Investigation report

B1/2010L

Aircraft accident in Porvoo on 23 April 2010

Translation of the original Finnish report

OH-PAM

Piper PA-28R-200 Arrow II

Onnettomuustutkintakeskus
Centralen för undersökning av olyckor
Accident Investigation Board

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SUMMARY

AIRCRAFT ACCIDENT IN PORVOO ON 23 APRIL 2010

An accident occurred at Emäsalo near the city Porvoo on 23 April 2010 at 11:32 Finnish time. A Piper PA-28R-200 Arrow II, owned by *Espoon Moottorilentäjät ry* (ESMO Flying Club), made a forced landing in the woods during an instrument check flight. The pilot was fatally injured and the flight examiner as well as the passenger was seriously injured.

The aircraft took off for an instrument check flight from Helsinki-Malmi aerodrome at 10:37. The intention was to carry out a similar check flight for the passenger on the following flight. To begin with, the pilot flew an instrument approach to Helsinki-Vantaa aerodrome, as per the flight's programme, after which he flew close to the VOR beacon at Porvoo. Before returning to Helsinki-Malmi, the itinerary included a simulated VOR/DME approach. The engine failed during the simulated approach. The aircraft crashed into the woods and was destroyed in the subsequent forced landing.

Prior to the flight pilots checked the actual (METAR) and forecasted (TAF) weather, but not the Significant Weather Chart (SWC) or the General Aviation Forecast (GAFOR). The forecast included moderate icing in cloud on their intended route. The weather in the accident area kept changing. For approximately four minutes prior to the collision with the ground the aircraft was flying in conditions where the ambient temperature varied between zero and a few degrees below freezing. Furthermore, on their route they encountered heavy snow, rain and snow mixed (a.k.a. sleet) and hail, which made horizontal visibility poor.

Ice formed on the fuel injector unit, which made the fuel-air mixture too lean. This caused the engine to fail when engine power was increased from a low power setting. The engine failed at the approximate altitude of 400 m in a descent during the simulated VOR/DME approach. The engine would not restart.

No traces of volcanic ash resulting from the eruption in Iceland were found in any parts of the aircraft or the engine's air filter. Technical inspections found no such defects that could have contributed to the accident.

The accident was caused because the engine failed due to ice formation in the fuel injector unit and because of the subsequent forced landing. Ice formed in the fuel injector unit when the flight was continued into a rain shower during the final simulated approach where the conditions for icing were favourable.

Contributing factors included the flight examiner's insufficient understanding of the consequences of the prevailing weather conditions on engine performance as well as the need to wrap up the almost completed check flight as planned. Moreover, the Operation Manual (OM) of the PA-28R-200 does not provide instructions for the preventive use of alternate air to avert ice formation in the fuel injector in icing conditions.

The investigation commission made a safety recommendation to the Federal Aviation Administration (FAA) in which the commission proposed updating the Operation Manual of the PA-28R-200 with a warning about the potential for ice formation in the fuel injector unit along with instructions on icing prevention, akin to later versions of the Operation Manuals for the same aircraft type.

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ABBREVIATIONS

CHT	Cylinder Head Temperature
DME	Distance Measuring Equipment
EGT	Exhaust Gas Temperature
ft	Feet
GAFOR	General Aviation Forecast
g	Normal Acceleration
gal/h	Gallons per Hour (US)
GPS	Global Positioning System
hPa	Hectopascal
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
inHg	Inches Mercury
IR	Instrument Rating
JAR	Joint Aviation Requirements
kN	Kilo Newton
kt	Knot(s)
lbs	Pound
MCC	Multi Crew Co-operation
METAR	Aviation routine weather report
MHz	Megahertz

NTSB	National Transportation Safety Board
QNH	Altimeter setting related to pressure on mean sea level
r/min	Revolutions per Minute
SWC	Significant Weather Chart
TAF	Aerodrome Forecast
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
VOR	VHF omnidirectional radio range

SYNOPSIS

An accident occurred at Emäsalo near the city of Porvoo on 23 April 2010 at 11:32 Finnish time. A Piper PA-28R-200 Arrow II, registration OH-PAM, owned and operated by *Espoon Moottorilentäjät ry* (ESMO Flying Club), was destroyed during an instrument check flight. The pilot was fatally injured and the flight examiner as well as the passenger was seriously injured.

At the time of the occurrence the aircraft was flying a simulated VOR/DME approach during an instrument check flight. As the pilot increased engine power during the approach the engine failed and, despite several attempts, would not restart. In the subsequent forced landing the aircraft crashed into the woods and was destroyed.

On 26 April 2010 Accident Investigation Board of Finland appointed investigation commission B1/2010L for this incident. Investigator Hannu Halonen was named Investigator-in-Charge, accompanied by Investigators Hannu Aaltio, Ismo Aaltonen and Esko Lähteenmäki serving as members of the commission. Jaakko Kulomäki, M.A. (psychology) from the National Defence Academy was invited as an expert to the commission to investigate human factors.

All times in this investigation report are in Finnish local time.

Accident Investigation Board of Finland (AIB) was informed of the occurrence at 11:34. On 23 and 24 April, AIB investigators conducted an on-scene investigation together with *Itä-Uudenmaa* Police. On 24 April 2010 the wreckage was transported to *Konekorhonen Oy's* hangar where it was inspected and the engine was disassembled and inspected. Patria Aviation's Mechanical Component Department inspected the fuel system. The onboard Engine Data Management recorder was sent to the National Transportation Safety Board (NTSB) in the United States for downloading. The downloaded data were analysed in Finland. The seat belts that broke in the accident were tension-tested at the product development laboratory of the Tampere University of Applied Sciences. The Defence Forces Technical Research Centre inspected the engine air filter for volcanic ash. Hans Tefke, an aircraft technician, analysed the aircraft's maintenance aspects. No such technical defects were found that could have contributed to the accident.

The accident flight was re-enacted on an aircraft that had a similar engine data management system. The results of the flight corroborated the investigation commission's view regarding the accident aircraft's flight path and how its engine was used.

The meteorological conditions at the time of the accident were established and analysed in conjunction with the Finnish Meteorological Institute.

The NTSB was informed of the accident on 19 May 2010.

Comments on the draft final report were requested from the parties concerned, Finnish Transport Safety Agency (Trafi), Finavia, Federal Aviation Administration (FAA) and European Aviation Safety Agency (EASA). Their comments were taken into account in the final report.

The investigation was completed on 23.5.2011 and the report was translated into English.

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

1 FACTUAL INFORMATION

1.1 History of the flight

On Friday, 23 April 2010, two instrument check flights were scheduled to be flown on OH-PAM, a Piper Arrow II owned by ESMO Flying Club. Prior to these flights the pilots went to Helsinki-Malmi aerodrome for a briefing and studied the meteorological conditions (METAR and TAF) at Helsinki-Malmi and Helsinki-Vantaa. The flight examiner filed the appropriate instrument flight plans, according to which he was the pilot-in-command. Additional pre-flight briefing was conducted inside the aircraft prior to takeoff. The flight examiner handled radiocommunications throughout the flight except the emergency transmission.

Takeoff occurred at 10:37 from Helsinki-Malmi aerodrome. In addition to the pilot who was flying his proficiency check and the flight examiner there was one passenger onboard. The intention was to fly an instrument check flight with him immediately after the first flight.

During the flight the pilot had an outside view-limiting screen in front of him. These are used in instrument training for the purpose of blocking the pilot's view straight ahead. Following takeoff, Malmi Tower (TWR) handed the aircraft over to Helsinki Approach (APP). The pilot flew an ILS approach to Helsinki-Vantaa runway 22L under the control of Helsinki APP. After this approach the pilot homed towards the Porvoo VOR beacon so as to continue with the check flight's itinerary. The flight was planned to be completed in a simulated VOR/DME approach in Visual Meteorological Conditions (VMC) to Helsinki-Vantaa runway 33, using the Porvoo VOR beacon.

At 11:20 the pilot began his descent from 3000 ft (900 m) to 2000 ft (600 m). At 11:22 the flight examiner called Helsinki APP, informing them that they would terminate the instrument flight plan and continue in VMC. At 11:29 the pilot began descending from 2000 ft, established on the final approach track of the simulated VOR/DME approach.

When they had descended to approximately 1300 ft (390 m) the pilot attempted to increase engine power. However, the engine did not respond. Instead, it failed. Soon after this the flight examiner took over the controls and commenced emergency procedures to restart the engine. He asked the pilot to report the engine malfunction to air traffic control. Despite the emergency procedures the engine would not restart. The flight examiner controlled the aircraft for the remainder of the flight. Prior to the forced landing the aircraft passed a GSM mast at a distance of 120 m to its side at the approximate height of 300 ft (90 m). The aircraft was destroyed in the forced landing in the woods at 11:32.

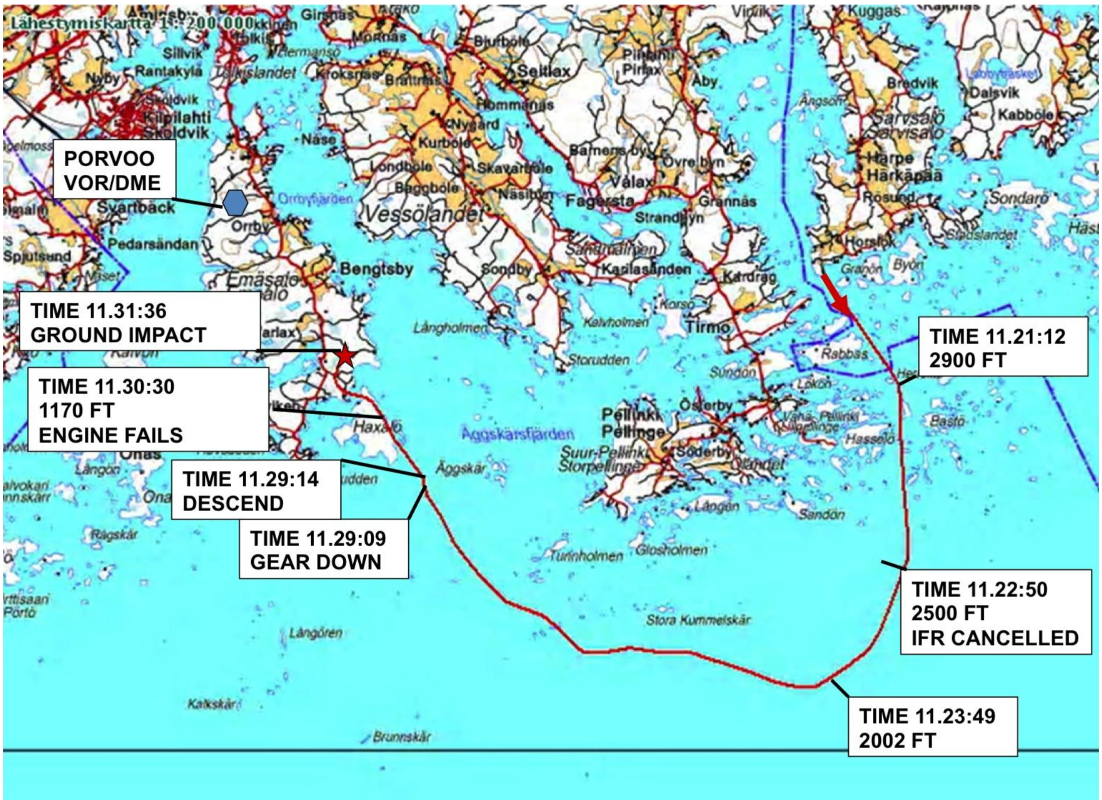

Figure 1. The profile of the flight from 11.18 onwards. Altitudes are recorded by GPS.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	1	-	-
Serious	1	1	-
Minor/None	-	-	-

1.3 Damage to aircraft

The aircraft was destroyed.

1.4 Other damage

The aircraft broke eleven log-sized trees. Approximately 140 l of aviation gas leaked onto the terrain.

1.5 Personnel information

Pilot-in-command	Age 68
Licences:	Private Pilot Licence, valid until 7 Jul 2014.
Medical certificate:	Class 2 IR with the remark: bifocals and spare glasses mandatory, valid until 27 Feb 2011.
Ratings:	Flight instructor. Single engine plane (land), valid until 31 Mar 2012.
	Flight instructor. Single engine plane (sea), valid until 31 Mar 2012.
	Flight instructor. Multi-engine plane (land), valid until 31 Mar 2012.
	Flight instructor (IFR). Single engine plane (land), valid until 31 Mar 2012.
	Flight instructor (IFR). Multi-engine plane (land), valid until 31 Mar 2012.
	Flight examiner, proficiency test, valid until 5 May 2012.
	IFR flight examiner, valid until 5 May 2012.
	MCC instructor, aeroplanes, valid until 1 Feb 2011.
	Towing pilot, revalidation not required.
	Night rating, aeroplanes, revalidation not required.
	IFR radiotelephony, revalidation not required.
	English skill level 5, valid until 7 Jul 2014.
	Finnish skill level 6, revalidation not required.

Flying experience	Last 24 hours	Last 30 days	Last 90 days	Total hours and landings
All types	00 h 54 min	22 h 00 min	54 h 00 min	27425 h 00 min
Type in question	00 h 54 min	13 h 00 min	18 h 00 min	2215 h 00 min

Pilot Age 55

Licences: Private Pilot Licence, valid until 6 Jun 2010.

Medical certificate: Class 2 IR with the remark: corrective glasses and spare glasses mandatory, valid until 24 May 2010.

Ratings: Single engine piston (land), valid until 6 Jun May 2010.

IFR rating: Single engine piston (land), valid until 31 May 2010.

Night rating, aeroplanes, revalidation not required.

IFR radiotelephony.

Flying experience	Last 24 hours	Last 30 days	Last 90 days	Total hours and landings
All types	00 h 54 min 0 landings	1 h 25 min 1 landing	1 h 25 min 1 landing	642 h 30 min 928 landings
Type in question	00 h 54 min 0 landings	1 h 25 min 1 landing	1 h 25 min 1 landing	153 h 40 min 154 landings

Passenger

The passenger had a Private Pilot Licence with an IFR rating. The intention was to fly an instrument check flight with him following the occurrence flight. His total flying experience was 1822 h 25 min, of which 1364 h 50 min in IFR.

Pursuant to Aviation Regulation TRG M1-5 no persons other than the aircrew deemed necessary for the conduct of the check flight may accompany the flight. Persons carrying out their own check flight in conjunction with that same flight also fall under the category 'necessary persons'.

1.6 Aircraft information

1.6.1 Basic information

The aircraft was a single four-cylinder piston engine, all-metal, low-wing, four-seat aircraft equipped with retractable landing gear.

Aircraft:

Type: Piper PA-28R-200 Arrow II

Registration:	OH-PAM
Owner and operator:	ESMO Flying Club (Espoon Moottorilentäjät ry.)
Usage class:	Normal
Manufacturer:	Piper Aircraft Corporation, USA
Serial number and year:	28R-7635265, 1976
Airworthiness valid until:	31 May 2010
Maximum takeoff mass:	1204 kg / 2650 lbs
Total hours:	3254 h 20 min

Engine:

Type:	Lycoming IO-360-C1C
Serial number:	L-15509-51A
Manufacturer:	Avco Lycoming, USA
Total running time:	3254 h 20 min
Running time:	645 h after complete overhaul
Fuel:	Avgas 100LL

Propeller:

Type:	McCauley B3D36C424/74SA-0
Serial number:	951118
Year of manufacture:	1993
Manufacturer:	McCauley Accessory Division, Cessna Aircraft Company.
Total running time:	1140 h 15 min

1.6.2 Maintenance analysis

The aircraft was registered on 24 June 1976. The most recent airworthiness certificate was issued on 11 May 2009. Following an inspection on 12 May 2009, an airworthiness review certificate was valid until 31 May 2010. Said certificate was issued in accordance with national requirements. On 8 April 2010 a 50 h maintenance was carried out at *Joen Service Oy* at the total hours of 3244 h, as per the aircraft's maintenance programme.

The maintenance analysis revealed shortcomings in the maintenance programme and in technical records. Judging by the documents that were provided to the investigation, supervision of continuing airworthiness did not materialise. Whereas the detected discrepancies did not affect airworthiness or the onset of the accident, the aircraft was not airworthy as per aviation standards.

1.6.3 Weight and balance

According to the weight and balance report, the basic weight of the aircraft was 816 kg. The combined weight of the flight instructor and the pilot was 189 kg, the passenger weighed 94 kg, the estimated weight of baggage was 5 kg and fuel weighed 124 kg. Takeoff weight was calculated at 1228 kg. The aircraft's maximum takeoff weight is 1204 kg. According to calculations the aircraft exceeded its maximum takeoff weight by 24 kg. The aircraft's centre of gravity was in the permissible range. No weight and balance or centre of gravity (CG) calculation was made for this flight. The excess weight had no bearing on the accident.

1.7 Meteorological information

According to the Finnish Meteorological Institute there was a extensive low front over Finland that included several sub-centres. An unstable northwesterly flow prevailed in Finland, generating widespread rain, rain and snow as well as snow showers during the course of the day. The west-northwesterly wind blew at 7–10 kt, gusting to 12–14 kt. When showers were not present, visibility was good. However, visibility decreased to 3–6 km in showers. Showers were particularly intense over the coastline, decreasing visibility to less than one kilometre in sleet and snow. The ambient temperature in dry areas varied between 2.0–2.5 degrees and in showers 0.4–1.3 degrees. Icing was at the very least moderate in cloud above the ceiling where showers were present.

In dry areas over the sea there were few (FEW) or scattered (SCT) clouds at 1500–2500 ft (450–750 m) and SCT or broken (BKN) clouds at 2500–4500 ft (750–1350 m). There were FEW or SCT clouds at the rain band at 300–1100 ft (90–330 m) and BKN clouds at 2200–4400 ft (660–1320 m).

Aviation routine weather report (METAR)

Helsinki-Malmi METAR at 10:20:

Wind 320 degrees 4 knots, visibility over 10 km, FEW clouds at 900 ft (270 m), SCT at 1100 ft (330 m) and BKN at 4700 ft (1410 m), temperature +4°C, dewpoint +2 °C, QNH 999 hPa.

Helsinki-Malmi METAR at 11:20:

Wind 320 deg 9 kt, vis over 10 km, FEW clouds at 1200 ft (360 m), SCT at 1500 ft (450 m) BKN at 7500 ft (2300 m), temperature +3°C, dewpoint +1 °C, QNH 1000 hPa.

Helsinki-Vantaa METAR at 09:50: Wind 320 deg 5 kt, vis over 10 km, BKN clouds at 700 ft (210 m), BKN at 3500 ft (1050 m), temperature +3°C, dewpoint +1 °C, QNH 999 hPa.

The two-hour trend forecast at the end of the METAR forecasted BKN cloud at 700 ft (210 m) and OVC at 1200 ft (360 m).

Aerodrome Forecast (TAF)

Helsinki-Malmi (EFHF) at 08:32:

Valid for 24 hours. Wind 300 degrees 4 knots, visibility over 10 km, SCT at 400 ft (210 m), OVC at 800 ft (240 m), from 09–10 a 30% probability for OVC at 400 ft (120 m). From 10–12 cloud base was forecasted to be BKN at 1000 ft (300 m) and OVC at 3000 ft (900 m).

Helsinki-Vantaa TAF was analogous with Helsinki-Malmi TAF.

Significant Weather Chart (SWC)

The SWC forecasted an occluded front for the planned route, including clouds from the ground up to FL 140 (14000 ft / 4200 m), rain and/or snow showers, drizzle and moderate icing in cloud.

General Aviation Forecast (GAFOR) for 6–15:

A narrow rain and snow and snow front in the southern part of the country was moving slowly to the southeast. It was followed by mostly dry weather at first but scattered rain and snow showers were to occur during the day. Northwesterly winds at 3–10 kt, 10–20 kt at 600 m. Moderate icing in cloud from the ground to FL 120 (12000 ft / 3600 m) as well as weak rain and snow. The zero temperature level was forecasted to be between the ground and 1000 ft (300 m).

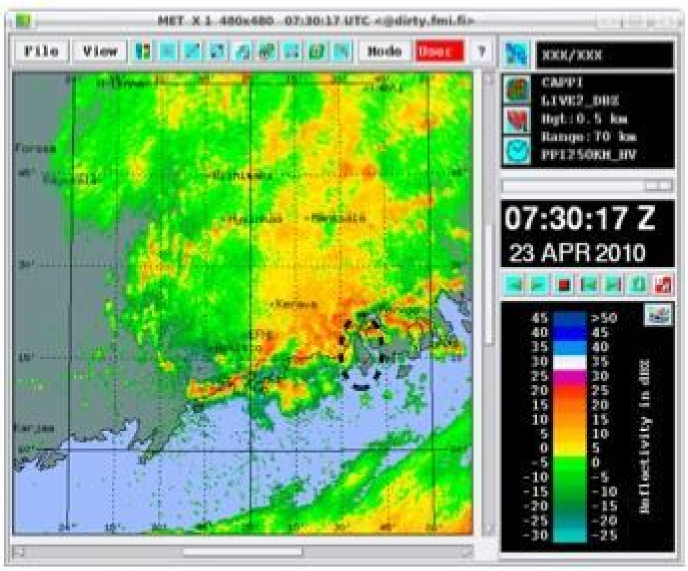

Figure 2. Weather radar image at 10:30. The developing rain band is visible over the coastline. It is still dry at Emäsalo (marked by an oval).

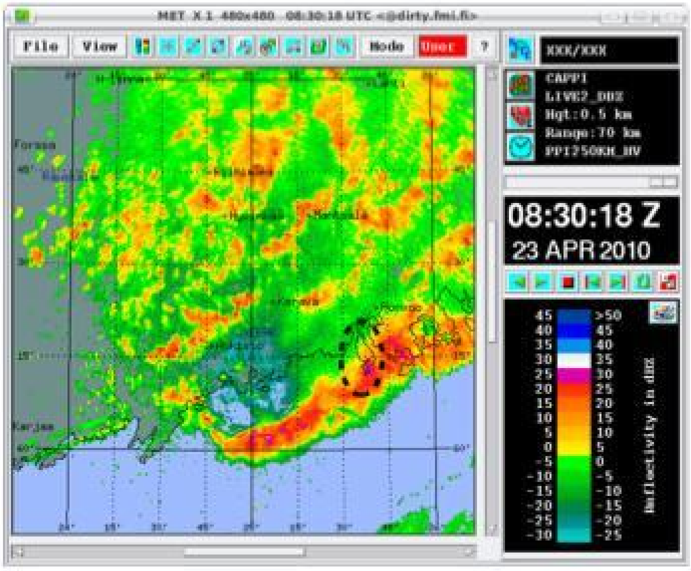

Figure 3. Weather radar image at 11:30. The intensifying rain band is moving south-southeast and has passed or is just about to pass over Emäsalo.

1.8 Aids to navigation

At the beginning of the occurrence flight the aircraft was controlled by Helsinki-Malmi TWR, followed by Helsinki APP. During the final stages of the flight the aircraft was in uncontrolled airspace. The aircraft's SSR transponder was operating normally.

1.9. Communications

The aircraft received its takeoff clearance on Helsinki-Malmi TWR frequency 131.250 MHz. After takeoff the aircraft was told to call Helsinki APP on 119.100 MHz. Later, during the ILS approach, the aircraft was instructed to call Helsinki TWR on 118.600 MHz. When the aircraft was approaching the Porvoo VOR beacon it was again told to change over to 119.100 MHz. The pilot reported the engine trouble on this frequency. Soon after this, radio contact was lost.

Radiocommunications were loud and clear throughout the flight.

Telephone communications between the ATC units worked flawlessly. Contact with the Emergency Rescue Centre (ERC) was promptly established.

1.10 Aerodrome and air traffic services information

The pilot took off from Helsinki-Malmi runway 36. The aerodrome provides air traffic control services and it is equipped with instrument approach systems. In the early stage of the flight the pilot flew an ILS approach to Helsinki-Vantaa runway 22L.

1.11 Flight recorders

The aircraft was not equipped with a Flight Data Recorder (FDR) or a Cockpit Voice Recorder (CVR). The passenger carried a GPS device and the data recorded therein were useful to the investigation. The aircraft was equipped with an Engine Data Management system (EDM-700) which records several engine parameters along with their timestamps. The information recorded by the EDM system was of particular importance in determining the cause of the engine malfunction.

1.12 Wreckage and impact information

The on-scene investigation was conducted in concert with Itä-Uusimaa Police on 23 and 24 April 2010. The forced landing occurred in fully-grown woods. The rock-strewn ground was relatively level. All peripheral parts of the aircraft were found at the accident site. This being the case, the aircraft had not disintegrated in mid-air before hitting the trees.

The wings hit several trees. The first contact occurred at the height of 18 m. The aircraft collided with the ground approximately 50 m from its first contact with the trees. When the aircraft collided with the trees the left wing detached at its root and, right before hitting the ground, the right wing also separated after having hit a tree. Following this, the fuselage crashed into the ground. At that time the roof of the cabin, having hit a tree, was crushed down to the bottom edge of the windows at the back.

The fuselage came to a halt in a level position, tilted at approximately 70 degrees to the left. The left side of the cockpit was deformed and crushed inwards a little, decreasing the legroom. The shoulder harness on the right front seat and the right rear seat belt were broken. The average dive angle after the first contact with trees was approximately 35 degrees.

Figure 4. The wreckage. In the background, trees broken by the aircraft.

The control wheels were pulled fully back; they were twisted approximately 20 degrees upwards and 40 degrees to the left. The engine control levers were bent forward, pushed against the instrument panel. The rudder pedals were in place. The other significant equipment and lever positions were as follows:

- Landing gear	down
- Flaps	10 degrees
- Fuel selector	left tank
- Electric fuel pump	OFF
- Master switch	ON
- Magneto switch	BOTH
- Pitot heat	ON
- Alt air	closed
- Trims	approximately centred

1.13 Medical and pathological information

A forensic autopsy was performed on the pilot at Helsinki University's Hjelt Institute Department of Forensic Medicine. The pilot had zero blood alcohol, nor was any narcotic substance detected. Blunt head and thoracic trauma were determined to be the cause of death.

The pilot had type II diabetes, including regular medication, which could affect the issuance of a medical certificate. The authority that issues said certificates was unaware of the illness or the medication. In this case the illness had no bearing on the accident.

The pilot-in-command had zero blood alcohol.

1.14 Fire

There was no fire.

1.15 Survival aspects

1.15.1 Alerting and reports

The pilot's radio call at 11:31:15 to Helsinki APP regarding engine trouble launched the rescue operation. The air traffic controller identified the aircraft on the radar when it was south of Porvoo. The controller asked whether the aircraft could continue towards Helsinki-Malmi aerodrome. The pilot said that this was not possible. Following this, radio and radar contact was lost. At 11:32 the air traffic controller alerted the ERC and the Aeronautical Rescue Co-ordination Centre (ARCC).

1.15.2 Search and Rescue

Helsinki APP informed Helsinki-Malmi TWR of the occurrence at 11:32. The deputy director of Helsinki-Vantaa ATC sent a last radar picture of the aircraft including map details to Helsinki-Malmi ATC and ERC. At 11:41 a twin-engine aircraft about to depart on a training flight took off on search and rescue duty. A Border Guard helicopter took off on a SAR flight at 11:45. Helsinki-Malmi ATC sent the pertinent aircraft photos and radar images to the Maritime Rescue Co-ordination Centre (MRCC) to be further promulgated among SAR units. Personnel from the Glosholma SAR Station, which was close to the accident site, searched the shorelines. Air traffic control radar information verified that the aircraft did not crash into the sea.

The Border Guard helicopter closed in on the location of the final radar echo from the direction of the sea. Due to the trees it was difficult to detect the wreckage. The rescue swimmer made visual contact with the wreckage when the helicopter passed over it. The helicopter crew gave the location of the target to rescue units by *VIRVE* Terrestrial Trunked Radio and informed them that no roads led to the site. The rescue swimmer, carrying his gear, was lowered down to the wreckage at 12:03.

The Medi-Heli air ambulance was alerted at 11:41. At 12:20 it landed in a clearing in the woods, approximately 200 m from the site, from where the doctor and the aeromedical assistant walked to the accident site.

Three ambulance units and six rescue units were alerted to the accident site. At 11:54 the first units arrived, 500 m from the site on the nearest road. The Border Guard helicopter guided the rescue personnel when they walked to the accident site. Following emergency care the injured were taken to hospital by ambulance. The pilot was declared dead at the accident site.

1.15.3 Survival aspects

According to the GPS data the aircraft hit the trees at a groundspeed of 67 kt (124 km/h). The trees slowed the aircraft down so from the first contact with the trees the aircraft travelled approximately 50 m. As the fuselage hit the ground it also hit a tree, which caused the rear part of the cabin roof to be crushed all the way down to the lower edge of the windows. The fuselage came to a halt with its nose in the direction of travel, tilted 70 degrees to the left. The left side of the cockpit was deformed and crushed inwards a little at the front of the cockpit. Otherwise the cockpit retained its shape.

The pilot’s seat belt and shoulder harness withstood the crash. Whilst the right front seat occupant’s seat belt remained intact, his shoulder harness broke. The right rear seat occupant’s seat belt broke and as a result he was flung forwards, partly on top of the front seat occupants and into the instrument panel.

The rear seats were not fitted with shoulder harnesses. The safety belts were original, manufactured in 1976. Judging by tension tests the occupants experienced acceleration forces well above 10 g. All tension-tested belts met their requirements even after having been deformed in the accident.

The rescue operation at the wreckage began approximately 30 minutes after the accident. The cockpit sheltered the victims from the rain. Despite the rapid response nothing could be done to save the pilot.

1.16 Tests and research

1.16.1 Propeller and engine inspections

Propeller

The tip of the spinner was crushed inwards. One propeller blade was intact. The second one was bent a little from the middle, exhibiting longitudinal and diagonal scoring. The third blade was badly dented, showing diagonal scoring along its length as well as nicks on the leading edge. This blade was slightly bent backwards from the middle and it had separated from the hub. All of the blades' pitch-change linkages inside the hub were broken.

Engine

The engine and the engine compartment were visually inspected before the engine was dismantled. The alternate air valve hit the firewall and was crushed as the engine shifted backwards in the crash. Marks on the firewall showed that the valve was in the closed position at the time of the crash. The gascolator bowl fastening was crushed and the bowl had come loose. The fuel filter was clean.

The starter ring gear was fractured. The intake manifolds for cylinders 2 and 4 were crushed and their gaskets were partly severed. The exhaust pipes were bent. Apart from the top spark plug for cylinder 1, which had a thin coating of soot, the spark plugs were in good condition and their insulators were of normal light colour. There was some lead fouling on the lower spark plug for cylinder 3. The magneto timing was correct and sparking occurred when the rotors were turned by hand. The magnetos were disassembled and visually inspected. The ignition coil resistance values were measured. The magnetos were in proper working condition.

On 27 April 2010 the engine was disassembled and inspected at Konekorhonen Oy's engine repair shop at Hyvinkää. The top of the left front (No. 2) cylinder head was fractured in the crash. The other cylinders, including all pistons, were in good condition. The camshaft and the valve assembly were in good condition. The valves were removed and inspected. All valve seats showed some pitting. The carbon deposit layer on the exhaust valve of cylinder No. 3 was thicker than on the other exhaust valves. Water droplets were detected on all intake manifold couplings and there was approximately one tablespoon of water in the intake manifold chamber under the oil sump.

The accessory bevel gear was in proper condition. The crankcase was opened and the crankshaft main bearings were inspected. They were in proper condition. Since the connecting rods moved freely, their bearings were not opened.

No traces of metal or impurities were found in the oil filter. The oil pump was opened and inspected. The pump was in proper condition. The fuel pump was dismantled and inspected. It worked normally. The nozzles were clean. The nozzle lines, the flow divider and the fuel injector unit were removed for testing.

1.16.2 Fuel injector inspection

On 11 May 2010 Patria Aviation's Mechanical Component Department conducted the manufacturer's recommended functional tests on the fuel injector unit as well as a general appraisal of its functioning. The test equipment used were certified for this purpose and calibrated. The manual was also up-to-date.

During the test the fuel injector unit reacted and operated normally when the test settings were being made and adjusted. Apart from one test item in which fuel flow was 0.6 lbs/min less than the manual's minimum value of 38.4 lbs/min, the settings were those prescribed by the manual. The test report stated: *The unit is fully functional and, apart from item 3 (the aforementioned pressure differential), even meets the adjustment criteria of a new unit. Such small deviations are commonplace in used equipment and they have a negligible effect on the practical functioning of the unit*.

The investigators continued to test the fuel injector unit as per their own investigation plan. The flow divider, nozzle lines and fuel filters were connected to the unit. The functioning of the unit was tested at various flow rates but there was nothing about their functioning that deserved a remark.

Testing also aimed to study the consequences of the fuel injector unit's possible icing on fuel flow. The situation was simulated by lowering the pressure of impact air and venturi suction. The test showed that even a minor drop in pressure significantly restricts fuel flow to the nozzles. Since the test had to rely on equipment and methods that were not stipulated by the test equipment manufacturer, it can only be regarded as a rough estimate.

After the tests the investigators disassembled the fuel injector unit. The fuel filter was clean and the air diaphragm as well as the fuel diaphragm were in good condition. The diaphragm chambers were dry and clean. The constant head idle spring was oxidized and the diaphragm axles exhibited some corrosion.

1.16.3 Alternate air door test

The alternate air door test aimed to establish engine behaviour when the air filter is blocked. The intake manifold of OH-PKN, a Piper Arrow II, was modified by removing the air filter and extending the hose that leads to the air filter box into the cabin. An adjustable valve specially designed for the test was attached to the end of the hose. It was steplessly adjustable from the fully open position to fully closed. To start with, the alternate air control lever was in the closed position.

The valve was slowly moved to the fully closed position at a power setting that is normally used during an approach, i.e. manifold pressure 17 inHg and engine RPM at 2400 r/min. The engine ran normally because the vacuum in the intake manifold automatically opened the alternate air door. At the power setting of 22 inHg and 2600 r/min the alternate air door generated clearly audible vibration. The vibration ended and fuel flow increased by 0.5 gal/h when the alternate air door or the adjustable valve were opened. The test was run at several different power settings from idle to takeoff power. At times the adjustable valve was fully closed. Its position did not markedly affect engine performance.

In addition, a test was run at the power setting of 16 inHg, 2400 r/min and 9 gal/h of fuel flow. When the adjustable valve was open, the fuel mixture was made leaner to 5 gal/h. Following this, the adjustable valve was closed. Manifold pressure increased to 22 inHg and engine RPM decreased to 1700 r/min. The engine began to run rough and the EGT surged. Once the mixture was made richer the engine ran normally again.

1.16.4 Engine Data Management system EDM-700

The aircraft was fitted with a J.P.Instruments-manufactured EDM-700 Engine Data Management system. The primary purpose of the system is to guarantee the best possible mixture for the engine. The aim is to optimise fuel consumption and engine temperature.

The system indicates the selected parameters in real time and records engine data in digital memory for several hours of flight. The recorded file can be transferred to a laptop for more detailed monitoring and analysis. The EDM-700 indicates and records the following parameters for each cylinder: Exhaust Gas Temperature (EGT), Cylinder Head Temperature (CHT), the Shock Cooling rate and the voltage of the electric system. Furthermore, the system measured fuel flow and total fuel consumption.

The system records the parameters every four seconds. However, when the Lean Find (LF) button is pressed, the display and recording rate is set to one second.

During the course of the accident the front and back plates of the EDM-700 detached and there were loose parts inside the box. The device was sent to NTSB. Despite the damage all recorded data could be retrieved for the purpose of investigation. In addition to the accident flight the memory contained the information from 31 other flights as well as one maintenance test run.

The values from the previous flights were compared to the values of the accident flight. On the accident flight the values were normal until 12 minutes before the accident, when the EGT of cylinder No. 3 slightly rose, only to return to the level of the other cylinders after approximately seven minutes. Fuel flow decreased to 4.5 gal/h and all cylinders' EGTs shot up approximately two minutes before the accident. Approximately 1.5 minutes later fuel flow increased to its maximum rate and the EGTs began to drop, continuing to decrease to the end of the flight. Although the fuel flow rate fluctuated, it remained quite high. Simultaneously, cylinder head temperatures rapidly decreased. Approximately 17 seconds before the accident the EGT of cylinder No. 1 increased while the others continued to decrease.

Apart from momentary voltage changes caused by extending and retracting the landing gear, electric voltage remained normal, i.e. 13.9 V, throughout the flight.

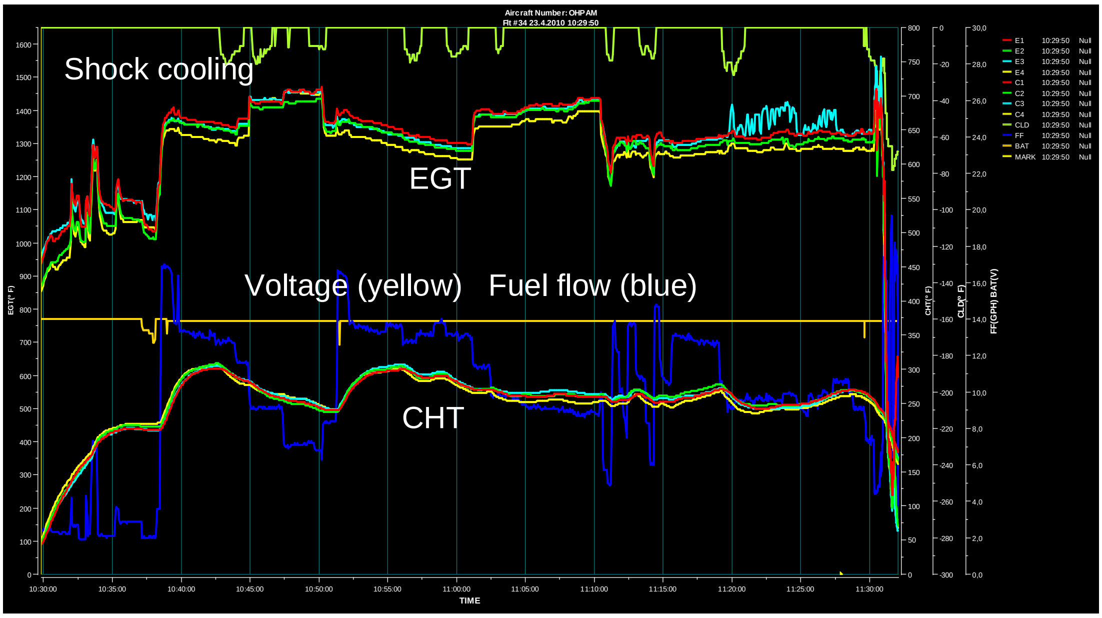

Figure 5. EDM-recorded engine parameters for the entire flight. The parameters can be studied in detail by zooming into them with the manufacturer's analysis program. A more detailed analysis of the parameters is presented in figure 11.

1.16.5 Seat belt breaking strength test

The investigation commission sent the right rear seat belt, right front seat shoulder harness, both of which broke in the accident, as well as the left rear seat belt, which was not used in the accident, to the product development laboratory of the Tampere University of Applied Sciences for tensile testing.

Four tension tests were conducted on the belts. The right front seat shoulder belt broke at 10.41 kN and the seat belt at 11.88 kN, respectively. The right rear seat belt broke at 17.05 kN and the left rear seat belt at 16.80 kN.

According to the placards on the belts they were manufactured in 1976. The placards carried the following information: *Rated Assembly Strength 2000 lbs* which corresponds to 8.90 kN. Aviation Regulation FAR23/EASA CS 23 requires that, in an emergency, safety belts must be able to withstand 9 g forward load from a 98 kg (215 lb) occupant.

All tension-tested safety belts met their requirements even after having been deformed in the accident.

1.17 Organizational and management information

ESMO Flying Club operated two airplanes for recreational aviation. Both airplanes had designated caretakers who took care of, among other things, maintenance arrangements. They had a contract with Joen Service Oy with regard to continuing airworthiness monitoring. The company also carried out scheduled maintenance for the airplanes.

ESMO Flying Club's Internet pages contain wide-ranging information for the purpose of flight operations. They include, among other things, operation manuals, weight and balance calculation sheets as well as bulletins and links, for example to web pages providing flight safety information.

1.18 Additional information

1.18.1 Previous similar occurrences

From the NTSB database the investigation commission found two occurrences in which the investigations had concluded that PA-28R-200 forced landings were caused by fuel injection system icing. Moreover, the investigation commission was told of an occurrence in which the engine failed without warning when flying in hail at FL 80 (8000 ft / 2400 m). However, the engine promptly restarted once the alternate air control was placed in the ON position.

Several flight safety articles have discussed the rare, but possible phenomenon of fuel injection system icing.

1.18.2 Flight re-enactment

In August 2010 the investigation commission flew a re-enactment on a similar PA-28R-200 airplane. The aim was to simulate the engine values, power settings and the flight path used in the VOR/DME approach during the accident flight. The following average values, derived from GPS and EDM data, were used during the approach.

- Fuel flow 4.7 gal/h
- Airspeed 90 kt
- Sink rate 800 ft/min

The landing gear was down and the flaps were set at 10 degrees.

During the re-enactment it was possible to achieve the desired flight path and fuel flow at the RPM of at 2500 r/min, 13–14 inHg manifold pressure with a lean mixture. When the mixture was rich, fuel flow was 5.1gal/h. When power was decreased the EGT values also decreased. However, during the occurrence flight the EGT values had increased.

1.18.3 Operation Manual

The Operation Manual (OM) of this type, the PA-28R-200, was most recently updated in October 2005. The OM did not provide instructions for the preventive use of alternate air to avert ice formation in the fuel injector in icing conditions. The OM, dated July 1995, of a later version of the aircraft type, the PA-28R-201, contains the following instruction: *The pilot should monitor weather conditions while flying and should be alert to conditions which might lead to icing. If induction system icing is expected, place the alternate air control in the ON position*.

The induction air and fuel systems of the PA-28R-200 and PA-28RT-201 are similar.

2 ANALYSIS

2.1 Pre-flight briefing and the events during the flight

The instrument check flight was to be flown below 4000 ft. The Piper Arrow II is approved for summer IFR operations in non-icing conditions. During the pre-flight briefing the pilots failed to study the Significant Weather Chart (SWC) or the General Aviation Forecast (GAFOR). These forecasted moderate icing in cloud as well as snow and rain and snow showers. Approximately 50 minutes before takeoff the Helsinki-Vantaa ceiling was 700 ft (210 m) and temperature +3 degrees Celsius. Judging by the meteorological data the conditions in cloud were favourable to icing during the course of the flight; the aircraft type was not approved for such conditions.

The flight examiner filed the instrument flight plans. No weight and balance or centre of gravity (CG) calculations were made for the occurrence flight. These must be done for all flights. The flight examiner handled radiocommunications during the flight except the emergency transmission. During a pre-flight briefing a flight examiner should establish that the person taking the test is capable of filing a flight plan and carrying out weight and balance as well as CG calculations. Furthermore, the flight examiner must make sure that the pilot is able to handle radiocommunications during the flight.

The flight proceeded according to plan until they began to home towards a simulated VOR/DME approach. At this time the EGT of cylinder No. 3 began to oscillate and surge. The temperature variation had no effect on the running of the engine. The oscillation may have been caused by moisture entering the engine through the air intake. Once the aircraft flew into dry weather and humidity decreased, the temperature returned to normal.

There was a delay in the onset of the descent, which caused the aircraft to remain above the planned glide path. Noticing this, the pilot significantly decreased power in order to increase the sink rate. At that point in time fuel flow was very low. Simultaneously, weather conditions deteriorated as the aircraft flew into a snow shower. The aircraft reached the normal glide path at approximately 1300 ft at which time the pilot increased engine power. However, the engine did not respond, but instead failed. The flight examiner took over the controls and commenced emergency procedures to restart the engine. He controlled the aircraft for the remainder of the flight, maintaining the airspeed at the best lift to drag ratio all the way down to the trees. Because of the restart attempts and the low altitude they had no time to carry out emergency landing procedures.

Trees in the forced landing site consisted of a tall evergreen forest. There was a nearly treeless clearance approximately 100 m to the left of the landing site. Prior to the forced landing the aircraft passed a GSM mast at a distance of 120 m to its side and at approximately 300 ft (90 m) height. It is likely that the poor visibility made it more difficult to select a landing site.

Figure 6. Aerial photo of the accident area. The red line indicates the trajectory in the air and the black line shows the flight path superimposed onto the terrain. The GSM mast is also visible in the photo.

2.2 Meteorological conditions during the flight

Excerpt of the Finnish Meteorological Institute's weather analysis for the accident area:

VMC conditions likely prevailed under the ceiling to the south of the rain band, outside the area of showers. Visibility was good, over 10 km, and the cloud base was approximately 2500–4000 ft (750–1350 m). It is likely that IMC conditions prevailed from the top of the raining clouds (ca. 3 km) to close to the ground in the area where the rain band passed; in other words below the ceiling as well. The following speaks for this:

Before the rain band arrived at Emäsalo, the temperature on the ground was approximately +2.5 degrees. However, it fell to approximately +0.4 degrees in the rain. Using the ICAO's standard, with an atmospheric change of 6.5 degrees / 1000 m it can be estimated that the zero level fell from 1300 ft (390 m) to approximately 200 ft (60 m) at its lowest. Any possible precipitation above the zero level is snow or snow grains. Moving towards the ground below the zero level it first appears as wet snow, followed by rain and snow mixed and, ultimately, rain, if the water particles have enough time to thaw before they fall to the ground. Furthermore, according to Helsinki-Vantaa METARs snow or rain and snow showers in this meteorological situation continued to be possible up to the temperature of +3 degrees when the dewpoint was at +1 degree.

Since surface synoptic observations recorded the minimum visibility in rain at 3–6 km, it is fully reasonable to presume that visibility was much worse at the altitude of 1000–2000 ft (300–600 m). Precipitation is heavier at higher altitudes because evaporation has not yet affected the rain particles. At higher altitude precipitation is mostly snow or snow grains. Concurrently, visibility is clearly worse in snow compared to rain at an equal intensity of precipitation. For example, when the intensity of precipitation is 4 mm/h, visibility in rain is approximately 4 km, but less than 1 km in snow. Weather radar echoes indicated that the rain band seemed to intensify soon after passing the weather stations. Following this, the rain band proceeded towards Emäsalo and beyond.

The GAFOR forecasted weak rain and snow mixed. Counter to the forecast, however, a very intense rain band formed along the coastline. Persons that were at Emäsalo before the accident said that visibility in the rain and snow was close to zero at times.

The passenger recounted that even when it was snowing before the accident, the ground below was visible. The flight examiner remembered good flying weather at the end of the flight. He has no recollection of having observed a rain shower or decreasing visibility. The pilot had a view-limiting screen in front of him during the flight. Since he was concentrating on instrument flying, his capability for outside observation was limited.

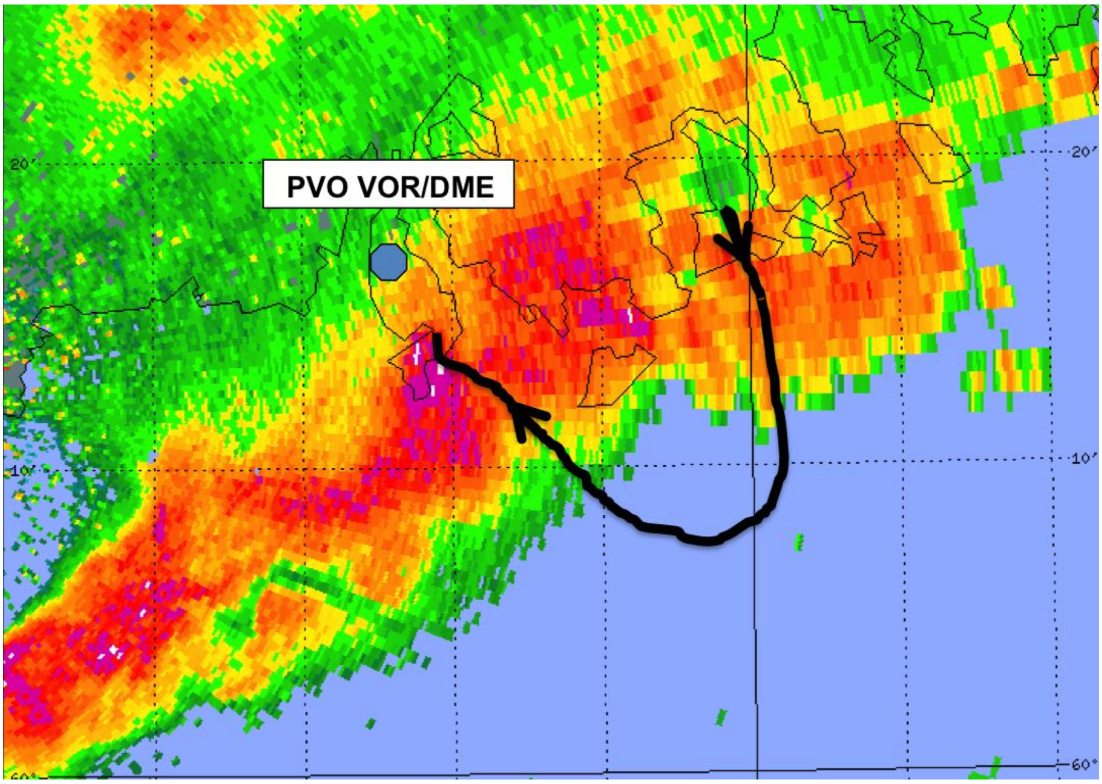

Figure 7. The aircraft's track and the rain / snow area at 11:30.

2.3 Human factors and decision-making

2.3.1 The Bow Tie model

In order to analyse the probable cause a so-called Bow Tie model was established for the accident. The Bow Tie model depicts an accident as a system comprising the following components: hazard, top event, threat, consequences and recovery controls (defence barriers) that prevent the threats from materialising, associated with consequence management. A hazard is an existing factor that, uncontrolled, can cause harm. A hazard can be, for example, a source of energy, material, a condition or an object. Hazards typical to aviation are, for instance, other aircraft, weather, the ground, etc. A top event describes a situation in which the control of a hazard is lost. A hazard materialises in a top event. Threats are vehicles through which a hazard can materialise. Threats result in a top event unless preventive controls (defence barriers) preclude this from happening.

Preventive controls can be rules, practices, equipment or persons meant to stop the progress of the causal chain before it turns into a top event. Consequences, in turn, describe the effects of a top event. Consequences represent the culmination of a causal chain. Recovery controls, in turn, aim to prevent or mitigate the consequences of a top event.

The Bow Tie model can demonstrate the way by which an inherent systemic hazard is ‘let loose’ through threats in a top event as well as its consequences. In order to establish the cause of the accident it is elemental to identify systemic threats as well as preventive controls, and estimate the functioning of preventive controls in the given situation.

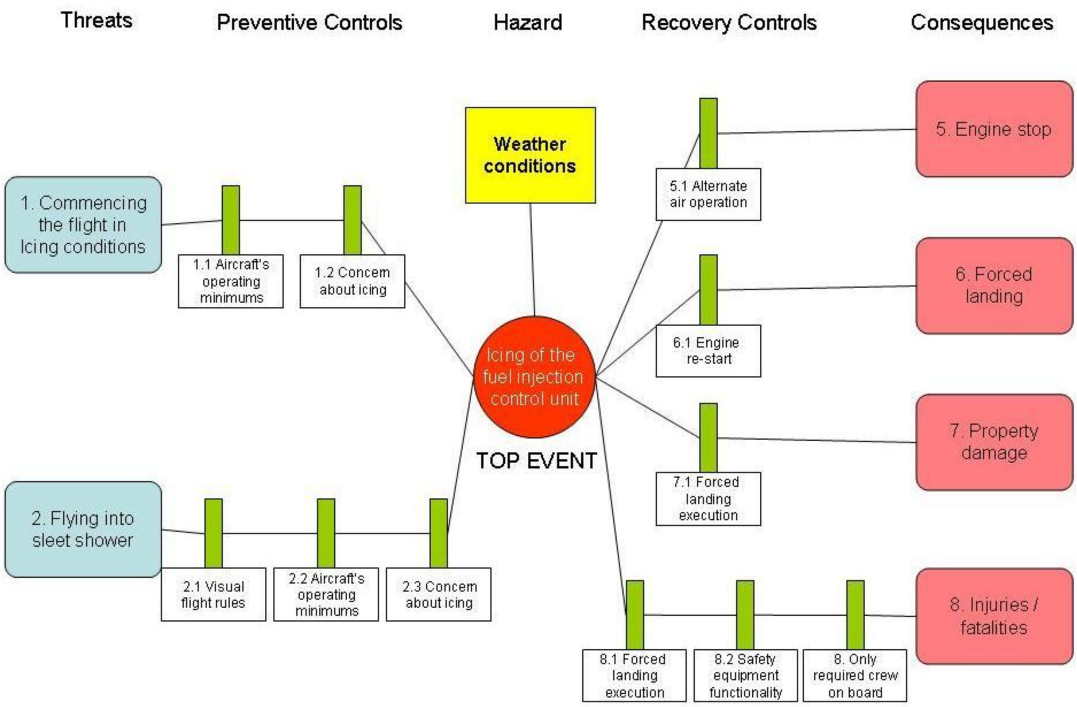

Figure 8. The Bow Tie model.

In this particular situation the prevailing weather conditions represented the hazard. It is possible to control weather hazards in aviation by taking into account the limitations the weather imposes, both during pre-flight planning as well as during the flight. Wrong or unsatisfactory decisions for the situation create threats through which weather hazards can materialise. When it comes to this instance, two key decisions led to the top event, which was ice formation on the fuel injection system, the decision to fly in icing conditions as well as the decision to fly into a rain shower during the last simulated approach. The following gives consideration to the reasons for these decisions as well as the factors which could have broken the causal chain. The numbering reflects the components of the Bow Tie model.

2.3.2 Commencing the flight in icing conditions

They decided to fly in conditions for which the weather information forecasted possible moderate icing. This aircraft type was not approved for icing conditions (1.1). While it is unclear to what extent the pilots were aware of the prevailing weather, it is likely that they did not have the best possible picture. During the pre-flight briefing the pilots failed to study the Significant Weather Chart (SWC) or the General Aviation Forecast (GAFOR), from which they could have noticed the possibility of moderate icing. The pilots hardly considered the possibility of fuel injector system icing, which ultimately led to the accident, as any kind of risk. Fuel injector icing is a relatively little known phenomenon, which they had never before encountered, let alone considered possible. The aircraft's Operation Manual did not mention this possibility.

The flight examiner's experience-based and limited understanding of the reliability of the fuel injection system, his lacking awareness of the prevailing weather as well as experiences from previous successful flights with this aircraft type in variable conditions probably led him to underestimate the risks for this flight (1.2). Furthermore, had they postponed the flight to a later date, this would have caused extra trouble. This may have bolstered their decision to carry out the flight at that point in time. The flight examiner's considerable flying experience probably increased the other participants' confidence in his reasoning and, on the other hand, made it more difficult to question his decision.

2.3.3 Flying into a sleet shower

The flight was uneventful until the last approach of the flight's itinerary. Prior to the onset of the approach the weather was probably fairly good because they decided to continue flying in VMC. During the approach the aircraft flew into a heavy shower and, as a result, the engine failed. The investigation commission believes that IMC conditions and icing conditions prevailed in the shower. The IMC conditions were probably discernible from the aircraft and the icing conditions could have been established during the pre-flight briefing. Flight according to VFR rules is not permitted when flight visibility is below 1.5 km (2.1) and the aircraft was not certified for icing conditions (2.2). The flight examiner's decision to continue the approach by flying into the shower created a risk.

It is typical for humans to continue operating as originally planned even if changing conditions would advocate the change of plans or halting an operation altogether. This subconscious disposition prevents them from taking into account information that would call for altering the original plan. This tendency dramatically impacts decision-making when the operation is about to come to an end (e.g. at the final phase of a flight). Any possibly negative consequences (loss of time and/or money) resulting from altering the plan only intensify this effect. Such consequences are typically associated with commercial aviation. Studies conducted on airline pilots show that the closer they are to the aerodrome of their destination, the more likely they will continue to fly to it although it is surrounded by thundershowers. When experience leads to the view that accidents are not likely to happen, a pilot may subconsciously believe risks are at a lower level and may even bend or break the formal rules. As a rule, veteran pilots have lots of experience in reaching their destination even in adverse conditions. They rarely encounter accidents or near misses.

No significant financial loss would have resulted from terminating the check flight. Still, the flight was nearing its end and aborting the last approach would have required arrangements for flying the test flight at a later date. It is possible that the aforementioned decision-making tendency influenced the flight examiner's decision to continue with the approach despite the weather hazard and VMC limitations. The flight examiner had plenty of experience as regards flying with fuel-injected engines in demanding conditions. This may have affected his judgment by making the situation seem less risky than it really was (2.3).

2.4 Alternate air operation

During the course of the investigation, the intake manifold was modified by removing the air filter and by installing an adjustable valve onto the end of the hose that leads to the air filter box. The valve, specially designed for the test, was steplessly adjustable from the fully open position to fully closed. The engine was run from idle to maximum power and the adjustable valve was fully closed at times. To start with, the alternate air control lever (Alt air) was kept in the closed position during the test run

The test run proved that the engine keeps running at all power settings even if the air filter becomes fully blocked. The alternate air will automatically open when the vacuum in the intake manifold sufficiently increases. It can also be manually opened from the cockpit. Once the alternate air opens, the engine receives its intake air from the engine compartment. The air in the engine compartment is heated by engine cooling. The alternate air door has no air filter.

2.5 The operating principle of a Bendix RSA-5AD1 fuel injector unit

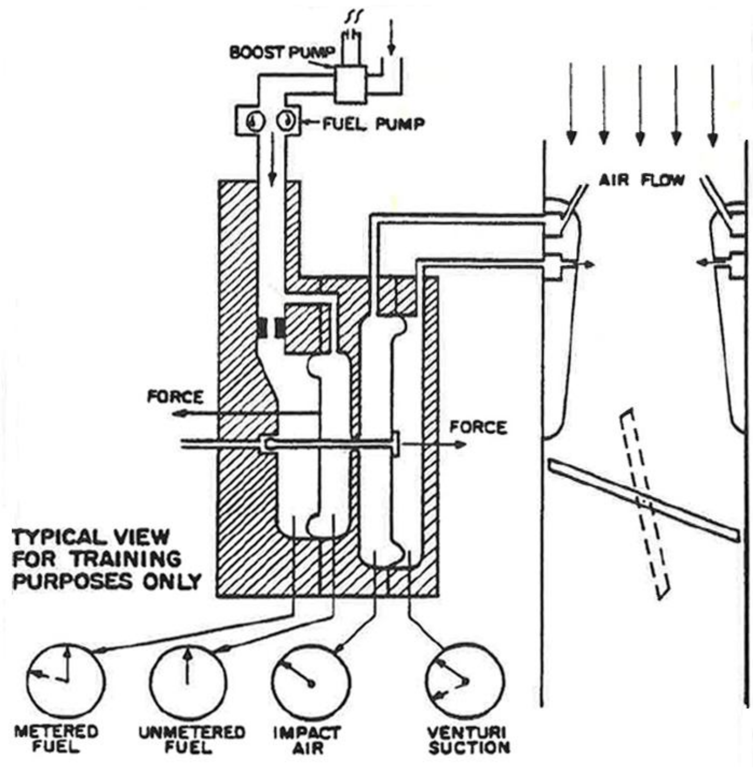

Figure 9. A schematic diagram of a Bendix RSA-5AD1 fuel injector unit. The picture does not show the idle valve (power control), the mixture valve or the connecting rod from the throttle valve to the idle valve. Picture: Precision Airmotive Corporation.

The fuel injector unit of this aircraft type is based on the principle of metering differential pressure, which balances air pressure against an optimal fuel/air mixture. If metering is inaccurate, the injected quantity of fuel is also incorrect. An incorrect fuel/air mixture, be it too lean or too rich, will result in misfire or even engine failure.

The air mass is metered with a venturi and four impact tubes facing the airflow inside the throttle body. In the image venturi suction affects the right side of the air diaphragm and the impact tubes affect the left side of the diaphragm. The resultant force caused by the pressure differential moves the diaphragm and its stem to the right. A ball valve, regulating fuel flow to the nozzles, is at the left end of the stem.

Another diaphragm is also attached to the stem. On its right side is the pressure of the fuel pump (unmetered fuel) and on the left side is the pressure of fuel flowing through the throttle valve (metered fuel). This valve (not shown in the image) is connected to the throttle valve inside the throttle body. This maintains a constant fuel/air ratio when the throttle lever is being used. Fuel pump pressure (unmetered fuel) tries to move the stem to the left. In other words, it attempts to close the ball valve. Correspondingly, pressure coming from the throttle lever-operated idle valve (metered fuel) attempts to keep the ball valve open. Since fuel pump pressure exceeds the other pressures, the ball valve tends to close. If no control pressure comes into the air diaphragm from the venturi or the impact tubes, fuel flow decreases and the mixture becomes leaner.

2.6 Fuel injector unit icing

The fuel injector unit has proved to be reliable and, unlike traditional carburettors, it is not prone to icing. Nevertheless, since it has a venturi tube, its design resembles a carburettor. Flow rate increases and temperature decreases in a venturi tube, which makes icing possible in certain temperature and humidity conditions.

The engine malfunction that ultimately led to engine failure began at 11:29:51 at which time the EGT values surged. The fuel injector fed an insufficient quantity of fuel to the engine, which made the fuel/air mixture too lean. The fuel injector unit was found to be fully functional after the accident. The investigation commission considers it likely that the malfunction was caused by ice formation inside the fuel injector unit. Because the fuel/air mixture was not rich, this means that neither the air filter nor the intake manifold was blocked with snow or ice. Rather, the mixture was lean, which was denoted by the high EGTs and clean spark plugs. The meteorological conditions in the accident area were extremely favourable to engine intake icing. Precipitation came as a wintry mix, snow, sleet and hail, and possibly even rain. Depending on the altitude, temperature varied from zero to a few degrees below zero Centigrade.

Judging by weather data and their route the aircraft had already flown in icing conditions before the engine malfunctioned. Water in all its three states had penetrated the air intake. Whereas the air filter retained the snow and hail, water made it all the way to the engine. Water was detected inside the air filter on the day following the accident. When the engine was disassembled four days after the accident water was also found on intake manifold couplings as well as in the intake manifold chamber. Corrosion was detected on the constant head spring inside the fuel injector unit's air diaphragm venturi chamber. These findings show that water passed through the fuel injector unit during the flight. It is likely that ice formed on the fuel injector unit's venturi tube, impact tubes or both.

The fuel injector unit had probably iced a little earlier, but this only manifested itself as a malfunction when the pilot decreased power in order to increase the sink rate. The pressure of 'metered fuel' decreased at that point. Icing disturbed the functioning of the air diaphragm, which is why the counter-pressure of 'unmetered fuel' was insufficient to keep the ball valve open. As a result, the fuel/air mixture became too lean.

Unlike carburetted engines, fuel-injected aircraft engines are not fitted with induction air preheating systems. Nonetheless, they have alternate air systems. This aircraft type is fitted with an automatically opening air door in case of air filter blockage. In addition, the door can be manually opened. Once the alternate air door opens the engine receives dry air from the engine compartment, preheated through engine cooling. When the alternate air system is being used, no ice formation in the fuel injector unit is possible.

The flight examiner stated that as soon as the engine failed he selected Alt air to the ON position for a moment. According to engine emergency procedures the alternate air should be placed and left in the ON position until the engine has restarted. Had they followed this procedure, the possibility for engine restart could have been higher. They had approximately one minute until the collision with the ground. The investigation commission is aware of an occurrence in which the engine failed without warning in a hail shower, but promptly restarted as soon as Alt air was placed in the ON position.

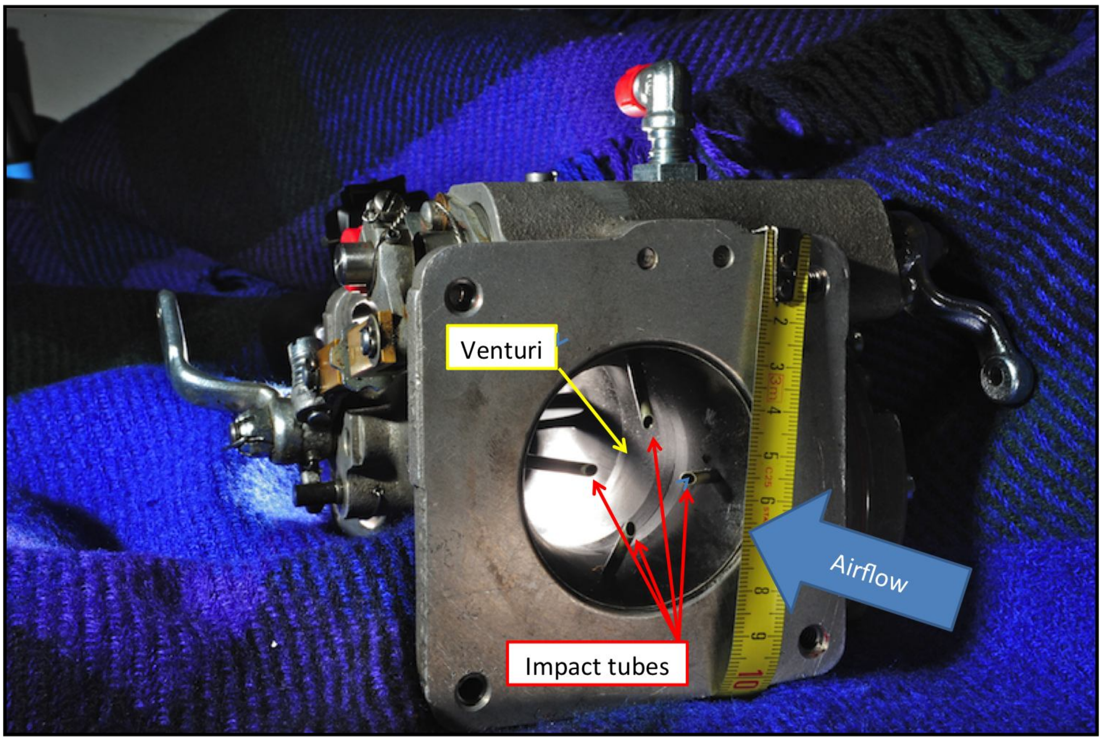

Figure 10. A Bendix RSA-5AD1 fuel injector unit.

2.7. Engine data analysis

The EDM recordings were the most important aid in analysing the cause of the engine malfunction. The commission also had access to weather information from the time of the accident, including weather radar images as well as flight path information (GPS recordings).

In order to make the mixture lean the pilot pressed the engine parameter monitoring LF (Lean Find) button approximately four minutes before the accident. This improved the scale of accuracy until the end of the flight because the device began to record engine parameters once every second instead of once every four seconds.

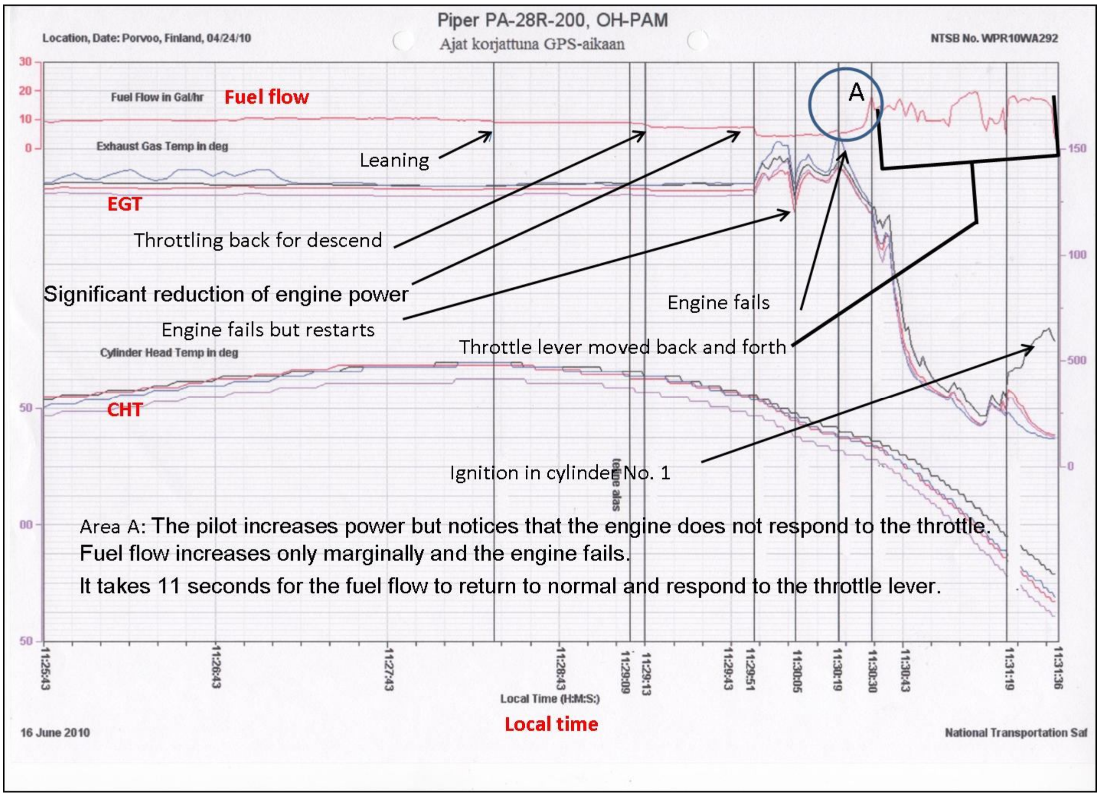

Figure 11. Engine parameter analysis from the terminal phase of the flight.

The recorded engine values from the previous 31 flights were compared to the ones from the accident flight. It was noted that all values had been within the normal range on the accident flight until 12 minutes before the accident, at which point the first signs of abnormal operation surfaced. At that time the EGT of cylinder No. 3 (blue line) rose above that of the other cylinders. Approximately seven minutes later the EGT returned to the level of the other cylinders. It is likely the lead fouling that was detected on the cylinder's lower spark plug caused the abnormal EGT, which in turn caused the spark plug to malfunction. When the air/fuel mixture was ignited by only one spark plug it burned so slowly that abnormally hot exhaust gas passed into the exhaust pipe and then into the EGT sensor when the exhaust valve opened. This phenomenon had a negligible effect on the functioning of the engine.

Prior to the onset of the descent at 11:28:23 the fuel/air mixture was made a little leaner: from 10.5 gal/h to 9 gal/h. The aircraft's voltage graph (not shown in the image) showed that the landing gear was extended at 11:29:09. At 11:29.13 engine power was reduced to the extent that fuel flow decreased to 7 gal/h. This is the normal value in a glide. Cylinder head temperatures (CHT) were decreasing and the other values, too, indicated normal values for that state of flight.

At 11:29:51 (1 min 45 s before the accident), as the descent continued, a significant fuel flow reduction to 4.5 gal/h is noticeable. At the same time the EGT lines rapidly climbed, which was the result of a lean fuel/air mixture in all of the cylinders. In contrast, on the flight re-enactment the EGT values decreased in the normal fashion. The pilot on the accident flight had rapidly decreased engine power because he needed to increase the sink rate during the approach.

The engine failed at 11:30:05. However, it immediately restarted. The pilot did not notice this because the propeller was windmilling. When he reached the correct glide path he began to increase power, at 11:30:19. He then realised that the engine was not responding to the throttle lever. The EGT lines show that the engine failed at that time in conjunction with the power increase. Following this, the throttle lever was probably pushed to the fully open position. Fuel flow increased dramatically (18.4 gal/h), albeit only after 11 seconds. The highest fuel flow rates of the previous flights had been in the range of 17 gal/h. At this point the engine was not running but the propeller continued to windmill. If the throttle lever was pushed to the maximum power position at the normal tempo (within ca. 3 s), fuel flow increased to its maximum rate exceptionally slowly, within 11 seconds.

The slow rate of increase in fuel flow was probably the result of ice in the fuel injector unit. A high fuel flow rate requires that the fuel injector unit's air diaphragm has begun to work and opened the ball valve fully. This, in turn, entails that ice in the unit has thawed. The flight examiner stated that he selected Alt air to the ON position for a moment. It is possible that this dislodged ice from the fuel injector unit.

The EGT lines show that the fuel/air mixture continued to ignite in cylinder No.1 during the final 17 seconds, when the engine was already off. The comparatively darker colour of the spark plugs in cylinder No.1 also supports this. The insulators of the other cylinders' spark plugs were very light, indicating a lean mixture. The EGT lines show a few thermal spikes that suggest random ignition, possibly even in the exhaust manifold. This normally causes backfire. People on the ground said that they heard such sounds.

The voltage graph indicates that the propeller was windmilling because the alternator generated the full 13.9 V voltage until the end of the flight.

Once the engine failed they did not manage to restart it. The fuel flow rate indicates that fuel flow was exceptionally high during the final minute, i.e. the throttle lever was mostly moved within the maximum power range while the propeller was windmilling. Since the engine RPM was low they should have moved the lever to the range that corresponded to the RPM. This would have created an ignitable fuel/air mixture and the engine might have started. Fuel flow rate and EGT lines indicate that ignition occurred in the cylinders when the fuel flow rate was momentarily lower (throttle pulled back).

2.8 Operation Manual

The Operation Manual (OM) of the PA-28R-200 does not provide instructions for the preventive use of alternate air to avert ice formation in the fuel injector in icing conditions. The OM of a later version contains this instruction. The investigation commission believes that the engine would not have failed had the aforementioned instruction been in the accident aircraft's OM and been followed.

The investigation commission considers that the OM of the PA-28R-200 should have been updated to be consistent with the OMs of the later versions because the induction air systems are similar and, correspondingly, the icing risks are the same.

Pilots commonly believe that fuel injector units will not ice. The flight examiner of the accident flight also shared this opinion. The investigation commission considers it likely that this mistaken notion is partly caused by the fact that the Operation Manual carries no mention or warning of the possibility of icing. Yet another reason for the erroneous view can be that fuel injector units rarely ice in any serious manner and that slight misfirings have not generally been associated with icing.

3 CONCLUSIONS

3.1 Findings

1. The flight examiner had the valid documents for this flight.

2. The pilot had the valid documents for this flight. When it comes to his medical certificate, he had not informed the Aviation Authority of his type II diabetes requiring medication. The illness had no bearing on the accident.

3. The aircraft had a certificate of registration, airworthiness certificate and an airworthiness review certificate. Due to shortcomings observed in the maintenance analysis the aircraft was not airworthy as per aviation standards.

4. The flight was an instrument check flight. The flight examiner was the pilot-in-command.

5. No weight and balance or centre of gravity calculations were made for the flight.

6. The investigation commission calculated that the mass of the aircraft exceeded the maximum takeoff mass by approximately 24 kg. The excess weight did not contribute to the accident.

7. There was a passenger onboard. Pursuant to Aviation Regulation TRG M1-5 passengers are not allowed on check flights.

8. The flight examiner filed the instrument flight plans and handled radiocommunications except emergency transmission.

9. When the engine malfunction occurred the aircraft was flying a simulated HEL VOR/DME 33 approach, using the Porvoo VOR beacon.

10. Neither the pilot nor the flight examiner checked the Significant Weather Chart (SWC) or the General Aviation Forecast (GAFOR).

11. Moderate icing in cloud was forecasted for the flight's planned route and altitudes. The Piper Arrow II is approved for summer IFR operations in non-icing conditions.

12. For the final four minutes the aircraft was flying in weather conditions in which the temperature varied between zero Centigrade and a few degrees below zero. At that time they encountered heavy snow, sleet and hail.

13. The pilot significantly decreased engine power in order to increase the sink rate.

14. The engine failed in a descent at the approximate altitude of 400 m when the pilot attempted to increase engine power.

15. They did not manage to restart the engine. The reason for this may have been the fact that the throttle lever was mostly moved within the maximum power range instead of a low RPM range setting.

16. They did not have the time to carry out emergency landing procedures before colliding with the ground.

17. The flight examiner made the forced landing in fully-grown woods. The wings separated in the forced landing, which slowed the aircraft down. For the most part, the fuselage retained its shape.

18. The pilot in the left front seat was killed and the flight examiner in the right front seat as well as the passenger in the right rear seat was seriously injured.

19. The shoulder harness on the right front seat as well as the right rear seat belt broke. The belts were the original ones manufactured in 1976. All tension-tested safety belts met their requirements even after having been deformed in the accident.

20. The search and rescue operation commenced without delay. Aided by radar recordings, the SAR helicopter located the accident site within 30 minutes of the accident. The helicopter's rescue swimmer, lowered to the wreckage, carried out the emergency care measures.

21. When the helicopter found the accident site the first rescue units were approximately 500 m from the site, at the end of the nearest road.

22. The search and rescue operation was properly conducted.

23. Ice formed on the fuel injector unit, which made the fuel-air mixture too lean. This caused the engine to fail when engine power was increased from a low power setting.

24. The Aircraft Operation Manual does not provide instructions for the use of alternate air in cold and humid conditions. The OM of a later version of the same aircraft type contains instructions regarding the prevention of ice formation in the air induction system.

25. The investigation commission believes that the engine would not have failed had the aforementioned instruction (finding No. 24) been in the accident aircraft's OM and had it been followed.

26. No such technical defects were found that could have contributed to the accident.

3.2 Probable causes and contributing factors

The accident was caused because the engine failed due to ice formation in the fuel injector unit and because of the subsequent forced landing. Ice formed in the fuel injector unit when the decision was taken to fly into a rain shower during the final simulated approach; the conditions for icing were favourable in the shower.

Contributing factors included the flight examiner's insufficient understanding of the consequences of the prevailing weather conditions on engine performance as well as the need to wrap up the almost fully completed check flight as planned. Moreover, the Operation Manual (OM) of the PA-28R-200 does not provide instructions for the preventive use of alternate air to avert ice formation in the fuel injector in icing conditions.

4 SAFETY RECOMMENDATIONS

4.1 Safety actions already implemented

On 27 January 2011 the investigation commission sent a notice to the European Aviation Safety Agency (EASA), the Federal Aviation Administration (FAA) and the Finnish Civil Aviation Authority (Trafi) regarding the shortcoming (subpara 4.2 of this report) noticed in the PA-28R-200's Operation Manual, dated October 2005. On 27 January 2011 the investigation commission released an interim bulletin on the AIB's Internet page regarding the aforementioned shortcoming.

4.2 Safety recommendations

1. The Operation Manual (OM) of the PA-28R-200, dated October 2005, does not provide instructions for the preventive use of alternate air to avert ice formation in the fuel injector in icing conditions. The OM, dated July 1995, of a later version of the same aircraft type, the PA-28R-201, contains instructions for the prevention of ice formation. The induction air systems of these aircraft are similar. The preventive use of alternate air can prevent ice formation in the fuel injector system.

   The investigation commission recommends that the Federal Aviation Administration (FAA) take measures to update the Operation Manual of the PA-28R-200 with a warning about the potential for ice formation in the fuel injector unit along with instructions on icing prevention, akin to later versions of the Operation Manuals for the same aircraft type.

4.3 Other remarks

Investigations into forced landings caused by several engine failures have revealed that the throttle lever has not been kept in the position of the proper RPM range during restart attempts. Therefore, an appropriate position must be found for the throttle lever so as to make the fuel/air mixture ignitable, making engine restart possible. This applies to carburetted and fuel-injected engines alike.

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