ACCIDENT

Aircraft Type and Registration:	Cessna 172S JT-A, PR-PTS
No & Type of Engines:	1 Technify Motors TAE 125-02-114 turbocharged diesel piston engine
Year of Manufacture:	2017 (Serial no: 172S12057)
Date & Time (UTC):	23 December 2017 at 2133 hrs (1733 local time)
Location:	Following takeoff from Providenciales Airport, Turks and Caicos Islands
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Fatal) Passengers - 1 (Fatal)
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Brazilian Commercial Pilot's Licence
Commander's Age:	44 years
Commander's Flying Experience:	At least 1,398 hours (of which at least 342 were on type) Last 90 days - unknown Last 28 days - unknown
Information Source:	AAIB Field Investigation

Synopsis

Shortly after takeoff from Providenciales Airport, Turks and Caicos Islands, the aircraft engine lost power, most likely due to a failure of, or detachment, of an intercooler induction hose. The pilot attempted to reposition for a landing at the airport but lost control of the aircraft whilst attempting to turn. Both the pilot and passenger were fatally injured.

History of the flight

The aircraft was newly-built at the manufacturer's facility at Independence, Kansas, USA. As part of the purchase the aircraft had been fitted with a diesel engine in accordance with an FAA Supplementary Type Certificate (STC) before being handed over to the ferry company pilot on 20 December 2017. There had been some delays in the delivery due to technical issues with the aircraft which had required some replacement parts to be fitted before the aircraft was released.

The aircraft was to be ferried to Sao Paulo, Brazil in order to receive its mandatory technical survey by the Brazilian authorities for importation. The crew consisted of a ferry pilot and a passenger who was an employee of the purchaser. Due to the size and range of the aircraft, the ferry flight was planned through Florida and the Caribbean islands before crossing into Brazil. In all, the flight was planned with ten stops before reaching its destination. The stop in Providenciales was originally planned as an overnight stay but due to the late delivery of the aircraft, and the time of year, suitable hotel accommodation was not available on the island. As a result, the flight was re-planned to proceed from Providenciales on to Punta Cana, Dominican Republic, a flight of approximately 2.5 hours. The crew were then planning to stay for the night before re-joining their original ferry plan.

On 20 December 2017, the pilot and his passenger left Independence, Kansas, in the aircraft for a 2.9 hour flight to Meridian, Mississippi, where the occupants stayed for a night. The next day they completed the 4.5 hour leg to Fort Lauderdale, Florida. The crew left Fort Lauderdale on 23 December 2017. The routing from Fort Lauderdale to Providenciales is around 520 nm and would have taken approximately 5 hours. The aircraft landed at Providenciales at 2022 hrs (1622 local time) and the occupants disembarked into the fixed base operator (FBO) terminal. The aircraft was refuelled for its onwards flight to Punta Cana. The aircraft occupants were reported by witnesses to be relaxed without any concerns about the aircraft or the route.

The weather in Providenciales was excellent with an easterly wind of 10 kt, visibility in excess of 10 km and a temperature of 28°C. It was daylight. At 2123 hrs (1723 local time) the pilot of PR-PTS requested taxi instructions from the tower at Providenciales for his flight to Punta Cana. Six minutes later he was cleared to enter and backtrack Runway 10. Another aircraft called on finals, and at 2131 hrs the pilot was asked by the tower if he could depart from his present position. The pilot answered that he could and at 2132 hrs PR-PTS was cleared for takeoff. The aircraft then made a 180° turn on the runway and began its takeoff roll.

As soon as the aircraft became airborne from the runway, the tower controller and assistant noticed smoke coming from the aircraft. Very shortly after takeoff the pilot requested an immediate return which was granted by the controller, who asked the pilot to report on finals. The controller and assistant then saw the aircraft start a turn to the left. They observed an increasing angle of bank in the turn before the nose dropped and the aircraft was lost to sight behind some buildings. Other aircraft on the frequency reported to the controller that the aircraft had crashed and the emergency procedure was initiated. Around a minute later the controllers could clearly see a large cloud of black smoke although they were unable to see the accident site.

The aircraft had struck the ground to the north of the airport and outside the perimeter fence (Figure 6). The accident site was a corner piece of undeveloped land bordered by roads and next to a petrol station. Police and fire services arrived at the scene quickly but a fierce fire had taken hold. The aircraft occupants were fatally injured. Post-mortem investigations showed that it is highly likely both occupants died instantly due to the initial impact.

Pilot

The pilot held a Brazilian Commercial Pilot's Licence. His logbook was kept electronically and could not be accessed after the accident. Evidence from the Brazilian authorities and from paper copies of aircraft technical logs indicated he had at least 1,398 hours total flying experience, although witnesses reported that the total was much higher at around

3,000 hours. The vast majority of this experience was in single-engine light aircraft. It could not be determined how much flying the pilot had completed in the previous 28 and 90 days. Having collected the aircraft from the manufacturer, the pilot had completed nearly 12 hours in the accident aircraft en route to Providenciales. It was reported that the pilot had ferried aircraft from the USA to Brazil on previous occasions but it has not been possible to verify this.

Accident site and on-site wreckage examination

The aircraft had struck the ground in a steep nose-down attitude, and had come to rest at the impact point (Figure 1) approximately 270 m north of the runway extended centreline. The impact heading was 010°M, 90° to the left of the departure runway heading. Both wing fuel tanks were ruptured on impact and a severe post-impact fire had developed, consuming the majority of the aircraft's cabin and inboard wing structure.

Figure 1
Accident site

All major components of the aircraft were located at the accident site. Continuity of the flying controls was established between the cockpit controls and the flying control surfaces. The flaps were fully up and the elevator trim tab was in a neutral position. The pre-impact position of the fuel selector valve could not be determined due to disruption of the cockpit during the accident.

There was insufficient fuel remaining in the fuel system from which to take a fuel sample, although traces of fuel with the appearance and odour of JET A were present in the engine's fuel rail. A fuel sample drawn from the fuel bowser that was used to refuel PR-PTS prior to the accident flight was tested and found to conform to the specifications of JET A fuel.

The post-crash fire had consumed most of the engine's air induction and coolant hoses. The intercooler was recovered with both hose clamps and a remnant of the silicone hose in position at the intercooler inlet. The intercooler outlet hose clamps had released from the intercooler during the impact and subsequent fire, but were later identified within the aircraft wreckage. The induction manifold inlet had both hose clamps still in position although the hose itself had burned away. The turbocharger compressor outlet coupler was secured to the turbocharger by its metal V-band clamp, however the single hose clamp that attaches the compressor outlet hose to the turbocharger was not located in the aircraft wreckage or at the accident site.

The engine's FADEC[1] unit, which was also burned, was recovered from the wreckage for analysis. The engine was removed from the aircraft for detailed examination at the engine manufacturer's facility in Germany.

Aircraft information

The Cessna 172S is a single-engine, four seat light aircraft with a high-wing and a fixed tricycle landing gear. The Cessna 172S JT-A is a conversion of the 172S, in which the Lycoming IO-360-L2A piston engine is replaced with a Technify Motors turbocharged diesel TAE 125-02-114 engine. The aircraft manufacturer discontinued production of the 172S JT-A in May 2018. For PR-PTS, this engine conversion was embodied as an STC modification, prior to delivery of the newly-built aircraft to the customer. During installation of the engine a modification was carried out to the cylinder head[2] and the fuel rail pressure regulation valve was replaced[3]. The modification to the cylinder head required the exhaust manifold and turbocharger to be removed from the engine, to provide access to the cylinder head. The necessary maintenance steps for removal of the exhaust manifold and turbocharger were specified in Chapters 72-40.03 and 72-04.01 of the engine Repair Manual, RM-02-02.

RM-02-02 contains the following turbocharger removal instructions:

> *'De-installation*
>
> 1. *Remove the clamp of the turbocharger air* [inlet] *hose and remove the air* [inlet] *hose from the compressor case. Seal the opening with an appropriate plug to protect it from contamination or dirt.*

Footnote

1 Full-Authority Digital Engine Control.
2 Repair Instruction RI-05-0014-01, carried out on 18 October 2017.
3 Service Bulletin TMG 125-1022 P1, carried out on 27 October 2017.

> *2. Remove the Wiggins clamp of the turbocharger pipe and remove the air pipe from the compressor case. Seal the opening with an appropriate plug to protect it from contamination or dirt.*
>
> *3. Remove the hoses from the wastegate control valve to the turbocharger. This requires the Cobra clamps to be removed.'*

The 'Wiggins clamp' referred to in step 2 above relates to a previous standard of TAE 125 engine, in which the induction air hose was connected to the turbocharger compressor outlet by a single clamp. This design was superseded when a turbocharger outlet adapter was introduced, which is attached to the turbocharger compressor outlet with a steel V-band clamp. The turbocharger compressor outlet air hose is secured to the outlet adapter with a single hose clamp. This later configuration of the TAE 125 engine was installed in PR-PTS.

The technician who performed RI-05-0014-01 stated that he loosened both hose clamps that attach the induction hose to the inlet of the intercooler, to permit removal of the turbocharger. The same technician reinstalled the turbocharger and air hose after completing the cylinder head modification. The aircraft's airworthiness certificate was issued on 18 December 2017 and at the time the accident occurred the aircraft had accumulated 32.4 hours and the engine 24.6 hours in operation.

The TAE-125-02-114 engine is equipped with a dual-channel FADEC to control the engine operation in response to pilot demands. The FADEC unit also records engine parameters during engine operation.

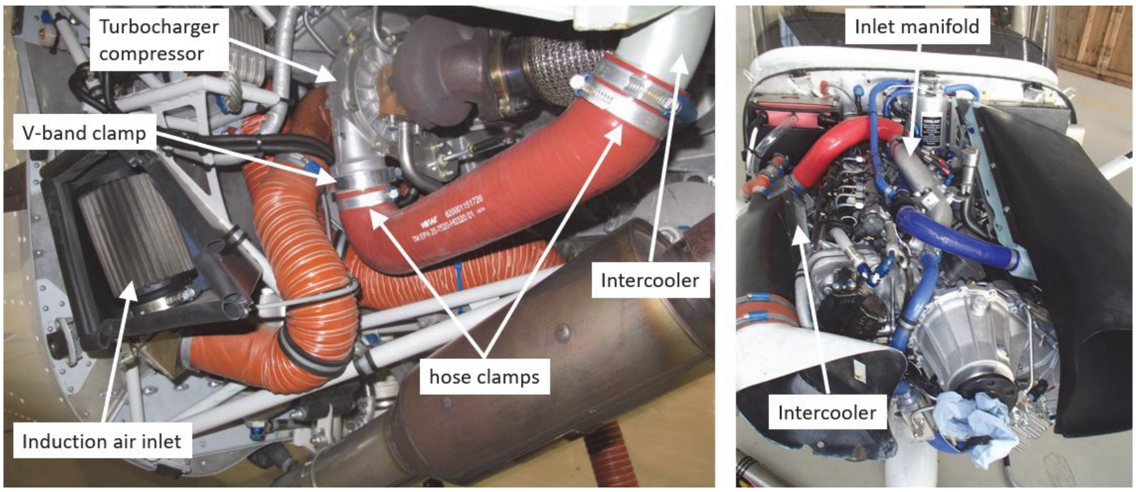

Figure 2

TAE-125-02-114 air induction system

Engine air induction system

Engine induction air is drawn though an inlet and filter on the right lower cowling, before being ducted to the turbocharger compressor inlet (Figure 2). Pressurised induction air passes from the turbocharger compressor outlet via a silicone hose to an intercooler where the induction air is cooled prior to being routed via a second silicone hose to the engine inlet manifold. Two manifold air pressure sensors, one for each FADEC channel, measure the induction air pressure at the inlet manifold.

The turbocharger compressor outlet has an adapter attached to it, secured by a metal V-band clamp. The silicone hose connecting the turbocharger compressor outlet to the intercooler is attached with a single hose clamp at the coupler end as there is insufficient space for two hose clamps. This hose has two hose clamps at the intercooler end. The silicone hose that connects the intercooler outlet to the inlet manifold has two hose clamps at either end of the hose.

Recorded information

There were no radar recordings. The radio transmissions were recorded and are described in the 'History of the flight' section of this report.

Recorded data was recovered from both control lanes of the fire-damaged FADEC by removing and downloading the memory chips. The data comprised event logs and continuous recordings.

The recordings included more than 41 hours of data covering 16 flights, starting in October 2017 and ending with the accident flight. They contained a comprehensive parameter set for each control lane, with an update rate of once per second. Altitude and position were not recorded.

Altitude was derived from the recorded barometric air pressure parameter and corrected to match the pressure altitudes the aircraft transponder was reporting during previous flights. The pressure recordings did not vary smoothly, but changed in increments of either two or three hPa, equating to 55 ft or 82 ft respectively near sea level.

There were two flights recorded on the day of the accident, the first with a duration of nearly five hours, the second was the accident flight with a very short duration, stopping shortly before impact. The data shows the test switch was used before each of these flights. There was also a brief period of running the engine at maximum rpm on the ground prior to the first flight of the day.

Accident flight

The pertinent parameters for the accident flight are shown in Figure 3.

The FADEC started logging data at a recorded time of 2118:31 hrs. The engine speed on the ground was generally held stable at 1,500 rpm. A test was carried out at 2130:49 hrs. Three minutes later the engine started developing full power and then the aircraft started to climb. Shortly after this the manifold air pressure (MAP) fell to approximately ambient pressure conditions and the engine waste gate was commanded to close to increase this pressure. The data stopped shortly after this. The displayed power had reduced to 49.8%.

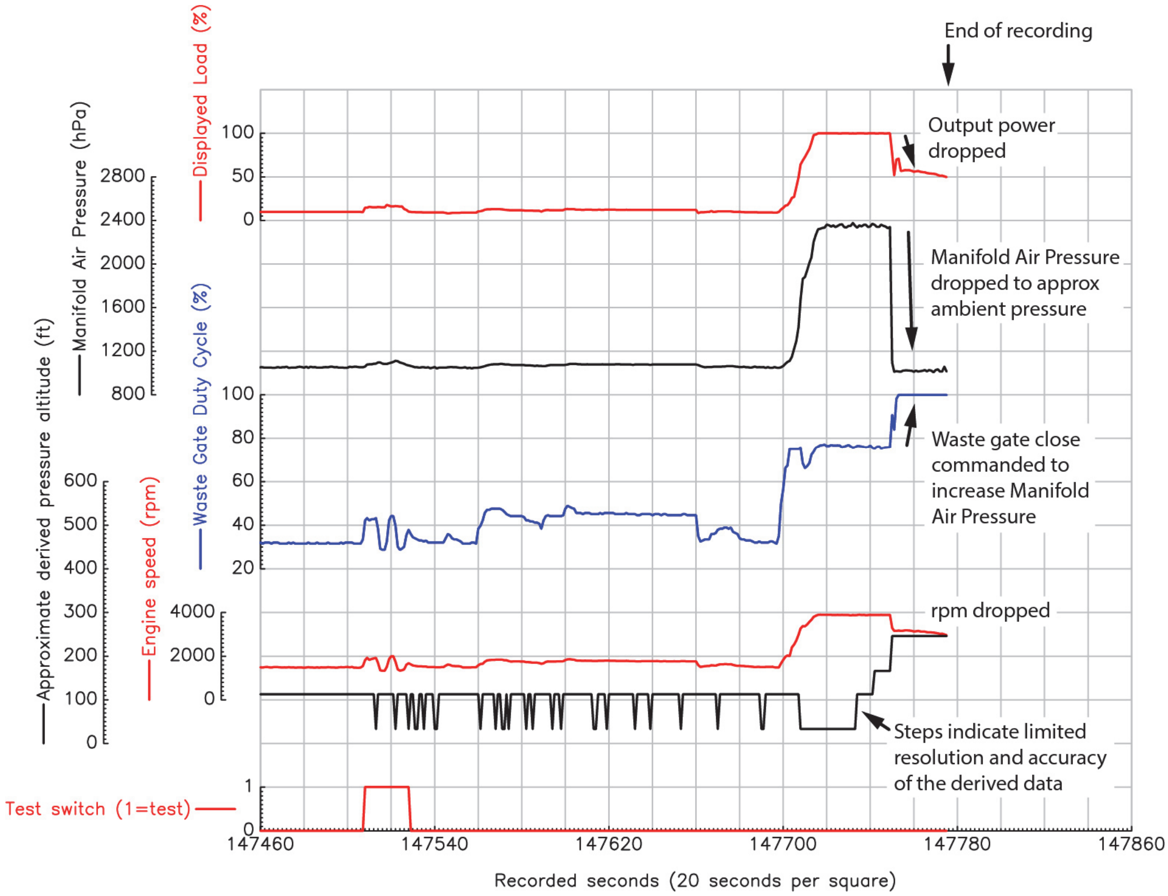

Figure 3

Extract from FADEC data – accident flight

The event log did not include any warnings associated with the time of the failure. A comparison of this initial takeoff with previous successful ones using the same aircraft did not find any anomalies up to moment when the MAP dropped.

Previous flight

During the first flight of the day (Figure 4), climbing through approximately 1,000 ft agl, there was a period where the MAP started to fluctuate with a peak-to-peak value of approximately 200 hPa (200 mbar). This stopped when the engine rpm was reduced after levelling off. The fluctuations returned to a lesser degree when climbing once more, reducing in amplitude as the climb progressed. The waste gate control values also fluctuated when the MAP was fluctuating.

As the MAP and waste gate parameters were only recorded once per second, it could not be determined whether the waste gate control fluctuations were driving the MAP fluctuations or reacting to them. The limited sample rate also means that the frequency of the fluctuations and an accurate amplitude for the fluctuations could not be determined.

The engine manufacturer stated that tests allowed up to 75 mbar of fluctuation but they are normally much less than this, 30 mbar at most.

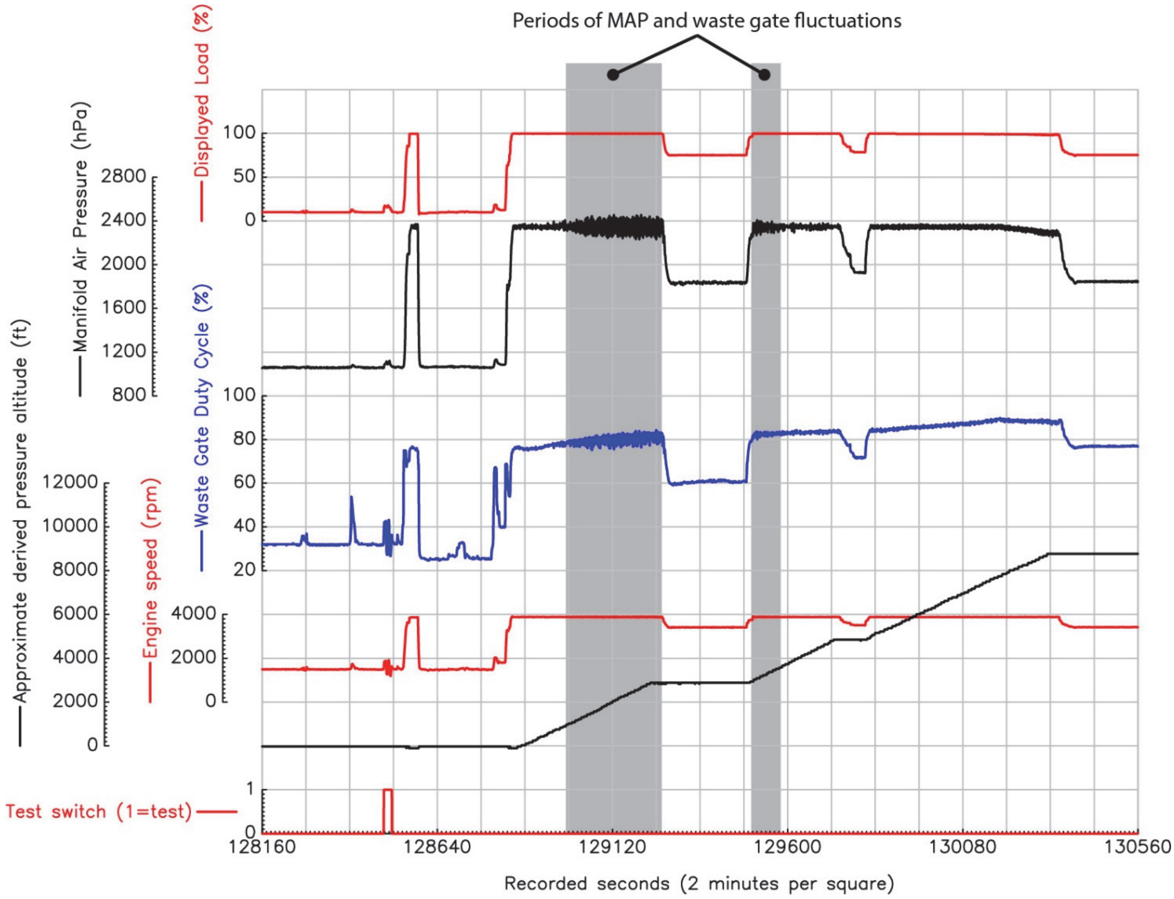

Figure 4

Extract from FADEC data – previous flight

The MAP fluctuations were also first observed with similar amplitudes, in excess of the manufacturer bench test limits, during a pre-delivery test flight conducted by the aircraft manufacturer on 16 December 2017. Similar MAP fluctuations were present on all subsequent flights. The data shows the MAP fluctuations on 16 December 2017 were present to a greater extent than that shown in Figure 4 but had not drawn the attention of the test pilot. The recorded displayed load parameters indicates that full power was available during the periods of MAP fluctuation.

The engine maintenance manual requires that the FADEC is downloaded and the data examined for anomalies every 100 hours of engine operation, or at the annual inspection, whichever occurs first. The engine manufacturer also routinely examines the FADEC data for anomalies when the engine is first run on a test bench, when it is first ground-run after installation in the aircraft, and after the initial test flight. In this instance, the engine manufacturer reported that downloaded FADEC data from PR-PTS had shown no abnormalities from the point of manufacture up to and including the initial test flight and the engine had not yet reached 100 hours of operation at the time of the accident.

Engine manufacturer

In the light of the data recovered from the FADEC in PR-PTS, the engine manufacturer reviewed past data from other engines, looking for previous cases of high MAP fluctuations. Although minor manifold pressure fluctuations are an inherent property of piston engines, the manufacturer could find no instances of fluctuations approaching those in PR-PTS (approximately 200 hPa (200 mbar)). There was therefore no basis, from service history, for determining the likely cause of this fluctuation in PR-PTS.

Engine examination

The engine was disassembled at the engine manufacturer's factory in Germany with oversight from the AAIB and the BFU. There was no evidence of a pre-accident mechanical failure within the engine and all damage to the engine was consistent with the ground impact during the accident.

The turbocharger turbine wheel blades had tip damage caused by contact with the turbine shroud, demonstrating that the turbocharger was turning at high speed at impact. The turbocharger shaft, which connects the compressor to the turbine, was fractured and a metallurgical examination of the fracture surface showed that the fracture was a ductile overload, caused by bending of the shaft during ground impact. The turbocharger waste gate operated normally when actuated by hand.

Ground-running tests of a TAE-125 engine

A series of ground-running engine tests were performed on a Piper PA-28 that was powered by a TAE 125 engine, similar to that fitted to PR-PTS. The tests were conducted to determine whether detachment of the hose which connects the turbocharger compressor outlet to the intercooler would result in a similar reduction in engine power to that observed in the FADEC data from the accident flight.

Three configurations of the securing of the turbocharger compressor hose were tested (Figure 5). The first test involved the turbocharger hose clamp being correctly positioned and loosened to the point where it was free to rotate about the hose, but still tight enough not to slide over the bulge in the hose due to the turbocharger outlet barb feature. When the engine was run at full power, the hose remained attached and the engine ran normally.

The second test involved removal of the hose clamp. The engine started and ran normally at idle power, but when the power lever was advanced the hose immediately detached from the turbocharger, before full power was reached. When the hose detached, the manifold pressure reduced to ambient pressure and the load reduced to approximately 55%. The exhaust gases were a dark, smoky colour due to an excessive level of unburnt fuel. The engine manufacturer confirmed that an abrupt reduction in manifold pressure would result in a lower air mass flow, leading to a sootier combustion which is visible in the black exhaust gases.

A third test was performed with the hose clamp incorrectly positioned over the bulge in the hose where it passed over the turbocharger barb. With the hose clamp loose enough to be rotated by hand, the hose detached when the engine ran before full power was reached, with similar results to the second test. A fourth test was performed with the hose clamp positioned as for the third test, but with the clamp tightened to the 5 N cm torque level, as required by the Aircraft Maintenance Manual (AMM). The hose clamp and hose remained attached during the subsequent engine run and the engine developed full power with a normal exhaust gas appearance. The clamp torque level was then reduced to 2.5 N cm, only 50% of the AMM-required level. Despite this reduction in clamp torque, the clamp and hose remained attached during an engine run to full power, including slam-throttle tests where the engine was rapidly accelerated from idle to full power.

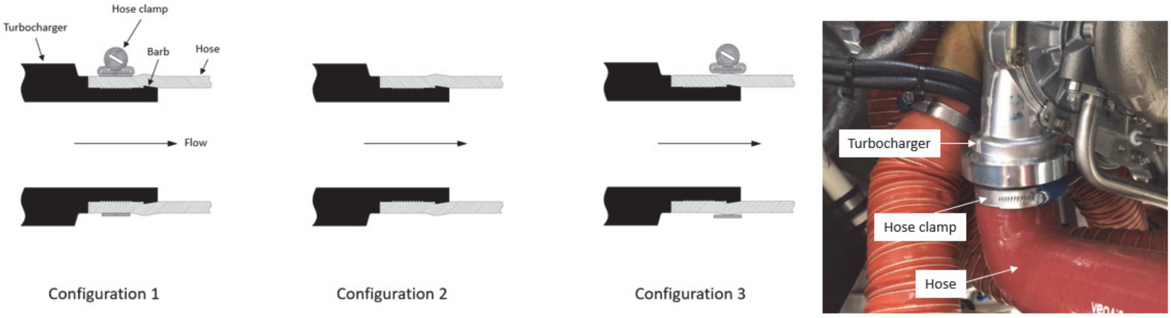

Figure 5

Turbocharger compressor outlet hose clamp

Weight and balance

Th aircraft was refuelled to full tanks in Providenciales. Using the weight of the pilot and passenger, as well as estimates for their baggage it was estimated that the aircraft was close to the maximum takeoff mass of 2,550 lbs. The aircraft balance was within limits.

Aircraft performance

Following the engine examination and ground-running tests, the aircraft manufacturer conducted a test flight with a Cessna 172S JT-A, to simulate the power loss which occurred in PR-PTS. The test aircraft was flown at a similar mass to PR-PTS and at a density altitude greater than that achieved during the accident flight. With a power setting the same as that seen on the PR-PTS FADEC-recorded data, the aircraft was able to complete a level turn at up to 15° angle of bank.

Airfield information

Providenciales is the main international airport serving the Turks and Caicos Islands. The airport is at 15 ft amsl and has a single runway orientated 10/28. The runway is 2,807 m long. At both ends of the runway there are areas of water. In the case of Runway 10, this is a shallow lagoon containing areas of mangroves. Figure 6 shows the general area of the airport and the areas of water at each end of the runway.

Figure 6
General area around the airport © Google Earth

Analysis

The cause of the power reduction

The FADEC recorded data showed that, shortly after takeoff on the accident flight, the manifold air pressure (MAP) fell to approximately ambient pressure. Testing later conducted by the engine manufacturer confirmed that this reduction in MAP would result in a substantial reduction in engine power, as seen during the accident flight. Tests also confirmed that the reduction in MAP recorded on the FADEC was consistent with a major leak in the air induction system, between the turbocharger compressor outlet and the engine intake manifold. This loss in manifold pressure resulted in a significant loss of engine power. The engine manufacturer confirmed that an abrupt reduction in manifold pressure would result in a lower air mass flow, leading to a sootier combustion which was consistent with the smoky appearance of the engine's exhaust gases observed by the witnesses in the control tower.

Through examination of the aircraft wreckage it was possible to eliminate the induction hose joints at both the inlet and exhaust of the intercooler and the inlet of the induction manifold as possible causes of the induction leak. It was also possible, after their inspection, to eliminate the intercooler and induction manifold. This leaves two remaining possibilities:

1. The induction hose connection to the turbocharger compressor outlet may have failed. Since the single hose clamp at this position was not recovered in the aircraft wreckage, it is possible that it detached during

the takeoff sequence although the absence of this component prevented further investigation into this scenario. Tests conducted by the engine manufacturer showed that, with the hose clamp either absent, or loose and misaligned over the turbocharger outlet barb, the induction hose did not remain attached to the turbocharger when the engine was run at full power. Therefore, as the aircraft had flown a number of flights successfully after the removal and reinstallation of the turbocharger and induction hose, for the modification RI-05-0014-01, it can be concluded that the hose clamp was present and was tight enough to retain the induction hose for at least the successfully completed flights.

2. As only a few fragments of the intercooler induction hoses remained following the post-impact fire, it was not possible to establish their condition prior to the accident. It is possible that one of the induction hoses may have failed, leading to the observed reduction in manifold pressure.

The cause of the recorded fluctuations in manifold pressure could not be determined. It is possible that the pressure fluctuations may have caused a component in the induction system to fail prematurely, leading to the significant loss in manifold pressure during the accident flight takeoff, but there was no remaining physical evidence available to support, or exclude, this.

Turnback decision

There are several reasons why a pilot may attempt to turn back towards the airport in the event of a complete or partial engine failure after takeoff. The primary reason would be that there are no areas in which to attempt a forced landing ahead. Other reasons may include a desire to 'save the aircraft,' a fear of landing in water, if that is what is ahead, and seeking the reassurance of a strip of runway. In many cases, the attempt ends in the aircraft entering a stall or spin with catastrophic results.

Decision making following engine failures requires a rapid appraisal of the conditions, followed by a prompt decision about the actions to be taken. When the situation is one of a partial or substantial power loss, but not a complete power loss, the decision making may be compounded by the need to rapidly assess the power available against that required to fly level or climb. Research by the Australian Transportation Safety Board (ATSB) concluded that partial power loss can be more challenging than full power loss, due to the choices confronting the pilot and general lack of training for such an event[4]. Training tends to concentrate on the complete loss of engine power.

When power is lost after takeoff (whether completely or partially), the priority must be to maintain control of the aircraft. This may require significant positive action by the pilot to avoid stalling, especially in a turn.

Footnote

[4] ATSB Transport Safety Report – Managing partial power loss after takeoff in single-engine aircraft (Canberra, 2011).

Conclusion

This aircraft suffered a power loss just after takeoff, which was confirmed by the recorded engine data. This power loss was consistent with a significant leak in the engine air induction system, which could have been caused by either the detachment of an induction hose or the failure of one of the induction hoses. The pilot's request to return shows that he was attempting to position the aircraft for a landing at the airport, but he then lost control in the turn. The aircraft bank increased, it is likely the lower wing stalled and the aircraft then descended rapidly into the ground. The pilot and passenger were almost certainly killed in the impact with the ground, not in the subsequent fire.

The loss of power was significant, but not complete, and the power available was sufficient to allow the aircraft to be flown level and to complete gentle turns. ATSB research shows that a partial and insidious loss of power may be more challenging for effective decision making than a full loss of power. In this instance, it is likely that a controlled forced landing into the shallow water ahead would have resulted in the probable loss of the aircraft but it is unlikely that it would have had fatal consequences.