the red zone begins at 16.5 psi), in reality it was quite far from the system's maximum limit of 32.5 psi.

This is an indication problem arising from the installation of a fuel pressure gauge that is not entirely suitable, as its range does not coincide with the operating range permitted by the system.

The aircraft's manufacturer became aware of this situation and added a note[4] to the flight manual, while at the same time initiating the process of replacing the fuel pressure gauges in all of the aeroplanes.

This is not considered to have had any influence on the accident.

With regard to the vibration coming from the front of the aircraft that was reported by the same crew during their flight, this may have been the first sign of the detachment of the rocker arm of cylinder no. 4, which was found to be loose. However, it may have had another cause, as the crew on the following flight did not notice anything.

In any case, there is no doubt that the rocker arm became detached during the flight involved in the accident.

The failure of this particular component caused the two valves on cylinder no. 4 to remain closed, thereby rendering the cylinder inoperative.

The engine was thus left running on three cylinders: this would significantly reduce the amount of power it was able to supply, as well as causing an imbalance in the engine that would manifest itself in the form of strong vibrations.

This is consistent with the pilot's account of the failure and with the subsequent behaviour of the aircraft, which demonstrates that the engine was supplying power for a number of minutes following the failure.

[4] See section 1.5.4.

2.4. Identification and initial management of the emergency

As has been established in the preceding two sections, the aircraft's engine did not stop completely after the failure occurred; rather, it continued to operate at a lower RPM and produced strong vibrations.

When the student was asked whether he had checked the engine instruments, tachometer, oil pressure gauge, etc., he replied that he had not, and did not know what their indications were. The student should have checked the tachometer, in order to see how much power the engine was supplying, and the other engine instruments the aircraft was equipped with. If he had checked them, he might have realised that the engine had suffered a loss of power but had not stopped; and it is likely that he would then have managed the situation differently.

However, when the failure occurred, he immediately assumed that the engine had stopped completely, and did not consider any other options or perform any other checks in order to confirm the failure.

This course of action seems to have stemmed from a certain suggestibility on the part of the pilot, in light of the fact that when confronted with the slightest indication that the engine was not working correctly, he concluded that it had stopped completely.

This suggestibility may have been induced by his awareness of the earlier problems with the fuel pressure warnings and vibrations, which had resulted in the rescheduling of one of the aircraft's planned flights.

The information provided by the student with regard to his slight altering of the flight trajectory in the area in which the emergency occurred, in order to improve his knowledge of the area in case he had to perform an emergency landing, would seem to support the hypothesis of suggestibility.

If the student had checked the instruments, he would have known that the engine was still running. The throttle lever remained in the position it was in while cruising, and although the engine was not supplying all of the power required by the throttle setting, the student should nevertheless have noticed that the aircraft's behaviour was not the same as when the throttle is idling (which he would have observed, for example, during his training on engine failure). The fact that the engine was supplying a certain amount of power meant that the pilot had an additional margin, of both time and range, in which to manage to the emergency.

However, the incorrect diagnosis of the emergency meant that the emergency procedure applied was not suitable for the situation at hand.

In this instance, the assumption that the engine had stopped completely led the student to apply the restart procedure while in flight. When this action did not produce any results, as the engine had not actually stopped, he decided to repeat the procedure from the very beginning; as a result of which he placed the ignition switch in the "OFF" position, thereby causing the engine to actually stop.

In order to manage any incident in the appropriate manner, you must first ensure you know as much as possible about the nature of the incident. A poor diagnosis does not usually result in a good treatment.

It is essential that student pilots learn and practise the use of techniques and/or procedures that improve their capacity to diagnose emergencies correctly during flight.

2.5. Management of the emergency and landing

In view of the aircraft's trajectory, it is clear that the student pilot applied the procedure for an off-field landing as described in the operating manual for students (see 1.17.2).

Around point P3, the student strayed from the plan he had prepared; it is therefore likely that the vibrations he noticed had begun prior to that point. However, the student did not commence the engine failure procedure until point P7. Between those two points, the student was flying for a total of 3 min 18 s.

The point specified in the procedure as High Ring (HR) would correspond to point P7 on the aircraft's trajectory. At that point, the aircraft's altitude was 1,194 ft. As the elevation of the terrain was around 650 ft, the aircraft's height above the ground was a little less than 544 ft.

The point specified in the procedure as Low Ring (LR) would correspond to point P11 on the aircraft's trajectory. At that point, the aircraft's altitude was 1,086 ft, equivalent to around 436 ft AGL.

Between HR and LR, the aircraft advanced around 1,600 m, during which time it descended 108 ft.

Without the drive supplied by the propeller, it would not have been possible to complete all of the stages of the procedure, given that the aircraft's height at both HR and LR was very low.

According to the procedure, at LR the aircraft should have been 1,500 ft above the ground. It also states that if the aircraft is at a higher altitude, it should lengthen the following section; or shorten it in the event that it is lower. In any case, it states that the section from HR to LR is to be flown in accordance with altitude. The LR point would correspond to the "abeam" point at the threshold of the runway the pilot is intending to land on.

After examining the airfield pattern manoeuvre executed by the pilot, and the characteristics and conditioning factors of the fields in the area, it was ascertained that the site the pilot chose for his landing lay on the path of his trajectory between points P17 and P18 and that of points P18 and P19, as the approach trajectory is clearly parallel to the rows of vines in the vineyard occupying the site in question. The length of said site is around 370 metres.

With regard to the Initial Aiming Point (IAT), it is estimated that the student pilot would have set it around point P18.

The section of the trajectory corresponding to the final section of the airfield traffic pattern would have started at point P15, with the aircraft already on its landing heading. At this point, the aircraft's height above the IAT was 390 ft. The distance to the IAT was around 500 m.

Between P15 and P17, the aircraft reduced its altitude by just 36 ft. This may have been due to the presence of a medium-voltage power line running perpendicular to the aircraft's trajectory between points P17 and P18, which the student pilot reported having seen. At

this point, it should be noted that the student would not have been able to limit the aircraft's descent if the engine had stopped; it must therefore still have been running.

At point P17, the aircraft was 200 m from the site and some 100 m above it. Under such circumstances, it would have been impossible to land on the site in question.

It would appear that the student pilot was unaware of the aircraft's reduced rate of descent, particularly during the final section. Or, if he was aware of it, he did not make a correct assessment; because if he had, he might then have taken some kind of action to reduce the excess height. A good exercise for enabling the student to ascertain the distance his aircraft can travel when gliding is to perform glide landings, from the downwind leg or base of the pattern, so that he can manage the descent and landing with the throttle idling and without applying power, unless it is necessary. This will enable him to acquire sufficient experience so that, in the event of an engine failure, he will know how far the aircraft can fly and will not encounter problems such as an inability to reach the chosen landing site, or overflying it without being able to land.

Once the pilot became aware of the impossibility of landing on the chosen site, he looked at the area further on; however, he realised that it was not suitable and decided to alter his trajectory in order to seek an alternative; to which end, he performed a very sharp turn, in which the aircraft's heading changed by around 180º.

The roll angle required for this turn would have been very pronounced, possibly in excess of 60º. At that moment, the aircraft was very low above the ground, with the aggravating factor that at that time its engine had stopped.

The stall speed under maximum weight conditions (800 kg), with flaps in the landing position and a roll angle of 60º, is 61 KIAS (111 km/h). As the aircraft's weight was lower (688 kg on take-off), its stall speed under the aforementioned flap and roll angle conditions would have been somewhat lower.

The GPS data show that the aircraft's speed during the turn remained at around 110 km/h; consequently, it must have been very close to stalling.

Every effort should be made to avoid making turns at low altitude, whatever the flight conditions, as it entails a great deal of risk due to the fact that the pilot has no margin for action in the event of an emergency (such as a stall). If making a turn is unavoidable, it must be done very gently, i.e. with a low roll angle.

In the case at hand, the flight conditions were worse than those of a standard flight, as the engine was not running.

With regard to the point at which the engine stopped, this can be determined using the data for the aircraft's trajectory; specifically, its speed/RoD ratio.

As such, it is estimated that the student stopped the engine shortly after point P17, as the RoD increased notably after this point. The aircraft's speed was 134 km/h, equivalent to approximately 73 KIAS, which is the recommended gliding speed.

When selecting the site for an emergency landing, it is necessary to assess the site's conditions and characteristics and those of the surrounding area, particularly with regard to

the presence of obstacles. One must also take into account the prevailing weather conditions, particularly those related to wind.

The site chosen by the student might have been suitable were it not for the presence of the power line. However, the presence and above all the failure to detect this obstacle during the approach meant that the site chosen was unsuitable, and that the feasibility of the operation was compromised by the late detection of the power line.

2.6. Analysis of the actions taken by the operator

The ATO that operated the aircraft has adopted a number of measures that we believe will help improve operational safety. One very positive measure in particular is the decision that all landings are to be carried out with the throttle at idle, so that students can perfect their knowledge of the aircraft's behaviour and actions. This will improve their capacity to manage an emergency resulting from an engine failure during flight.

However, despite the multitude of measures that have been adopted, there are several aspects that came to light during this investigation yet appear to fall outside the scope of said measures.

For this reason, a safety recommendation has been issued to the E-ATO-247 Rego Foundation, so that it can bolster its students' training with a view to perfecting their skills in the following areas.

- Identification and confirmation of emergencies/anomalies during a flight.
- Selection of landing sites and the early detection of obstacles.
- Performance of turns/manoeuvres close to the ground without engine power.

3. CONCLUSIONS

3.1. Findings

- The aircraft took off from Reus Airport at 14:20 in order to carry out a local flight lasting 1.5 h.
- At around 17:34:47, the aircraft suffered an engine failure while it was flying at around 2,000 ft and on a heading of 040.
- The student pilot misidentified the emergency as a complete stop on the part of the engine.
- At 17:35, the student pilot radioed to declare an emergency (Mayday) due to engine failure.
- The transponder code was changed to 7700 (the emergency code) at 17:36:47.
- After the engine partial failure, the aircraft glided for 4 min and 55 s, maintaining an average rate of descent of 255 fpm.
- The student pilot was not aware that the engine was still running.
- The student pilot selected a site in which to perform an emergency landing, and commenced the procedure for an off-field landing.
- During the final part of the approach, the student pilot observed a power line that would interfere with the approach and make it impossible to land on the chosen site.
- The aircraft performed an extremely tight turn of around 180º and at a very low altitude, in order to land on a site next to the one initially chosen.
- Shortly after 17:40, the aircraft landed in a vineyard, perpendicular to the rows of the vineyard's espalier structure.
- The exhaust valve rocker arm in cylinder no. 4 of the aircraft's engine was found to have detached.

3.2. Causes/contributing factors

The investigation has concluded that the accident was probably caused by the emergency landing, which itself was the result of engine failure during the flight.

We have also identified a number of other factors (specified below) that we believe contributed to the accident:

- Incorrect identification of the fault with the engine, which led the pilot to assume that the engine had stopped entirely.
- Late detection of the power line located very near to the site chosen for the landing, which prevented the landing taking place in the chosen location and with the intended heading.

4. OPERATIONAL SAFETY RECOMMENDATIONS

Over the course of the investigation, four (4) urgent safety recommendations were issued (see section 1.18) to the manufacturer of the engine that was fitted to the aircraft. As of the date of this report, Teledyne Continental Motors has responded to these recommendations and confirmed that they are currently being assessed.

Moreover, during the investigation a number of deficiencies have come to light that affect (or could affect) operational safety. As a result, the ATO that operated the aircraft has adopted a number of corrective measures, which it is believed will help improve operational safety.

However, there are various deficiencies that were detected during this investigation yet appear to fall outside the scope of the measures adopted by the ATO. Specifically, these concern the incorrect diagnosis of the engine failure, the inadequate inspection of the landing area chosen, and the performance of manoeuvres at low altitude that entailed a high risk of stalling.

For this reason, a safety recommendation has been issued to the Rego Foundation ATO, so that it can bolster its students' training in these areas.

REC 18/22. It is recommended that the Rego Foundation ATO bolster its students' training with a view to perfecting their skills in the following areas:

- Identification and confirmation of emergencies/anomalies during a flight.
- Selection of emergency landing sites and techniques for the early detection of obstacles.
- Performance of turns/manoeuvres close to the ground with and without engine power.