Investigation report

C 4/2006 L

Engine failure and emergency landing at Joensuu airport on 24 March 2006

Translation of the Finnish original report

OH-CVB

Cessna 172P (TAE 125 diesel engine)

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SUMMARY

On Friday 24 March 2006, at approximately 17:10 local time, an incident occurred at Joensuu airport, when a Cessna 172P aircraft, owned by Tervalentäjät ry and equipped with a diesel engine, was damaged in an emergency landing. The pilot, who was alone in the aircraft, sustained only minor injuries. On 4 April 2006 the Accident Investigation Board Finland (AIBF) appointed in its decision no. C 4/2006 L an investigation commission with Chief Air Accident Investigator Esko Lähteenmäki as investigator-in-charge and investigators Hans Tefke and Tuukka Takala as members of the commission.

Before the incident flight a 200 hour scheduled maintenance check and annual inspection was performed on the aircraft. As a part of the maintenance work, the oil pressure sensor was replaced. Replacing the sensor required either the removal of the flexible intake air tube located on top of the engine or at least opening of the tube attachment clamp at the front end (intake manifold end). The mechanic opened the front end attachment and changed the sensor. After doing this he proceeded to another aircraft and asked another mechanic to bind the sensor wires and reattach the open end of the tube. Whilst attaching the tube the second mechanic noticed tension forming in it, so he loosened the aft end attachment of the tube (the attachment is an ordinary worm-drive clamp). After assembly the aft tube attachment was left untightened. After completion of the work, the first mechanic visually checked the assembly, and the tube appeared to be correctly attached. A ground test run was performed on the engine and the aircraft was released to the pilot.

According to his account, the mechanic had performed an engine test-run using the FADEC test routine. The use of maximum power during the test run was brief due to the apron surface being so slippery that the aircraft did not hold still when maximum power was applied. The engine maintenance checklist state that maximum power should be applied for 30 seconds. According to the engine manufacturer, application of maximum power for the time specified is important and it enables the opening and the consequent detection of possible loose intake air tube attachments.

During takeoff, as the aircraft was climbing at an altitude of approximately 300 ft, the loose intake tube attachment opened completely, the flexible rubber tube was sucked in and blocked and the engine stopped instantly. The pilot performed an emergency landing into the front sector touching down into snow outside the runway area. During the flare the aircraft rolled over.

The engine stopped during the initial climb after takeoff. The runway length remaining was insufficient for landing because the takeoff had been initiated from the runway midpoint. The engine stopped due to the opening of the intake tube attachment which had been left loose during maintenance. The loose attachment was not detected in the final inspection or during the engine ground test run.

The investigation commission made two safety recommendations. The commission recommended that the engine manufacturer and maintenance personnel should seal tube attachment clamps using paint marking or safety-wire, enabling an easy visual detection of opened attachments in the final maintenance inspection. The investigation commission also recommended that takeoffs with single-engine aircraft be performed using the entire takeoff distance available, from

the departure end of the runway, even in cases where the minimum takeoff distance requirement indicated in the aircraft manual is less than the runway length available.

The final draft of the investigation report was sent for comments to the Finnish Civil Aviation Authority, the engine manufacturer, the pilot and the maintenance personnel involved. Comments were received by 10.10.2006. The investigation was closed on 3.11.2006.

This table of contents and investigation report have been abridged from the original investigation report in Finnish, which follows the ICAO Annex 13 table of contents.

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ABBREVIATIONS

Abbreviation	Explanation
ATC	Air Traffic Control
bar	Bar (unit of pressure)
°C	Degrees Celsius
cm	Centimetre(s)
E	East
ECU	Engine Control Unit
FADEC	Full Authority Digital Engine Control
ft	Feet
h	Hour(s)
hPa	Hectopascal
JAR	Joint Aviation Requirements
KIAS	Knots Indicated Air Speed
kg	Kilogram(s)
km	Kilometre(s)
kt	Knot(s)
m	Metre(s)
N	North
QNH	Altimeter sub-scale to obtain elevation when on the ground
TAE	Thielert Aircraft Engines

1 FACTUAL INFORMATION

1.1 History of the flight

A 200 hour scheduled maintenance check and annual check had been performed on the aircraft. As part of the maintenance work the oil pressure sensor was changed. Changing the sensor required either removal of the flexible intake air tube located on top of the engine or at least opening of the tube attachment at the front end (intake manifold end).

When the pilot arrived to receive the aircraft, it was being test-run and refuelled. The pilot filed a flight plan by telephone to the air traffic control tower. After receiving taxi instructions the pilot lined up on the runway via a taxiway located near the runway midpoint. After backtracking for about 200 m he turned the aircraft into the takeoff direction. From this point the length of runway available for takeoff was approximately half the total length of runway 28.

According to the pilot, the pre-takeoff check was standard and there were no unusual indications. The takeoff roll was normal. When the aircraft was at an altitude of approximately 300 ft above the runway elevation the engine stopped with the propeller probably windmilling. According to the pilot the engine stopped very quickly.

A witness standing outside on the apron in front of the service centre hangar recalled the engine stopping “in one stroke”, after which he saw the aircraft sinking.

The pilot recalled that after the engine stopped he checked the position of the fuel selector and tested the operation of the power lever. The pilot reported the engine malfunction and his intention to make an emergency landing by radio to the control tower. The pilot steered right of the approach path to avoid collision with the runway 10 approach lights. As the nose wheel touched down in the snow the aircraft banked right, after which the right wingtip also touched the snow. The aircraft rolled over its nose and right wingtip coming to a halt upside down.

After the aircraft had come to a halt the pilot turned off the master switch, climbed out of the aircraft and called the control tower by mobile phone to report that he was uninjured.

Figure 1. The aircraft after the emergency landing

1.2 Personnel information

Pilot: Age 41 years

Licenses: JAR Private Pilot License (Aeroplane) PPL(A), valid until 6 Oct 2009

Flight experience: 103 h 50 min, 264 landings (30 h 40 min and 58 landings on type).

Mechanic: Age 63 years

Licenses: Aircraft Maintenance Mechanic License, granted 10 May 1973, valid until 4 Jun 2010

Type rating for single-engine aircraft of weight below 2000 kg and 13 heavier aircraft as well as the following types of piston engines: Continental, Franklin and Lycoming.

Mechanic: Age 27 years

Licenses: Aircraft Maintenance Mechanic, granted 29 May 1999, valid until 7 Mar 2010

Type rating for single-engine aircraft of weight below 2000 kg and helicopter HU269 as well as the following types of piston engines: Continental, Lycoming and the Thielert TAE 125 diesel engine.

1.3 Aircraft information

The Cessna 172P is a four seat all metal construction high-wing aircraft. The aircraft had been retrofitted with a Thielert TAE 125 diesel engine.

Aircraft

Type:	Cessna 172P
Registration:	OH-CVB
Registration number:	1338
Manufacturer:	Cessna Aircraft Co, USA
Manufacturing number:	17275246
Year of manufacture:	1981

Engine

Type:	TAE 125-01 Centurion 1.7 diesel engine
Serial number:	02-01-0311-SL01-004-0165
Manufacturer:	Thielert Aircraft Engines GmbH, Germany
Total time since new:	475 h
Fuel:	JET A-1

Propeller

Type:	MTV-6-A-187/129
Serial number:	03422

1.4 Test and research

1.4.1 Examination of the aircraft

All three blades of the propeller had broken off approximately 20 cm from the root. The spinner and back plates were dented. The lower engine cowling was dented and the composite air intake channels had minor damages. The leading edges of both wings were dented for a length of approximately 30 cm and the outermost wing ribs and wing-tips were torn. The auxiliary spars had buckled at the fuel tank position. The cockpit rear window was cracked. The vertical stabilizer tip was crushed, the beacon light had broken off and was hanging from its wiring. After the aircraft had warmed to room temperature in the aircraft hangar, fuel samples were taken from the wing fuel tanks and fuel filter. The fuel samples contained a few drops of water. The fuel was of the right colour and odour.

There was no damage to the engine compartment. The oil and fuel lines as well as the engine ancillary equipment, sensors and controllers were attached and no leaks were observed. The high pressure fuel pump, which had been replaced in the maintenance check, was removed and by rotating the pump shaft was found to transfer fuel. In the engine examination the long intake air tube situated between the intercooler and the intake manifold was found detached at the intercooler end. The loose end of the tube was pointed towards the hose connecting the air filter to the turbocharger, and the tube had buckled at the intake manifold end. The attachment clamp was found resting on the tube. When tested, the tube was easily pushed back on to the metal tube coming from the intercooler, and it was possible to slip the attachment clamp back on to the tube using moderate finger strength.

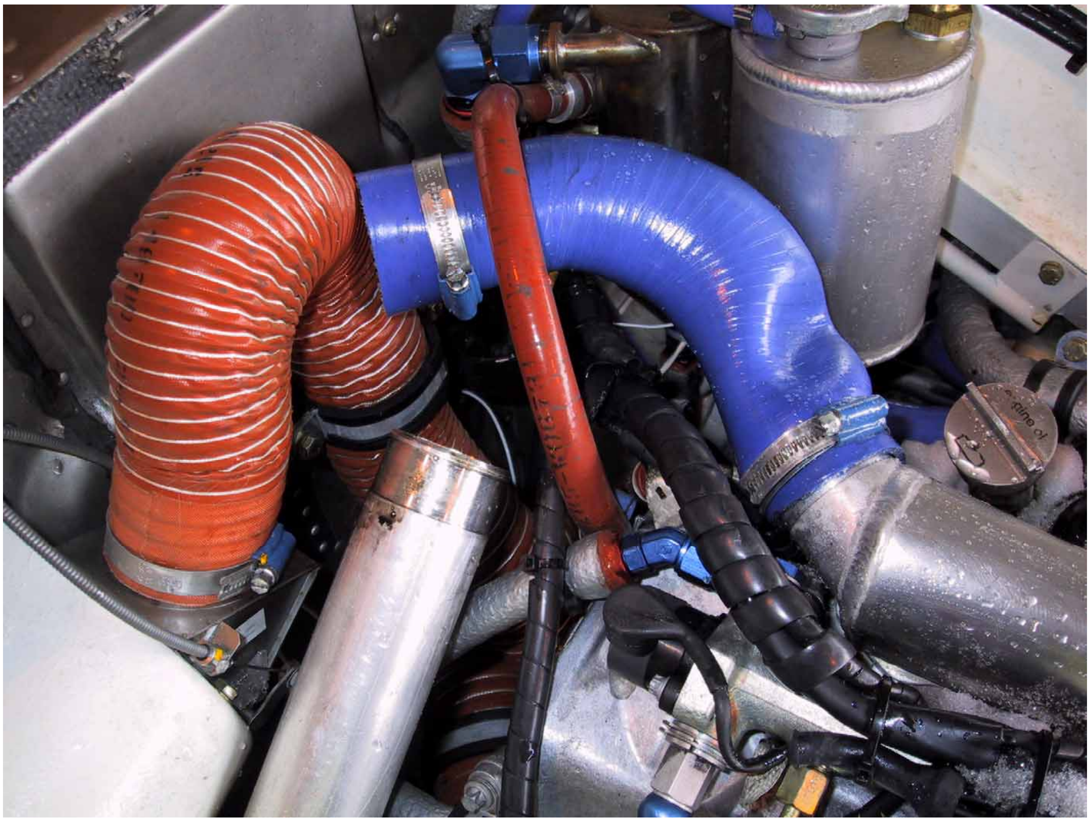

Figure 2. The detached intake tube as it was found after opening the engine cowling

1.4.2 Examination of the air intake system

The investigation commission made an engine ground test run on another aeroplane of the same type retrofitted with a TAE 125 engine. The aim of the test run was to measure the temperature of the intake air in the flexible tube which came loose during the incident flight and to observe the effect of heating on the tube material. A temperature sensor was fitted into the intake air tube air flow.

With the engine operating on takeoff power the measured intake air temperature reached a maximum of 44 °C. At the same time the value measured in the intake manifold by the FADEC system was 52 °C. The highest overpressure in the intake air tubing was 1.3 bar. The flexibility of the tube was observed manually in the aircraft hangar ambient temperature and immediately after the test run. There was no noticeable change in the flexibility of the tube between the two observations. The tube is made of fibre-reinforced silicon rubber.

A groove has been machined on the metal tube to which the flexible tube is attached, at the point where the attachment clamp should be positioned and tightened. The tube slides easily out of place if the attachment clamp is loose but stays firmly attached when the attachment clamp is tightened on the groove.

1.4.3 Examination of the engine data

The FADEC (Full Authority Digital Engine Control) system stores engine parameters for the last four hours of operation into two log files, one for each Engine Control Unit (ECU). These files are only accessible to the engine manufacturer. In addition, a list of faults and abnormal engine indications is stored in the system (event log), readable to the engine maintenance personnel.

The data from the FADEC system was downloaded on the day following the incident at Joensuu airport. There were no events recorded in the event log for the incident flight. The engine parameter logs were sent to the engine manufacturer for analysis. According to the engine manufacturer, the engine experienced a loss of manifold pressure.

1.5 Engine maintenance and ground test run

As part of the maintenance work the oil pressure sensor was changed. Changing the sensor required either removal of the flexible intake air tube located on top of the engine or at least opening of the tube attachment clamp at the front end (intake manifold end). The junior mechanic opened the front end attachment and changed the sensor. After doing this he proceeded to another aircraft and asked another mechanic to bind the sensor wires and reattach the open end of the tube. Whilst attaching the tube the second mechanic noticed tension forming in it, so he loosened the aft end attachment of the tube (the attachment is an ordinary worm-drive clamp). After assembly the aft tube attachment was left untightened. After completion of the work, the first mechanic visually checked the assembly, and the tube appeared to be correctly attached.

The junior mechanic taxied the aircraft to the refuelling station and during the taxi carried out a test run on the engine. During the taxi and test run the engine cowlings were not in place. According to the mechanic, the use of maximum power was brief during the test run due to the slippery apron surface, which caused the aircraft to slip during the test run. The test run was uneventful and all indications normal. After a visual check of the engine the cowlings were installed.

2 ANALYSIS

2.1 The loose attachment clamp

The maintenance tasks on the engine had been performed by a mechanic type-rated on the engine. This mechanic had also opened the front end of the intake air tube. After completion of the maintenance work he asked a second mechanic, who did not have an engine type-rating to the engine in question, to bind the sensor wires and reattach the open end of the tube. Whilst attaching the tube the second mechanic noticed tension forming in it. He loosened the aft end attachment of the tube to relieve the tension, but forgot to retighten it. The mechanic who had given the task visually checked the assembly, concentrating mainly on the oil pressure sensor wire binding and the front end attachment that he had opened. The loose attachment clamp would have been impossible to notice visually, this would have required testing the tightness with a screwdriver.

It is the view of the investigation commission that the fact that the maintenance work was finalized by a mechanic who was not type-rated on the diesel engine was not significant in the course of events which led to the aft attachment clamp being left untightened. The tasks given to the mechanic were simple basic tasks and he had himself loosened the attachment which was left loose. Generally speaking, interrupting a maintenance task and leaving it to be completed by another person incurs an elevated risk of something being left undone. There are no specific instructions on practices when changing mechanic in maintenance work in the service centre manuals (shift and task handover).

The coming of diesel engines to aircraft is new, likewise the is use of tubing with ordinary attachment clamps. In the engine type in question, such clamps are used widely in systems critical to engine operation, for example the induction and engine cooling systems. Due to the overpressure in the induction system, a loose attachment easily detaches. The tightness of the tubing is of primary importance to engine operation. Despite the fact that there are currently only a few diesel-powered aircraft engines in Finland, there has already been a previous case of intake tubing attachment being left loose and becoming detached.

A human work error of the kind now under investigation is possible in the future, since the mistake in question is difficult to detect in a visual inspection, even when a separate inspecting organisation exists. Maintenance in small-scale service centres is mostly one-man work with no separate inspecting organisation.

The attachment clamps were installed by the engine manufacturer. A clamp of this type may be left loose without it being visually detectable. Even though such clamps do not loosen with time, it is the view of the investigation commission that the attachment clamps should be sealed with an inspection paint marking or safety-wire. Sealing the attachment is an aid in the detection of possible loose attachments. According to the engine maintenance checklist, attachment clamps should be checked by visual inspection. There is no specific instruction to check the tightness of attachment clamps.

Figure 3. Examples of sealing methods using paint marking and safety-wire

According to his account, the mechanic had performed an engine test-run using the FADEC test routine. The use of maximum power during the test run was brief due to the apron surface being so slippery that the aircraft did not hold still when maximum power was applied. The engine maintenance checklist state that maximum power should be applied for 30 seconds. According to the engine manufacturer, application of maximum power for the time specified is important and it enables the opening and the consequent detection of possible loose intake air tube attachments.

Slipping of the aircraft on a slippery surface can be prevented using wheel chocks, for example. The chain of events in question demonstrates the importance of the engine ground test run.

Engine failure

After opening during takeoff, the detached end of the tube turned towards the hose connecting the air filter to the turbocharger. The tube collapsed due to suction and became completely blocked. Consequently the engine was not supplied with intake air and it stopped quickly. After bending to the side the tube buckled, contributing to the blocking up of the tube. A drop in manifold pressure could be observed from the FADEC engine data sent to the engine manufacturer.

If the intake air tube opens but does not collapse, the engine does not stop but functions without turbocharging producing a maximum power of approximately 80 %.

2.3 Pilot actions

After starting the engine and receiving ATC clearance the pilot lined up on runway 28 near the runway midpoint. During takeoff when the aircraft was at an altitude of approximately 300 ft above the runway level the engine stopped. The pilot reported to the control tower the engine malfunction and his intention to make an emergency landing straight ahead. The pilot made an emergency landing into the front sector avoiding the runway approach lights by steering right. According to the approved Pilot’s Operating Handbook, the correct actions in an engine failure immediately after takeoff are:

- Airspeed 60-65 KIAS depending on flap setting
- Fuel Selector OFF
- Engine Master OFF
- Wing flaps as required (40º recommended)
- Main Bus and Battery switches OFF

The pilot chose to land with the wing flaps retracted because, according to his account, he did not want to glide too far. However, the use of full flap would have given the aircraft a much higher rate of descent than in the flaps retracted configuration. The stalling and touchdown speeds are also decreased with flap extension, so the use of flap is advantageous in almost all emergency landing situations.

Measured from the starting point of the takeoff run, the length of available runway was 1300 m. Air traffic control did not hurry the taxi or takeoff. The total length of the runway is 2500 m. Had the takeoff been commenced from the end of the runway, with the landing profile used by the pilot, flaps retracted, approximately 900 m of runway would have remained unused after the emergency landing. By using the method described in the Pilot’s Operating Handbook even more runway would have remained unused.

3 CONCLUSIONS

3.1 Findings

1. The pilot had a JAR Private Pilot License and JAR Medical Certificate, which were valid.

2. Both mechanics involved in the maintenance had valid Aircraft Maintenance Mechanic Licenses. One of the mechanics had a type rating for the diesel engine.

3. The Certificate of Airworthiness and Certificate of Registration of the aircraft were valid.

4. The intake air tube attachment clamp that had been loosened during the maintenance check had not been tightened and this was not detected in the inspection made by the second mechanic.

5. Due to the slippery surface of the apron the use of maximum power in the engine test run was shorter than required.

6. The intake air tube attachment opened during takeoff and the engine stopped.

7. The pilot made an emergency landing into snow in the front sector, where the aircraft rolled over.

8. The pilot started the takeoff roll from approximately the runway midpoint. Had the takeoff been commenced from the departure end of the runway, the emergency landing could have been done on the runway.

9. The pilot landed with the flaps retracted.

3.2 Probable cause

The engine stopped during the initial climb after takeoff. The runway remaining was insufficient for landing because the takeoff had been initiated from the runway midpoint. The engine stopped due to the opening of an intake air tube attachment which had been left loose during maintenance. The loose attachment was not detected in the final inspection or the engine ground test run.

4 RECOMMENDATIONS

Tube attachment clamps have been used widely in the critical systems of the Thielert TAE 125 engine and due to human factors it is possible that a clamp may be forgotten loose in the future.

1. The investigation commission recommends that the engine manufacturer and maintenance personnel should seal the tube clamps using paint marking or safety-wire, enabling an easy visual detection of opened attachments in the final maintenance inspection.

The pilot started the takeoff roll from approximately the runway midpoint and had to make an emergency landing on the runway extension into snow, where the aircraft rolled over and was damaged. Had he commenced the takeoff from the departure end of the runway, the emergency landing in its entirety could have been done on the runway.

2. The investigation commission recommends that takeoffs with single-engine aircraft be commenced from the departure end of the runway, even in cases where the minimum takeoff distance requirement indicated in the aircraft manual is less than the runway length available.

Helsinki, 3 November 2006

Esko Lähteenmäki Hans Tefke Tuukka Takala

LIST OF SOURCES

The following material is stored at the Accident Investigation Board Finland:

1. The Accident Investigation Board Finland decision no. C 4/2006 L
2. Investigation report
3. Incident reports
4. Interview transcripts
5. Weather data
6. Excerpts from the engine maintenance and part manuals
7. Correspondence between the engine manufacturer and the investigation commission
8. Comments by the Finnish Civil Aviation Authority, the pilot and the engine manufacturer
9. FADEC data files (CD)
10. Photographs (CD)