Investigation report

C7/2007L

Emergency landing on Porvoo motorway on 28 September 2007

Translation of the original Finnish report

OH-CAU

Cessna 172N, diesel engine TAE 125-01

Onnettomuustutkintakeskus
Centralen för undersökning av olyckor
Accident Investigation Board

Osoite / Address:	Sörnäisten rantatie 33 C FIN-00500 HELSINKI	**Adress:**	Sörnäs strandväg 33 C 00500 HELSINGFORS

Puhelin / Telefon: (09) 1606 7643
Telephone: +358 9 1606 7643

Fax: (09) 1606 7811
Fax: +358 9 1606 7811

Sähköposti: onnettomuustutkinta@om.fi tai etunimi.sukunimi@om.fi
E-post: onnettomuustutkinta@om.fi eller förnamn.släktnamn@om.fi
Email: onnettomuustutkinta@om.fi or forename.surname@om.fi

Internet: www.onnettomuustutkinta.fi

Henkilöstö / Personal / Personnel:

Johtaja / Direktör / Director	Tuomo Karppinen
Hallintopäällikkö / Förvaltningsdirektör / Administrative Director	Pirjo Valkama-Joutsen
Osastosihteeri / Avdelningssekreterare / Assistant	Sini Järvi
Toimistosihteeri / Byråsekreterare / Assistant	Leena Leskelä
Ilmailuonnettomuudet / Flygolyckor / Aviation accidents	
Johtava tutkija / Ledande utredare / Chief Air Accident Investigator	Hannu Melaranta
Erikoistutkija / Utredare / Air Accident Investigator	Tii-Maria Siitonen
Raideliikenneonnettomuudet / Spårtrafikolyckor / Rail accidents	
Johtava tutkija / Ledande utredare / Chief Rail Accident Investigator	Esko Värttiö
Erikoistutkija / Utredare / Rail Accident Investigator	Reijo Mynttinen (vv.) Erkki Hainari (→ 28.2.2010)
Vesiliikenneonnettomuudet / Sjöfartsolyckor / Marine accidents	
Johtava tutkija / Ledande utredare / Chief Marine Accident Investigator	Martti Heikkilä
Erikoistutkija / Utredare / Marine Accident Investigator	Risto Repo
Muut onnettomuudet / Övriga olyckor / Other accidents	
Johtava tutkija / Ledande utredare / Chief Accident Investigator	Kai Valonen

---

Translation: R&J Language Service

SUMMARY

An air accident occurred at 16:30 on Friday 29 September 2007 at Sipoonlahti, west of the city of Porvoo. A Cessna 172N, registration OH-CAU, owned by the Malmi Aviation Club made an emergency landing on Porvoo motorway, close to the Sipoonlahti exit. In addition to the pilot there were two passengers onboard. No-one was injured; however, the aircraft sustained major damage. The incident caused no harm to road traffic. The aircraft was fitted with a TAE 125-01 diesel engine and the aircraft used JET A1 jet engine fuel.

Accident Investigation Board Finland (AIB) appointed investigation commission C7/2007L for this accident. Investigator Jouko Koskimies was named investigator-in-charge, accompanied by the former Chief Accident Investigator Esko Lähteenmäki and Air Accident Investigator Tii-Maria Siitonen as members of the commission.

OH-CAU departed Helsinki-Malmi aerodrome at 16:16 for a local flight over Sipoonlahti bay. Meteorological conditions were good. The flight headed towards the edge of the Porvoo oil refinery protection zone via reporting point “Deger”. Altitude was 900 FT and airspeed was 100 KT at 75 % cruising power. Engine power suddenly decreased to 25−30 % east of Sipoonlahti bay. The pilot immediately turned left towards the village of Box and at 16:27 he reported the loss of engine power to Malmi air traffic control. Malmi ATC cleared OH-CAU for the Control Zone with a heading directly towards the aerodrome and launched the appropriate emergency procedures.

At 16:28 the pilot informed the ATC that engine power was now at only 31 %. A moment later he realized that they would not make it to Malmi and decided to make an emergency landing on the motorway instead. Dense road traffic prevented a landing before the Hangelby Bridge. Therefore, the pilot landed on the right hand lane of the motorway leading to the Sipoonlahti exit.

Touchdown occurred approximately 250 m past Hangelby Bridge. The pilot was unable to stop the aircraft before the exit ramp. The right wing collided with a light pole on the right side of the road, followed by the left wing hitting a traffic sign at the onset of the ramp. The left main undercarriage straddled the crash barrier, the nose gear broke off, the nose of the aircraft fell and the propeller blades broke as they hit the crash barrier.

At 16:28 the air traffic controller declared an aviation emergency to the Emergency Response Centre and the aerodrome fire department. Rescue units were alerted between 16:33−16:36 and the first units arrived at the accident site at 16:42. The police performed a breathalyzer test on the pilot at 17:10. The result indicated zero blood alcohol.

When the engine was later inspected metal shavings were detected in the fuel system. The damaged high-pressure (HP) fuel pump was found to be the source of the shavings. The fuel system parts were sent to the engine manufacturer in Germany. The fuel was analysed in Finland and in Germany and it was found to meet the requirements set for JET A1.

JET A1 is refined to be a jet engine fuel. Its lubricity is significantly inferior to that of diesel fuel. The lubricity of JET A1 is measured with the Ball-On Cylinder Lubricity Evaluator (BOCLE) test method. The highest permissible BOCLE value is set at 0.850 mm.

The High Frequency Reciprocating Rig (HFRR) test method evaluates the lubricity of diesel fuel. The highest permissible value is set at 0.460 mm. JET A1 is not tested with the HFRR method;

nor are there any internationally accepted HFRR value requirements for this fuel. The values derived from BOCLE and HFRR testing are mutually incompatible.

The values denote the size of the wear scar generated on the tested surface. Low values indicate high lubricity.

The HFRR value of the fuel used was measured at 0.835 mm. The European Aviation Safety Agency (EASA) informed the commission that the HFRR value of the fuel used in this type of HP pump's certification testing is 0.780 mm.

The accident was caused by a chain of events. The damage to the HP fuel pump caused the common rail pressure control valve to jam almost fully open. This caused the power loss because the remaining fuel pressure in the common rail could only sustain idle power. A metal shaving from the damaged HP fuel pump eccentric cam bearing surface probably caused the pressure-control valve ball to remain open. The damage on the eccentric cam bearing surface has initiated several flight hours earlier. The damage has caused by water in the fuel. The water has probably come via the loose fuel filler cap. There was no water in the fuel samples taken prior and after to the accident flight.

The investigation commission recommended that EASA take action to establish whether JET A1 can safely be used as aircraft diesel engine fuel, and if it can, the required measures. In addition, the investigation commission recommended that EASA consider whether a new type certificate test be required for TAE engine high-pressure fuel pumps, using such JET A1 fuel which meets the lowest permissible lubricity value set for jet engine fuel. Further the investigation commission recommended that EASA take action to ensure that required maintenance instructions will be published concerning the fuel tank filler caps adjustment on the aircraft equipped with TAE-engines.

TABLE OF CONTENTS

ABBREVIATIONS

BFU	Bundesstelle für Flugunfalluntersuchung, German Federal Bureau of Aircraft Accidents Investigation
BOCLE	Ball-on Cylinder Lubricity Evaluator
CSI	Crime Scene Investigation
EASA	European Aviation Safety Agency
ERC	Emergency Response Centre
FADEC	Full Authority Digital Engine Control
Ft	Feet
GPS	Global Positioning System
HFRR	High Frequency Reciprocating Rig
JAR	Joint Aviation Regulations
Kt	Knot(s)
Mediheli	Rescue helicopter at EFHK
MHz	Megahertz
MSSR	Monopulse Secondary Surveillance Radar
PPL	Private Pilot Licence
QNH	Altimeter setting
TAE	Thielert Aircraft Engines
USG	U.S. Gallon
VFR	Visual Flight Rules
VHF	Very High Frequency (3–300 MHz)

SYNOPSIS

An air accident occurred at approximately 16:29 on Friday 29 September 2007 at Sipoonlahti, west of the city of Porvoo. A Cessna 172N, registration OH-CAU, owned by the Malmi Aviation Club made an emergency landing on Porvoo motorway, close to the Sipoonlahti exit. In addition to the pilot there were two passengers onboard. No-one was injured; however, the aircraft sustained major damage. The incident caused no harm to road traffic.

All times in this investigation report are in Finnish time.

Accident Investigation Board Finland (AIB) appointed investigation commission C7/2007L for this accident. Investigator Jouko Koskimies was named investigator-in-charge, accompanied by the former Chief Accident Investigator Esko Lähteenmäki and Air Accident Investigator Tii-Maria Siitonen as members of the commission.

On 12 Nov 2007 the investigation commission sent a Notification of an Accident to the German Federal Bureau of Aircraft Accidents Investigation, the BFU. On 15 Nov 2007 the BFU designated MSc Thomas Karge as their accredited representative.

In order to ascertain the cause of the occurrence the fuel system parts were removed from the engine and sent to Germany for inspection. A representative of the investigation commission, accompanied by the BFU's accredited representative, visited the engine manufacturer's plant where some of the parts of the fuel system were being tested. The EASA and the Civil Aviation Administration were informed of the detected low lubricity of the fuel. At the behest of the BFU the fuel was also analysed in Germany.

Pursuant to the Decree on accident investigation, the draft final report was promulgated for statement to the Finnish Civil Aviation Authority, Finavia, Neste Oil Oyj, the German Federal Bureau of Aircraft Accidents Investigation (BFU) and the EASA. The report was also dispatched as information and for comment to the pilot of the accident aircraft, Malmi Aviation Club, Konekorhonen Oy as well as to the Emergency Response Centre of East and Central Uusimaa. Comments from Finland were received on 19.1.2009 and from BFU 27.2.2009. EASA did not give any comments.

The investigation commission has included into the investigation report the statistics mentioned in the BFU comments, item 1. The investigation commission, however, could not agree with the points of view of the BFU comments, items 2 and 3. The BFU comments are, therefore, the Appendix 1 in the investigation report.

The investigation was completed on 6.3.2009. The investigation commission issued three recommendations and the investigation report was translated into English.

The material used in the investigation is archived at the Accident Investigation Board of Finland.

1 FACTUAL INFORMATION

1.1 History of the flight

On 28 September 2007 at 16:16 local time a Cessna 172N, registration OH-CAU, owned by the Malmi Aviation Club departed Helsinki-Malmi aerodrome for a local training flight. In addition to the pilot there were two passengers onboard. The aircraft was fitted with a TAE 125-01 diesel engine, using JET A1 jet engine fuel.

The pilot arrived at the aerodrome at approximately 16:00. He conducted a walk-around inspection and took a fuel sample into the sampler cup from the drainers of both fuel tanks and from the fuel filter drainer. He said that he detected minuscule bubbles in the first sample and, therefore, took new samples from both tanks. He told that these samples were clean. Since the fuel gauge indicated 10 USG of fuel in both tanks, i.e. 20 USG (75 litres) total fuel, he did not refuel the aircraft. He intended to fly a 30 minute flight via reporting point “Deger” to Sipoonlahti bay following the north side of the motorway. Then he planned to turn northeast and fly to the north of Porvoo, from where he would return to Malmi aerodrome.

During the test run the engine performed normally and the pilot did not notice anything out of the ordinary. He departed runway 36 at 16:16. The aircraft passed point “Deger” at 16:20 at which time they climbed to 1200 ft, heading towards Sipoonlahti. However, since the cloud base was irregular, the pilot descended to 900 ft so as to remain clearly below clouds.

At the request of the passengers the pilot circled the Sipoonlahti residential area, from where he continued towards the edge of the Porvoo oil refinery protection zone. He was flying at approximately 100 kt at 75% cruising power. Suddenly engine power dropped. The pilot turned immediately towards the village of Box and informed the passengers that they would be returning to Malmi aerodrome. At 16:27 the following radio communication ensued:

OH-CAU:	*Malmi tower, we are losing power for some reason. We’ll be heading towards the airfield following Porvoo motorway.*
TWR:	*OAU, OK. You’re cleared into the control zone, straight towards the airfield. Tell me if you want to climb; in which case we will request clearances.*
OH-CAU:	*OAU*

The air traffic controller initiated the appropriate emergency alert action and told the aircraft in the traffic circuit to land, so as to ensure an unobstructed approach for OH-CAU.

OH-CAU began to lose height and the channel A warning light of the Full Authority Digital Engine Control (FADEC) started to flash. The system changed over to channel B. However, this had no effect and the channel B warning light also began to flash. The pilot said that he tried to regain engine power by restarting both control units but this did not help. Engine power had now decreased to 25−30%. The aircraft continued to lose height and the pilot maintained 70-75 kt airspeed. They were still above a wooded area, heading towards the motorway. A little further ahead there was a field and the pilot later said that he considered an emergency landing on the field. However, he decided to try to make it back to Malmi.

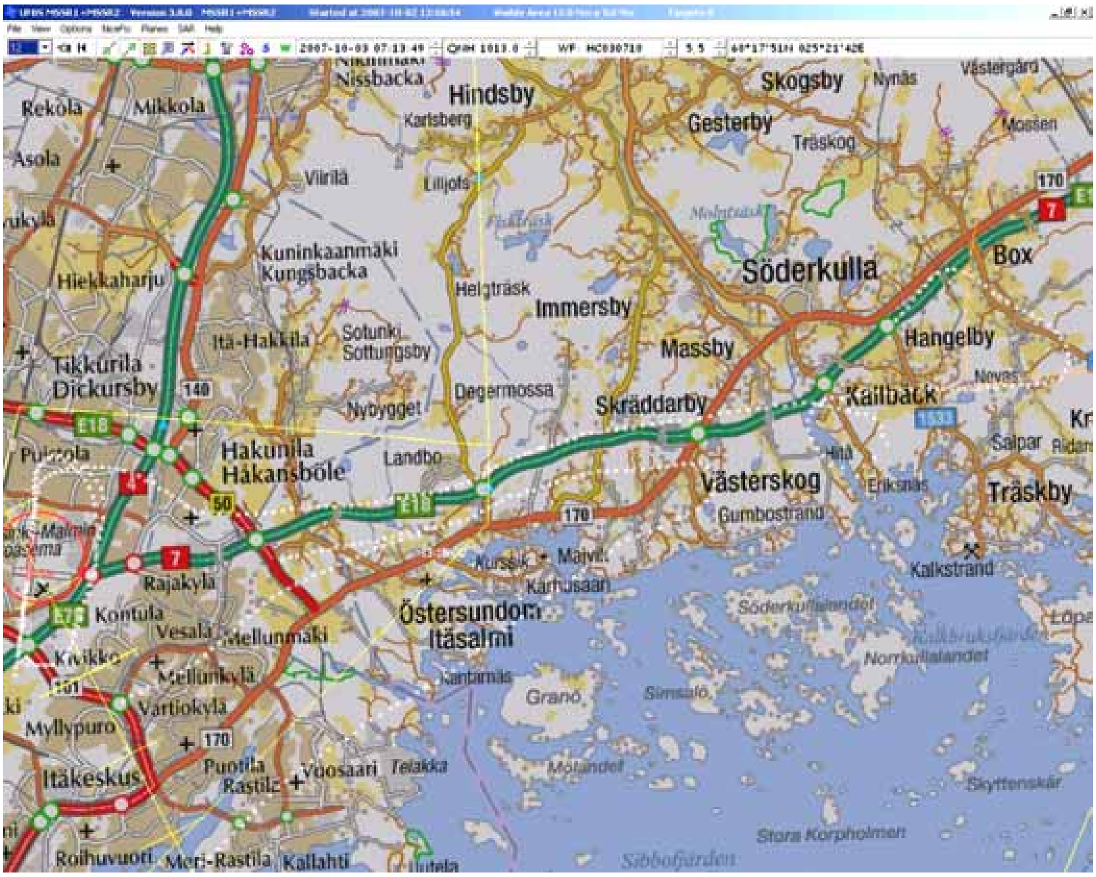

Figure 1 Helsinki-Vantaa aerodrome radar recording of the aircraft's track (upper white dotted line).

The pilot flew towards Malmi aerodrome over Porvoo motorway. This made navigation easier while he was trying to regain engine power. He restarted the electronic control units (ECU), turned the electric fuel pump as well as the Force-B switch on (forcible move from FADEC channel A to channel B) and tested various positions of the throttle lever. The engine did not respond to any of the measures and both FADEC channel warning lights were now on.

At 16:28 the pilot reported the following to the Air Traffic Control:

> *"We only have 31% engine power left. We're flying over Porvoo motorway and are trying to make it to you".*

This was the last contact with the ATC. The pilot realized that the plane would no longer make it to Malmi. There was a small field south of the motorway but since the aircraft was continuing to descend, he decided to make an emergency landing on the motorway.

First he intended to land before the Hangelby Bridge some 400 m ahead but, due to heavy road traffic, this was impossible. Nevertheless, with the help of the residual power the engine still produced he made it over the bridge.

Figure 2 The passenger took this photo as they were approaching the site of the emergency landing. They barely made it over the Hangelby Bridge up ahead.

The pilot observed the road traffic from his side window and noticed that the cars were slowing down. Once he cleared the cars he steered towards the right hand lane leading to the exit ramp so as to avoid ramming into the cars travelling ahead of him. He said that he switched the fuel and main power off right before touchdown. When the aircraft was inspected after the emergency landing, they were found in the “off” position.

The aircraft touched down approximately 250 m beyond Hangelby Bridge. The pilot said that because of obstructions on both sides he steered forcefully and stood on the brakes so as to stay in the middle of the lane leading to the exit ramp. Nevertheless, the right wingtip broke when the wing hit a light pole on the right side of the road. Immediately after this the left wing hit a traffic sign at the onset of the exit ramp. The aircraft turned 30 degrees to the left and rolled, followed by the left main gear straddling the crash barrier. The aircraft rode approximately 15 m on the barrier. The nose wheel broke off and the nose fell, followed by the propeller blades breaking when they hit the crash barrier.

Judging by the marks, the aircraft came to a halt after a 143 m landing roll at approximately 16:30.

Figure 3 The aircraft resting on the crash barrier after the emergency landing.

After the aircraft came to rest the passengers and the pilot deplaned through the door on the right hand side. Prior to takeoff the pilot had demonstrated to the passenger on his side how to open the door. Fuel began to drip onto the road through the right hand fuel tank filler cap.

1.2 Injuries to persons

There were no injuries to persons.

1.3 Damage to aircraft

The aircraft sustained major damage during the emergency landing.

1.4 Other damage

A traffic sign at the onset of the exit ramp was toppled sideways.

1.5 Personnel information

Pilot	Age 25
Licences	JAR private pilot licence, PPL(A), aircraft, valid until 14.4.2009
Medical certificate	JAR class 2, valid until18.8. 2011, and an air traffic controller's medical certificate, valid until 18.8.2008.
Ratings	All required ratings were valid.

Flying experience	Last 24 hours	Last 30 days	Last 90 days	Total hours and landings
All types	0 h 13 min	0 h 55 min 7 landings	4 h 40 min 16 landings	63 h 10 min 166 landings
Type in question	0 h 13 min	0 h 55 min 7 landings	4 h 40 min 16 landings	4 h 40 min 23 landings

1.6 Aircraft information

The Cessna 172N was a single diesel engine TAE 125-01, four seat, all-metal high-wing aircraft

Aircraft

Type	Cessna 172N
Registration	OH-CAU
Certificate of registration	1224
Manufacturer	Cessna Aircraft Company, USA
Serial number and year of manufacture	17272511, 1979
Maximum take-off weight	1043 kg
Owner and operator	Malmi Aviation Club
Flying time	1856 hours

The calculated take-off-weight was 920 kg. The centre of gravity was in the permissible range.

Engine

Type	TAE 125-01, 135 hp (99 KW)
Serial number	02-01-1029
Manufacturer	Thielert Aircraft Engines GmbH (TAE), Germany
Running time	299 hours
Fuel	JET A1

Propeller

Type	MTV-6-A-187/129, three-blade wood/composite, hydraulic pitch controlled constant speed propeller
Serial number	03509
Manufacturer	MT Propeller Entwicklung GmbH, Germany
Running time	1004 hours

Engine information

The engine is a turbocharged diesel engine. It is fitted with a 1.69:1 propeller reduction gear. There is a single-plate dry clutch between the engine and the transmission, providing momentary slippage during engine start and stop.

A Full Authority Digital Engine Control (FADEC) controls engine power and speed. The FADEC incorporates two computers. The pilot adjusts the desired engine power to the FADEC with one fly-by-wire throttle lever. A FADEC computer controls manifold pressure and fuel supply and adjusts engine speed by turning propeller blade angles. The pilot sees the propeller speed in his instrument panel, which is converted from engine speed by the computer using a transmission ratio. No indication of true propeller speed is given; neither is engine speed indicated. The instruments indicate engine power in percentages. The FADEC fault memory unit stores 16 parameters, mostly related with engine performance.

There are two fuel tanks in the aircraft fuel system. They supply fuel via a selector shut-off valve to an electric pump and onwards to the filter which houses a water separator. Downstream of this, fuel is fed via the low-pressure feed pump to the HP pump.

Fuel is fed in a Common Rail system. The engine-driven HP pump has three radially arranged pumping elements (cylinders and pistons) at 120 degree angles from each other. The pistons are driven by an eccentric cam. Pump pressure, 1,350 bar at maximum, is delivered to the so-called common rail on the top of the engine from which fuel lines go to the injectors. Injectors are fitted with nozzles as well as electric control circuits and solenoid valves. Pressure in the common rail is measured by an electric rail-pressure sensor and controlled by an electric pressure control valve. FADEC controls fuel flow and the length of the injection phase. Some of the fuel fed to the HP pump returns to the low-pressure stage. Fuel comes to the fuel return line from the HP pump, injectors and the common rail.

1.7 Meteorological information

METAR

EFHF at 16:20: Wind variable at 6 kt, visibility over 10 km, overcast at 1300 ft, temperature + 11°C, dewpoint +9°C, QNH 1027.

TAF 28.9. at 12–21

EFHF: Wind 20 degrees at 8 kt, visibility over 10 km, scattered cloud at 1200 ft, temporarily between 12:00-14:00 broken cloud at 1200 ft.

GAFOR 28.9. for areas 11/17 (western and southern Finland) at 15–24:
Ceiling at approximately 1000 ft, the next layer of cloud at 2000 ft. Visibility good, weather NIL.
Winds:

- Surface 020–050 deg /8–12 kt
- 2000 ft: 060–090 deg/10–15 kt
- 5000 ft: 070–140 deg/5–10 kt

0 °C level at FL 70–80
Local moderate icing above the 0 °C level. Moderate turbulence above FL 180.

The weather had no effect on the occurrence.

1.8 Aids to navigation and radars

The aircraft was fitted with a fixed GPS. The transponder operated normally. Helsinki-Vantaa MSSR radar was able to track the flight almost to the very end. The aircraft disappeared from radar at the Hangelby exit, approximately one kilometre from the site of the emergency landing.

1.9 Communications

The aircraft's VHF radios operated normally. Radiocommunications and telephones at Malmi aerodrome, including communications recorders, operated normally.

1.10 Aerodrome information

The aircraft departed from Helsinki-Malmi aerodrome. Aerodrome information is available in the Aeronautical Information Publication (AIP) Finland.

1.11 Flight recorders

The aircraft was not fitted with flight recorders. The memory of the aircraft's fixed GPS was not downloaded.

1.12 Wreckage and impact information

1.12.1 Impact investigation

An AIB chief accident investigator arrived at the scene approximately 30 minutes after the occurrence. He investigated the site of the emergency landing, the aircraft and the damage to the aircraft. He also interviewed the pilot. A Vantaa CSI agent conducted the on-site investigation and completed a scale drawing of the accident site.

According to the scale drawing the first detectable point of touchdown was a tyre mark, measured 143 m from the tail at the spot where the aircraft came to rest. At the final stage of the landing roll the right wingtip hit a light pole on the right side of the road, measured at 118 m from the first tyre mark. Thereafter, the left wing collided with a traffic sign on the left side of the road. The sign was at 123 m from the first point of touchdown. The distance from the light pole to the traffic sign was 11 m. The wing span of the aircraft is 11 m. After colliding with the traffic sign the aircraft still moved for approximately 25 m. The tyre had left a clearly distinguishable skid mark on the ground, curving to the left.

1.12.2 Wreckage investigation

Every blade of the wooden propeller was broken approximately in half and the broken pieces were lying on the ground next to the propeller. The lower engine cowling was dented and bent upwards. The nose wheel had broken off the firewall and the lower edge of the firewall was bent. The right wingtip was broken and there was a collision mark at the tip of the wing. The rear fuselage and the empennage were undamaged. Due to the damage to the wing the roof of the cabin was dented. The entire left wing root was bent and the trailing edge flap had broken the left back window of the cabin. The leading edge of the wingtip was dented inwards at a length of approximately two metres. The left main gear strut cowling was dented.

When the nose wheel broke off, the aircraft came to rest in a nose-down attitude. This caused fuel to leak onto the ground through the right fuel tank filler cap. No other leaks were detected. After the accident site was inspected and photographed the rescue personnel lashed the tail to the crash barrier, thereby lifting the nose and stopping the fuel leak.

Marks left on the road surface, the attitude of the aircraft, outer damage as well as the indications and positions of instruments and switches were photographed prior to moving the aircraft. When the cockpit was inspected it was noted that the main power was OFF, the fuel shut-off valve was closed, the throttle lever was fully closed, all electrical switches were in the OFF position and the trailing edge flap lever was in the fully extended position.

The fuel tanks were drained into four 20 litre plastic canisters and the remaining amount into a bucket. The fuel quantity was approximately 85 litres. With the help of rescue personnel a mechanic who was familiar with the aircraft type detached the wings. A transport vehicle was summoned in order to move the aircraft from the site. A second AIB investigator arrived at the scene at approximately 21:00 and supervised the wing removal and the transport of the aircraft to Helsinki-Malmi aerodrome.

1.13 Medical and toxicological information

The three emergency response units that arrived at the scene examined the pilot and the passengers. No injuries were detected. None of the persons examined went to see a doctor. The police performed a breathalyzer test on the pilot at 17:10. The result was zero blood alcohol.

1.14 Fire and damage to the environment

There was no fire. At first, because of the abnormal attitude of the aircraft, fuel leaked onto the road through the incorrectly adjusted fuel filler cap on the right wing. The fire brigade soaked up the spilled fuel before it became an environmental hazard. When the aircraft was moved away from the site, the fire brigade hosed off the road surface.

1.15 Rescue operations and survival aspects

At 16:27 the pilot reported the engine malfunction to Malmi ATC, at which time the ATC issued an aircraft emergency alert to the ERC of Helsinki and the fire rescue service of Malmi aerodrome. When the pilot reported that he had lost engine power the air traffic controller estimated that the aircraft would have to make an emergency landing and, hence, issued an aircraft accident alert. Based on the aircraft's coordinates displayed on his radar monitor he gave the ERC an estimate of the location of the emergency landing. Malmi aerodrome rescue units were on standby in case the aircraft made it to the aerodrome or its immediate vicinity.

OH-PTC had departed Malmi at 16:26 towards reporting point "Nokka" and at 16:28 the air traffic controller ordered it to turn towards reporting point "Deger" and call OH-CAU on the radio. However, OH-CAU no longer responded.

The ERC of Helsinki alerted Helsinki Rescue Department at 16:27. At 16:29 the appropriate emergency response units were on their way to Malmi aerodrome. The response comprised a fire officer on duty, one medical (doctor) unit, two ambulances, one rescue unit, one transport unit and a fire tanker unit. Malmi aerodrome had a crash/foam truck. The response was standard and the smallest possible dispatched during an impending aviation accident. When the units were on their way word reached them that the accident site was in Sipoo and the ATC informed them that the emergency landing had been successful. The alert was cancelled and the units returned to their station.

The Emergency Response Centre of East and Central Uusimaa received six calls of an emergency landing. The first call at 16:30 came from a mobile telephone. The aircraft probably landed at 16:30. From 16:33–16:36 the ERC dispatched an on-duty fire officer, three rescue units, three ambulance units and a tanker unit from the East Uusimaa Rescue Department. In addition, the ERC dispatched the Mediheli air ambulance. Moreover, two personnel transport vehicles from Box Volunteer Fire Department and three police units were dispatched to the site. The regular units took off between 16:34–16:39 and the voluntary fire brigade units between 16:38–16:46. Mediheli was alerted at 16:34 and departed at 16:40. The ambulances and one rescue unit were the first ones to arrive at the scene from 16:42–16:45. After an ambulance unit informed Mediheli by radio that it would not be needed, it turned back to base at 16:44.

Rescue department and police units arrived at the scene approximately 5–20 minutes after the alert. The first to arrive was an ambulance unit at 16:42. After it was determined that there was no harm to road traffic, there was no fire and that people had not sustained injuries, the units returned to their station. One fire suppression unit and two personnel transport units remained at the scene, helping to dismantle the aircraft and ensuring its transport away from the site. The mission of the fire suppression unit ended at 01:00 the following day.

The persons onboard made it out of the aircraft on their own accord, immediately after it came to rest. The seats in the aircraft remained in place, the safety harnesses performed as designed and the right hand side door opened freely. The left hand side door did not fully open. Furthermore, the crash barrier would have impeded egress through it.

1.16 Test and research

1.16.1 Engine

Both engine control channels have memories. They store engine speed, throttle lever position, manifold pressure, coolant temperature, intake air temperature, oil temperature and pressure, fuel pressure in the common rail, FADEC voltage, the settings of the rail-pressure sensor and pressure limiter, FADEC channel selection (A or B), transmission temperature and FADEC time.

Both channels had stored identical data, providing the following information:

- The engine was started at 16:03. Warm-up lasted approximately three minutes
- Taxiing began at 16:08
- The test run was performed at 16:13–16:14; all engine parameters were nominal during the test run
- The aircraft taxied onto the runway at 16:15; takeoff occurred at 16:16 at full power
- Engine power was reduced to 80% at 16:18; a minute later engine power was further reduced to 70%
- At 16:21 engine power was increased to 100% for approximately 1½ minutes when the aircraft climbed to 1200 ft. After this, engine power was reduced to 80%
- At 16:26 engine power was increased to 100% for thirty seconds after which it was reduced to 80% at which time the fuel pressure and engine power rapidly fell to approximately 30% almost immediately. At 16:27 the engine provided only 25–30% power and FADEC had switched over to channel B; the engine was still running at approximately 3000 rpm
- The pilot had moved the throttle lever back and forth and finally moved it into a fully open position. This, however, had no effect on engine performance
- The engine was stopped at 16:30.

Prior to the rapid loss of fuel pressure at 16:27 there were no abnormalities in engine properties.

1.16.2 Inspection of the engine and the clutch

When the engine was visually inspected, it was found intact, clean and dry, apart from a small area around the breather orifice under the bell housing, which displayed traces of transmission oil. The transmission oil level was correct as was the level of engine oil. The oil filter was detached and inspected. It was clean. The exhaust turbine and turbocharger were in good condition and turned freely.

The transmission was detached. The bell housing was dry and clean and there were no signs of any oil leaks on the engine side. On the transmission side there was some moisture, originating from an oil leak through the clutch shaft gasket. The clutch assembly was dismantled. Its bolts were properly fastened. The thickness of the clutch plate was 2.7 mm. There were dark spots on the surface of the plate. The plate itself was intact, displaying no signs of overheating. The pressure plate surface and the flywheel friction surface were in pristine condition. The flywheel was removed, at which time it was found that neither the crankshaft or oil sump gaskets leaked.

1.16.3 Inspection of the fuel system

The right fuel tank filler cap seal was incorrectly adjusted and it did not seal properly. All four prefilters in the fuel tanks were inspected. Because the edge of the left fuel tank was bent, the rear filter in the tank was damaged during removal. The filter displayed some dark-coloured fibrous contaminants and two small aluminium shavings (length approx. 1 mm). The other prefilters were clean. The fuel system water separator filter was dismantled and inspected. There were steel particles on the top of the filter and on the bottom of the cup. In order to establish the origin of the shavings the low-pressure pump and the high-pressure pump were detached. Moreover, the common rail and the return fuel line joining the injectors were detached. The low-pressure pump was opened and found to be in good condition.

The high-pressure pump

Figure 4 Damages of the eccentric cam and the driveshaft on the HP pump.

The part number of the HP pump was 02-7310-04005R6-U and its serial number was 12155. The numerical code on the frame of the pump indicates that the pump had been modified by the manufacturer. The time between overhauls was 600 hours. The running time on the pump was 298 hours. The pump pistons, bearings and bearing surfaces are lubricated by JET A1 fuel. The three pistons are radially arranged and actuated by an eccentric cam. The pump's set (maximum) pressure is approximately 1,350 bar.

The pump cylinders and pistons were as good as new. When the cylinders were being detached, metal particles were discovered inside the pump. The surface of the drive-shaft and the eccentric cam bearing were badly scuffed. Particles had come loose from the bearing's steel surface. Early-stage corrosion was found on the three surfaces of the eccentric cam which come into contact with the pump pistons.

The investigation commission measured the wear on the driveshaft cam and the eccentric cam. The results showed that the diameter of the driveshaft cam at the unworn spot was 23.95 mm. Maximum wear was 0.08 mm. The eccentric cam bearing was worn out of round. The diameter of one end of the bearing was 24.49 mm and the corresponding reading at the other end was 25.01 mm. Measurements showed that driveshaft cam and eccentric cam clearances varied between 0.62–1.14 mm, averaging at 0.88 mm. The stroke length of an unworn pump piston is 6.92 mm. Therefore, due to wear, stroke was approximately 13% shorter than normal.

Pressure control valve

Figure 5 Metal particles in the pressure control valve

The pressure control valve at the rear of the common rail was detached. It contained metal particles. The HP pump, the nozzles and the pressure limiter were sent to BFU in

Germany who, in turn, forwarded them to the manufacturer for testing. Testing was conducted under the supervision of the authorities. During testing the injectors and the pressure control valve performed flawlessly. On 13.2.2008 the engine manufacturer sent an inspection report to AIB regarding the damage on the HP pump of the OH-CAU. The report stated that the damage was unique and that the manufacturer is not aware of any similar damage elsewhere. The manufacturer strongly assumes that there has been water in the fuel, probably on some other earlier flight, and it had initiated the damage.

1.16.4 Fuel analysis

In October 2007 Neste Oil Oyj laboratory analysed the fuel sample taken from the fuel tank of the aircraft. A member of the investigation commission witnessed the analysis. The sample was analysed for lubricity, density, viscosity, distillation curve as well as lead and water content. With regard to the tested properties the fuel met all requirements set for JET A1 fuel (ASTM D1655). In accordance with the ASTM D6304 test method the fuel had low water content (43 mg/kg). Three separate test methods failed to detect any lead in the sample.

The lubricity of the fuel onboard was tested with two separate methods. Whereas the Ball-on Cylinder Lubricity Evaluation (BOCLE) test measures the lubricity of JET A1 fuel, the High Frequency Reciprocating Rig (HFRR) test measures the lubricity of diesel fuel. The average of three BOCLE tests produced the value of 0-640 mm. The maximum permissible value is 0−850 mm. Two HFRR tests averaged at 0.835 mm. The maximum permissible value for diesel fuel is 0.460 mm. However, the values measured with BOCLE and HFRR testing methods are mutually incompatible.

Both the BOCLE and HFRR test results indicate the length of a wear scar on a cylindrical shape. The diameter of the scar is given in millimetres or micrometres.

At the behest of the BFU the investigation commission asked Neste Oil Oyj to conduct additional testing on four batches of JET A1 fuel refined in October 2007. BOCLE testing was completed on 25.1.2008 and the results proved that all of the batches met the requirements set for JET A1 fuel. HFRR test results averaged at 0.855 mm, ranging from 0.835–0.870 mm.

In answer to an investigation commission’s query, on 11.3.2008 the EASA informed the commission that the highest HFRR reading for the fuel used in the TAE 124 engine’s type certification testing was 0.780 mm. Since the numbers achieved in Neste Oil Oyj’s tests were considerably higher, the investigation commission sent a written report of this to the EASA and the Finnish CAA. On 18.3.2008 the CAA informed the Finnish owners and operators of Thielert engines of the matter by a circular letter.

On 5.5.2008 the German Federal Bureau of Aircraft Accidents Investigation (BFU) informed AIB that they would like to have the German armed forces’ laboratory (Wehrwissenschaftliches Institut für Werk-, Explosiv- und Betriebsstoffe, WIWEB) test the Neste Oil Oyj’s JET A1 fuel. For this purpose, three 0.8 litre samples from previously analysed Neste Oil August 2007 JET A1 batches were sent to Germany. The WIWEB’s results were received on 31.10.2008 and the samples met all requirements set for JET A1 fuel. HFRR test values ranged between 0.902–0.955 mm.

1.17 Other information

The investigation commission received from TAE an investigation report of the OH-CAU HP pump failure. The report OIR-02-01-28-09-2007 was dated February 13, 2008. TAE strongly assumed in the report that the HP pump failed due to corrosion, caused by free water in the fuel. The report included also statistics concerning HP pumps installed in Finland registered aircraft. According to the report TAE has evidence of 4717 operation hours of HP pumps without any defects. Due the scheduled maintenance/company inspection TAE has evidence that on 12 HP pumps operated in Finland registered aircraft no defects or unusual wear have been detected.

After receiving this report the investigation commission, for a point of reference, examined the HP pump on the OH-CAZ, p/n 02-7310-04005R5, s/n 11901. The running time on the pump was 332 h and the time between overhauls 300 h. After the pump was disassembled it was noted that the pump pistons and cylinders were in good condition and the driveshaft cam was pristine. The Teflon coating of the eccentric cam bearing had partly come off and it was uneven. This was most evident in three areas, at 120 degree angles to each other. However, the Teflon coating was also damaged in narrow streaks between these areas. The damaged area encompassed approximately one half of the area of the bearing.

See the picture on next page.

Microscopic analysis revealed that the Teflon coating was so badly worn in three places that it revealed the copper-coloured coating under it. Part of the Teflon had worn off and some of it was partly loosened. The pump was sent via BFU to TAE, where it was tested. TAE report stated that while the pump was in worse than normal condition, it was still operable.

The investigation commission also examined the HP pump on the OH-CME, p/n 02-7310-04005R6, s/n 12166. The running time on the pump was 513 h and the time between overhauls 600 h. The pump was found to be in mint condition, which was reported to BFU and TAE. According to BFU advice the pump was returned to the owner of the aircraft.

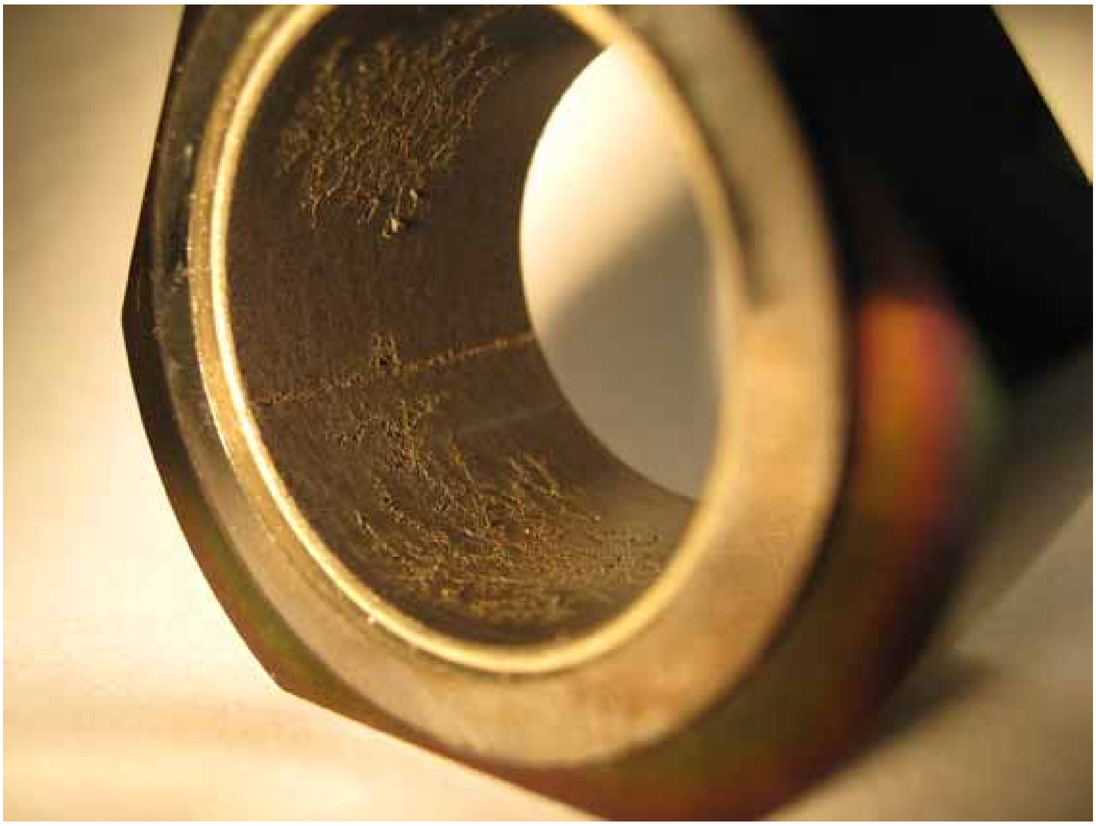

Figure 6 Wear marks on the OH-CAZ's HP pump eccentric cam bearing Teflon coating.

1.18 Test methods used

Routine methods were used in testing. The fuel in the tanks was analysed. Tests verified that Neste Oil Oyj's JET A1 meets both the ASTM D1655 and AFQRJOS quality requirements. The lubricity of the fuel was tested with BOCLE and HFRR methods. Fuel distillation was analysed with the ASTM D86 test method, kinematic viscosity with the ASTM D445 method, density with the ASTM D4052 method and the amount of water in the fuel with the ASTM D6304 method. Lead content was tested with the following three methods: NM101, NM412 and ASTM D3237.

2 ANALYSIS

2.1 Fuel analyses

With regard to the tested properties, samples taken from the fuel tanks of the accident aircraft met all requirements set for JET A1 fuel.

The HP pump of the TAE 125-01 diesel engine is lubricated only by the fuel. There is not any separate lubricate system. Because of this the fuel analyses parameters involved lubricity, water content and lead content.

The BOCLE lubricity value for JET A1 was 0.640 mm. Being that the maximum permissible value is 0.850 mm, the fuel met its requirements. At the request of TAE the fuel was also tested with the HFRR method, used in determining the lubricity of diesel fuel. The result was 0.835 mm. The maximum permissible value for diesel fuel is 0.460 mm. The EASA informed the commission that the highest HFRR reading for the fuel used in the TAE 124 engine's HP pump certification testing was 0.780 mm.

Water content in the sample was 43 mg/kg, corresponding to approximately one half of the maximum permissible. Lead could have been introduced into the fuel system, for example, by incorrect refuelling. None of the three testing methods, however, revealed any traces of lead.

Test results show that the lubricity of JET A1 is clearly inferior to that of diesel fuel. During the refining process a lubricant additive is added to diesel fuel. In order to function reliably, the HP pump and nozzles in a diesel engine demand adequate lubricant properties from the fuel.

In January 2008 Neste Oil Oyj was asked to provide the lubricant properties of four batches of JET A1 refined in August 2007. They were as follows:

Test method	15 Aug batch	7 Aug batch	12 Aug batch	2 Aug batch	Unit	Method
BOCLE	0.80	0.79	0.79	0.81	mm	ASTM D5001
HFRR	870 0.870	867 0.867	847 0.847	835 0.835	µm/60 °C mm/60 °C	ENISO12516-1

The BOCLE values were good. The HFRR average was 0.855 mm. Still, a random test was conducted in May 2008, providing the HFRR average of 0.755 mm. This is 0.100 mm less compared to the average from the batches tested in January. No explanation was found to this.

On 10.9.2008 WIWEB tested three August 2007 batches of Neste Oil Oyj JET A1 in Germany. The results were the following:

Test method	Batch 1	Batch 2	Batch 3	Unit	Method
BOCLE	0.763	0.785	0.781	mm	ASTM D5001
HFRR	0.902	0.914	0.955	mm	DIN ISO 12516-1

The BOCLE readings are almost identical to the values achieved in Finland. The HFRR values are higher than those achieved in Finland.

While the HFRR analysis in Finland produced an average of 0.855 mm, the corresponding figure of the tests conducted in Germany was 0.923 mm. In the Finnish HFRR analysis the lubricity of Neste Oil’s JET A1 was, on average, 0.080 mm higher than the value given by the EASA (0.780 mm). The HFRR average in the German tests was 0.150 mm higher compared to the EASA’s value.

2.2 Loss of engine power

When the pilot increased power to 100% and then decreased it to 80% during the cruise phase, this was almost immediately followed by a rapid drop in fuel pressure and manifold pressure to approximately 30%. Although the engine did not fail, it ran at 25–30% power. The position of the throttle lever had no effect on engine performance. FADEC records show that the fuel pressure in the rail plummeted from 1,000 bar to approximately 200 bar. The FADEC’s target value was approximately 950 bar. The remaining engine power was insufficient to maintain level flight.

The wear of many flight hours had shortened the pump piston stroke by approximately 13%. Although this decreased maximum performance, considering the pump’s capacity it is unlikely that wear caused the rapid loss of pressure during the flight. Instead, the most likely explanation is that a metal shaving got caught in the pressure control valve, a computer-controlled solenoid ball valve located at the end of the rail, causing it to jam partly open and, thus, collapsed the fuel pressure.

The injectors (nozzles) and the pressure control valve were tested at the engine manufacturer’s plant. During the tests they operated normally. The investigation commission considers it a possibility that the metal shaving had cleared the valve ball, returning normal function to the valve.

2.3 High-pressure pump failure

The engine manufacturer, when developing the engine, had modified the HP pump so as to allow for the lubricity of JET A1 fuel. With regard to this incident, the Teflon coating on the eccentric cam bearing, including the bronze surface underneath it, were almost completely worn off and even some parts of the bearing’s steel frame had disintegrated. The surface of the driveshaft cam was worn. In addition, the two other bearing surfaces of driveshaft facing the eccentric cam, those receiving the highest loading, exhibited wear scars. TAE specialist stated that this kind of late-stage bearing damage must have already begun several flight hours before it was detected.

When the pump was inspected rust was detected in a steel bushing that leads fuel into the eccentric cam chamber for the purpose of lubrication. According to TAE statement the rust indicated that free water had been in the fuel at some stage. As per the statement, water was the probable root cause for the HP pump bearing failure.

On 25.9.2007 a momentary engine malfunction was experienced on the very same aircraft. The malfunction occurred when engine power was increased to 100%, at which time engine speed began to strongly oscillate. When engine power was decreased to 75%, the engine ran normally again. The aircraft then returned to Helsinki-Malmi aerodrome without incident. The engine was inspected on 26.9.2007 but nothing out of the ordinary was detected. Neither was any water detected in the fuel. Prior to that flight the pilot took fuel samples from three separate places and no water was detected in any of the samples. Apart from a few drops, no water in the fuel was detected after the aforementioned flight. The investigation commission noticed that the fuel filler cap on the right hand side tank was adjusted in such a manner that it did not properly seal. Instead, rain water was able to pass through into the tank. Even though the aircraft was mostly stored in a hangar, in the summer of 2007 it also stayed outside exposed to the elements. On 21.9.2007 Malmi Aviation Club published a circular letter in which it reminded everyone of the importance of removing free water from the fuel tanks as the summer had been rainy and water had been detected in the OH-CAU's systems.

Checking of the fuel tank filler cap sealing and the tightness adjustment belongs to the hundred hour's maintenance program of Cessna. The fuel tanks filler caps of the aircraft involved were, however, changed in connection with the engine change, and thus the Cessna maintenance program did not include the new fuel filler caps. TAE had not included the fuel filler cap adjustment instructions into the new engine maintenance manual.

If water makes it into the HP pump the result is an engine malfunction. However, in such a case the water separator must be filled with water. Even if no more water comes in from the tanks while the engine is running, some water still remains in the filter cup. At the next free water removal, provided that the sample is properly taken with a sampler cup, the amount of water should raise attention. However, if the fuel sample is drained directly on the ground, the water would probably remain undetected.

Three TAE engine HP pumps were disassembled in Finland, all of which used the same Finnish refinery's JET A1 fuel. Even though the HP pump on the OH-CAU, the aircraft that made the emergency landing, had only been running half of the time between services, it was completely broken. The pump on the OH-CAZ, which had been running 10% past its service time, was more worn than normal, albeit operational during test runs. The detected wear had not affected engine performance in flight operations. The HP pump on the OH-CME, having run 513 hours of its 600 hours between overhauls, was in mint condition and performed flawlessly.

According to TAE statement the damage to the HP pump on the OH-CAU was caused by free water in the fuel. The investigation commission considers this plausible because water could have entered the fuel system through the tank filler cap, the seal of which was adjusted incorrectly. There was no water in the fuel samples taken prior and after to the accident flight. The damage of the HP pump had initiated earlier.

As per the statement of TAE, the wear on the pump on the OH-CAZ was within acceptable limits. Since the HP pump on the OH-CME was effectively as good as new, it was not sent to the manufacturer.

Another possible cause could have been a temporary interruption in lubrication which resulted in minor scarring on the bearing surface. The scars, in turn, prevent a solid film of lubricant from forming between the bearing surfaces and, thus, induce progressive wear. The eccentric cam bearing can also break when the engine fails in mid-air due to fuel starvation and the propeller continues to windmill, or if the engine is stopped by turning off the fuel shut-off valve, for example, during test runs. In both situations the HP pump eccentric cam bearing remains without lubrication. No evidence of such instances, however, was found during the investigation.

It is also possible that the lubricity of different refineries' JET A1 is insufficient for the HP pump of a diesel engine.

2.4 The significance of fuel properties

Airports do not supply aviation-grade diesel fuel. For this reason the engine manufactures have tried to construct a diesel engine which can run on JET A1 fuel.

According to Neste Oil statement the lubricity is not continuously monitored during the production of JET A1. Lubricity is only measured when the product includes more than 95 % hydrogen treated material, of which more than 20 % is strongly hydrogen treated. Conversely, lubricity is always measured when the product includes synthetic components. These criteria are rarely met in JET A1.

JET A1 is refined to be jet engine fuel. It follows the JIG regulations in product content, processing, analysis and monitoring. Its lubricity is significantly inferior to that of diesel fuel. The lubricity of JET A1 is measured with the BOCLE test method ASTM D 5001. However, the method provides a poor description of the lubricity required by diesel engines. The highest permissible BOCLE value is set at 0.850 mm.

According to Neste Oil one of the most important parameters in the use of diesel fuel is the ignition quality of the fuel, indicated by the Cetane Number (CN). This number must always be specified in the fuel used in diesel engines. It has its own minimum values, which the typical jet fuel will not meet. In JET A and JET A1 production the Cetane Number is not monitored, nor are any minimum values guaranteed.

The HFRR test method evaluates the lubricity of diesel fuel. The highest permissible value is set at 0.460 mm. JET A1 is not tested with the HFRR method, nor are there any internationally accepted HFRR value requirements for this fuel. The values derived from BOCLE and HFRR testing are mutually incompatible.

By modifying the HP pump the engine manufacturer attempted to make it safe for JET A1 fuel as well. Nevertheless, the problem seems to be that there are no universally accepted JET A1 lubricity standards for diesel engines. This being the case, lubricity was controlled by HFRR test values which are not used in JET A1 quality control. Since there are several types of JET A1 in existence, all of which pass the minimum standards, their lubricity in diesel engines is an unknown factor.

On 17.11.2008 Exxon Mobil sent a letter to its distributors that Exxon does not support or endorse the supply of jet fuel to aircraft powered by diesel engines, unless the customer will sign a valid indemnity agreement. During the investigation the other fuel companies have not released equivalent information or taken it into the consideration. In general the use of product is under responsibility of the operator, the engine manufacturer and the competent authority.

JET A1 refined in Finland meets all requirements set for jet fuel. However, its HFRR value, indicating the lubricity of diesel fuel, is higher than 0.780 mm which the EASA gave as the HFRR value of fuel used in TAE engine HP pump certification testing. The BOCLE value is unknown. Neither is there information on any possible lubricant additives. A list, pursuant to Defence Standard 91-91, issue 6, of approved JET A1 lubricant additives was made available to the investigation commission. Neste Oil Oyj abides by this list.

On 18.3.2008 the Finnish CAA published a circular letter 96/70/2007 explaining that the lubricity of the fuel pump in the TAE 125 engine can be improved by using automotive diesel fuel or a mixture of diesel fuel and JET A1 in engines. The engine manual also permits the use of diesel fuel.

2.5 Pilot action

The pilot’s total flying experience was 63 hours. He had flown five hours on the OH-CAU. Nevertheless, he mastered the engine emergency procedures and correctly completed the flight manual’s procedures. As soon as the engine malfunction appeared, he turned back towards Malmi and reported the occurrence to the ATC. The passengers said that he remained calm the whole time and informed them of the occurrence and of his intentions. Evacuation after landing proceeded normally. As soon as he made it out of the aircraft the pilot called the ATC by mobile telephone and reported the emergency landing as well as the location.

The pilot determined that the great loss of power involved a serious malfunction. However, engine power oscillated so much that he thought that he might still recover normal engine performance and, hence, continued the flight. As per his statement, there were no suitable fields for emergency landing in the area where the engine troubles started. As they flew on, such fields were fewer and farther between and some of the fields had deep furrows. An emergency landing on a field, or in any kind of terrain for that matter, always carries the risk of somersaulting or hitting a ground obstacle.

Landing in road traffic carries the risk of colliding with vehicles or obstacles at the side of the road. Risk factors include the space available, density, speed and direction of traffic in relation to the aircraft, the size of the aircraft, fuel loads as well as the relative speed difference between the aircraft and road traffic. Bridges constitute a serious danger. It is possible to land on a road, provided that the traffic is light enough for the aircraft to merge in. If this is not the case, it is more prudent to make an emergency landing in terrain or in the woods. In this case the westbound traffic on the motorway, travelling in the direction of the landing, was light enough. Furthermore, when the drivers noticed that an aircraft was about to land in front of them, they slowed down.

The pilot's decision to stay on the right hand lane of the motorway, steering towards the exit ramp, was wholly justified. Had he continued the landing roll on the motorway he would have run the risk of hitting vehicles ahead of him. Now the damage was caused by hitting obstacles on the side of the road. Since the distance between the light pole and the traffic sign was the same as the wingspan, i.e. 11 metres, in theory he could have squeezed through. Still, it is very difficult to estimate the space available from the cockpit and it is almost impossible to steer the aircraft into this space without causing any damage.

The landing roll measured from the first visible touchdown mark was143 metres. According to the flight manual the length of the landing roll is 520 ft (158 m). It was impossible to determine the final touchdown spot. The pilot said that he switched off the main power and the engine right before touchdown. This didn't, however, manage because FADEC readings show that the engine stopped only when the aircraft came to rest on the crash barrier. Besides, all the propeller pieces were under the wreckage. So the engine has generated 25–30% power during the entire landing roll. The pilot said that he applied heavy brakes. Still, there were no skid marks on the road. According the pilot he was forced to apply strong control movement with the pedals, and apply the brakes was decreased. The fact that the aircraft straddled the crash barrier shows that speed at that stage must have been fairly high.

2.6 Air traffic controller action

There were two air traffic controllers on duty at Malmi ATC. They reacted immediately when they learned of OH-CAU's engine trouble. The tower controller cleared the aircraft directly into the control zone without restrictions. Runway 36 was in use at the time. Later he recleared the aircraft to approach runway 27, onto which the aircraft could make a straight-in approach from Porvoo motorway. The air traffic controller alerted Malmi's own fire rescue units as well as the ERC of Helsinki.

The air traffic controller told the aircraft in the aerodrome's traffic circuit to land, so as to clear the airspace for OH-CAU, which was in trouble. Furthermore, at 16:28 he told OH-PTC, heading towards reporting point "Nokka", to turn towards reporting point "Deger". His intention was to use OH-PTC as a radiocommunications relay. Since Malmi cannot always read loud and clear aircraft approaching from the east and at low level, OH-PTC could have relayed the radio messages between Malmi ATC and OH-CAU. However, since OH-CAU had already made the emergency landing, no radio contact was made with it.

When the air traffic controller heard the last transmission of the OH-CAU at 16:28 he estimated that the aircraft was forced to make an emergency landing. Still, in his action he did not wholly exclude the option of OH-CAU making it to the airport. Both air traffic controllers worked together in this situation and at 16:31 they thought that they would have to issue an aircraft accident alert. However, at 16:32, the pilot of the incident aircraft called Malmi ground control and reported a successful emergency landing. After this the situation defused.

2.7 Rescue service action

At 16:27 Malmi Air Traffic Control issued an aircraft distress alert to the ERC of Helsinki which, in turn, alerted the Helsinki Rescue Department in 40 seconds. Rescue units were on their way within two minutes from the alert. The response of the ERC and the Rescue Department was both good and correct.

The ERC of East and Central Uusimaa received six calls of an emergency landing. The first call came at 16:30. The ERC alerted the East Uusimaa Rescue Department after approximately four minutes. The delay was longer than the one at the ERC of Helsinki. However, the ERC of East Uusimaa had to plot the exact position of the accident site as well as estimate how many rescue units were required and which units were the most suitable as regards their locations. The response readiness of regular units (Porvoo and Sipoo) met the requirements. The tanker unit of Tolkkinen Volunteer Fire Department was on its way approximately four minutes from the alert and the rescue and transport units of Box Volunteer Fire Department (VFD) 13 minutes from the alert. The reason why it took longer for VFD to respond was because they dispatched 13 men, whose assembly took more time. Nonetheless, response time was good and within the requirements. The scope of the response dispatched to the accident site was fairly substantial. Still, bearing in mind that the emergency alert involved a light aircraft landing on a motorway in the middle of Friday afternoon rush-hour traffic, the ERC had to prepare for the possibility of multiple serious road accidents.

3 CONCLUSIONS

3.1 Findings

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

2. The pilot had a valid licence and the required ratings.

3. The air traffic controller had valid licences and the required ratings.

4. The aircraft was equipped with a TAE 125-01 diesel engine, using JET A1 fuel. The previous engine had been replaced with a brand new one on 2.9.–3.11.2006.

5. Water had been detected in the aircraft's fuel system during the autumn of 2007. According to the pilot's statement there was no water in the fuel samples which he took prior to the flight.

6. Within approximately 13 minutes into the flight an abnormal sound was heard from the engine compartment, engine power decreased to 25–30% and both FADEC channel warning lights came on.

7. In spite of the pilot's action the engine failed to produce sufficient power and so the pilot made an emergency landing.

8. The fuel filler cap of the right hand side fuel tank was incorrectly adjusted. It did not seal properly and, therefore, it was possible that rain water could get into the tank.

9. Engine inspection revealed that the high-pressure (HP) pump was badly damaged.

10. According to the engine manufacturer's statement, the damage to the HP pump's eccentric cam bearing surface had begun prior to this occurrence. The damage has caused by water in the fuel. This was a one-of-a-kind failure, caused by free water in the fuel.

11. According to the engine manufacture's statement per 13.2.2008 the TAE HP pumps installed in Finland registered aircraft had 4717 operation hours without any defects. Further TAE has evidence that on 12 HP pumps operated in Finland registered aircraft no defects or unusual wear have been detected.

12. Three TAE HP pumps were disassembled in Finland. One was badly damaged (OH-CAU), one was worn (OH-CAZ) and the third one was in mint condition (OH-CME).

13. Fuel analyses proved that the fuel refined by Neste Oil meets all requirements set for JET A1 fuel.

14. In analyses conducted in Finland and Germany, the BOCLE lubricity values were good.

15. In the Finnish analysis the HFRR lubricity value was 0.835 mm. The EASA informed the commission that the HFRR value of the fuel used in the pump's certification testing was 0.780 mm. There are no internationally adopted requirements for JET A1 fuel which would certify its usability in diesel engines.

3.2 Probable cause

The accident was caused by a chain of events in which the HP pump failure caused the common rail pressure-control valve to jam almost entirely open. This resulted in loss of engine power because the residual fuel pressure in the common rail could only sustain engine idle.

A metal shaving from the HP pump eccentric cam bearing surface probably caused the pressure-control valve ball to jam open.

The damage on the eccentric cam bearing surface had begun already earlier, when there has been free water in the fuel. Water has probably got into the fuel system trough the incorrectly adjusted fuel filler cap. The fuel samples taken prior and after the occurrence flight there was no water in the fuel.

4 RECOMMENDATIONS

4.1 Actions taken during the investigation

On 18.3.2008 the Finnish CAA sent a circular letter to the Finnish owners and operators of aircraft fitted with TAE engines. Instructions were issued with regard to improving the lubrication. Furthermore, the importance of water removal from the fuel was underscored.

4.2 Recommendations

Justifications:

The accident was caused by failure in the aircraft's fuel system. JET A1 fuel used in the aircraft may have been a contributing factor. JET A1 fuel is refined to be jet engine fuel. Its lubricity is clearly inferior to that of diesel fuel which is meant to be used in diesel engines. The lubricity of JET A1 is not monitored regularly during the refining process. There are no internationally adopted requirements for JET A1 fuel which would certify its usability in diesel engines.

The accident was probably caused by free water, which had entered into the fuel system via the fuel filler cap. The new cap was installed in connection wit the engine change. The maintenance instructions for the installed fuel filler cap adjustment are missing.

1. *The investigation commission recommends that the EASA take action to establish whether JET A1 can safely be used as fuel in diesel engine-equipped aircraft, and if it can, the required measures.*

2. *The investigation commission recommends that the EASA consider whether a new type certificate test be required for TAE engine high-pressure fuel pumps, using such JET A1 fuel which meets the lowest permissible lubricity value set for jet engine fuel.*

3. *The investigation commission recommends that EASA take action to ensure that required maintenance instructions will be published concerning the fuel tank filler caps adjustment on the aircraft equipped with TAE-engines.*

Helsinki 6.3.2009

Jouko Koskimies Esko Lähteenmäki

Tii-Maria Siitonen

The comments to the Finnish report C7/2007L by the German Federal Bureau of Aircraft Accidents Investigation (BFU) on 27 February 2009

Dear Sir or Madame

Thank you for the opportunity to comment the a.m. report.

The BFU has the following comments:

1. to item 1.17:
TAE provide AIB Finland with information about the condition of other HP Fuel Pumps operated in Finland - see TAE Report OIR-02-01-28-09-2007, Sec. 2.5. As mentioned in this report TAE has evidence of 4717 operation hours of High Pressure Pumps installed in Finland registered aircraft without any defects on HPP. Due to scheduled maintenance/company inspection TAE has evidence that on 12 HPP operated in Finland registered aircraft no defects or unusual wear have been detected.
BFU believes that this information should be included in the factual section of the report and should be considered in analysis.

2. to item 2.4:
Page 20, Cetan Number (CN): BFU believes that the CN does not have any influence to the sequence and the cause of the accident. Different CN number of Jet A or Jet A1 vs. Diesel fuel was neither determined as fact nor mentioned in the factual section of the report.

3. to item 3.2:
BFU believes that one cause of the accident was the decision of the pilot to land on the highway. Under section 2.5 of the report the increased risk of a landing on a highway was described. Especially a flight with a single engine aircraft at low altitude outside the range to a suitable landing site increases the risk of an accident. BFU would like to propose to add this consideration into the analysis.
The pilots' intention to return to Malmi Airport was not appropriate at this situation (distance to AP ca. 17,5 km, altitude ca. 900ft).

This section does not address the occurrence of water in the fuel as probable cause of alteration of fuel properties. In conjunction with this the incorrect adjustment of the R/H wing fuel filler cap (see 3.1, item 8.) should be considered as route cause for this accident.