FINLAND

Accident report

B 2/1996 L

Translation of the Finnish original report

Aircraft accident at Oulunsalo, Finland 20. December 1994

N-911SG
Beech Duke B 60

According to Annex 13 of the Civil Aviation Convention, paragraph 3.1, the purpose of aircraft accident and incident investigation is the prevention of accidents. It is not the purpose of aircraft accident investigation or the investigation report to apportion blame or to assign responsibility. This basic rule is also contained in the Investigation of Accidents Act, 3 May 1985 (373/85). Use of the report for reasons other than improvement of safety should be avoided.

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Synopsis

SYNOPSIS

On Thursday, 20 December 1994 around 16.27 local time there was an aircraft accident near Oulu airport in Oulunsalo, Finland, in which a Beechcraft B 60 aircraft registered N-911SG was destroyed. The aircraft was owned by the American financing company Interlease Aviation Corporation, leased to a German undertaking named Andrea Szymanski-Ehrhardt Fischversand and operated by the German company United Seafood GmbH. The passenger, who was a male German citizen, was instantly killed in the accident. The pilot, who also was a male German citizen, was severely injured and died from his injuries on 30 December 1994. A male German citizen marked as a crew member, who was the general manager of the aircraft operator company, sustained severe injuries.

The Finnish Civil Aviation Administration appointed on 21 December 1994 a commission to investigate the accident in accordance with Aviation Act, section 56, subsection 1. Airline pilot Martin Blomqvist was appointed investigator-in-charge. Lieutenant Silvo Lenkkeri and detective chief constable Esko Hagman from the National Bureau of Investigations, Oulu district, were appointed members of the commission.

After the responsibility for aircraft accident investigation was transferred to the Ministry of Justice by amendment of law on 1 March 1996, the commission was assigned to complete the investigation in accordance with the above mentioned regulation and with the same composition as an Accident Investigation Board set up under the Ministry of Justice.

Rovaniemi area control centre reported the accident on the same day to the Civil Aviation Administration’s accident investigation department. The investigation team travelled to Oulunsalo, where they examined the accident site on the same night and switched off the ELT transmitter. Oulu police isolated the area, which was then guarded by a detachment from Oulu garrison. The investigators from Oulu Crime Investigation Centre started photographing and charting the accident site.

On the next day the investigation team photographed the wreckage and examined the cabin and cockpit. Luggage was gathered up and listed. The investigators from the National Bureau of Investigations, Oulu district, assisted in the examination and photographing of the accident site. The investigation commission arrived at the site and worked out a plan for the removal of the wreckage together with the CAA investigators. Hearings were started on the same day to find out the sequence of events.

The hearings were continued on Thursday 22 December. The engines and wings were removed from the wreckage and transferred to Oulu airport for detailed inspection.

On Friday 23 December the hearings went on and the fuselage was moved to Oulu airport for inspection. The charting of the accident site was completed. The components separated from the aircraft were gathered up and marked.

Detailed inspection of the wreckage and the engines was started in a hangar at Oulu airport on 27 December 1994. A representative of the aircraft manufacturer was present, and most of the inspections were completed in January 1995.

Specific examinations were carried out for the investigation commission by Neste Oy, Finnair Oy and Trimble Navigation. Radar engineer Olavi Hettula from Rovaniemi performed the analysis of Oulu airport MSSR recordings concerning the accident flight. An expert opinion on the medical substances found was obtained from the Poison Information Centre *(Myrkytystietokeskus).*

In order to obtain information on crew qualifications, training and experience as well as issues related to aircraft operation, the investigation commission contacted the aviation authorities of USA, where the aircraft had been registered, and Germany, which was the native country of the aircraft operator and its occupants.

The regulations and instructions relating to airworthiness and flight characteristics of the accident aircraft were reviewed with assistance of the Finnish Civil Aviation Administration, aircraft manufacturer Raytheon Beechcraft Company, General Aviation Manufacturers Association, the Finnish Air Force, individual pilots, aircraft repair shops, oil companies as well as refuelling equipment manufacturers and suppliers.

After the accident the general manager of the aircraft operator company was treated at Oulu central hospital, where the investigation commission interviewed him on 2 January 1995. He was transferred to Germany for further treatment on the same day, and therefore his actual hearing could not be conducted in Finland. The investigation commission conveyed a request through the National Bureau of Investigations for the German judicial authorities to conduct the hearings in Germany. However, the investigation was hampered and delayed by judicial difficulties relating to this request for assistance, and the general manager registered as a crew member could not be questioned during the investigation.

Moreover, the investigation commission did not have access to the original flight logs of the pilot-in-command or the crew member. It only obtained low-quality photocopies, which were only partly legible and did not cover the entire flight logs. Therefore the crew members' flying experience, total flight time and experience on different aircraft types could be determined only partially.

In order to study technical data and operational information as well as to verify some facts that came out during the investigation, the investigator-in-charge travelled to Germany and, together with a representative of the German aviation authority, visited the aircraft possessor and operator company general manager in Bremerhaven.

The investigation report was completed on 30 September 1996. The commission sent the draft of this aircraft accident report to the accident investigation authorities of Germany and USA for comments according to ICAO Annex 13 respectively on 11 and 14 March 1997. Their comments are reflected in the report.

1. FACTUAL INFORMATION

1.1 History of the flight

The aircraft registered N-911SG arrived in Oulu on a private flight from Bremerhaven, Germany (EDWB) on 20 December 1994, with the intention to continue the flight to Murmansk, Russia (ULMM). Landing time at Oulu airport was 15.03. The aircraft had one passenger in addition to the pilot-in-command and a representative of the operator company, who had been marked as a crew member.

After the landing the pilot-in-command contacted air traffic control by radio and told that the aircraft needed refuelling, without mentioning the fuel type required. The ATC officer transmitted the information by telephone to the fuel company, saying that the aircraft would take JET. According to the delivery receipt, the aircraft was refuelled with 664 litres of jet fuel, JET A-1, whereas the proper fuel type for the aircraft would have been AVGAS 100LL.

The aircraft was refuelled on a stand situated in front of the terminal building. The fuel was delivered by a tanker car used only for JET A-1 refuelling and equipped with labels clearly indicating the fuel type. The representative of the aircraft operator/possessor company, who had been registered as a crew member in the aircraft log book, was present during refuelling, and the tanks were filled up according to his instructions on the quantity of fuel needed. He also accepted the fuel sample presented to him and signed the delivery receipt. He paid for the fuel in cash.

The fuel tanks had not been marked with the minimum fuel grade of aviation gasoline used, as provided for in the airworthiness requirements. The filling orifices were equipped with restrictors in order to prevent jet fuel nozzles from going in and thus to prevent incorrect refuelling.

The tanker car replenishment nozzle had been manufactured with an expansion, which had been shaped and dimensioned to fulfil the requirements set for jet fuel nozzles in different standards. The expansion is intended to prevent jet fuel nozzles from fitting into the orifices of aviation gasoline tanks. However, after the expansion the nozzle tip had been shaped as a Camlock coupling, which was smaller in dimension than the expansion and thus fitted into the reduced filling orifices, making it possible to fill the aviation gasoline tanks with jet fuel.

During refuelling, the pilot-in-command visited meteo and paid for the landing.

The aircraft had an IFR flight plan drawn up by the pilot-in-command for the continued flight from Oulu to Murmansk. According to the plan, flight time was one hour and 35 minutes, alternate aerodrome Ivalo (EFIV) and endurance 5 hours. The aircraft left for this planned flight from Oulu, runway 30, at 16.19. It had been cleared to Murmansk and to climb after take-off to FL 160 with a right turn.

According to the ATC officer who had monitored the take-off, the gradient of climb was rather low. Four minutes after take-off the ATC officer gave the departure time to the aircraft and asked the crew to change over to Rovaniemi Area Control Centre radio frequency. The crew acknowledged the frequency. Without contacting Rovaniemi ACC the crew called again at Oulu ATC frequency at 4 min 47 sec after take-off, stating that they wanted to return to the airport because they were having some problems. The ATC officer cleared the aircraft to call on final 12. Approximately 10 seconds after this transmission the ATC officer asked whether any emergency equipment was needed, and the answer was negative. At 16.25.25, when the ATC officer asked if the crew had the field in sight, the crew confirmed this and reported that their DME distance was 6 nm.

At 16.26.11 the crew called mayday, stating that both engines were stopping. At 16.26.38 the mayday call was repeated and emergency landing reported.

Rovaniemi ACC monitored the aircraft by radar, and the last reliable radar contact was established at 16.26.30. On the basis of recorded radar data, the crash site was estimated to be approximately 1 NM from Laanila NDB, in the direction of 60°. Rescue units found the aircraft in a forest at 17.06. It had struck into trees, turned upside down and been destroyed. The aircraft door was shut and the occupants were still inside. The passenger on the back seat had been thrown away from his seat and was found dead at the accident site. The pilot-in-command was on the left front seat, seriously injured and unconscious, with his seat belt fastened. The right crew seat occupant was injured but conscious, and his seat belt was fastened as well. It came out during the investigation that he was actually a passenger.

1.2 Injuries to persons

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

1.3 Damage to aircraft

The aircraft was destroyed.

1.4 Other damage

Trees were cut, scratched or fallen down within an area of approximately 140 x 10 m along the wreckage path. Additionally the soil was contaminated, since the fuel tanks burst in the crash and fuel was spilled along the wreckage path and on the crash site. The accident site was located in a groundwater area from which water is supplied to local inhabitants.

1.5 Personnel information

1.5.1 Pilot-in-command

Personal data:	male, 51 years, German citizen, domicile Bremerhaven, Germany
Licences:	Commercial Pilot Licence issued by the German aviation authority on 17 November 1969, last renewed on 13 July 1994, valid until 24 August 1995. Required to wear corrective lenses. FAA Commercial Pilot Licence, issued on 31 July 1993, subject to validity of the German licence.
Ratings:	Multi-engine IFR. IFR rating valid until 24 August 1995. Last instrument check flight performed on 12 July 1994. Rating for aero-tow flights.
Type ratings:	Single-engine, land, MTOW less than 2000 kg Beech 55,56,58,60,76,95 Commander 680T, V, W, 681, 690
Flying experience:	The investigation commission did not have access to the PIC's personal flight log, and therefore his flying experience could not be determined in detail. According to the information obtained from the German aviation authorities, his total flight time in July 1993 was 2024 h, of which 1641 hours were on single-engine aeroplanes, 101 hours IFR flights and 4 hours night flights. From July 1993 to July 1994 he had accumulated

142 flying hours, of which 120 h en-route, 11 h on Beech 60 and 5 h on Beech 95.

Flying training: Information on initial training was not available.
According to the information obtained from the German aviation authorities, the Commercial Pilot Licence had been issued on 17 November 1969.
Detailed information on training was not available.

Experience on the type: According to the accident aircraft journey log book, he had flown the aircraft for the first time on 8 August 1993. His command experience on the type was 23 h 51 min, gained between 8 August 1993 and 20 December 1994. The total number of flights was 11 and of landings 18.

1.5.2 Fuelling crew

The aircraft operator company representative and a serviceman were present during refuelling.

1.5.2.1 Operator company representative

In the flight plans filed for the accident flight and the flight preceding it, UTS Seafood GmbH had been marked as the operator. The possessor was Andrea Szymanski - Ehrhardt Fischversand, to which the aircraft had been leased.

The operator’s representative at the refuelling site was the general manager of the operator company, who was a 55-year-old male German citizen, resident in Bremerhaven, Germany. He held a Private Pilot Licence issued by the German Aviation Authority on 20 July 1990 and last renewed on 18 August 1993, valid until 21 August 1995. He had ratings for single-engined land aeroplanes, MTOW 2000 kg, Beech 55, 56, 58, 60, 76 and 95, no IFR rating. A requirement to wear corrective lenses had been marked on the licence. His Radio Operator's Licence entitled him to operate on VFR flights only and in the German language. He also held an FAA Private Pilot Licence with single and multi-engine class ratings issued on 4 June 1993, which was valid subject to validity of the German licence.

1.5.2.2 Serviceman

The accident aircraft was refuelled by a serviceman working for HR Aviation, a company which delivers and sells Shell aviation fuel and lubricants. He is a 22-year-old Finnish citizen resident in Oulunsalo, who has been employed by the company since March 1994. He was given the basic training for aircraft refuelling duties at HR Aviation by an active partner of the company.

According to the report presented to the investigation commission, the basic training was given in March 1994 and the associated fire fighting drill carried out in May 1994. The serviceman had also worked approximately 1,5 years for an airline in aircraft towing and version change duties.

1.6 Aircraft information

The aircraft was a pressurised, twin-engined, low-wing, 6-seater piston-engine aircraft.

Nationality and registration:	N-911SG
Registration number:	
Owner:	Interlease Aviation Corporation 466 Central Avenue Suite 27 Northfield, IL 60093, USA
Possessor (lessee):	Andrea Szymanski-Ehrhardt Fischversand Halle X Abt. 3 - 7 27572 Bremerhaven, Germany

Operator (as marked in the flight plan):	United Seafood GmbH Halle X Abt. 3 - 7 27572 Bremerhaven, Germany
Manufacturer:	Beech Aircraft Corporation, USA
Type:	Beech Duke B60
Serial number and year of manufacture:	P-510, 1979

The engines were six-cylinder boxer engines equipped with fuel injection and turbocharger.

Manufacturer:	Textron Lycoming, USA	
Type:	TIO-541-E1C4	
Serial numbers:	left L-1563-59	right L-1569-59
Running time:		
- total	left 3414 h	right 3414 h
- since overhaul	left 239 h	right 239 h
Fuel used:	Avgas 100 LL	

The propellers were three-bladed, featherable constant-speed propellers.

Manufacturer:	Hartzell Propeller Inc.	
Type:	HCF-3YR-2UF	
Serial numbers:	left DA 1343	right DA 1339

Registration certificate:	FAA, Registration Not Transferable AC Form 8050-3(8/92) Interlease Aviation Corporation 466 Central Avenue Suite 27 Northfield, IL 60093, USA - issued 28 May 1993

Airworthiness certificate: FAA, Standard Airworthiness Certificate
FAA Form 8100-2 (8-82)
Category: Normal
- issued R 29 June 1979

The aircraft type certification was defined in FAA Data Sheet No A12CE. The type B60 was certificated on 5 October 1973 under FAR Part 23, entered into force on 1 February 1965.

The total flight time of the aircraft was 3310 h. The last annual inspection required by FAR Part 91.409 had been performed in Germany on 2 May 1994. The aircraft was found airworthy, while the total flight time was 3305 h. The engines had been overhauled on 8 April 1993, when the total time was 3175 h, and after this they had been running for 239 h installed in the aircraft.

The Certificate of Airworthiness had been issued at the factory of Beech Aircraft Corporation on 29 June 1979, and the aircraft was then registered N-555MT. It has also been registered as N-1NG.

The aircraft MTOW is 6775 lbs (3073 kg), and with this mass the certificated centre of gravity forward limit is 134,6” and aft limit 139,2”. The calculated fuel mass is 1392 lbs (631 kg) with the tanks full of aviation gasoline. After the accident it was found that there was 22 lbs (10 kg) of luggage in the nose compartment and 47 lbs (21,3 kg) inside the plane. In addition, there were route manuals, equipment and catering intended to be consumed during the flight, the total mass of which was approximately 11 lbs (5 kg). The actual weight of the back seat passenger was 201 lbs (91 kg). The combined weight of the crew seat occupants was 375 lbs (170 kg).

Determined on the basis of these figures, the take-off weight was 7005 lbs (3178 kg), which is 230 lbs (104 kg) more than allowed. Centre of gravity position was 135,9”, which is outside the limits specified in the Aeroplane Flight Manual.

In Oulu the aircraft was refuelled, instead of AVGAS 100LL, with 664 litres of JET A-1, the calculated mass of which is 1156 lbs (524 kg). The mass difference compared to the same quantity of aviation gasoline is 103 lbs (47 kg). Therefore the actual take-off weight was 7108 lbs (3224 kg), which is 333 lbs (151 kg) more than allowed, and the centre of gravity position was 136,0” and outside the certificated centre of gravity limits.

The excess weight has affected the aircraft take-off distance, climb rate and cruising speed.

1.7 Meteorological information

Weather at Oulu airport at the time of take-off (16.19) was: wind 210/10 kt, variation 170-250°, visibility 30 km, clouds 6/8 1700 ft, 7/8 2200 ft and 8/8 3000 ft, temperature +2°C, dewpoint -1°C, QNH 1004 hPa.

In Oulu the sunset was at 14.03. During the refuelling, which was started at 15.20 and finished at 15.30, the twilight was changing into darkness, intensified by the cloudiness. On the other hand, the aircraft stand area next to the terminal building had a good general lighting, and the thin snow cover probably reflected the light and reduced the effect of twilight and beginning darkness.

On 22 December, the sun is reported to set in Oulu at 14.04, twilight time is 1 h 28 min and darkness lasts 17 h 31 min.

1.8 Aids to navigation

The aircraft was equipped with 2 ADF, 2 VOR/ILS/DME, 2 transponders, encoding altimeter, gyrosyn compass, magnetic compass and a GPS-navigator. The required route and aerodrome charts were on board. Aids to navigation did not contribute to the accident.

1.9 Communications

Radio communications between the crew and Oulu TWR were recorded when the aircraft arrived in Oulu, when it departed for the accident flight and during the flight until the message on forced landing was received.

Time [UTC]	**Station**	**Radio communications between the accident aircraft and Oulu TWR when the aircraft arrived in Oulu**
12.49.19	N911SG	Oulu TWR good afternoon, N911SG
12.49.27	TWR	Good afternoon N911SG, Oulu, go ahead
12.49.31	N911SG	Inbound LAA, eighteen miles to go, descending passing 5000 feet descending to 3000 feet
12.49.41	TWR	NSG roger, you are cleared to LAA, cleared to 2000 ft, QNH 1003 (one double ouh three), runway 12 in use latest metreport at 11.50 UTC: Wind 210/11 kt, visibility 15 kilometers and rain, clouds 2/1800 feet, 4 / 2200 feet, temperature plus 2, dewpoint minus 1, braking action is good, friction quefficients 50, 39, 52 and for your information in the middle part of the runway is partly very slippery
12.50.38	N911SG	SG that is copied, call you next LAA
	(TWR)	(press of the transmit button)
12.53.55	TWR	NSG request your altitude please
12.53.57	N911SG	Roger reaching 2000 feet
12.54.01	TWR	Thank you. Finnair 444 you are cleared ....
	N911SG	NG passing LAA outbound
12.55.32	TWR	LSG you are cleared for ILS-approach rwy 12 check QNH 1004 now
12.55.41	N911SG	Cleared ILS 12 and QNH 1004
13.00.39	N911SG	NSG is established ILS 12
13.00.54	TWR	Roger, report outer marker
13.00.57	N911SG	Next outer marker, SG
13.01.11	N911SG	SG passing outer marker inbound
13.01.19	TWR	SG cleared to land , wind is 210 degrees 11 kts
13.01.29	N911SG	Cleared to land 12, NSG
13.01.52	TWR	NSG in case of mist approach climb 4000 feet on rwy heading
13.02.05	N911SG	NSG, roger
13.02.40	N911SG	Wind check please
13.02.45	TWR	210/12 gustings up to 15 kts
13.03.42	TWR	NSG landed at time 03 taxi to the apron and stand number 3 is for you
13.03.58	N911SG	Stand number 3 NSG
13.04.12	N911SG	NSG wants to refuel, have we to go to the station or is a car coming
13.04.50	TWR	A Shell-car is coming to you on the apron
13.04.56	N911SG	Thank you
13.05.29	TWR	NSG, request passengers on board
13.05.34	N911SG	2 pilots, one passenger
	TWR	Thank you

Time [UTC]	Time +/- to take-off	Station	Radio communications between the accident aircraft and Oulu TWR when the aircraft departed from Oulu
14.14.52	- 4 : 08	N911SG	Tower good afternoon, N911SG
		TWR	Good afternoon N911SG Oulu, go ahead
14.14.58	- 4 : 02	N911SG	Request taxi for a IFR-flight to Murmansk 255 FL clearance
14.15.05	- 3 : 55	TWR	N911SG you are to line up runway 30 or 12, wind is 200/11 kts, QNH 1004
14.15.19	- 3 : 41	N911SG	QNH 1004 we will take rwy 30
14.15.24	- 3 : 36	TWR	Roger
14.16.36	- 2 : 24	TWR	NSG your clearance
		N911SG	Go ahead please
14.16.41	- 2 : 19	TWR	N911SG you are cleared via flight en route to Murmansk to climb FL 160 to squawk 6574
14.16.52	- 2 : 08	N911SG	N911SG is cleared to Murmansk flight en route FL 160 and the squawk is 6574
14.17.03	- 1 : 57	TWR	Oulu tower
14.18.47	- 0 : 13	N911SG	We are ... ???...dy for takeoff
14.18.50	- 0 : 10	TWR	NSG, you are cleared for takeoff, right turn out
14.18.57	- 0 : 03	N911SG	Cleared for takeoff, NSG
14.23.05	+ 4 : 05	TWR	N9elevenSG airborne at 19, contact Rovaniemi Control at 124,2. Good evening
14.23.12	+ 4 : 12	N911SG	1242 NSG
14.23.47	+ 4 : 47	N911SG	... NSG we want return to the airport, we have a little trouble
14.23.53	+ 4 : 53	TWR	Ok, call on final 12
14.23.58	+ 4 : 58	N911SG	NSG, roger
14.24.10	+ 5 : 10	TWR	NSG, do you need any emergency equipments
14.24.14	+ 5 : 14	N911SG	Aaa...negative
14.25.25	+ 6 : 25	TWR	NSG, confirm you have the field in sight
14.25.36	+ 6 : 36	N911SG	We have the field in sight, we have 6 miles to go DME
		TWR	OK
14.26.11	+ 7 : 11	N911SG	Mayday, mayday SG both engines stopping
14.26.20	+ 7 : 20	TWR	(In Finnish:) Attention, emergency! Attention, emergency! On final runway 12, six miles, American twin engine aircraft
14.26.38	+ 7 : 38	N911SG	Mayday, mayday, mayday NSG going touchdown now
14.26.46	+ 7 : 46	TWR	SG Oulu reading you thats's cloud
14.30.30	+11 : 30	TWR	NSG Oulu
14.31.40	+12 : 40	TWR	NSG Oulu

1.10 Aerodrome information

The aircraft took off from Oulu international airport, RWY 30, the length of which is 2500 m and width 60 m. The aerodrome altitude is 15,5 m (47 ft).

1.11 Flight recorders

The aircraft was not equipped with flight recorders.

1.12 Wreckage and impact information

1.12.1 Accident site

The accident site is situated in Oulunsalo municipality, Salonpää village at about 6 km from the end of Oulu airport runway 30, in the direction of 305°. The coordinates are N 64 58’ 15” and E 025 13’ 40”. Elevation of the site is 3 m (9 ft) AMSL. Terrain is even, and the area is woodland growing conifer trees. The crash site was in a strip of woods where taller trees grow between two areas of young trees. The strip is 150 - 200 m wide at the point where the aircraft first hit the trees.

The aircraft approached the site in a low gradient from north-west, over an area of young trees of 5 - 7 m in height, and hit the taller trees at the edge of the area. The first impact mark was at the top of a pine at the height of 16 m and the second at 8 m from this in the direction of travel, at the top of a pine at front left side at the height of 17 m.

After the first impacts the aircraft travelled 130 - 140 m in a forest growing mainly pines and spruces, which are approximately 20 m high and have a base diameter of 20 - 25 cm. The aircraft hit several trees, at first cutting them and later cutting and tearing up by the roots.

The aircraft struck the ground in inverted position and came to rest with the fuselage turned about 40° left from the wreckage path. Parts that had broken and separated from the aircraft when it hit the trees were found on the ground.

At first the aircraft cut trees at the height of 15,5 m and after 50 m at the height of 14,5 m. The wreckage path was 10,5 - 12 m wide and the total number of trees cut was 31. At this time the aircraft was moving with wings nearly in level position. The left wing was cut when the fuel tank forming the tip of the wing was torn off and the midwing fuel tanks were burst on impact.

After about 60 m from the first impact marks, the wreckage path became narrower and was approximately 4,5 wide at the distance of 100 - 110 m. In this narrower section the aircraft hit 18 trees, of which 15 were cut. At first the trees had been cut at the height of 14 m and later at 9,5 m. In this section the aircraft was in a right bank, nose up, and the rear end of the fuselage struck the trees.

In the final part of the wreckage path, the aircraft tore trees up by the roots and treetops were cut on impacts. The first fallen trees were at a distance of 110 m from the first impact marks. The first tree had fallen forward and to the right from the aircraft movement direction, and the top of this tree had been cut at 16 m from the base. The next tree had fallen parallel to the direction of travel and been cut at the height of 10,5 m. At the end of the wreckage path, in an area that was 25 m long and 12 m wide, 14 trees had been torn up by the roots and treetops been cut at 5,6 - 7,5 m from the base. At this time the fuel tank forming the right wingtip separated and other wing sections were damaged as well. Both propellers were torn off on impact.

At the last stage, the aircraft turned upside down and hit the ground in inverted position, gliding sidewards and nose down. The nose struck into a tree base of approximately 25 cm in diameter and the vertical stabilizer hit the ground. Before coming to rest the aircraft, which was still upside down, continued to move forward, downward and to the side. After the vertical stabilizer hit the ground, the fuselage turned 15 - 20° to the right. The aircraft came to rest on the ground in inverted position, with the fuselage in the direction of 90°. Separated treetops had been thrown on the fuselage, while tree bases had fallen parallel to the wreckage path.

Under the left engine there was the base of a small pine, which had been torn off by the root, fallen parallel to the wreckage path and cut. The treetop was on the left wing, and the base had been thrown away from the aircraft in the direction of travel. The tree had been cut at 1,8 m from the base. At the breaking point there was an impact mark left by the propeller. At the treetop, on the cutting surface left by the propeller, there was black paint that had come off from the backside of the propeller blade.

There was a strong smell of jet fuel at the accident site.

1.12.2 Wreckage

The fuselage was upside down on the ground, and the nose had been crushed up to the windshield. At the right wing the fuselage had slightly yielded and the left foremost side window was broken, but still in its place. The right foremost side window was broken and entirely out of its place. The right cabin windows were intact and the emergency exit window frame was in its place. During rescue operations, the door had been broken open and cut into several pieces, and fuselage structure had been broken aft of the doorway. The windows next to the door had been smashed when breaking in. The rescue crew had also tried to get inside the aircraft by breaking fuselage structure at the right side. Otherwise the fuselage had maintained its form relatively well at the pressure cabin area. Behind the aft wall of the cabin there were crumples and folds in the skin plate, and the fuselage bottom near the horizontal stabilizer was broken on impact.

Cockpit and cabin seats had been cut off during the rescue operations and they were found outside near the aircraft.

The right horizontal stabilizer was severely damaged, and only part of the skin plate and a spar bent backwards were left of it. The elevator had been separated. The left horizontal stabilizer and elevator were in their places, but their top ends were damaged. The vertical stabilizer had bent to the left (looking at the inverted aircraft from behind). The rudder was broken and almost torn off. The rudder trim tab was in the mid position.

The left wing had been crushed and cut at approximately 80 cm from the engine. The auxiliary fuel tank forming the tip of the wing had separated when the aircraft struck into trees. The rubber-bag-type fuel tank inside the wing had been torn and was empty. The landing gear was in its bay and the doors were shut. The wing flap spindle actuator was short, in the flap up position. Engine oil was found both on the upper and the lower surface of the wing flap. The left engine cowlings were damaged. The propeller had separated at the junction between the extension attached to the engine crankshaft flange and the propeller hub, while some of the attachment bolts had been cut and some torn off from the propeller hub. The propeller was on the ground under the aircraft nose.

The right wingtip was crushed and several impact marks were found on the leading edge of the wing. The auxiliary fuel tank forming the tip of the wing had separated on impacts into trees. The rubber-bag-type fuel tank inside the wing had been torn and was empty. The landing gear was in its bay and the doors were shut. The wing flap spindle actuator was short. The wing flap had been crushed, its tip was almost loose and had bent downward (when seen in the inverted position of the aircraft), the bending point was at the outer edge of the engine cowling. The propeller had separated at the junction between the extension attached to the engine crankshaft flange and the propeller hub, while some of the attachment bolts had been cut and some torn apart from the propeller hub. The propeller was found near the left engine, in front of the aircraft at approximately 1,5 m from it.

1.12.2.1 Examination of the cockpit

Instrument readings as well as positions of levers, switches and circuit breakers were recorded at the accident site. Some instruments and avionics were with digital displays and had no indications since the aircraft was without power. Some devices and control panels were broken on impact.

The rescue crew had moved some actuating levers and switches. Most of the original settings were found out during the interviews with the rescue crew.

It came out that the luggage inside the aircraft had not been secured and it had been thrown in all directions in the cabin on impact.

1.13 Medical and pathological information

1.13.1 Pilot-in-command

The pilot-in-command was severely injured. He was unconscious since the accident and died on 30 December 1994 without regaining consciousness. He was subjected to a complete medicolegal autopsy.

The death had been caused by strong impacts on the head and upper body, and there were abrasions and bruises in the abdominal membranes in the pelvic area. He had only his lap belt fastened.

1.13.2 Passenger on the crew seat

The general manager of the aircraft operator company, who was sitting on the right crew seat during the accident flight, was severely injured. He was treated at Oulu central hospital from 20 December 1994 to 2 January 1995, after which he was transferred to Germany for further treatment. He suffered from injuries in the upper body area. He had both his lap belt and shoulder harness fastened.

1.13.3 Passenger on the back seat

The passenger sitting on the right back seat died immediately in the accident. He was subjected to a complete medicolegal autopsy.

The passenger had sustained severe injuries in the head, upper body and limbs. He had only his lap belt fastened.

1.14 Fire

There was no fire.

1.15 Rescue operations and survival aspects

1.15.1 Search and rescue operations

After the first distress message, the ATC officer alerted the airport rescue units of an emergency. When the aircraft sent another distress message and reported a forced landing, the alert was changed into an aircraft accident alert and the ATC officer notified the accident to Oulu regional emergency centre as well. Search operations were started immediately by rescue units from the airport and Oulu regional emergency centre.

The aircraft was equipped with an ELT transmitter. A Finnish Air Force liaison aeroplane, which was on its way from Oulu to Rovaniemi at 25 NM south of Oulu on FL 90 at the time of the accident and was equipped with an ELT locator, came to assist in the search operations.

The search aircraft detected the ELT signal at 15 NM from Laanila NDB on FL 65 when in a downward glide, but did not receive directional indication for the target at that time. The aircraft passed the Laanila beacon in cloud to the sector altitude, flew the beacon pattern and continued the flight below cloud. During the glide, while the heading was 330°, the locating device displayed the direction, which was straight forward. In this direction, below cloud and at approximately 1600 ft QNH the search aircraft flew, following the directional indication, to about 10 NM from Laanila beacon, from where it turned back under the control of Rovaniemi ACC to the estimated crash site determined on the basis of radar data. As the search continued, a swinging and occasionally disappearing directional indication was received at 800 ft. Despite the weak indication, the estimated location of the accident aircraft could be determined with three bearings. Because of the darkness, however, the wreckage could not be seen, and the search aircraft continued to fly above the suspected location of the wreckage.

The ground rescue units were moving towards the estimated accident site determined according to radar detections, when the regional emergency centre informed them of a report by an unidentified person, stating that an aircraft may have crashed in the direction of Pajulampi nearby. The rescue units were proceeding towards this area, when they saw the search aircraft turning above and assumed that they were approaching the crash site. They pointed the torches to the forest at the roadside and saw the aircraft, which was upside down and partly covered with cracked trees. The wreckage was found at 17.06. The rescue units arrived at 17.10 and the area was foamed.

The ELT signal was also detected by Cospas/Sarsat satellite system for the first time at 14.54 UTC. The indicated position deviated from the actual location of the wreckage for 11,7 km at the direction of 325°, which was nearly parallel to the first bearing received by the search aircraft. The search and rescue units were not aware of the ELT equipment in the aircraft, and the ELT transmitted for several hours after the wreckage was found. Several detections of the ELT signal were reported by satellites, while the indicated locations varied 7,7 - 39,2 km from the actual location during the 2 h period. The most accurate satellite detections located the ELT signal at 0,9 km from the actual site 3 h after the accident. Satellite data was not available to the search units while the search went on, but was recovered later on during the investigation.

Having come to rest after the ground impacts, the accident aircraft had remained upside down and the ELT antenna installed under the skin plate at the forward part of the vertical stabilizer was left at a blind angle under the fuselage and the broken horizontal stabilizer. It is probable that due to the blind angle and interference caused by broken structures, the ELT signal was weak, which made its location more difficult.

Several rescue crew members tried to open the aircraft door by the outside handle, without succeeding. They broke the door window as well as cabin windows on both sides of the door and tried to open it by the inside handle through the broken windows, but the door could not be opened in this way either.

Hydraulic cutters and stretchers were then used for breaking the fuselage structure at the door and between the doorway and the aftmost cabin sidewindow, and the rescue crew managed to break the door open. At the same time, they tried to get inside the aircraft by piercing a hole at the right side of the cabin. When the door opened, the piercing was discontinued.

The rescue crew did not attempt to open the aircraft emergency exit, nor did they try to get inside through it. The emergency exit had not been marked outside the aircraft and it could only be opened from inside. The rescue crew did not know that there was an emergency exit in the aircraft.

In order to get the persons on the crew seats out of the aircraft, which was upside down, the crew seats and the empty middle seats were cut off.

The right crew seat occupant was given oxygen through the broken sidewindow. The medical unit that had been called to the accident site from Oulu central hospital arrived while the rescue operations went on, and they started immediately giving first aid to the injured as soon as they had been got out from the wreckage.

Darkness made the work more difficult: at first the rescue operations were conducted in the light of hand torches only.

1.15.2 Survival aspects

Before hitting the ground, the aircraft struck several trees and turned upside down on impacts. Moving forward, downward and to the side, the aircraft hit the ground still in inverted position and came to rest when the nose crashed into a tree base of approximately 25 cm in diameter. Due to impacts and changes in the aircraft movement direction, the occupants were subjected to strong acceleration and deceleration forces and thrown against the aircraft internal structures.

The breaking and deformation of the aircraft structure on tree strikes reduced its speed before the ground impact. This lessened the deceleration forces, and the fuselage maintained its form relatively well at the pressure cabin area because of the strong construction of the aircraft type. These factors reduced the injuries and wounds sustained by the occupants.

The passenger on the right back seat had not fastened his shoulder harness, and as the light-metal attachment bracket of the right lap belt broke, he was thrown out of his seat, hit the cabin structures and was severely injured. He died immediately in the accident. If the shoulder harness had been fastened, the load on the seat belt would have been distributed among three belt sections, and thus the seat belt would have sustained the impact forces without breaking and the passenger would have remained on his seat. In this case he would certainly have suffered less injuries and might have survived.

The shoulder harness of the pilot-in-command had not been fastened. He was severely injured and died from his wounds later in the hospital. If the shoulder harness had been fastened, he would probably have suffered less injuries and might have survived.

The right crew seat occupant’s safety belt sustained the impacts without breaking. The shoulder harness had been fastened as well, which partly prevented the passenger from hitting into aircraft structures and very much softened the impacts.

The shoulder harness protected him particularly from head injuries. He was severely injured in the accident, but survived.

1.16 Tests and research

1.16.1 Flight path

The examination and analysis of the accident aircraft flight path was carried out on the basis of radar recordings from Oulu airport secondary surveillance radar (MSSR).

Using the recorded radar data and Oulu ATC radio communication recordings, the handling of the accident aircraft on the ground was examined, the accident flight path was drawn and the timing of radio communications at different stages of flight was determined. The flight path data has been treated as it was read out from the recordings, without taking any instrument errors into account. Therefore the data is not absolutely correct and the numerical data is shown as approximate values, the error margin being ± 5 %.

It was revealed during the investigation that the timing in the different recordings did not match. According to the radar recordings (UTC times), the aircraft transponder was switched on using the code 3765 of the previous flight at 14.15.03. This is 5 min 21 sec before the start of the take-off run, which according to the recorded radar data took place at 14.16.54. The radio communication recording shows that air traffic control reported the aircraft to be airborne at 14.19. In order to coordinate the time data, it was determined that the take-off took place when the take-off run was started according to radar recordings, and the take-off time was established to be the same as the departure time 14.19.00 given to the aircraft by ATC. The time references relating to the flight path have been corrected to match this timing. According to the corrected timing, the aircraft transponder was thus switched on at 14.13.39 using the code of the previous flight.

According to ATC radio communication recordings, the aircraft asked for taxiing clearance 4 min 2 sec before take-off and according to the recorded radar data started to taxi at 3 min 17 sec before take-off. During taxiing the ATC gave the route clearance and a new transponder code, which was 6574. The aircraft acknowledged the clearance and switched the transponder into the new code 1 min 53 sec before take-off.

According to radar recordings, the aircraft taxied without stopping to the take-off position on runway 30. The radio communication recordings show that it was reported to be ready for take-off at 14.18.47, which is 13 sec before take-off. The aircraft acknowledged the take-off clearance 3 sec before the actual take-off. On the basis of recorded radar data, the aircraft stood still at the take-off position for 53 sec and was airborne after approximately 18 sec from the start of the take-off run. Take-off distance was about 500 m.

The radar recordings show that the aircraft climbed after take-off in a low gradient and was above the end of runway 12 at the height of approximately 250 ft QNH at 57 sec from take-off. 1 min 15 sec after take-off it flew over the locator beacon situated at 1,08 km (0,58 NM) from the end of runway 12 at approximately 350 ft QNH and with a ground speed of about 115 kt. Thereafter the aircraft continued the flight in a low climb gradient, turning gradually 5° to the right and increasing ground speed to approximately 125 kt.

Above Laanila NDB the aircraft was 2 min 38 sec after take-off at about 1150 ft QNH. It passed the beacon approximately 0,5 km to the right from the extended centerline of runway 30 at a distance of about 7,6 km (4,1 NM) from the airport. After Laanila beacon the aircraft continued climbing and while the climb rate and level flight speed were decreasing, it reached the height of approximately 1250 ft QNH at 3 min 2 sec after take-off. The aircraft recovered to level flight at about 8,9 km (4,8 NM) from the airport.

According to the recordings, ATC contacted the aircraft 4 min 5 sec after take-off, reported the departure time, asked the crew to contact Rovaniemi ACC and gave the frequency. The crew acknowledged the report, read back the frequency and gave briefly their own call sign (NSG).

During the radio communication the aircraft started gradually to lose height, turned 30° to the right, continued the flight after straightening and maintained the direction for approximately 30 seconds, and then started turning left. The aircraft contacted Oulu ATC again at 14.23.47, which is 4 min 47 sec after take-off, and reported that they wanted to return to the airport because they were having some problems. The ATC officer cleared the aircraft to call on final 12. According to the recorded radar data the aircraft was then at 950 ft QNH and at a distance of 15 km (8,1 NM) from the airport, turning left with a ground speed of approximately 105 kt and losing height about 500 ft/min.

The aircraft turned approximately 250° to the left in one minute, losing height at the same time, straightened and continued the flight turning slightly to the right towards the airport VOR/DME beacon. The height was approximately 850 ft QNH and the distance from airport about 14 km (7,6 NM). While the flight went on, the aircraft drifted slightly to the left and lost height at a low gradient.

When the aircraft was at the final stage of the turn, the ATC officer asked whether any rescue equipment was needed, but the answer was negative.

At 14.25.25, 6 min 25 sec after take-off, ATC asked if the crew had the field in sight. The reply was affirmative, and the aircraft was reported to be at a DME distance of 6 NM. According to radar recordings, the aircraft was then at a height of approximately 500 ft QNH and about 1,6 km to the left from runway 12 approach line, while the ground speed was about 110 kt.

At 14.26.11, which is 7 min 11 sec after take-off, the aircraft called mayday and reported that both engines were stopping. The recorded radar data shows that the aircraft was then at about 9 km (4,8 NM) from the airport, at a height of 350 ft QNH. The ground speed was approximately 100 kt before the distress message.

The aircraft disappeared from radar screen at 14.26.30, 7 min 30 sec after take-off. At that time the QNH height was about 50 ft and distance from airport approximately 8,2 km (4,4 NM).

The aircraft called mayday again at 14.26.38 UTC, 7 min 38 sec after take-off, and reported a forced landing.

1.16.1.1 Flight path drawings

The graphs were drawn on the basis of Oulu MSSR recordings. The detections have been marked at the changing points of altitude based on the secondary surveillance radar information and numbered 1 - 27. In the graphs, the time references corresponding to detections are UTC times corrected to match the time indications in Oulu ATC radio communication recordings. The time indicated in the graphs is the time from the start of take-off run according to the recorded radar data.

The accident flight radio communications were transcripted from Oulu ATC recordings, and the written text was added to the graphs. The time references of radio communications indicate the time from the start of take-off run.


2444 OULU
TOPOGRA
2533
PERÄMERI
HAILUOTO
OULUN LÄÄNI
HAUKIPUDAS
Santonen
Luodonselkä
Oulunselkä
Ojakylänlahti
2442

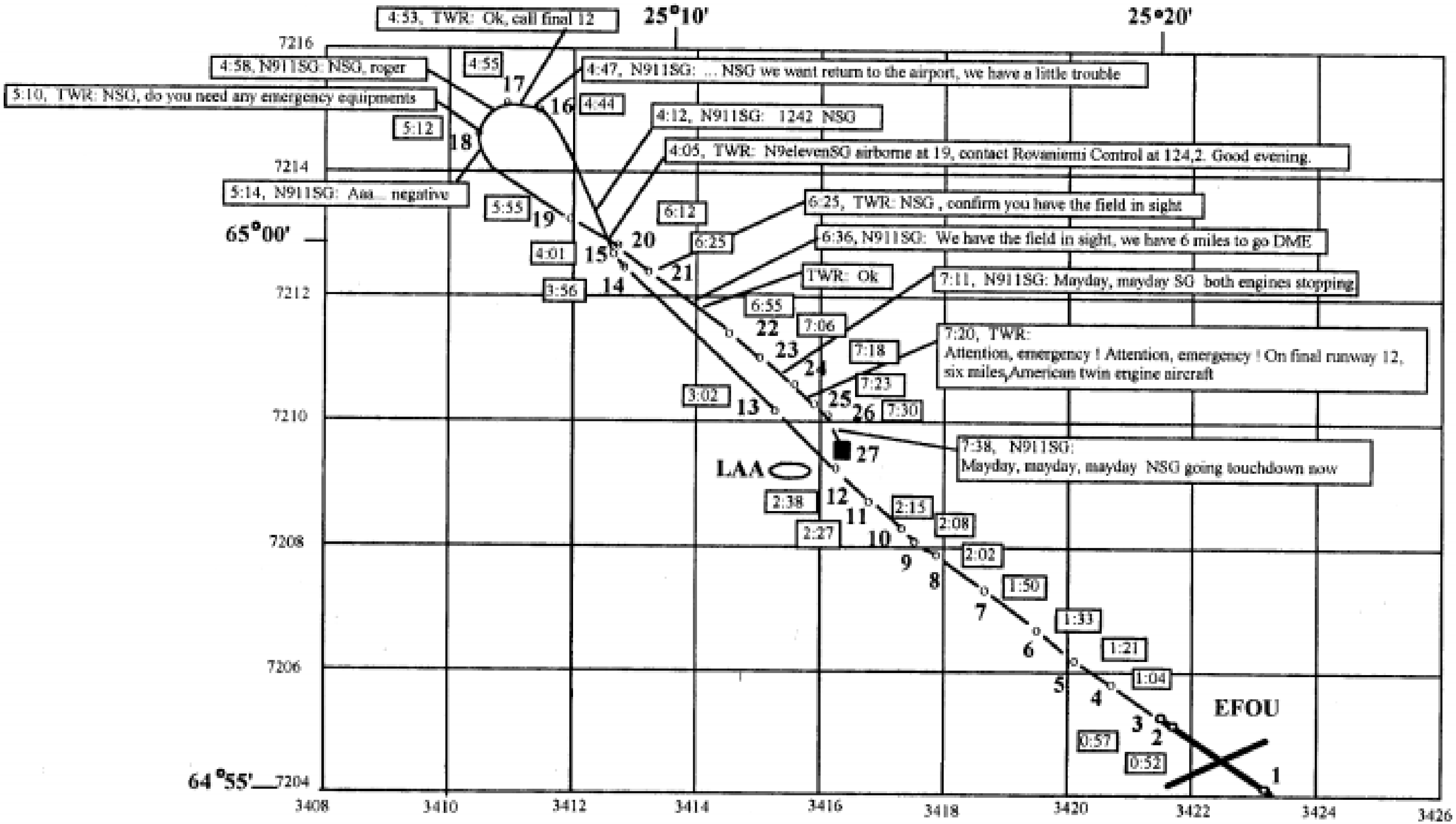
Accident flight position, altitude, time, distance and speed data

Radar detection point	Y	X	Transpond altitude (Ft)	Altitude (Ft) QNH 1004	Altitude change [Ft]	Time (corrected) (UTC)	Measure-ment interval/ antenna rotation (1/r)	Measu-rement interval (sec.)	Time from take-off	Distance flown [NM]	Calculated rate of climb (Ft/min)	Calculated ground speed (KTS)	REMARKS
R0	3423190	7204448	Ü	Ü	Ü	14.13.39	Ü	Ü	-5:21	Ü	Ü	Ü	transponder switched on at the stand
R0 **1**	3423190 3423414	7204448 7204049	Ü	Ü	Ü	14.15.43 14.17.49	Ü	Ü	- 3:17 - 1:11	Ü	Ü	Ü	taxiing started stop at take-off position rwy 30
1	- " -	- " -	300	48	Ü	14.19.00	Ü	Ü	0	Ü	Ü	Ü	at the take-off position
1.2	3423014	7204273	Ü	Ü	Ü	14.19.18	3	Ü	0:18	Ü	Ü	Ü	take-off, 1 - 1.2 take-off run appr. 500 m
2	3421567	7205195	400	148	+ 100	14.19.52	Ü	Ü	0:52	Ü	Ü	Ü	
3	3421272	7205374	500	248	+ 100	14.19.57	1	5,92	0:57	Ü	+ 1000	Ü	Radar data was recorded with the accuracy of one second,
4	3420689	7205783	600	348	+ 100	14.20.09	2	11,84	1:09	0,384	+ 500	117	and therefore the measurement intervals vary 5 -7 seconds
5	3420123	7206177	700	448	+ 100	14.20.21	2	11,84	1:21	0,374	+ 500	114	causing inaccuracy in the speed calculations.
6	3419545	7206640	800	548	+ 100	14.20.33	2	11,84	1:33	0,400	+ 500	122	In the recordings, the radar detection points have been
7	3418610	7207341	900	648	+ 100	14.20.50	3	17,76	1:50	0,632	+ 340	128	indicated once per antenna rotation, the antenna turning
8	3417914	7207805	1000	748	+ 100	14.21.02	2	11,84	2:02	0,452	+ 500	137	at constant speed.
9	3417625	7208037	1100	848	+ 100	14.21.08	1	5,92	2:08	0,200	+ 1000	122	In order to compensate for the error resulting from the
10	3417335	7208268	1200	948	+ 100	14.21.15	1	5,92	2:15	0,200	+ 1000	122	time scale used in the radar recordings, the mean antenna
11	3416823	7208724	1300	1048	+ 100	14.21.27	2	11,84	2:27	0,371	+ 500	113	rotation speed of 5,92 sec/rotation was used in the climb
12	3416296	7209192	1400	1148	+ 100	14.21.38	2	11,84	2:38	0,381	+ 500	116	rate and ground speed calculations.
13	3415309	7210120	1500	1248	+ 100	14.22.02	4	23,68	3:02	0,732	+ 250	111	
14	3412944	7212315	1500	1248	0	14.22.56	9	53,28	3:56	1,752	0	118	
15	3412654	7212545	1400	1148	-100	14.23.01	1	5,92	4:01	0,200	- 1000	122	
16	3411546	7214925	1300	1048	-100	14.23.44	7	41,44	4:44	1,454	- 140	126	
17	3410965	7215043	1200	948	-100	14.23.55	2	11,84	4:55	0,325	- 500	99	
18	3410444	7214520	1100	848	-100	14.24.12	3	17,76	5:12	0,421	- 340	85	
19	3411957	7213184	1000	748	-100	14.24.55	7	41,44	5:55	1,200	- 140	104	
20	3412762	7212670	900	648	-100	14.25.12	3	17,76	6:12	0,516	- 340	105	
21	3413289	7212316	800	548	-100	14.25.25	2	11.84	6:25	0,343	- 500	104	
22	3414619	7211275	700	448	-100	14.25.55	5	29,6	6:55	0,912	- 200	111	
23	3415134	7210932	600	348	-100	14.26.06	2	11,84	7:06	0,334	- 500	102	
24	3415660	7210465	500	248	-100	14.26.18	2	11,84	7:18	0,381	- 500	116	
25	3415897	7210229	400	148	-100	14.26.23	1	5,92	7:23	0,180	- 1000	110	
26	3416065	7210002	300	48	-100	14.26.30	1	5,92	7:30	0,153	- 1000	93	
27	3416160	7209720											accident site N 64° 58’15” E 025° 13’40”

(911Lentr.doc)

THE ROUTE AND RADIO TRAFFIC OF N911SG ACCIDENT FLIGHT

(911ROUTE.key)



SCALE 1: 100 000

1.16.2 Pre-flight preparation and aircraft loading

IFR flight plans signed by the pilot-in-command for the flights Bremerhaven - Oulu and Oulu - Murmansk were found in the aircraft. For the first route segment, Turku (EFTU) and Jyväskylä (EFJY) had been entered as alternate aerodromes, flight time was given as 3 h 45 min and endurance 5 hours. The plan for the second route segment showed Ivalo (EFIV) as the alternate aerodrome, flight time 1 h 35 min and endurance 5 hours. According to the information obtained from the departure aerodrome in Germany, the aircraft had been refuelled there on the date of departure with 532 litres of aviation gasoline. In the second refuelling in Oulu, the tanks were asked to be filled up and the quantity taken was 664 litres. According to the Flight Manual, the endurance of 5 hours requires the fuel tanks of 237 U.S.GAL (897 litres) to be full, and so the tanks have been filled up in both cases.

Operative flight plan (OFP) forms were found in the aircraft, but they were empty and any completed forms for the above mentioned flights were not found. Also a computer printout with e.g. Bremerhaven - Murmansk route beacon frequencies as well as distance and direction information for the route segments was recovered, but any written mass and balance calculations or flight time and fuel estimates for different segments of these flights were not found.

In the pilot-in-command’s luggage there was an invoice for an order by which he had acquired from Jeppesen, Frankfurt, two weeks before the accident, the Eastern Europe route manual EEU 04, Airway Manual Trip Kit and general information on the Trimble GPS navigator used in the aircraft.

The GPS navigator was removed and sent to the manufacturer, Trimble Navigation, USA. It was found out there that the device was inoperative, but it became clear that an activated flight plan had not been entered. However, the last position 65 58,293 N, 25 13,436 E had been recorded. The route data which may have been programmed in the device disappeared when it broke, and therefore it could not be determined for sure whether route data relating to the flight had been entered. Since the last recorded position corresponds with the site of the accident, it can be concluded that the device was in operation during the accident flight.

The general manager of the aircraft operator company, who was in the accident aircraft as a passenger but had been registered as crew member, told in the interviews after the accident that in his opinion, the pilot-in-command did not draw up a written mass and balance calculation before the flight. He did not remember whether the pilot-in-command completed an OFP form during the flight, but stated that the PIC had followed the route chart and GPS navigator. Additionally he told that mass calculations were not usually made for the aircraft in question when the number of persons on board was as on the accident flight, since it had been established that the aircraft mass and centre of gravity remained in the certified limits even if the tanks were full.

When planning the flight, the pilot-in-command had inquired on 18 December 1994 by telefax about the operational hours of the airports and the possibility to refuel with Avgas 100LL between 20 and 23 December 1994. He addressed the inquiries to the airports of Ivalo, Kajaani, Kokkola, Oulu and Vaasa. All of them had replied and confirmed the possibility of taking the fuel type in question. However, any refuelling order had not been placed.

1.16.3 Sequence of events during refuelling

The ATC radio and telephone communication recordings were copied on a new tape for investigation purposes by the airport telecommunications staff. On this occasion it came out that a converter in the recording system for ATC digital phone calls had had a malfunction and the calls in the digital system had not been recorded. The calls in the analogical systems and the radio communications had, however, been recorded as usual.

Radio communication recordings showed that when the aircraft landed at Oulu airport, it was cleared to taxi to apron stand 3. After acknowledging the clearance, the pilot-in-command contacted ATC again and told that the aircraft needed refuelling, without mentioning the type of fuel, and asked whether they had to go to the refuelling site or if a car was coming. According to the ATC radio communication recordings he said: ”NSG wants to refuel, have we go the station or is a car coming.”

There had been a change of shift in the air traffic control before this exchange. However, the ATC officer of the previous shift was still in and overheard the conversation. When he heard that the aircraft needed refuelling, he telephoned the enterprise which delivers and sells aviation fuel and lubricants of a multinational oil company at the airport. An active partner of the enterprise answered the call, but this telephone conversation was in the digital system and was not recorded due to the malfunction.

The ATC officer who made the telephone call told in the interview that he had heard the request for refuelling and stated: ”I cannot remember exactly how the request was presented, so I do not recall what kind of fuel they asked for. I do not remember whether they told from the aircraft what kind of fuel they wanted.” He told having said in the telephone, when he conveyed the request, that ”an American plane is coming and asks for Jet”. In addition he told to have said ”Check that anyway”, if he remembers right.

The partner of the fuel company, who had answered the call, told that the ATC officer had said: ...”there is a turboprop with American markings waiting for jet fuelling in front of the new terminal...”.

The ATC officer who was on duty at the time of the accident and who had been in radio contact with the aircraft told that the ATC officer of the preceding shift had said to him, after the aircraft had asked for refuelling, that ”Shell knows”. After this he said to have reported to the aircraft: ”Shell is coming”. According to the ATC radio communication recordings, this message was: ”A Shell car is coming to you on the apron.”. Based on the time references in the radio communication recordings, the interval between the request for refuelling and ATC officer’s reply was 38 seconds.

The airport marketing manager had come to receive the aircraft when it taxied to the apron. He had obtained the information on its arrival from air traffic control, where he had telephoned after the customs had asked him the arrival time of the aircraft. When calling the ATC, the marketing manager had conveyed a request presented by the customs that the aircraft should be led to stand 3 in front of the terminal building for customs clearance. The marketing manager told that because an airliner from Helsinki was bound to arrive, he had gone to receive the aircraft and shown it the stand 2 instead of stand 3, which was originally given. After the aircraft had stopped, the marketing manager welcomed the three persons coming out and showed them the way to the customs.

After the customs clearance, the male person pointed out by the marketing manager during the investigation, identified as the general manager of the aircraft operator company, had asked him: ”Where can we get fuel?”. He did not mention the type and used always the word ”fuel” when talking about it. When the marketing manager was going to make a telephone call on the basis of the conversation, the general manager stated that ”a tanker car is coming”. At that time the marketing manager told to have noticed that a Shell Aviation tanker car was coming towards the aircraft. The marketing manager stated that the general manager had then gone out to the tanker car and talked with the driver. They had seemed to exchange a few words and after this the car had moved to the front of the aircraft.

At Oulu airport, aviation gasoline can only be taken from a fixed refuelling station and jet fuel is delivered by tanker cars. According to the established practice, the ATC officers advise those who have asked for avgas refuelling to go to the fixed station. Those who intend to take jet fuel are guided either to the parking stand near the control tower or to stands in front of the terminal building, and the tanker car comes to the aircraft.

The aircraft was refuelled by a serviceman working for the fuel company HR Aviation. He had started his work shift at around 15.00 and his foreman (a partner of the fuel company) had assigned him the task of refuelling a foreign aircraft, which would take Jet.

When the serviceman saw the aircraft taxiing, he set out to perform the refuelling task given to him by the foreman. He took a tanker car used for delivering JET A-1 and started to drive towards the stand where the aircraft was heading for. When starting off, he telephoned from the car to his foreman in the company office and asked the international price of the fuel. The foreman did not remember the price and advised the serviceman to get the price list from the other office of the company.

The serviceman went back to the office, took the price list and drove then to the aircraft which had stopped in front of the terminal building. Near the aircraft he talked with the person who he assumed to be the captain and, after exchanging greetings, asked: ”How much do you take?”. He was asked to fill the tanks up. The fuel type was not mentioned in the conversation.

Before starting to refuel, the serviceman asked about the method of payment. He was told that the payment would be made in DEM, though he was first offered a credit card of another fuel company. At this stage he telephoned his foreman again, since he noticed to have taken, by mistake, the domestic price list instead of the international, and asked someone to bring the international price list.

The refuelling was started from the right-side tanks, from their outboard orifice. The serviceman told that the person who he assumed to be the pilot had pointed at this orifice and said that the whole tank could be filled from this one orifice.

During refuelling, the foreman came to the refuelling site and showed to the pilot the price list, which he had brought with him.

At the upper left corner of the price list there was a text written in Finnish:

KÄTEISHINNASTO	(CASH PRICE LIST)
15.08.1994 (Huom! Kurssit 3.11.1994)	(Note! Exchange rates on 3.11.1994)
LENTOPETROLI	(JET FUEL)

The foreman thought that the pilot would not understand the word LENTOPETROLI written in Finnish on the price list, and therefore he pointed at the word and then at the fuel price DEM/litre in the column below it, which showed the price according to locality. He believed to have got the pilot to understand the fuel price per litre as marked in the price list and that in addition to the fuel price, the bank charges for money exchange would be collected.

The foreman told that when showing the price from the list and talking about jet fuelling, he recalled to have used the word ”fuelling” and possibly also ”jet fuelling”.

The foreman left the refuelling site after showing the price list, while the filling of the right wing tanks was about to be finished.

According to what the serviceman told, the refuelling nozzle fitted well into the orifice. He had to keep the nozzle in a diagonal position so that the nozzle tip was towards the wing base, because otherwise the nozzle would have been near the bottom of the tank and fuel would have splashed out of the orifice during pressure refuelling. He also told that the person who he assumed to be the pilot had been present during the whole refuelling and assisted him. When the serviceman had been closing the cap of the right-side filling orifice, he had not managed to close it yet when this person had come to help him and closed the cap.

When he moved to fill up the tanks in the other wing, the pilot came to watch the refuelling on the other side too, and held the nozzle while the serviceman went to the car in order to bring a ladder to make refuelling easier. According to the serviceman, this was done because the wind had caused the fuel to splash on him from the orifice.

The serviceman told that after the refuelling had been finished, he had taken a fuel sample from the filter of the tanker car to a two-litre vessel and shown it to the pilot, who had been checking the oil level of the right engine (seen from the nose of the aircraft). He stated that when he had shown the sample and said: ”If you want, you can check our jet”, the pilot had said ”it’s good”. Moreover, the serviceman told that the pilot had then said that his hands were dirty, dipped both hands into the fuel sample and wiped them with a cloth given to him.

The serviceman further stated that after showing the sample, he had filled in the delivery receipt in the tanker car cabin. He told to have marked the quantity of fuel taken, 664 litres, in the delivery receipt and ticked the box JET A-1. He also told to have marked the fuel price in DEM, as well as the charge for money exchange. He said to have presented the delivery receipt completed as described above for signature to the person who he had assumed to be the pilot, or captain, of the aircraft.

The pilot undersigned the delivery receipt and wrote himself the name of his company on it. He effected the payment of DEM 508 in cash.

According to the serviceman, the pilot appeared to be in a hurry when signing the delivery receipt and did not examine or check it carefully. During the refuelling it was already dark, but the serviceman stated that the documents were still easily readable.

The serviceman told to have ticked the cash payment box later on the delivery receipt copy left to him, and so this marking cannot be seen in the copy given to the customer.

The calculations made by the investigation commission proved that if the payment for jet fuel marked in the delivery receipt would have been for the same amount of AVGAS 100LL, which was 0,54 DEM/l more expensive, the price would have been DEM 856 instead of DEM 508 paid for the jet fuel. The list price for jet fuel was 0,75 DEM/litre and for AVGAS 100LL it was 1,29 DEM/l.

The general manager of the aircraft operator company, who had been present during refuelling, told in a discussion after the accident that the refuelling had been started from the right wing filling orifice. He also stated to have opened and closed the tank caps himself.

It was established that the general manager had worn eye glasses at the refuelling site.

1.16.4 Identification of fuel types and required markings

To facilitate the identification of different fuel types and to distinguish them from each other, as well as to prevent mixing of fuel types and incorrect refuelling, aviation fuel companies worldwide use the fuel type marking and colour code system described in API Bulletin 1542 (API = American Petroleum Institute).

According to the system, there are three categories of commercial aviation gasoline (AVGAS). The categories are marked in white characters on red background, and each fuel type is coloured with its distinctive colour. The categories and colours for aviation gasoline are: AVGAS 80 red, AVGAS 100 green and AVGAS 100 LL blue.

The system also comprises three categories of commercial jet fuel used for turbine engines: JET A, JET A-1 and JET B. The jet fuels are uncoloured, whereas the natural colour varies from clear to light yellowish. The types are marked in white characters on black background.

In order to prevent misfuelling, General Aviation Manufacturers Association (GAMA) has also introduced fuel type decals based on the API colour code system. In this context it has issued GAMA Specification No. 3, which defines the colour codes and markings used in the decals to be attached to the aircraft. Aviation gasoline markings also show the alternative fuel types approved to be used in the aircraft.

As prescribed in GAMA Specification No. 3, the decals for aviation gasoline are outlined in red and marked with the text AVGAS ONLY. They also include symbols of refuelling nozzles coloured according to the colour codes of fuel types accepted for the aircraft, and the fuel grade has been marked under each symbol. The symbols and the texts are arranged from left to right in the priority order of fuel types. The jet fuel decals are black-edged and marked with the text JET FUEL ONLY, and the nozzle symbol is black.

The fuel types accepted for the accident aircraft were listed in the General Specifications section of the Aeroplane Flight Manual, chapter FUEL, as follows: 100 LL (Blue) or 100 (Green) Aviation Gasoline. If not available, use 115/145 (Purple) Aviation Gasoline.

1.16.5 Fuel tank filling orifices and their markings

1.16.5.1 Filling orifices

A modification had been carried out on the accident aircraft fuel tank filling orifices, in which the orifices had been equipped with restrictors and smaller caps. At the time of the accident, the modification was based on Beechcraft Mandatory Service Bulletin No. 2045, Rev. III, published by the aircraft manufacturer in May 1989. The purpose of the modification is to prevent refuelling with jet fuel instead of aviation gasoline. In the modification the original filling orifices, the diameter of which was 75 mm, had been reduced to 60 mm by installation of restrictors. Any airworthiness directive relating to the modification had not been published in the aircraft manufacturing country, nor in Finland.

During the investigations, the restrictor of the outboard filling orifice in the left wing came off when opening the cap. The restrictor got stuck to the cap and went back to its place when the cap was replaced imitating the normal closing movements. When reopening the cap, the restrictor remained in its place, but came off again when the opening movements were repeated several times. The restrictor came off repeatedly when the cap was turned beyond its usual movement range in the opening direction, using mild force.

It came out that the restrictor got stuck to the cap when during opening, the cap was forced beyond its normal movement range in the opening direction by turning the opening handle, slightly lifting the cap upwards at the same time, or when the handle was turned 1 - 2 mm to the closing direction after opening and the cap was lifted up from the orifice with the handle in this position. If the above mentioned movements were not made when opening the cap, the restrictor did not get stuck to the cap but loosened and remained in the filling orifice. The restrictor was in the orifice and remained there when the cap was opened for the first time after the accident.

After this loosening had been noticed, installation of the other restrictors was also checked. The restrictors did not come off when turning the caps by the usual movements, but the ones in the central filling orifices in both wings came off when the caps were turned, slightly forcing, beyond their normal movement range in the opening direction. The restrictor of the outboard orifice in the left tank section could be loosened in the same way, but this required more force. The area of this filling orifice had been deformed on impact, which possibly increased friction in the restrictor attachment surfaces.

It was found out that the restrictors of all fuel tank filling orifices had been installed in the same way. The restrictors had been fitted into the original filling orifices by turning in the closing direction of the caps. The installation had been done incorrectly, so that one of the three attachment claws in the restrictor was in contact with the cap chain holding bracket, which was at the edge of the original filling orifice. In this position the restrictors were prevented from moving in the closing direction of the cap, but not in the opening direction.

The restrictors should have been installed so that the three locking tabs in the restrictors would have been placed at the three fixing notches of the original caps, which were located at the edge of the original filling orifices. The restrictors should have been locked in this position by pressing the locking tabs of each restrictor into the notches. In this way, the restrictors would have been prevented from turning in either movement direction of the caps.

1.16.5.2 Markings

The following markings were found in the labels attached to the wing surface, near the filling orifices:

- left and right wing, outboard filling orifice:

FUEL
118.5 US GAL CAPACITY
(116 US GAL USABLE) (left wing marking partly unclear)

- left and right wing, inboard filling orifice:

INTERCONNECTED TANKS-
CHECK OUTBD FUEL
LEVEL FIRST
FUEL
103.5 US GAL CAPACITY
(101 US GAL USABLE) (both markings partly faded, but legible)

According to the markings, the total capacity of the tanks was determined to be:

2 x 118,5 U.S.GALL = 237 U.S.GALL (= 897 l)

(2 x 116 U.S.GALL = 232 U.S.GALL, usable) (= 878 l)

The markings correspond with the fuel tank capacity values given in the type certification, FAA Data Sheet No A12CE.

The outer surfaces of filling orifice caps had the following markings:

U.S.GALLONS, OPEN and **CLOSE**, plus arrows showing the directions.

The cap handles were marked:

LIFT & TURN.

The inner surfaces of filling orifice caps had e.g. the markings:

SIZE 60 MM, <u>AVGAS</u> <u>ONLY</u>.

Airworthiness requirement FAR Part 23.1557(c)(1), under which the aircraft was certificated, prescribes that the word FUEL shall be marked at the fuel tank filling orifices or near them. In piston-engined aircraft, also the minimum fuel grade shall be marked.

On 17 September 1982, U.S. Department of Transportation, FAA has issued the Advisory Circular AC No. 20-116 on filling orifice markings. This AC authorizes the use of fuel type markings in accordance with GAMA Specification 3, provided that the markings do not conflict with the information given in airworthiness requirements for the aircraft type. The term AVGAS on the decals is considered to be equivalent to the word FUEL specified in the airworthiness requirements.

It was found during the investigation that fuel type decals defined in American Petroleum Institute (API) Bulletin 1542 as well as decals in accordance with the General Aviation Manufacturers Association (GAMA) Specification No. 3 cited in the above mentioned AC No. 20-116 are used in Finnish aircraft.

Fuel tank markings were not among the placards shown in the accident aircraft Flight Manual.

The spare parts list for the aircraft type contained information on fuel tank markings. Some of these were shown with the text written on the decals and in others only the name of the decal was given. Fuel type or minimum fuel grade was not indicated in the markings shown.

In November 1992 the aircraft manufacturer had issued the Optional Service Bulletin No. 2405, in which the necessity of checking the markings e.g. if the aircraft has been repainted is emphasized. This SB does not state which markings each aircraft type should have, and for the markings used in different aircraft types reference is made to Beechcraft Kit Catalog P/N 888-30935/0191.

On the basis of operating and maintenance manuals for the aircraft type, it was not possible to find out exactly which markings were required by the manufacturer.

During the investigation it was noted that in a Beechcraft Duke B60 aircraft registered in Finland, the fuel markings on the wing were otherwise similar to those in the accident aircraft, but between the filling orifices on the upper side of the wing there was a note concerning the nozzle position during refuelling, as well as the minimum fuel grade as prescribed in FAR Part 23.1557.

The aircraft manufacturer was inquired about the fuel tank markings of the aircraft type in question. According to the reply, the accident aircraft should have had, in addition to the markings found, the following text between the filling orifices on the upper side of the wing:

CAUTION
DO NOT INSERT FUEL NOZZLE
MORE THAN 3” INTO TANK
AVIATION GASOLINE
GRADE 100LL OR 100
FOR ALTERNATE FUELS SEE
PILOTS OPERATING MANUAL

There were no such markings on the wing of the accident aircraft. The wing surface painting was in good condition and any traces of decals or faded texts could not be seen.

1.16.6 Refuelling equipment

The aircraft was refuelled from tanker car No. 8037 manufactured for Shell and intended for pressure and overwing refuelling with JET A-1. The serial number of the car is 94006 and year of manufacture 1994. The tanker car was painted with the logo and colours of Shell. Fuel type decals in accordance with API Bulletin 1542, which had the text Shell Jet A-1 in white characters on black background, had been affixed at the front and back of the car, on both sides of the tank, as well as on the refuelling device box cover and inside the box. The decals were clearly visible.

The body of the replenishment nozzle used for overwing refuelling was black, and thus it was in compliance with the colour code for JET A-1 as defined by API and prescribed in the Airports Operations Manual.

The tanker car refuelling nozzle was fitted with a shaped metal tip. The nozzle tip had been developed by Shell, which had also had it manufactured and installed to the nozzle. The overall length of the nozzle was 21 cm. It consisted of a straight tube from the nozzle body towards the tip, the outside diameter of which was 4 cm and length 14 cm, and a 7 cm long tip attached to it. The tip was equipped with an expansion, which was elliptically shaped with a diameter of 50 x 70 mm after the tubular part of the nozzle. After the expansion, the tip had been shaped as a Camlock coupling, the diameter of which was 45 mm and length 30 mm.

The nozzle was not coloured with the black identification colour of the fuel type, nor did it have the fuel type indication JET A-1.

No aviation regulation relating to dimensions of aircraft refuelling nozzles has been issued in Finland, and the investigation commission could not find out about any other national regulations or standards published on the subject either. It was established that, among others, the following international standards have been issued as recommendations about the dimensions of aircraft fuel tank filling orifices and refuelling nozzles:

- SAE AS 1852 Gravity Refueling Nozzles and Ports Interface Standard for Civil Aircraft: Issued 3/22/84,
- ISO 102: 1990 Aircraft - Gravity filling orifices,
- BS 2C13 : 1988 Size of aircraft gravity filling orifices and associated replenishment nozzles (metric series).

In SAE AS 1852, the dimensions of aircraft fuel tank filling orifices and refuelling nozzles are determined as follows:

Filling orifices and refuelling nozzles

Type of Service Fuel	Standardized Limitations	Refuelling Port-Free Opening Metric Units (mm)	English Units (inches)
Aviation Gasolines	Maximum Opening Diameter	60	2.36
Aviation, Turbine Fuels	Minimum Opening Diameter	75	2.95
Type of Service Fuel	**Standardized Limitations**	**Refuelling Nozzle Tip Dimensions Metric Units (mm)**	**English Units (inches)**
Aviation Gasolines	Maximum Nozzle Tip Diameter	60	1.93
Aviation Turbine Fuels	Minimum Nozzle Tip Diameter *	75	2.95
	Maximum Nozzle Tip Width *	50	1.97
* Turbine fuel nozzles must adopt an elongated or elliptical tip cross section with maximum and minimum axes within dimensional limits noted above.			

The standards ISO 102 and BS 2C13 are identical in their content. ISO 102 defines the dimensions of aircraft fuel tank filling orifices and refuelling nozzles as follows:

Filling orifices

	Dimensions in millimetres	
	Internal diameter	
Fluids	**min.**	**max.**
Aviation gasoline (AVGAS)	55	60
Turbine fuel	75	-
NOTE - If a filter is fitted at any of the orifices it should not result in a reduction of the relevant minimum internal diameter.		

Refuelling nozzles

	Dimensions in millimetres	
	External diameter	
Fuel	**min.**	**max.**
Aviation gasoline (AVGAS)	-	49
Turbine fuel	67	70

Recommendations on the dimensions of aviation gasoline and jet fuel replenishment nozzles, in compliance with the above mentioned standards, were available to Shell Aviation in the Shell Airport Operations Manual.

The company that carried out the refuelling had at its disposal the Airports Operations Manual in Finnish (*Ilmailuhuollon toimintaohje*), which showed the replenishment nozzle types used by the company and tips approved to be fitted to them. It was stated in the manual that jet fuel nozzle tips manufactured for Shell were to be installed in the replenishment nozzles before use and that the use of any other tip was prohibited.

The purpose of the shaped expansion, the dimensions of which were 50 x 70 mm, was to prevent the nozzle intended for JET A-1 refuelling from fitting into the reduced filling orifices of aviation gasoline tanks, not more than 60 mm in diameter. The expansion should go into the filling orifices of aircraft using jet fuel. In practice, however, there are aircraft running on jet fuel in which the fuel tank filling orifices are smaller in dimension than recommended in the above mentioned standards, and into which the expanded jet fuel nozzles do not fit.

Shell had solved this problem by fitting the above mentioned Camlock coupling to the refuelling nozzle. This made it possible to add different extensions, which were smaller in dimension than the expanded part. By means of these extensions, jet fuel could be delivered to aircraft using jet fuel but equipped with small-diameter filling orifices, such as certain helicopters. In addition, the reduced extensions are needed for example when jet fuel is filled into barrels or jerry cans.

The original design of the replenishment nozzle was in accordance with the recommendations given in Shell Airport Operations Manual and in the standards cited above. However, after the expansion the tip of the nozzle was smaller in dimension and fitted into the reduced filling orifices of the accident aircraft, which made it possible to fill the tanks with JET A-1 instead of AVGAS 100LL.

1.16.7 Regulations and instructions on aircraft refuelling

1.16.7.1 Regulations and instructions issued by the Finnish aviation authority

The Finnish Civil Aviation Administration has issued Aviation Regulation AIR M1-12, AIRCRAFT REFUELLING, amendment 2, 25 May 1994, which entered into force on 15 June 1994, as well as Advisory Circulars OPS T1-16, Prevention of incorrect refuelling, 30 August 1979, and AIR T1-11, Fuel used in aircraft engines, 17 June 1983.

Aviation Regulation AIR M1-12, AIRCRAFT REFUELLING, gives provisions on refuelling operations. It contains e.g. the following requirements and definitions:

Paragraph 1: Applicability
This Regulation shall be applied to aircraft refuelling in Finland.

Paragraph 2: Definitions
Fuelling crew
Fuelling crew consists of those who participate in the refuelling operations and have received appropriate training for aircraft refuelling.

Operator
Operator is the owner of the aircraft or a person to whom the aircraft has been assigned to be used on his own account.

Refueller
Refueller is the company delivering jet fuel or aviation gasoline, or an undertaking or person entered into a delivery contract or co-operation agreement with such a company and performing aircraft refuelling operations.

Paragraph 3.1: Refueller’s responsibilities
The refueller shall be responsible for ensuring that appropriate refuelling equipment and procedures are used and that the fuelling crew complies with relevant instructions and regulations in force. The refueller shall also answer for that the fuel type and quantity delivered are in accordance with the order.

Paragraph 3.2: Operator’s responsibilities
The operator of the aircraft to be refuelled shall be responsible for ensuring that the aircraft, its components and equipment used at the refuelling site are appropriate. He shall also answer for that the fuelling crew nominated by him and

the passengers comply with relevant instructions and regulations in force. The operator shall nominate a person to supervise refuelling on the ground.
The operator is responsible for and shall also verify that the fuel type and quantity stated in the order given by him to the refueller are correct. (See also Advisory Circular OPS T1-16).

4.2 Refuelling equipment, paragraph 4.2.1:
Aircraft refuelling shall be carried out using only such equipment that meet the relevant requirements in force.

Advisory Circular OPS T1-16, Prevention of incorrect refuelling, gives instructions on e.g. the following:

Paragraph 1:
When placing an order, always advise the fuelling personnel clearly of:
- aircraft type and identification;
- type of fuel, oil or other substance ordered;
- location of tanks in the aircraft and the quantity to be filled in them.

Paragraph 4:
By monitoring the refuelling operations in person, you can ensure that the right type of fuel or oil is delivered in proper quantity and in the right place.

Paragraph 6:
The oil company is responsible for ensuring that the fuelling crew employed by it complies with safety regulations and that the type and quantity of fuel delivered are in accordance with the order. The responsibility of the pilot-in-command is to ensure that the type and quantity of fuel stated in his order are correct and also that the fuel is filled in the appropriate tanks.

Advisory Circular AIR T1-11, Fuel used in aircraft engines, prescribes e.g. the following:

Paragraph 3: Placards and markings

Total capacity of the tanks and fuel grade shall be marked near the filling orifice in accordance with the airworthiness requirements.

Decals obtainable from oil companies are recommended to be used for marking the fuel type.

For jet fuel, use decal ”JET A-1”, white characters on black background.

For aviation gasoline, use decal ”AVGAS”, white characters on red background.

1.16.7.2 Regulations and instructions issued by fuel companies

The company delivering and selling Shell aviation fuel and lubricants had at its disposal a copy of the Airports Operations Manual, written and updated by Shell. The manual includes, among other things, the above mentioned Aviation Regulation AIR M1-12. The instructions are based on the Shell Airport Operations Manual, which was used by Shell Aviation but not by the company that carried out the refuelling. Moreover, Shell has published an Operators Handbook for the use of fuelling personnel to complement the Airports Operations Manual.

The Airports Operations Manual contains instructions on refuelling equipment serviceability checks and components to be used, quality monitoring of different products, staff training, aircraft refuelling and ensuring the use of correct fuel type. On aircraft refuelling and checking the correct fuel type, the Airports Operations Manual gives e.g. the following instructions:

- checks to be made before starting off;
- refuelling procedures and safety instructions;
- verifying the use of correct fuel type before refuelling and instructions on how to proceed if the aircraft to be refuelled does not have the appropriate markings indicating the fuel type.

The Airports Operations Manual gives e.g. the following instructions on ensuring the use of correct fuel type:

- In case the fuel type is not clearly indicated near the filling orifices, always use the order form I-8. It must be signed by the customer before the refuelling is started.

- In case the aircraft does not have any fuel type markings and you cannot get the signature, REFUELLING IS PROHIBITED.
- For example, a refuelling order received by telephone can only be carried out if the aircraft is equipped with fuel type markings.
- Check the type placard in the refuelling device and the nozzle colour to ensure that you are using the correct type of fuel.
- For additional safety it is recommended that the customer should always be present during refuelling.

The Operators Handbook supplementing the Airports Operations Manual contains instructions on verifying the use of correct fuel type before refuelling. It also includes colour pictures of JET A-1 and AVGAS decals in accordance with API Bulletin 1542, and a sample of the refuelling order form. The manual recommends e.g. the following:
- All aircraft should have a decal indicating the fuel type adjacent to the filling orifice.
- In case a decal cannot be found, the pilot or the mechanic shall complete and sign an order form.
- If there is no label or order form, **refuelling is prohibited**.

1.16.8 Qualifications of the fuelling crew

It is provided in the Aviation Regulation AIR M1-12 that the personnel participating in refuelling must have received appropriate training for aircraft refuelling. Specific qualification requirements for fuelling crew are not given in Finnish aviation regulations, nor are there any further instructions on the training.

The aircraft operator's representative and a serviceman working for the oil company were present at the refuelling site and participated in the operations.

The general manager of the aircraft operator company was present during refuelling. He held a valid Private Pilot Licence issued by the German aviation authority, with type rating for the aircraft in question, and a corresponding licence issued by FAA and valid subject to validity of the German licence. During the type training, he had been given information on the fuel type used in the aircraft and procedures followed in its refuelling. As the general manager of the aircraft operator company, he had the right to act as the operator's representative at the refuelling site, and holding the type rating he was also qualified for the fuelling crew duties.

The aircraft was refuelled by a serviceman working for the oil company. His foreman had assigned him the task, and he was qualified to perform refuelling duties on account of the basic training given to him by the employer. The instructor was the same foreman who assigned him the refuelling task, and the foreman had also authorized him to work as an aircraft refueller for the company after the training.

1.16.8.1 Serviceman's training

The Airports Operations Manual includes a chapter on familiarisation of new Shell employees with their duties. In this chapter, the subject matters and organization of the training are presented in the form of a table, under the headings: Work stage - Training method - To be read.

Under the heading 'Work stage', the following topics were required to be covered: Refuelling operations, Quality monitoring, Equipment maintenance, Product knowledge, Paperwork, Driving instruction, Operation of equipment. The column 'Training method' contained instructions on how the training for each work stage should be given. For practical tasks, the trainee was first required to watch someone to carry out the task for a few times and then perform it himself under the instructor's supervision.

Under the heading 'To be read', either the Operators Handbook or the relevant paragraph in the Airports Operations Manual was required to be studied for each work stage. In addition, some specific films and slide presentations on quality monitoring and safety issues were recommended to be used in the training.

For the duration of the training, the Airports Operations Manual specified that the initial training of a new serviceman should take at least two weeks.

The Airports Operations Manual did not give any detailed training syllabus for each subject, which would have specified the exact time to be used for studying each work stage and the issues to be dealt with, nor did it include any requirement to work out such a syllabus. The manual did not give instructions on how to check whether the training material had been assimilated.

According to the instructor, the serviceman had been taught the subjects listed in the training section of the Airports Operations Manual during his initial training. At the beginning he had watched others to carry out the tasks and later performed them himself under supervision.

Any syllabus or records had not been retained of the training. The month and year when the training was given were entered in the company training matrix. Any specific training certificate had not been given.

Before the training was started, the instructor had given the Operators Handbook to the serviceman for self study. The serviceman told that he had studied the booklet for about one and a half weeks before the training.

In order to ensure that the subjects dealt with during the training had been assimilated, the instructor had prepared theory questions for the trainee. The instructor had presented the questions orally, and the trainee had answered them orally as well. The answers had not been written down or retained in any other way, and therefore it was not possible to find out how the serviceman had assimilated the issues covered in the training.

In the opinion of the serviceman, the training had mainly been practical and the instructor had not put much emphasis on studying the literature; however, the Airports Operations Manual had always been at disposal. The serviceman saw that the instructor had particularly stressed the importance of fuel sampling. He told to have started refuelling on his own approximately 2,5 weeks after receiving the Operators Handbook. Additionally he told that he had not been given any specific training on aircraft types, but stated that he knew the usual types of aircraft due to his previous experience in aviation-related duties and because he had parachute jumping as a hobby. Concerning the identification of different aircraft types, he told that the instructor had given as a rule of thumb that if the propeller cones were chromium plated, then it was a turboprop.

1.16.9 Fuel tests

The aircraft fuel system consisted of two separate tank sections, of which the left was for the left engine and the right for the right engine. Each section comprised five separate wing tanks interconnected by fuel balance pipes. The total capacity of each tank section was 118,5 U.S. Gall and the combined capacity of all fuel tanks 237 U.S. Gall (897 litres). According to the serviceman, refuelling had been carried out through the outboard filling orifice of each tank section and the tanks had been filled up. As marked on the delivery receipt, the quantity delivered was 664 litres of JET A-1, and thus the quantity of AVGAS 100LL remaining after the previous flight can be calculated to have been 233 litres. Based on the calculations, the percentage of jet fuel was 74 % and that of aviation gasoline 26 % of the total tank capacity after refuelling.

The fuel tanks were burst and emptied on impact, and therefore any samples of the fuel in the tanks could not be taken. However, samples were taken from both fuel pump manifolds and analyzed at Neste Technology Centre in Porvoo by request of the investigation commission.

Quality information relating to the JET A-1 taken in Oulu was received from Shell and that concerning aviation gasoline replenished in the accident aircraft in Germany from Bremerhaven. Based on the results of fuel sample analyses and the information obtained, Neste Technology Centre determined the quantity of aviation gasoline in the fuel samples.

The results showed that the density of the left engine fuel sample was 783,9 kg/m^3 (+ 15°C), lead content 0,09 g Pb/l and proportion of aviation gasoline 18 ± 3 %. The density of the right engine fuel sample was 780,0 kg/m^3 (+ 15°C), lead content 0,11 g Pb/l and proportion of aviation gasoline 22 ± 3 %.

1.16.10 Inspection of the engines

The engines were removed from the aircraft at the accident site and transferred to Oulu airport premises for inspection.

The aircraft had been initially fitted with cylinder head and exhaust gas temperature measuring systems. In both engines, the sensors of the cylinder head temperature measuring system were in their places. They had been installed in the place of the uppermost igniter plug gasket of the fifth cylinders.

Both engines were equipped with temperature measuring sensors for the Graphic Engine Monitor system, which had been installed to the aircraft as an accessory. Cylinder head temperature measuring sensors had been installed to all cylinders. The sensors were in their places at the sockets attached to the cylinder heads. Exhaust gas temperature measuring sensors had been installed in the exhaust pipe of each cylinder, as well as in the Y pieces of exhaust gas intake manifolds of the turbochargers.

Engines were also fitted with flow indicator sensors for the fuel consumption measuring system.

Both engines were equipped with a propeller unfeathering system. The pressure accumulators and oil manifolds of the system seemed to be intact.

Engine mounts, exhaust and intake manifolds, cooling baffles, some components and accessories as well as part of the cylinders had been deformed or damaged on impacts into trees.

The compressor and turbine housings of the turbocharger were intact, the rotors rotated freely and no impact marks or other damage could be found in the vanes.

Throttle and mixture control lever actuator cables were deformed. Judging from the location of deformations, the engines were set at full power and mixture at full rich at the moment of impact. Propeller setting was high RPM / small blade angle.

In both engines, the direct-current generator drive belts were in the grooves of their wheels and intact.
The left generator was externally undamaged, impact marks could not be found and the rotor rotated normally.
The right generator attachment mechanism had partly broken on impact, and there were deformations in the generator belt wheel and at the backside of the wheel at the cooling fan. The fan was deformed and in contact with the flange at the forward section of the generator, obstructing the rotor when tested. Any marks caused by rotating movement could not be found in the imprints left on the flange by the fan, and it can thus be concluded that the generator was not turning at the moment of impact and the engine was not running. The impact was directed towards the front and bottom of the generator, and the engine was probably upright.

In both engines, the starter bendix drive gear had been moved forward, to the starting position.

The components and accessories were not removed or inspected in more detail.

The crankcases and suction chambers, as well as accessory drive casings were intact.

Oil filter elements of both engines were removed and broken open. Both filters had an abnormal and considerable amount of metal deposit, which seemed to be roughly equal in both engines.

In order to examine the internal condition of the engines, the plugs, cylinders, pistons and connecting rods were removed.

The combustion chambers and exhaust ports of all cylinders were covered with soot, they were oily, damp with fuel, and smelled of kerosene. The valves were not removed. In the visual check, they were found to be intact and after the cylinders had been removed, the valves closed normally into their sockets, pressed by the springs.

There were no visible deformations in the connecting rods. They moved somewhat sluggishly in the crank bearings, bearing shells were scratched and bearing metal had come off in places. The crankshaft connecting rod bearing journals were slightly blue, but undamaged. In cylinders 1, 3, 5 and 6 of the left engine, and in all cylinders of the right engine, the pressure side surfaces of the piston pin bushings had become shiny and scratched due to high surface pressure. The piston pins of cylinders 2 and 4 had been stuck in the pistons; therefore the piston pin bearing surfaces could not be checked and the connecting rods were removed from the engines together with the pistons.

Crankshaft rotation was tested by turning the large starter gear. Both shafts turned sluggishly and required more force than usual, but rotated without becoming jammed.

The engines were not further disassembled, but it could be seen through the cylinder attachment ports that the crankcases were undamaged from the inside and that the camshaft cams and valve lifter plate surfaces were in good condition; moreover, the crankshaft dynamic counterbalances seemed intact and moved freely when turned manually.

The left engine cowl flap actuator had separated on impact, and the flap control lever attached to the actuating screw had bent. Otherwise the actuator was externally undamaged. The actuator cover was opened; in the visual check, the screw inside it was found to be intact. The location of the contact section of the electric limit switches on the actuating screw corresponded with an 80% open cowl flap position. The actuator worked when electrically tested. It had been operational before the impact.

The right engine cowl flap actuator had been dislodged from its firewall support on impact, and the eye end of the cowl flap actuating rod driven by the actuating screw had been bent. Otherwise the actuator was externally undamaged. The actuator cover was opened; in the visual check, the screw inside it was found to be intact. The pin operating the limit switches was missing and was not found inside the actuator. Based on the location of the pin attachment point, it was concluded that the actuator was in the cowl flap position 50% open. The actuator gearbox was dismantled and the electric motor driving the gear system was removed. The gearbox bearing surfaces and the cogs of the epicyclic gear were badly corroded. From the rusty surfaces it could be concluded that the gear had been out of operation for a long time. The commutator had been damaged by melting at the brushes, and other parts of the commutator were scratched, blackened and corroded. When tested, the motor could not be rotated by electrical means. The actuator was not operational at the time of the accident.

1.16.10.1 Cylinders, pistons and plugs of the left engine

Cylinder No. 1

Cylinder sleeve walls were undamaged. The piston was intact, piston head was brown and sooted, damp with oil/fuel, no carbon deposit. The piston sides were covered with soot. Piston rings were undamaged and moved sluggishly in their grooves. The piston pin also moved sluggishly in the piston and in the connecting rod bushing. The uppermost igniter plug was black, sooted and oily[*], the bottom plug was dry and covered with soot.

[*] The engine was upside down and there was a small amount of oil inside the cylinder.

Cylinder No. 2

There were moderate seizure marks on the cylinder sleeve wall. The piston had badly melted near the exhaust valve, at the edge of the piston head. The gas blow had damaged the piston side down to the piston pin. The piston head was black, sooted and damp with oil/fuel, no carbon deposit. Piston rings had been damaged at the combustion gas blow areas, and in the undamaged part of the piston they were sooty and jammed. Seizure marks were found at the piston skirt. Piston pin had stuck to the piston and moved sluggishly in the connecting rod bushing. The uppermost igniter plug was black, sooted and oily*, the bottom plug was dry and covered with soot.

Cylinder No. 3

Cylinder sleeve walls were undamaged. The piston was intact, piston head was brown and sooted, damp with oil/fuel, no carbon deposit. The piston sides were covered with soot. Piston rings were undamaged and moved sluggishly in their grooves. The piston pin also moved sluggishly in the piston and in the connecting rod bushing. The uppermost igniter plug was black, sooted and oily*, the bottom plug was dry and covered with soot.

Cylinder No. 4

There were moderate seizure marks on the cylinder sleeve wall. The piston had badly melted near the exhaust valve, at the edge of the piston head. The gas blow had damaged the piston side down to the piston pin. The piston head was black, sooted and damp with oil/fuel, no carbon deposit. Piston rings had been damaged at the gas blow areas, and in the undamaged part of the piston they were sooty and jammed. Seizure marks were found at the piston skirt. The piston pin had stuck to the piston and moved sluggishly in the connecting rod bushing. Both igniter plugs were dry and covered with soot.

Cylinder No. 5

The cylinder sleeve wall was slightly scratched. There was a small melt mark at the edge of the piston head, near the intake valve. The piston head was brown and sooted, damp with oil/fuel, no carbon deposit. The uppermost compression ring had been cut, whereas the other piston rings were covered with soot and moved sluggishly in their grooves. The piston sides were sooted. The piston pin moved sluggishly in the piston and in the connecting rod bushing. Both igniter plugs were black, sooted and damp with fuel.

Cylinder No. 6

There were small scratches and corrosion caused by water in the cylinder sleeve wall** . Beginning melt damage was found at the edge of the piston head, near the exhaust valve. The piston head was white and dry**, no carbon deposit. The uppermost compression ring had been cut, whereas the other piston rings were covered with soot and moved sluggishly in their grooves. The piston sides were sooted. The piston pin moved sluggishly in the piston and in the connecting rod bushing. The uppermost igniter plug was dry, partly greyish blue and partly sooted. The bottom plug was damp with water and had corrosion marks**.

1.16.10.2 Cylinders, pistons and plugs of the right engine

Cylinder No. 1

Cylinder sleeve walls were undamaged. There was a small melt mark at the edge of the piston head, near the intake valve. The piston head was brown and sooted, damp with oil/fuel, no carbon deposit. Piston rings were undamaged and moved sluggishly in their grooves. The piston sides were covered with soot. The piston pin moved sluggishly in the piston and in the connecting rod bushing. The uppermost igniter plug was black, sooted and oily, whereas the bottom plug was dry and covered with soot; the central electrode had come loose and the edges of the electrode hole were white.

Cylinder No. 2

There were moderate seizure marks on the cylinder sleeve wall. The piston had badly melted near the exhaust valve, at the edge of the piston head. The gas blow

** When the engine was turned upright before the cylinders were removed, water came out of the cylinder. During rescue operations the aircraft had been foamed and the engine had been cooled by water spraying at the accident site. The water inside the cylinder has caused the colour change in the piston head and the corrosion.

had damaged the piston side down to the piston pin. The piston head was black, sooted and damp with oil/fuel, no carbon deposit. Piston rings had been damaged at the combustion gas blow areas, and in the undamaged part of the piston they were sooty and jammed. Seizure marks were found at the piston skirt. The piston pin moved very sluggishly in the piston and sluggishly in the connecting rod bushing. The uppermost igniter plug was greyish black, sooted and damp with fuel/oil, whereas the bottom plug was damp with fuel, greyish black and sooted.

Cylinder No. 3

Cylinder sleeve walls were undamaged. The piston was intact, piston head was brown and sooted, damp with oil/fuel, no carbon deposit. Piston rings were undamaged and moved sluggishly in their grooves. The piston sides were sooted. The piston pin moved sluggishly in the piston and in the connecting rod bushing. The uppermost igniter plug was black, sooted and damp with fuel, the bottom plug was dry and covered with soot.

Cylinder No. 4

There were moderate seizure marks on the cylinder sleeve wall. The piston had badly melted near the exhaust valve, at the edge of the piston head. The gas blow had damaged the piston side down to the piston pin. The piston head was black, sooted and damp with oil/fuel, no carbon deposit. Piston rings had been damaged in the gas blow areas, and at the undamaged part of the piston they were sooty and jammed. Seizure marks were found at the piston skirt. The piston pin moved very sluggishly in the piston and sluggishly in the connecting rod bushing. The uppermost igniter plug was damp with oil/fuel and greyish blue, the bottom plug was dry, black and sooted. The other body electrode was missing.

Cylinder No. 5

There were moderate seizure marks on the cylinder sleeve wall. The piston head edge had moderately melted at the exhaust valve, the piston head was black and sooted, damp with oil/fuel, no carbon deposit. Piston rings had been damaged at the point where the piston had melted, whereas at the undamaged part the rings were sooted and moved sluggishly in their grooves. Seizure marks were found at the piston skirt. The piston pin moved sluggishly in the piston and in the connecting rod bushing. Both igniter plugs were black, sooted and damp with fuel.

Cylinder No. 6

Small scratches were found on the cylinder sleeve wall. There was beginning melting damage at the edge of the piston head near both valves, the piston head was greyish black and damp with oil/fuel, no carbon deposit. The uppermost compression ring had been cut, whereas the other piston rings were sooted and moved sluggishly in their grooves. Soot and small seizure marks were found on the piston sides. The piston pin moved sluggishly in the piston and in the connecting rod bushing. The uppermost igniter plug was black, sooted and damp with fuel, the bottom plug was dry and covered with soot. Both body electrodes were missing.

1.16.11 Inspection of the propellers

Both propellers had separated from the engines on impact. At the accident site, the other propeller was found under the aircraft nose and the other was in front of the wreckage near the left engine.

The propellers had been attached to the crankshaft flanges by using extension pieces. Both propellers had separated at the junctions between the extensions and propeller hubs, while the extensions remained attached to the crankshaft flanges.

Due to impact forces, some of the six attachment bolts of both propellers had been cut at the junctions of the attachment pieces. Some of the broken bolts remained attached to the propeller hub from their bases, while some of the bolt pieces at the nut side got stuck to the extensions, which had still remained connected to the crankshaft flanges. Propeller hubs had been torn at the areas where the attachment bolts had not failed, and the unbroken bolts had separated from the hubs and remained in contact with the extensions. The propellers were identified by comparing the attachment bolt positions and cracks in the attachment bolt holes. The propeller found under the aircraft nose was from the left engine and the one found in front of the aircraft, near the left engine, was from the right engine.

Deformations and impact marks were found in the hub structures and blades of both propellers. The blades had not been feathered. The left propeller hub cylinder had broken on an impact into tree, the cylinder oil had flowed out and could be detected on the left wing and on the skin plates of the left wing flap. Judging from the deformations and impact marks on the propeller blades, the engines were not running when the propellers were subjected to impact forces.

The holes of the broken attachment bolts in the extensions and propeller hubs were deflected, they had become elliptical and deformations forward and backward could be seen at the edges. Any deformation in the direction of propeller rotation or in the opposite direction could not be found in the visual check. In the propeller hubs, the cracks were at the back edge of the attachment bolt holes. Judging from the deformations and ruptures in the attachment pieces, the forces that caused the bolts to break and the holes to yield were mainly directed forward and backward. Therefore the engines have not been running and propellers not rotating when the propellers separated on impact.

1.16.12 Inspection of the door and emergency exit

1.16.12.1 Door

During the rescue operations, the rescue crew could not open the door in the normal way and it had been forced open by breaking the structure.

The opening and closing handle outside the door was located in a cavity in the shape of the handle, which was embedded in the skin plate. The words **OPEN** and **CLOSED** had been marked on the handle in approximately 6 mm high black letters with arrows showing the movement direction. At the forward end of the handle, the word **PRESS** had been written in black letters approximately 3 mm in height. By pressing at this point, the handle could be taken out of its cavity and turned to open or close the door. Above the handle in the door construction, protruding 8 mm out of the skin plate, there was a locking mechanism release button, which was round, 5 mm in diameter and pin-shaped. The button had not been made easier to see in any way, and there were no indications of its purpose or use in the door outside the aircraft.

The operation of the outside handle was tested with the remains of the broken door:
- the handle could be taken out of the cavity only by using a tool; when the test was renewed, the handle became more easily operable and could be taken out manually without using any tools,
- the locking mechanism release button was rather stiff at the first time, but became more easily operable when tested again,
- by pushing the release button and turning the handle, the locking pin, which had remained intact in the broken door, could be moved to the opening position,
- without pushing the release button, the handle could be turned approximately 2/3 of its maximum movement in the opening direction. In this movement range, the locking pin did not move.
- no such wear or lack of maintenance which could have caused the stiffness was detected in the mechanisms. Therefore the difficulty of operation during the first tests must have been caused by deformations resulting from breaking of the door structure.

The handle inside the door was intact. The words **OPEN** and **CLOSED** had been marked in black letters of approximately 6 mm in height on the base plate, which was made of aluminium and unpainted. Next to the texts there were aligning marks indicating the handle position, as well as arrows showing the movement direction. The release button, 9 mm in diameter and protruding 12 mm out of the base plate, was located at the rearmost bottom corner of the base plate. Close to the button there was a text **PUSH TO UNLOCK** in black letters of approximately 6 mm in height.

When testing the operation of the inside handle, the handle could be turned all the way in its normal movement range when pressing the release button, and the locking pin moved to the opening position.

1.16.12.2 Emergency exit

According to what the rescue crew told, they had not been aware of the emergency exit and had not tried to open it during rescue operations. There were no markings of the emergency exit outside the aircraft. Inside the plane it had been marked with a red placard attached to the interior lining over the upper left corner, when seen from the inside, of the emergency exit. The placard had the following text in white characters:

EMERGENCY EXIT
PULL CURTAIN ASIDE

At the left-hand edge of the emergency exit, there was a red cover plate hinged from its upper edge, which had the following text in white characters on its lower side:

EMERGENCY EXIT
LIFT COVER , RELEASE CATCH
& PULL HANDLE DOWN FULLY

Under the cover plate there was a red handle, in the upper part of which was a red, square-shaped button with the white text:

PUSH

The opening of the emergency exit window cover was tested when the fuselage had been moved away from the accident site and turned upright. The catch of the emergency exit opening handle was found rather stiff at first, but after pushing the catch for a few times the handle lock could be released. After the lock had been released, the handle turned down when pushed and the window cover locks opened, but the cover could not be removed in the normal way. The forward edge of the window cover and the frame had been deformed, which prevented the window cover from coming out, but by prising the damaged part with a tool the cover could be removed rather easily.

1.16.13 Inspection of the seats and safety belts

1.16.13.1 Seats

The crew seats were deformed in the accident but had still remained attached to the floor. The crew seats and the unoccupied middle seats had been removed by cutting and breaking during rescue operations.

The back seats were in their places, and the left seat had remained intact. The passenger had been sitting on the right back seat, which was a ”Seat Toilet Installative” assembly. He had been thrown out of his seat and the lap belt had broken. The removable cover of the seat had come off, but otherwise the seat was undamaged and still in its place, attached to the floor.

1.16.13.2 Safety belts and their operating instructions

Crew seats and the rearmost passenger seats were equipped with three-point safety belts. The belt assembly consisted of a two-piece lap belt and one shoulder strap fitted with an inertia reel and attached to the lap belt fastener. The rearward facing middle passenger seats were only equipped with lap belts.

The lap belts had been fixed to the hinge/attachment bolts of the reversable backrests by installing a bushing over the bolt. The length of the bushing and the adapter piece fitted between the holes of the metal brackets enabled the belts to move freely for approximately 10° to the left and to the right without causing the bracket to bend.

The crew seat inertia reel assemblies had been mounted on the backside of the cockpit interior lining, in the side wall structure. Those of the passenger seats had been fixed in the backrest construction, behind the backrests and under the protective lining.

The safety belts of the right crew seat occupant had been cut open during rescue operations. The lap belt was fastened and the shoulder harness was fixed to the lap belt fastener. The seat belts had sustained the impact load without breaking.

The left section of the pilot-in-command's lap belt had been cut open during rescue operations, the lap belt was fastened and the belts had sustained the impact load without breaking. The shoulder strap was wound on the inertia reel and only about 15 cm of it could be seen outside the cockpit lining. The metal bracket of the belt was undamaged. The shoulder harness attachment pin in the lap belt fastener was intact.

The shoulder strap was fed to the inertia reel assembly installed in the cockpit side wall structure, behind the lining, through an opening in the interior lining. Due to impact forces, the lining plate had been deformed at the opening and left an imprint on the belt. The mark was at approximately 15 cm from the metal attachment piece intended to be fitted to the lap belt fastener, which indicates that the shoulder harness had not been fastened at the moment of impact.

The light-metal attachment bracket of the back seat passenger's right lap belt (P/N 58 - 530219-61) had broken at the belt attachment point. The piece to be attached to the seat was intact, but at the edge of the mounting hole on the aisle side there was an imprint left by the attachment bolt base plate. The bracket had also bent towards the fuselage centerline.

There were marks caused by sliding and friction almost all over the belt. The left belt section was intact and had remained attached to the seat. The piece between the belt and the seat was made of steel alloy. The lap belt lock was fastened.

The shoulder harness was not attached to the lap belt fastener. The shoulder strap was wound on the inertia reel and only about 15 cm of it could be seen outside the backrest lining. The metal attachment piece intended to be fitted to the lap belt fastener was intact. Any damage could not be found in the shoulder harness or backrest construction.

All safety belts were from the same manufacturer. They had the certification marking FAA - TSO - C22f and rated strength value of 1500 lbs.

In order to determine the strength of the light-metal lap belt attachment bracket that broke in the accident, the undamaged left-side middle seat and back seat belts, P/N 130498C-19 and P/N 58-530219-61, were removed from the wreckage and subjected to a tensile test at Finnair NDT department. These belts were equipped with light-metal brackets identical to that broken in the accident.

In the test, at a traction speed of 22 mm/min, the light-metal brackets broke at the same point as the passenger's lap belt bracket in the accident. The bracket of the belt P/N 130498C-19 broke at the load value of 990 kg (2182,5 lbs) and that of the belt P/N 58-530219-61 at 1007 kg (2220 lbs).

Instructions for the use of shoulder harness on crew seats were given in the left-hand cockpit side window (the right-hand window was broken and out of its place) as follows:

**SHOULDER HARNESS
MUST BE WORN AT
ALL TIMES WHILE AT
PILOT POSITIONS**

Instructions for the use of shoulder harness on passenger seats were given in the side window adjacent to the right back seat (the left-hand window was broken and out of its place) as follows:

**SHOULDER HARNESS
MUST BE WORN DURING
TAKE OFF AND LANDING
WITH SEAT BACK UPRIGHT**

Similar instructions were given in the Aeroplane Flight Manual.

According to the Flight Manual, it should be ensured during the pre-flight inspection that the lap belts and shoulder harnesses were fastened. It was not found out in the investigation whether the pilot-in-command gave safety instructions before take-off, whether he asked the passengers to fasten the shoulder harness as well and whether he checked that they actually fastened it.

When interviewed after the accident, the general manager of the aircraft operator company recalled that this kind of safety instructions had not been given in Germany before take-off, and was not sure if they had been given in Oulu before take-off either.

1.17 Other information

It came out during the investigation that the radio communication and radar recordings were not synchronized. It also appeared that part of Oulu ATC telephone conversations had not been recorded due to a technical malfunction.

Correspondence with the US accident investigation authority, National Transportation Safety Board (NTSB), revealed that during the period 1983 - 1996, refuelling of piston-engined aircraft with jet fuel had caused ten reported aircraft accidents in the USA.

1.18 Investigation techniques

Oulu airport secondary surveillance radar (MSSR) recordings were used in the investigation. By means of a computer program developed by the Finnish Civil Aviation Administration, Air Navigation Services Department, Radar Systems Division, data could be gathered from the recordings and analyzed so that aircraft speed and position could be calculated on the basis of transponder responses. Using this information, the aircraft flight path could be determined, located in the coordinate system and drawn on a map.

2 ANALYSIS

2.1 General

The accident aircraft, N-911SG, was owned by an American finance company Interlease Aviation Corporation. It had been leased to a German company named Andrea Szymanski-Ehrhardt Fischversand, which had started to operate the plane in spring 1993. The aircraft was on an IFR flight from Bremerhaven, Germany, to Murmansk, Russia, and made an intermediate stop in Finland at Oulu airport for refuelling. According to flight plans drawn up for the route by the pilot-in-command, the operator was a German company United Seafood established in Bremerhaven. The flight had been indicated as an IFR flight and the type of operation as G, i.e. general aviation. Since the aircraft was registered in the United States, it was to be operated under the provisions of FAR Part 91. The aircraft was equipped for IFR operations.

Information obtained from the German aviation authorities revealed that the company given as the aircraft operator in the flight plan is not an air operator company, nor does it have any authorization for this kind of operations.

The investigation commission got the impression that the aircraft possessor company Andrea Szymanski-Ehrhardt Fischversand, as well as the operator company United Seafood, were using the aircraft for company purposes without any written guidelines on flight operations. What had been agreed between the companies about the use of the aircraft was not examined during the investigation.

The general manager of the aircraft operator company United Seafood (hereafter referred to as the operator’s representative or the operator), who was in the aircraft on the accident flight, is also involved in the operations of Andrea Szymanski-Ehrhardt Fischversand. He had undersigned the aircraft leasing agreement together with his wife.

The operator’s representative told that the flight to Murmansk was made because the passenger was doing business with a fishing company in Murmansk, and United Seafood was interested in co-operating with it. He stated that the flight was a private, non-revenue flight related to the company’s operations and the aircraft had been borrowed from Andrea Szymanski-Ehrhardt Fischversand for this particular flight.

The operator’s representative also explained that the pilot-in-command of the accident flight was not employed by the operator. They had got to know each other because they both had flying as a hobby, and therefore the pilot occasionally flew the company aircraft. The pilot was not paid for this, only the costs were covered.

The operator company did not have a full-time pilot at its service, nor did it have any maintenance facilities of its own. Aircraft maintenance, repair, modifications and annual inspections were carried out by certificated mechanics outside the company.

The operator estimated that the aircraft was airworthy and the documents and manuals were up to date and consistent with the aircraft equipment. He stated that the aircraft maintenance, repair and modifications had been performed at licensed repair shops and saw these shops as responsible for their correct implementation and making the required notifications.

The overall condition of the accident aircraft was good. However, it was found out during the investigation that the aircraft did not fulfill the applicable airworthiness requirements in every respect, and that there were some deficiencies in the Aeroplane Flight Manual and technical records. While Andrea Szymanski-Ehrhardt Fischversand was in possession of the aircraft, the maintenance and annual inspections had been carried out regularly, which indicates that the company wanted to maintain the aircraft in good condition. It is evident that the company was not aware of the deficiencies or did not regard any deficiency reports given by the repair shops as having effect on airworthiness, since the aircraft had always been reported airworthy in the maintenance records.

2.2 Crew requirement and qualifications

2.2.1 Crew requirement

The flight was conducted in a non-commercial purpose, without any remuneration being collected from the passengers. The aircraft was equipped with an autopilot enabling e.g. auto-coupled approach, and the Aeroplane Flight Manual allowed it to be used with a single-pilot crew. Therefore the flight could be conducted as a single-pilot operation under IFR.

2.2.2 Crew qualifications

In the aircraft journey log book entries for the flight EDWB-EFOU preceding the accident flight, two names had been marked in the 'crew' column, so that the pilot-in-command's name was given first and the operator's representative below it. The number of crew members had been marked as 2. According to the radio communication recordings, when asked ”NSG, request passengers on board”, the pilot-in-command replied ”two pilots, one passenger”. In the customs clearance documents signed in Oulu by the pilot-in-command, both for arrival and departure, the pilot-in-command's name had been entered in the 'Capt' column and the name of the operator's representative in the F/O column. The number of passengers was indicated as 1. There were no entries relating to the accident flight in the log book.

The pilot held a valid German commercial pilot licence with multi-engine and IFR ratings, as well as type rating for the accident aircraft. He also had a corresponding US pilot licence, which was valid subject to validity of the German licence. He was qualified to act as a pilot on the flight marked in the flight plan.

The operator's representative, who had been marked as a crew member, held a German private pilot licence with a type rating for the accident aircraft. His radio operator's licence only entitled him to operate on VFR flights and in the German language. He did not have an IFR rating. According to the information provided by FAA, he had been issued an American private pilot licence with single and multi-engine class ratings, which was valid subject to validity of the German licence. He was not qualified to act as a flight crew member on the IFR flight conducted in accordance with the flight plan.

When interviewed after the accident about any division of tasks in the cockpit during the accident flight, the operator told having been there only as a passenger, without being assigned any duties by the pilot-in-command before the flight or during it.

When he was asked who had made the last entries to the log book in Oulu, the operator could not remember it first. However, after he was shown the log book entry, he confirmed having written it himself. It thus came out that he had marked himself as a crew member.

The operator's representative told having understood that when sitting on the crew seat, he could credit half of the flight time for himself, which was the reason why he had marked himself as a crew member. His flight log was not up to date, and so it could not be determined by comparing the aircraft log book and his personal flight log, how he had counted the flight hours to his credit on earlier flights entered in the log book in a similar way. Whether he had performed crew duties on those flights could not be determined either.

The pilot-in-command and the operator's representative must have discussed the latter's qualification to act as a crew member. In the radio communications with ATC as well as in the documents filled in during customs clearance on arrival and departure, the pilot-in-command had given him as a crew member. It can therefore be concluded that the pilot-in-command regarded the operator's representative as a crew member or accepted him to be marked as such and acted accordingly.

The crew was probably under the impression that the aircraft operator, holding a Private Pilot Licence and a type rating for the aircraft, could act as a co-pilot on a flight performed by the operator company in a non-commercial purpose and without any charge being collected from the passengers. Thus they decided to conduct the flight using a two-pilot crew. Therefore it is probable that the operator performed crew duties during flight preparation and in flight, and the pilot-in-command assigned him duties within the normal division of tasks between the captain and co-pilot.

The operator marked himself as a crew member after the landing in Oulu. The pilot-in-command accepted this and acted accordingly, since he cited the operator as a crew member in the radio communications with ATC and in the customs clearance documents.

The investigation commission sees that the pilot-in-command accepted the procedure despite knowing that it was against regulations. Therefore an unsound relationship was formed between the pilot-in-command and the ”co-pilot”, which may have adversely affected their performance on the accident flight.

It did not come out during the investigation that the operator’s representative would have performed any crew duties in flight. At the refuelling site he had checked the engine oil levels; this might be regarded as a crew duty, but can on the other hand be considered a normal action by the operator responsible for the use of the aircraft, seeking to ensure its airworthiness for his part. Since he held a type rating for the aircraft, he had the knowledge and skill required for this function.

2.2.3 Pilot-in-command’s experience and performance

The investigation commission did not have access to the pilot-in-command’s personal flight log, nor did it receive full information on his flight training. Only incomplete, one-sided information was obtained about his flying skills, cockpit work and performance as a pilot-in-command. Details on his flights, duty periods and performance immediately before the accident flight were not obtained, and so his alertness could not be assessed.

According to the entries in the aircraft log book, the pilot-in-command had flown the accident aircraft for the first time on 8 August 1993. His command experience in the accident aircraft was from the period 8 August 1993 - 20 December 1994. The number of flights was 11 and of landings 18, the total flight time being 23 h 51 min. In 1993 he had flown 6 h 46 min and performed 12 landings, the rest had been gained in 1994. On these flights the aircraft had been fitted with the same navigation and engine monitoring systems as on the accident flight, and the pilot-in-command was therefore familiar with its equipment and their operation.

Judging from the incomplete information obtained by the investigation commission, the pilot-in-command had sufficient flying experience to perform the flight in question. However, he had little experience on the aircraft type.

The inquiry about the refuelling possibilities and operational hours of the airports, as well as the fact that new route manuals were ordered, indicate that the flight was carefully prepared. However, the pilot-in-command did not make the mass and balance calculations in writing and did not fill in the OFP (Operational Flight Plan) form, by which he showed indifference towards safety procedures to be followed during flight preparation and in flight.

The fact that the pilot-in-command accepted the operator’s representative as a crew member, although he did not have sufficient qualifications, indicates that the pilot-in-command either misinterpreted the regulations, did not care to follow them or lacked authority.

2.3 Training and experience of the serviceman

Since there are no specific aviation regulations on the training and qualifications of refuelling personnel, setting the requirements as well as planning, implementation and supervision of training has remained the responsibility of oil companies and their internal quality control.

The Airports Operations Manual used by the refuelling company gives the general outline and subjects for the basic training of an aircraft refueller.

In the chapter dealing with refuelling training, the Airports Operations Manual requires the Refuelling Manual and chapter 6, Refuelling, of the Airports Operations Manual to be read. These passages contain detailed instructions on refuelling operations and procedures for checking the correct fuel type before refuelling.

The serviceman told that he was familiar with the contents of the chapter ‘Overwing refuelling’ in the Airports Operations Manual. In his opinion, the most important rule in this chapter was that in case the aircraft does not have decals indicating the fuel type, order form I-8 must always be used and confirmed with the customer’s signature. He stated that the same instruction was also given in the Refuelling Manual, which is a summary of the Airports Operations Manual. He told having been aware of the instructions, because he had read them.

According to what the serviceman told, the required procedure was not followed in the company. In practice, refuelling orders received by telephone were accepted. He stated that the instructor had advised him to fill in the written order form only if it could not be determined from the conversation which fuel type was needed.

The instructor, who was a partner in the refuelling company, told that the established company practice was to use the order form only when it could not be otherwise determined what kind of fuel the customer wanted or if the request was unclear. For example if the refuelling order was received through the air traffic control, the order form was not used.

This procedure followed by the refuelling company and taught to the serviceman was accepted by the company partner, but it was not in compliance with the Airports Operations Manual.

The company partner had not regarded this as an absolute requirement, and had adopted a less stringent interpretation to be used in the company operations. He had wanted to make the operations more flexible by not filling in the forms, which he considered unnecessary when the order was received through air traffic control or in a direct conversation with the customer.

However, by proceeding like this he watered down the principle of quality assurance aimed at in the Airports Operations Manual. The investigation commission sees that the purpose of using the form I-8 was to achieve absolute certainty of the correct fuel type when the decals were missing and specifically to eliminate the risk of misunderstanding inherent to verbal communication.

If the serviceman had been taught to comply with the instructions without exception and if the instructions had always been followed, verifying the fuel type markings would have become an automatic measure to be taken before refuelling. The exceptions made the instructions seem less binding than was originally meant, and the quality assurance by verifying the fuel type markings as required in the instructions had not developed into a routine for the serviceman.

The Airports Operations Manual did not give exceptions to the rule. The Manual was not the operating instruction for the company as far as the use of form I-8 is concerned, since the company followed a different practice.

On the identification of different aircraft types, the instructor had given as a rule of thumb that if the propeller cones were chromium plated, then it was a turboprop. This rule is not based on any actual aircraft classification, though it is known among aviators, and it is in fact an erroneous and misleading criteria for identification. However, when mentioning this rule, the serviceman stated that he had ”never identified aircraft on that basis alone”.

The accident aircraft had chromium-plated propeller cones, which may have contributed to the fact that it was assumed to be a turboprop.

The serviceman had been carrying out refuelling duties without supervision for less than a year before the accident. The investigation commission considers his experience as scarce.

2.4 Fuel ordering and refuelling

On 18 December 1995, the pilot-in-command had inquired by telefax about the operational hours of Oulu airport and whether it was possible to refuel with 100LL. The air traffic controller in duty had replied by telefax on the same date, stating that ”Refuel of 100LL is available H 24 from Shell automat (accepts Euro Shell Card) and 05 - 19 UTC daily on service (accepts Euro Shell, Shell Aviation Carnet, VISA)”.

The reply is correct, but does not explain how the fuel is delivered on service. Therefore the person who sent the inquiry may have got the impression that service refuelling would be carried out from some other refuelling point than an automat, and he might have tought that refuelling would also be possible from a tanker car.

Even though the pilot-in-command had inquired about the chances for refuelling with the fuel type and got a reply, he had not placed an order. The flight plan EDWB-EFOU drawn up by the pilot-in-command in Germany did not contain any remarks on the refuelling.

The actions that can be regarded as an order for refuelling started when the pilot-in-command reported by radio to the air traffic control that the aircraft needed refuelling. In this context, he asked where the refuelling would take place but did not mention the fuel type: ”NSG wants to refuel, have we go to the station or is a car coming?”.

There had been a change of shift in the tower slightly before the accident aircraft landed. The ATC officer of the previous shift had cleared the aircraft to land, whereas the next officer had given it landing time and clearance to taxi to the stand in front of the terminal building. The ATC officer of the previous shift was still in when the aircraft ordered refuelling and he overheard the conversation. According to a usual practice, he telephoned the fuel company and reported that refuelling was needed.

The investigations revealed that neither of the ATC officers, nor the fuel company knew about the inquiry sent by the pilot-in-command on the airport operational hours and availability of 100 LL. They did not know about the reply given to it either. The fuel company had not received any advance order for refuelling the aircraft in question, and so it was not aware of its intention to refuel before the telephone call from ATC, nor did it know the fuel type needed.

Why did the pilot-in-command fail to mention the fuel type in the radio exchange with ATC?
It can be assumed that the fuel type was not mentioned simply because this was only an inquiry about the possibilities for refuelling, addressed to ATC, and not an order placed to the fuel company. By his telefax, the pilot-in-command had verified that the correct fuel type was available. Perhaps he took it for granted that the air traffic control knew about the aircraft coming to take 100LL, the availability of which had been asked for beforehand. During the radio communications he only confirmed the need for refuelling notified earlier and therefore did not mention the fuel type.

It is also possible that the pilot-in-command took it for granted that the ATC officer knew, on the basis of the type information given in the flight plan, that it was a piston-engined aircraft and would use aviation gasoline.

By asking ”...have we go to the station or is a car coming?” the pilot-in-command wanted to check if the aircraft should go to a fixed refuelling station or if there was a car coming to the stand shown to the aircraft. This indicates that the pilot-in-command was not sure where the refuelling could be carried out.

The radio communications between the pilot-in-command and the air traffic control aimed at clarifying that fuel was needed and finding out where the aircraft should go to get it and whether the refuelling could be carried out at the stand where the aircraft was taxiing. The pilot-in-command stated that the aircraft needed refuelling and wanted to confirm the place by suggesting the fixed station and asking about a tanker car as an alternative.

The pilot-in-command may have intended this as an order to be transmitted to the fuel company. However, it can also be understood as a mere notice to the air traffic control, so that it could show the aircraft a place where it could be refuelled.

At busy airports, air traffic control does not convey refuelling orders, but at less congested airports this is often an established practice. When reporting the need for refuelling and asking about the arrangements, the pilot-in-command may have tried on purpose if the air traffic control would convey the request to the fuel company and explain where and when the refuelling could take place, or only give information about refuelling procedures without conveying the message. The question was so formulated that both interpretations were possible, but it cannot be considered a direct order for refuelling.

In response to his question the pilot-in-command was told: ”A Shell car is coming to you on the apron”. Thus the pilot-in-command was assured that the refuelling issue was in order and fuel would be delivered at the stand. He also believed that the fuel company had been informed, because the reply indicated that a car would be coming to the stand. At this stage the pilot-in-command did not have to give further thought to refuelling, since the matter seemed to be clear.

The air traffic controller who telephoned the fuel company had understood the conversation as a request for refuelling. Before the change of shift, he had given the aircraft approach instructions and cleared it to land. He had seen the flight plan and therefore knew that it was a US-registered aircraft which was relatively fast (220 kt) and came from a high level (FL 210). The type marking showed that it was a Beech aircraft, and in Finland, Beech aircraft operated at a high level are usually turbopropeller-powered. From this information the air traffic controller may have concluded that it was a turboprop which he knew would use JET A-1.

When telephoning the fuel company, the air traffic controller spoke according to his own impression and reported that the aircraft had asked for refuelling. He added the fuel type himself, saying: ”an American plane is coming and asks for Jet”. During the interview, the air traffic controller first told about this conversation and then added that if he remembers right, he had also asked them to check the matter anyway.

The investigations did not bring out any such information given to the ATC officer which would have actually indicated that the aircraft was using jet fuel. Therefore it can be concluded that he had created himself a wrong idea of the fuel type used and conveyed it to the fuel company.

The partner of the fuel company, who answered the telephone call, understood the request conveyed by the air traffic controller as a jet refuelling order addressed to his company.

In the Finnish language, the word ”jenkkikone” is a common nickname for American aeroplanes, and ”jet” is often used for jet fuel in spoken language. It is therefore certain that both parties of the conversation understood what was meant by these expressions.

The notice given by the air traffic controller indicated that the aircraft had asked for a certain fuel type. If the air traffic controller had mentioned about checking the matter, it would have been logical that the other party had wanted to verify what should be checked. Neither of the parties told about any such conversation when interviewed. It therefore seems probable that the air traffic controller did not remark on checking the matter during the telephone conversation.

On the basis of the conversation with the air traffic controller, the partner of the fuel company assigned the refuelling task to a serviceman who had just started his working shift. When giving the assignment, he took it for granted that ”...there is a turboprop with American markings waiting for jet fuelling in front of the new terminal...”. He saw that the aircraft was in the right place for jet fuelling, and as the air traffic controller had said that it would take ”jet”, he did not express any doubt on the fuel type to be delivered.

If the air traffic controller had not mentioned the fuel type, the fuel company would probably have asked about it. Since he reported that the aircraft would take jet, the fuel company started to proceed accordingly without verifying whether it was the correct fuel type.

The air traffic controller on duty did not reply immediately to the question asked by the aircraft. According to radio communication recordings, the interval between the question and the reply was 38 seconds. During this period the air traffic controller may have checked the information available about the aircraft in order to find out whether it had asked for refuelling earlier and which kind of fuel it had ordered. Having noticed that there was no such indication, he might have intended to ask the other air traffic controller, who had been in contact with the aircraft before, but saw that he was on telephone. When the other air traffic controller - after the telephone conversation or during it - stated that ”Shell knows”, he got the information he needed and reported to the aircraft: ”a Shell car is coming to you on the apron”.

When interviewed, the air traffic controller who had told the aircraft that a tanker car was coming stated that he had not heard the telephone conversation between the other air traffic controller and the fuel company. He claimed not to know when the telephone call had taken place or which words the other air traffic controller had used when making the order.

However, he told about this telephone conversation, which indicates that he knew that the other air traffic controller ordered the refuelling by telephone. Therefore he must have been aware of the conversation.

The air traffic controller did not say anything about a car coming to the aircraft. Why did the other air traffic controller then report to the aircraft that ”a Shell car is coming...”?

Because of the layout of air traffic control premises, the air traffic controller had to reach over the other’s right shoulder to make the telephone call. The fuel company number could be selected using a quick-dial button, and a light then indicated where the call was taken. Therefore the air traffic controller on duty was able to see that the other air traffic controller was on telephone and that he was calling the fuel company. Without paying close attention to the conversation, he may have overheard part of it and subconsciously realized that the other air traffic controller informed the fuel company about the aircraft’s need for refuelling. Having heard ”jet refuelling” mentioned in the conversation and the statement ”Shell knows” by the other air traffic controller, he may have summed these up with his own knowledge that jet refuelling is carried out from a car. This is probably the reason why he gave the above mentioned reply to the pilot-in-command.

According to the usual practice, the air traffic control had informed the customs of the foreign aircraft. The customs officers had come to the airport before the aircraft arrived and asked the airport marketing manager whether he knew its exact time of arrival. The marketing manager called the air traffic control to ask the time of arrival, reporting also that the customs officers wanted the aircraft to be guided to stand 3 in front of the terminal building for customs clearance.

It is possible that this request for the aircraft to be shown a particular stand, together with the other air traffic controller reporting that ”Shell knows”, have also contributed to the fact that the air traffic controller on duty understood the fuel company to know about the aircraft and its need for refuelling. He got the impression that refuelling had been agreed to take place at the stand where he had cleared the aircraft to taxi. Knowing that refuelling at the stand would be carried out from a tanker car, he reported that a car was coming to the stand.

The air traffic controller did not ask which type of fuel the aircraft used. If the crew had mentioned the fuel type during the conversation, it is certain that the air traffic controller would have responded to this and advised the aircraft to the fixed refuelling station for aviation gasoline.

The pilot-in-command had drawn up the flight plan to Murmansk and decided to make an intermediate stop in Oulu for refuelling. In response to his inquiry on refuelling possibilities, he was informed about the credit cards accepted at Oulu airport. It came out that the Esso credit card used by the operator company would not be accepted, and so the refuelling would have to be paid in cash or using some other credit card.

It is evident that the operator's representative knew about the route plan, since it was his company's flight. The crew must have discussed about the refuelling before the flight and agreed how it should be paid for.

The operator told that the pilot-in-command had asked him to take care of the refuelling in Oulu. He stated to have accepted the task and regarded it as his responsibility.

It was not found out during the investigation if the pilot-in-command had assigned him the task of supervising the refuelling as a crew member or simply in the capacity of operator.

It can be assumed that the division of tasks during the stopover was made spontaneously so that the operator's representative as a ”host” would supervise refuelling and pay for the fuel, whereas the pilot-in-command would take care of other duties as well as verify the meteorological and other information needed for flight preparation. The purpose of this division was probably to hasten the departure for the next flight. While the operator's representative took care of refuelling, its payment and walk-around checks of the aircraft, the pilot-in-command visited meteo.

Alternatively, the division of tasks during the stopover may have been based on the crew member duties. This is the case if the operator's representative actually was on the flight as a crew member as recorded in the aircraft log book.

The paragraph ”Operator's responsibilities” in the Finnish aviation regulation AIR M1-12, Aircraft refuelling, prescribes that the operator should nominate a person to supervise refuelling on the ground.

The investigation showed that the operator's representative participated in the refuelling operations at the site. The investigation commission sees that he was acting as a member of the refuelling crew as defined in the regulation AIR M1-12 and represented the aircraft operator during refuelling.

According to the regulation, the operator is responsible for and shall also verify that the fuel type and quantity stated in the refuelling order are correct. Therefore the operator's representative was responsible for reporting the correct fuel type and quantity as well as for verifying that the type and quantity delivered were correct.

The aviation regulation AIR M1-12 further prescribes that the refueller shall be responsible for ensuring that the fuel type and quantity delivered are in accordance with the order.

The serviceman had been assigned the refuelling task by his foreman with the instructions: ”there is a foreign plane in front of the new terminal, which will take jet”. Because the foreman had mentioned the fuel type to be delivered, he took it for granted that it was a jet refuelling task and acted accordingly. He took the tanker car used by the company solely for JET A-1 refuelling and drove to the aircraft stand in front of the terminal building.

When assigning the task to the serviceman, the foreman did not mention that the order had been received by telephone, nor did he ask him to verify the correct fuel type before refuelling. Therefore the serviceman had no reason to doubt whether the fuel type was correct; on the contrary, he had been assigned the task of delivering a particular type of fuel.

When in front of the terminal building, the serviceman saw that there were no other foreign aircraft at the stand and concluded that he was in the right place. He presumed that the aircraft was the one he had been assigned to refuel, and on the basis of the assignment, he knew which type of fuel should be delivered.

When the tanker car arrived in front of the terminal near the aircraft, the operator’s representative came to the car. They started conversating, and after exchanging greetings the serviceman told having asked about the quantity of fuel to be taken. It can be concluded that the serviceman initiated the conversation about refuelling.

The serviceman understood that the fuel type was known and therefore inquired only about the quantity, by asking: ”How much do you take?”. The fact that the serviceman started the conversation about refuelling and only asked about the quantity made the operator’s representative believe that he already knew about the need for refuelling and the fuel type required. The operator answered the question spontaneously by stating the quantity and told the serviceman to fill the tanks up. Since he was not asked about the fuel type, he did not mention it in his reply.

During this conversation, both the operator’s representative and the serviceman should have checked the fuel type and quantity. They agreed upon the refuelling and the quantity came out from the reply ”fill the tanks up”, but neither of the parties stated which fuel type was required. Both members of the refuelling crew failed to confirm the type.

If both parties in the conversation had focused on stating the required fuel type and quantity, it would certainly have come out that the correct fuel type was aviation gasoline and not jet fuel.

According to the Airports Operations Manual and Refuelling Manual used by the fuel company, the serviceman should have checked the aircraft fuel type markings before refuelling. Because there were no such markings, he should have used the order form I-8 and got it signed by the customer. The serviceman probably did not check the markings, since he did not respond to the fact that they were missing.

In the lighting conditions prevailing at the airport, the serviceman should not have had any difficulty in reading the fuel type markings. He regarded the lighting as sufficient for reading the documents, and so the larger markings in the aircraft should have been easy to discern, as well as to see that they were missing. It can thus be concluded that the serviceman did not check the fuel type markings to ensure the correct fuel type before refuelling, which would have been his responsibility.

Since the foreman had assigned him the task of delivering a particular type of fuel, the serviceman had no doubt of the fuel type and started refuelling as usual. The importance of checking the fuel type markings had not been emphasized during his training and it had not developed into an absolute routine. This contributed to the fact that they were left unnoticed.

If the aircraft had been provided with fuel grade markings in accordance with airworthiness requirements and as prescribed by the manufacturer, the serviceman would probably have seen the markings and noticed that he was about to refuel it with wrong type of fuel.

While refuelling went on, the serviceman's foreman came to the refuelling site and brought the price list. He was still under the impression that the fuel delivered should be JET A-1, and so he pointed at the jet fuel prices when showing the price list to the operator's representative.

Jet fuel prices were at the top of the A4-sized page and those for aviation gasoline at the lower half. For jet fuel, the symbol JET A-1 was not used in the list, whereas the marking AVGAS 100LL was found in the title for aviation gasoline. The price list was not clear for someone not knowing Finnish; since the symbol JET A-1 was missing but AVGAS 100LL was there, it could be understood that it only listed aviation gasoline prices by different criteria.

As a result of language difficulties or wrong choice of words, it was not clearly expressed during the conversation that the fuel type delivered was JET A-1. It did not come out either that the correct fuel type would have been AVGAS 100LL.

On the basis of the information given by the air traffic controller, the foreman believed that the aircraft was a turboprop and would take jet fuel. When visiting the refuelling site, he acted according to this belief and did not verify if the fuel type was correct. He took this for granted, because he saw that the type was the one reported to him by air traffic control and mentioned in the assignment given to the serviceman.

The foreman received the order by telephone and delegated the task to his subordinate. He saw the aircraft himself when visiting the site, but did not verify that the fuel type was correct. The foreman should have observed the provisions of the Airports Operations Manual on procedures to be followed when receiving an order by telephone: it prescribes that refuelling may only be carried out if the aircraft is equipped with fuel type decals. The foreman failed to accomplish his supervisory responsibilities when visiting the site.

After refuelling the serviceman took a fuel sample from the tanker car and showed it to the operator’s representative, saying: ”If you want, you can check our jet”. Looking at the sample, the operator’s representative stated ”It is good”, and the serviceman understood that he had accepted the sample. Moreover, the serviceman told that the operator’s representative then noticed that his hands had become dirty when checking the engine oil levels, dipped his hands into the fuel sample and wiped them with a cloth given to him by the serviceman.

Because the operator’s representative held a type rating for the aircraft and knew the colour of AVGAS 100LL, he should have noticed that the fuel sample was of a different colour than aviation gasoline. When he dipped his hands into the sample and wiped them, he should also have smelled that it was some other type than aviation gasoline.

The question arises whether the operator’s representative actually thought that the serviceman, who explicitly mentioned ”...our JET”, had shown the sample in the mere purpose of presenting the company’s jet fuel. Therefore he did not realize that the serviceman showed for acceptance the fuel with which the aircraft had been refuelled under his supervision.

It is also possible that he fixed his attention to his hands being dirty and therefore failed to check the quality of the sample.

At present, aviation gasoline is usually delivered from fixed refuelling stations and often from self-service automats. It is rarely delivered by a tanker car, and a quality sample is seldom presented to the crew.

The importance of taking fuel samples had been stressed during the serviceman’s training. His working shift had just begun and this was the first refuelling in that shift. He took the sample in order to make sure that the fuel was clean, and wanted to prove it to the customer as well by showing the sample. The operator’s representative may have regarded this as an unusual procedure. He probably reacted only to the fact that the sample was clean and accepted it by saying ”It is good”, without paying attention to the serviceman’s statement that it was jet fuel.

When interviewed during the investigation, the operator’s representative recalled that he had been presented some kind of sample, but he had taken it as a joke. After refuelling he signed the delivery receipt, in which stage he should have verified at the latest that the fuel type was correct. However, he accepted the fuel type and quantity by signing the receipt without noticing that the fuel delivered was of the wrong type.

In the delivery receipt, the box next to JET A-1 had been marked with an X and the box for AVGAS 100LL could be clearly seen to be empty. The twilight was changing into darkness while the refuelling went on, but the area has a good general lighting. The serviceman told that despite the twilight, the documents were still easily readable.

In the opinion of the serviceman, the operator's representative seemed busy when signing the receipt and did not read and check the document properly. Nevertheless, he wrote himself the operator company's name on the receipt in the appropriate box, which indicates that he did not only sign the document hastily without reading it.

The operator's representative also paid for the fuel in cash without noticing anything unusual about the price. He had been shown the price list during refuelling and pointed out the unit price of the fuel in DEM, which was his native country's currency. The payment was also made in DEM.

The operator's representative probably did not realize that he was shown jet fuel prices when studying the price list written in Finnish. However, it seems odd that he did not notice that the fuel was much cheaper than what the same amount of AVGAS 100LL would normally have costed, especially considering that he is a businessman himself.

When he went to the aircraft in order to assist in the refuelling, the operator's representative should have focused on making sure that the fuel type and quantity were correct and followed this principle in all his actions. He was wearing eyeglasses at the refuelling site, and so he should not have had any difficulty to carry out the operator's responsibilities in the prevailing lighting conditions. The investigation commission sees that he did not attend to his share of duties in verifying the correct fuel type.

On the flight there was an employer - employee relationship between the operator's representative and the pilot-in-command. This is probably the reason why the pilot-in-command only asked the operator to take care of refuelling instead of giving a firm order, which may have affected the operator's attitude towards the task. Having been asked to carry out the task, he regarded it merely as his duty. If the pilot-in-command had ordered him to take care of refuelling, he would have taken it more as an obligation to carry out an order. Then he would have focused on following the order and, as a pilot's licence holder, would have paid attention to the procedures to be followed in aircraft refuelling.

2.5 Fuel tank markings and filling orifices

The accident aircraft fuel tank markings were not in accordance with the applicable airworthiness requirements. The fuel grade markings specified for the type by the aircraft manufacturer were missing. The word FUEL was mentioned in the markings, but there was not any information about the fuel type or grade on the wing surface. The text AVGAS ONLY at the lower side of the caps cannot be considered as a marking in accordance with airworthiness requirements.

The colour of the accident aircraft was different from the original colour delivered from the manufacturer. According to the documentation, the aircraft had been repainted on 18 August 1986. The fuel type decals may have been removed from the wing at this time and when the new decals were affixed, the fuel grade marking was left out. The inadequacy of the markings had not been noticed during maintenance and annual inspections, possibly because the marking requirements were poorly expressed in the aircraft operating and maintenance instructions.

The fuel tank filling orifices had been fitted with restrictors and smaller caps. In the modification, the orifices of 75 mm in dimension were reduced to 60 mm, which is in accordance with the published standards on filling orifice dimensions.

It was found during the investigations that the right outboard filling orifice restrictor came off when opening the cap and remained stuck to it. This was possible because the restrictor had been installed incorrectly and hence the blocking mechanism did not function properly.

The serviceman told that when refuelling the first tank section ”the wing was so narrow at the area of the first filling orifice that the refuelling nozzle had to be kept in a diagonal position and pointed towards the wing base. If the nozzle was held upright, it would have been so near the tank bottom that fuel would have splashed during pressure refuelling”.

This was exactly the same filling orifice from which the restrictor came off when tested. The restrictor was so loosely attached that it may have come off when the cap was opened and got stuck to the cap, so that the refuelling crew did not notice it.

Without the restrictor the filling orifice dimension was 75 mm. If the restrictor was loose when refuelling was started, the refuelling nozzle equipped with a 50 x 70 mm elliptical extension would have gone into the orifice and inside the tank without difficulty. Therefore the serviceman did not notice anything unusual, except that the nozzle was too close to the tank bottom unless it was kept in a diagonal position.

When interviewed about filling the other tank, the serviceman told to have brought a ladder to make refuelling easier, because fuel had splashed on him due to wind. Actually the fuel may have splashed because the restrictor was in its place and the nozzle equipped with an expansion was left outside the tank, while only the Camlock coupling fitted in. Since the orifice dimension was smaller, the nozzle could be only slightly inclined and was therefore directed towards the tank bottom, which caused the splashing. When standing on the ladder, the serviceman got the nozzle in a better position in the reduced orifice and the fuel splashed less, or he was simply above the nozzle and the splashing was therefore less disturbing. Thus the refuelling was completed without anything unusual being noticed in the filling orifices or nozzle fitting.

During the investigation the operator's representative told that on one flight, the take-off run had to be abandoned because the right-side fuel tank cap had opened. When closing the cap, they had noticed that the restrictor was loose. He stated that after this incident, he had always opened and closed the caps himself, and this was the reason why he had hastened to open and close the caps in Oulu as well.

It is possible that when refuelling was started, the right wing outboard filling orifice restrictor came off with the cap and remained stuck to it. The refuelling crew did not notice this at any stage, and when the cap was closed, the restrictor went back to its place. If this was the case and especially because the refuelling was started from this orifice, it has contributed to the fact that the refuelling crew did not notice anything unusual about the fitting of the nozzle into the filling orifice and therefore was not alerted of the mistake being made.

2.6 Refuelling equipment

The tanker car used was intended only for JET A-1 refuelling. It was equipped with clearly visible labels indicating the fuel type, which had the text ”Shell JET A-1” in white characters on black background. The labels were in accordance with the American Petroleum Institute (API) international recommendations. The car had no markings which could have given the impression that it contained AVGAS 100LL.

The operator's representative was present during refuelling and he should have checked that the fuel type was correct. He could have seen from the markings in the tanker car that it contained JET A-1, and there where no markings which would have indicated that there was aviation gasoline.

The nozzles are colour-coded to indicate the fuel type. The colours correspond to the aircraft fuel type decals so that if the colours match, it shows that the fuel type is correct. If the colours are different, it is an alert of a wrong fuel type.

In the tanker car used for refuelling the accident aircraft, the nozzle body was black to indicate that it was for jet fuelling. The aircraft did not have any fuel type decals. Therefore the correct fuel type was not confirmed by the colours, since the absence of decals was not responded to.

The expanded nozzle section was within the dimensions specified for jet fuel nozzles in the standards and Shell Airport Operations Manual. However, the Camlock coupling was smaller than required and fitted into the reduced filling orifice without difficulty, which made it possible to fill the tanks with JET A-1 instead of AVGAS 100LL although they were equipped with restrictors.

The nozzle and its expansion were not coloured black, nor did they have the fuel type marking JET A-1. The investigation commission could not find out whether any regulations or standards exist on the markings and colours of replenishment nozzles. It came out, however, that the American General Aviation Manufacturers Association (GAMA) has developed colour-coded self-adhesive tapes to be attached to the nozzles to indicate the fuel type. In addition, one oil company has made a proposal on colouring the nozzles with the colour indicating the fuel type, and one nozzle manufacturer has black expansions with the text JET A-1 in its product range.

2.7 Regulations, instructions and recommendations on refuelling procedures

The Finnish aviation regulation AIR M1-12, amendment 2, issued on 25 May 1994 on aircraft refuelling, clearly defines the responsibilities of the aircraft operator and the refueller.

The fuel type markings to be used in aircraft and refuelling equipment are not specified in Finnish aviation regulations. Advisory Circular AIR T1-11 refers to airworthiness requirements as to the markings and recommends the use of fuel type decals. The investigations showed that there was much variety in the fuel type markings of Finnish aircraft. This variety may have caused and may still cause the refuelling staff to become less inclined to respond to the deficiencies.

The Airports Operations Manual written and maintained by Shell gives instructions on checking the correct fuel type markings before refuelling. The investigation commission regards these instructions as correct and sufficient.

Had the instructions been complied with, the deficiencies in aircraft fuel type markings would have been noticed. The Airports Operations Manual describes the procedure to be followed in case the aircraft does not have clear markings on the fuel type used: since the markings were missing, the oil company form I-8 should have been given to the operator’s representative to be completed. The operator’s representative should have marked the fuel type on the form and confirmed it by his signature.

In addition to the Airports Operations Manual, the company staff used the Refuelling Manual published by Shell and containing principally the same instructions on checking the fuel type. It requires the order form I-8 to be used when the aircraft does not have fuel type decals and contains illustrations of the decals recommended in API Bulletin 1542.

Paragraph 23.1557 of the airworthiness requirement FAR Part 23 applicable to the accident aircraft prescribes that the word ”FUEL” as well as the lowest fuel grade accepted should be marked to the filling orifice caps or near them. According to FAA Advisory Circular No 20-116, these markings could have been substituted or supplemented by fuel type decals recommended in GAMA Specification 3. The decals in accordance with API Bulletin 1542 are used worldwide, but they were not included in the accident aircraft airworthiness requirements.

The instructions contained in the Refuelling Manual may give an impression that even if the aircraft has the fuel grade marking prescribed in the airworthiness requirements, but not the decals in accordance with API Bulletin 1542, order form

I-8 should be used. This procedure would confuse aircraft operators whose markings are in accordance with airworthiness requirements.

Paragraph 4.2.1 of the Finnish aviation regulation AIR M1-12 prescribes that only such equipment which fulfill the current requirements shall be used in aircraft refuelling. The Finnish aviation regulations and advisory circulars in force at the time of the accident did not set any requirements on fuel nozzle dimensions.

The aviation authority of the accident aircraft manufacturing and registration country (FAA) has issued on 29 January 1991 an Advisory Circular on preventing incorrect refuelling (AC No 20-122A, Anti-Misfueling Devices: Their Availability and Use). This AC deals with fuel type markings, installation of restrictors and nozzle dimensions. Whether the accident aircraft operator, pilot-in-command and maintenance staff were familiar with this circular was not examined, but the deficient markings indicate that it was not complied with in every respect.

During the investigation, the commission got the impression that the standards issued in other countries on the dimensions of fuel nozzles and filling orifices were not known to Finnish aircraft operators, oil companies and refuelling staff. This conclusion is based on the fact that when these standards were inquired from several oil companies, aircraft repair shops and operators, the documents were not available in their original form.

2.8 Intermixing of the fuel types in the aircraft fuel system and composition of the mixture fed to the engines

In the accident aircraft, fuel was fed to the engines from the lowest tank section at the wing base. There was some aviation gasoline left in the fuel manifolds and filters even after the refuelling, and therefore the engines started up normally. During taxiing and run-up, the aviation gasoline at the lowest tank sections had not yet been mixed with the jet fuel filled through the orifices near the wing tip. The engines were running normally or at least the crew did not notice anything unusual.

The analysis of samples taken from the fuel manifolds after the accident showed that JET A-1 and Avgas 100LL had been intermixed in the tanks. The fuel fed to the engines did not have the properties of aviation gasoline, but the mixture contained more jet fuel than aviation gasoline in both engines.

The composition of the fuel fed to the engines depended on how much aviation gasoline was remaining before refuelling and how the jet fuel and gasoline had been intermixed. Factors affecting the fuel composition and the differences in composition between the engines were for instance:
- amount of aviation gasoline remaining in the tanks before refuelling;
- flow rate and nozzle position during refuelling;
- differences in the specific gravity of fuel types;
- differences in engine power settings and running times;
- direction and rate of movement during taxiing and in flight;
- crossfeed selection, if used.

2.8.1 Fuel mixture properties

The required fuel grade for AVGAS 100LL is 100 with lean mixture and 130 with rich mixture. The amount of lead tetraethyl used for improving the knock rating is limited to 2,0 ml/U.S.Gall or 0,56 g(Pb)/l. The specific gravity is 0,690 - 0,739 kg/l and the identifying colour blue.

The knock rating for JET A-1 is not specified, and it does not contain any lead tetraethyl. Its knock rating is considerably lower than that of aviation gasoline. The specific gravity of jet fuel is 0,770 - 0,849/l and the colour is clear.

Aviation gasoline has a considerably higher self-ignition temperature compared to jet fuel. The mean value for AVGAS 100LL with lean mixture is approximately 515°C and for JET A-1 around 250 - 270°C, the average being 258°C.

The fuel sample analysis showed that the amount of aviation gasoline was 18 ± 3 % in the left engine and 22 ± 3 % in the right engine. Before the engines stopped, they were running on a mixture of JET A-1 and AVGAS 100LL. Judging from the properties of fuel types forming the mixture, the knock rating and self-ignition temperature were very low compared to aviation gasoline. When the fuel types were intermixed, the colour of the mixture gradually turned from blue to clear.

2.9 Engine damage

The external damage to the engines resulted from the impacts.

The right engine generator drive belts were in the grooves of their wheels and intact, and so the generator would have rotated if the engine had been running. The belt wheel had been deformed on impact and was in contact with the generator body. There were no impact marks caused by rotation, and it can be concluded that the engine was not running at the time of the impact.

The propeller blades were deformed on impact in both engines and both propellers were separated. Judging from the impact marks in the blades, their direction and shape as well as the ruptures in the propeller attachment parts, the engines were without power and the propellers not rotating when the deformations and the separation were caused. The engines were not running when the aircraft hit the trees.

Judging from the positions of engine power control mechanisms and their deformations, throttle control levers were set at maximum power, mixture at full rich and propellers at high RPM and small blade angle at the time of the impact. It seems that the crew tried to obtain maximum power from the engines before the impact.

The damage caused to pistons, piston rings, cylinders and connecting rod bearings in both engines and some plugs in the right engine was typical of engine knock. The melt damage to the pistons was also found mainly in places which indicate engine knock, i.e. as far from the plug as possible.

In both engines, the connecting rod and piston pin bearing surfaces of all cylinders had been damaged due to high pressure, and there was some metal deposit in the oil filters. Momentary knocking does not cause damage to bearings, and so the knocking must have been going on for a longer period.

As JET A-1 and AVGAS 100LL were intermixed in the fuel tanks, the composition of fuel fed to the engines gradually reached the knock limit. The piston damage was not identical in all cylinders, which indicates that the knocking did not start at the same time and with the same intensity in all cylinders. As the fuel types were intermixed, the knocking started as moderate and while the fuel composition became less and less resistant to compression, the knocking increased. In the less effectively cooled cylinders which were running hottest, the knocking started earlier and the anomalities in the engine working cycle developed more rapidly than in the better cooled cylinders.

It can be concluded from the differences of damage inside the pistons and cylinders that the damage started gradually and increased with an accelerating rate until the engines flamed out due to internal damage and increasing frictional forces.

It is probable that the knocking did not start simultaneously in both engines. Therefore the engine damage and power loss also developed at different times and with different intensity. However, any clear difference could not be found as to the damage sustained by either engine, and so it could not be determined in which engine the knocking continued longer or was more intense.

When the knocking started, there were probably first changes in the engine temperatures and slight fluctuation in the boost pressure and fuel flow indications, while the compressor control systems tended to maintain the selected power setting. As the engine cycle was disturbed, the engines gradually lost their power and started to run irregularly. While the knocking increased, the power loss was accelerated. If the engine power was at the climb or cruise setting, the constant-speed propeller control systems were able to maintain the engine rotation speed, but the airspeed gradually deteriorated as the blade angles decreased. Thrust reduction lessened the knocking and increase of thrust accelerated it.

While the abnormal engine operation went on, the temperatures inside the engines exceeded the normal operational limits. The increase in temperature inside the cylinders accelerated the knocking. The overheated parts were subjected to rapid pressure loading typical of engine knock and the pistons began to suffer damage. As the damage spread, the engine lost more and more power and the compressor and propeller control systems were no longer able to maintain the selected power setting, which led to a gradual decline of engine rotation speed.

As the fuel types were intermixed, the self-ignition temperature gradually became considerably lower than that of aviation gasoline. It is possible that in the most overheated cylinders the carbon deposit started to glow in places due to the temperature increase caused by knocking. This may have led to pre-ignition of the fuel and further power loss. The phenomenon is usually of short duration, since it causes the engine working cycle to change and the hot points in the carbon deposits cool down in such an extent that self-ignition no longer occurs. If the internal parts of the cylinder become very hot and remain in the self-ignition temperature, the engine power is not restored and the disturbed working cycle will continue resulting in considerable power loss. When the fuel mixture composition is at the knock limit, the burning process started as pre-ignition leads to knocking and the internal parts of the cylinders are rapidly damaged.

The accident aircraft was fitted with Graphic Engine Monitor (GEM), Cylinder Head Temperature (CHT) and Exhaust Gas Temperature (EGT) measuring systems. The cylinder head temperatures of all cylinders and exhaust gas temperatures in both engines could be seen simultaneously on a display. The GEM display must have shown a slight decline in the EGT value of the knocking cylinder(s) as well as a considerable increase in CHT.

There have been seizures between the pistons and cylinder walls in the more severely damaged cylinders. When the seizures begun, engine power was considerably reduced and the seizures increased as a result of growing frictional forces. The power loss may have been very abrupt before the engines stopped.

It seems possible that the engines did not stop at the same time. When the other engine was lost, the pilot certainly increased the power in the remaining engine. This increased the knocking and the other engine flamed out as well due to internal damage.

In both engines the starter bendix drive gear was in the forward, or starting, position, which indicates that the crew had tried to restart the engines. If this was the case, it can be concluded that the attempt was not successful since the bendix gear moves away from the starting position when the engine starts. However, the gear may have moved to the forward position on impact.

The right engine cowl flap actuator was out of order already before the accident, and the flow of cooling air into the engine could not be regulated. The aircraft was not fitted with a cowl flap position indicator, and so the pilot was not able to detect that the cowl flap did not move. During run-up and take-off, the temperature increased faster in the right engine than in the left. The fact that the cowl flap was immovable and only 50 % open contributed to the knocking when the engine temperature rose. Insufficient cooling also affected the rate and amount of engine damage.

2.10 Search and rescue operations

The wreckage was found in the dark forest about half an hour after the accident, which must be regarded as a successful search operation. Several factors contributed to the rapid discovery of the wreckage.

Oulu airport and Rovaniemi area control centre maintained radar contact with the aircraft during the entire flight. Therefore the suspected crash site could be determined with reasonable accuracy on the basis of the radar data.

The area control centre was aware of the other aircraft operating in the airspace, and so they were immediately able to find an aircraft to assist in the search operations. Incidentally, the search aircraft was equipped with an ELT locating device.

The area control centre assisted the search aircraft by radar. It also advised the aircraft back to the estimated crash site when it drifted away from there because of the weak ELT signal. The search aircraft and the radar controller managed to determine the probable location of the ELT signal, and the search aircraft continued circling above the suspected crash site.

It was a coincidence that the search aircraft happened to fly over the wreckage at exactly the same time as the ground rescue units were passing the accident site. The crew in the airport rescue unit leading vehicle knew that an aircraft was also used in the search operations, and when they saw the aircraft they assumed that it might have already found the wreckage and was flying above it to show the place. They pointed a torch towards the roadside and saw the wreckage.

The ground rescue units did not know that the accident aircraft was equipped with an ELT transmitter and that it had been activated after the accident. Therefore the ELT transmitted several hours after the wreckage was found and rescue operations finished.

The airport rescue units had installed an ELT locator in one vehicle for testing purposes; other rescue units did not have these devices. The tests had shown that the device worked well in off-road search drills carried out with snow mobiles, but there had been interference when the device was used inside a rescue vehicle. The device was not in use this time because the search operations were conducted by cars. The investigation commission sees that all rescue vehicles used by airports and municipalities in their vicinity should be equipped with ELT signal locating devices and this equipment should be suitable for use inside the vehicles as well.

The air traffic control VDF was tuned in the emergency frequency, but did not detect the ELT signal. The signal was probably blocked by terrain and the fact that the wreckage was upside down, which left the ELT antenna installed under the skin plate in front of the vertical stabilizer at a blind angle under the fuselage and the broken horizontal stabilizer. Therefore the signal was only transmitted upwards and to certain directions on the ground.

After the accident aircraft sent the second distress message, the air traffic controller alerted Oulu Area Emergency Centre, which then activated all appropriate rescue services according to the pre-established plan. They also prepared for extending the search operations by calling off-duty airport staff and alerting a helicopter from Rovaniemi to be on call and to participate in the search if needed. Aircraft owners and aviators living in Oulu region were also contacted and asked to assist in the search operations.

The equipment used in the search and rescue operations was sufficient. The first aid given immediately at the accident site by the medical staff of the rescue units and Oulu University Central Hospital emergency unit was crucial for the survival of the aircraft operator who was injured in the accident.

The accident site was in the vicinity of the airport and a search plan had been elaborated for the area in case of an aircraft accident. On the basis of this plan and their knowledge of the area, the airport rescue units knew the usable routes, which contributed to the fact that the crash site was found rapidly.

The investigators determined the route of the accident aircraft by using radar data recorded at the area control centre, which enabled its position at different stages of flight to be located on a map. The investigation commission sees that with a similar programme, the flight path data could be immediately analyzed and drawn on a map display in an accident situation and transferred to the rescue units using modern teletechnology. By this means it would be easier for the rescue units to compare the route on the map display with the surrounding terrain and direct the main search effort to the right area. This would make search operations more effective in less familiar regions as well.

A6574 ELT SIGNAL DETECTIONS BY SATELLITES

A-CODE	TIME UTC (hh:mm:ss)	TIME from ACCIDENT (hh:mm:ss)	Y_{A-6574} (m)	X_{A-6574} (m)	DIS-TANCE (m)	SEARCH AREA (km^2)	NOTE
MAP OLD	14:24:24	0:00:00	3 415 988	7 209 759	451	0,64	MAP/OLD
MAP NEW	14:24:24	0:00:00	3 416 308	7 209 440	0	0,00	ACCIDENT AREA
MSSR	14:24:24	0:00:00	3 416 066	7 210 003	612	1,18	MSSR LAST DET.
ELT/177	14:54:00	0:29:36	3 409 700	7 219 209	11 793	436,94	ELT detection
ELT/179	15:46:00	1:21:36	3 425 224	7 212 271	9 355	274,96	ELT detection
ELT/180	16:00:00	1:35:36	3 441 189	7 239 795	39 249	4 839,62	ELT detection
ELT/181	16:11:00	1:46:36	3 421 063	7 215 539	7 733	187,88	ELT detection
ELT/182	16:38:00	2:13:36	3 409 582	7 217 911	10 816	367,51	ELT detection
ELT/183	17:31:00	3:06:36	3 416 672	7 210 267	903,18	2,56	ELT detection
ELT/185	19:15:00	4:50:36	3 419 153	7 205 923	4 524	64,30	ELT detection
ELT/186	21:38:00	7:13:36	3 414 621	7 210 139	1 825	10,47	ELT detection
ELT/AVER			3 419 650	7 216 382	10 775	364,74	ELT AVERAGE

2.10.1 Chances for opening the door during rescue operations

Several rescue crew members tried to open the aircraft door by the handle in order to get inside the wreckage, without succeeding. Finally the door was broken open.

According to what the rescue crew told, they did not know that the locking mechanism release button should have been pushed at the same time when turning the handle. Those who tried to open the door did not know or notice that there was a release button and did not push it when turning the handle.

Because the release button was not pushed and since there was a large idle movement in the outside handle, a person not knowing the correct opening method may have thought that the handle could be moved but the door did not open.

The release button outside the door was not easily discernible and it had not been marked. Since the rescue crew did not know that there was such a button, they did not notice it, nor did they see the release button inside the door.

According to the aircraft manufacturer, there should have been a text **PRESS TO RELEASE** outside the door above the release button. Such a text could not be found, nor any traces or marks left by it. It could be seen that the door had been repainted in the area of the opening handle and release button; the marking may have been removed in this connection and a new marking has not been made. The fact that the text was missing had not been noticed during scheduled maintenance or annual inspections.

The fuselage around the door and the door frame had maintained their form relatively well. If the rescue crew had known the operating principle of the locking mechanism or if the release button and its use had been clearly indicated outside the door, they would have been able to operate the mechanism correctly. Therefore they would probably have managed to open the door in the normal way and got inside the wreckage more quickly and without breaking the structure.

The rescue operations and observations were hampered by darkness and the fact that the wreckage was upside down.

2.10.2 Chances for using the emergency exit

The rescue crew told that they were not aware of the emergency exit in the aircraft. They did not notice it either, because it had not been marked outside the aircraft, and they did not see the markings inside.

The airworthiness requirement FAR Part 23 in force when the accident aircraft was certificated did not require the emergency exit to be marked outside the aircraft.

The fuselage structure and the emergency exit were slightly deformed on impact. If the rescue crew had known about the emergency exit, they would probably have been able to open it by breaking the window and turning the inside handle. Therefore they would have got inside the wreckage through the emergency exit, which might have helped to speed up the rescue operations. However, it would have been extremely difficult to get the victims out through the emergency exit because the wreckage was in inverted position.

2.11 Seats and safety belts

The seats were deformed on impact, but remained attached to the floor. The seat deformations did not contribute to the injuries sustained by the occupants.

The light-metal bracket of the back seat passenger's right lap belt section broke on impact. The lap belt had been fastened, but it was found out after the accident that the shoulder harness had not been attached to the lap belt lock.

The broken lap belt had the certification marking FAA-TSO-C22f and a rated strength value of 1500 was marked on it as required in the certification.

FAA-TSO-C22f requires compliance with certification requirements to be shown by specific tests. According to the TSO, compliance with seat belt strength requirements must be shown as specified in the National Aircraft Standards (NAS) Specification 802, revised May 15, 1950. Nevertheless, the TSO also gives exceptions from the NAS 802 requirements.

According to NAS 802, paragraph 4.3.2 ”Complete Belt Assembly Tests” and its subparagraph 4.3.2.1 ”Tensile Test - Rated Strength”, the belt assembly strength must be determined by a tensile test as specified in the above mentioned paragraph. Paragraph 4.1.1 ”Rated Strength of Belt Assembly” requires that the belt assembly, including the belt, release mechanisms and all components needed to install it must be designed for a rated strength value of at least 3000 lbs. TSO-C22f grants an exception from this requirement and sets a minimum rated strength value of 1500 lbs.

In order to determine the static breaking strain value for the lap belt attachment bracket, a tensile test was carried out on two belt assemblies. The test showed a strain value of 990 kg (2182,5 lbs) for one assembly and 1007 kg (2220 lbs) for the other. The values were higher than the tensile strength of 1500 lbs (680 kg) required by FAA-TSO-C22f, and therefore the light-metal attachment brackets used in the accident aircraft safety belts met the applicable strength requirements.

The passenger's shoulder harness was not fastened at the time of the impact, and therefore the lap belts were subjected to higher loads than they were designed to sustain. As the maximum load capacity was exceeded, the light-metal attachment bracket of one lap belt section broke while the other belt section attachment bracket, made of steel, sustained the load without breaking.

Since the shoulder harness was not fastened, the entire load was directed on the lap belt assembly and distributed between the two attachment points. The breaking of the right belt section attachment bracket was caused by the passenger mass increasing manyfold on impact and thus exceeding the load capacity of the bracket.

Presuming that the load was evenly distributed on both lap belt sections, the forces acting on them were equal and can be calculated using the formula $\Sigma F = F_{LH} + F_{RH}$. With the passenger mass of 91 kg, the limiting load factor (= F_{RH}) required to break the right lap belt attachment bracket, the tensile strength of which was 990 kg*, would have been 990 kg : 91 kg = 10,88 g** and the total load directed on the lap belt assembly (= ΣF) 21,8 g.

* 990 kg = the lowest breaking strain value measured in the tensile test carried out during investigation

** g = load factor

The pilot-in-command's lap belt sustained the impact load without breaking, although his shoulder harness had not been fastened either. According to the formula given above, with the pilot-in-command's mass of 77 kg, the limiting load factor required to break the lap belt attachment bracket would have been 12,85 g and the total load directed on the lap belt assembly 25,7 g.

Hypothetically it can be assumed that all occupants of the accident aircraft were subjected to parallel and simultaneous acceleration and inertial forces. The locations of the lap belt attachment points were identical in the crew seats and passenger seats, and so the loading on the belts was parallel in direction. It can therefore be assumed that the belts were subjected to equally strong forces at the same time.

Based on this assumption it can be concluded that the occupants were subjected to acceleration forces in excess of 21,8 g, because the attachment bracket of the passenger's lap belt broke. It can also be concluded that the forces were not greater than 25,7 g, since the pilot-in-command's lap belt bracket did not break.

If the back seat passenger's shoulder harness had been fastened, the seat belt loading would have been distributed between three attachment points. In this case the loading on the shoulder harness would have been directed to the left lap belt section. The shoulder harness and the left lap belt section together would have taken 2/3 of the total load, while the right lap belt section would have been subjected to 1/3 of the load. Therefore the passenger's lap belt would have sustained the impact forces without breaking, since the total loading on the belt assembly required to break the attachment bracket would have been more than 32,6 g.

However, the facts developed above are based on static breaking load values. In reality, the seat belts were subjected to dynamic loading. The loading was not equal on different seats because of mass differences, body positions, tightness of the belts, frictional factors depending on clothing etc. In addition, the breaking of the brackets was not necessarily caused by direct tractional forces, but they may also have been subjected to bending due to sideward movements.

The lap belt attachment brackets allowed for a sideward movement of approximately 10° without being subjected to bending. The mixed loading produced a shearing force, which caused the bracket to break more easily than with direct traction. Marks of sideward loading and slight bending could be found on the passenger's lap belt attachment bracket.

The investigation commission sees that the exact direction and amount of loading that caused the attachment bracket to break cannot be determined. However, judging from the static strength calculations it can be concluded that if the back seat passenger's shoulder harness had been fastened, his seat belt would have sustained the load without breaking. This is supported by the fact that the operator's representative, who weighed 93 kg (2 kg more than the back seat passenger) had fastened his shoulder harness and his seat belt did not break.

Paragraph 23.785 (Seats, berths, litters, safety belts and shoulder harnesses) of the airworthiness requirement FAR Part 23 applicable to the accident aircraft sets requirements on seats and safety belts as well as their fittings. In paragraph 23.562, Emergency landing dynamic conditions, it also prescribes the safety requirements to be taken into account in the design and installation of these devices.

In paragraph 23.562 requirements are set for the protection of aircraft occupants during emergency landing. Compliance with the requirements is to be shown by dynamic tests or comparable analysis. In the tests, the strength of seats, safety belts and other devices must be shown on given directions and values of loading and in specified conditions, using a test dummy weighing 170 lbs (77 kg). Additionally it must be shown that the safety belts do not cause excessive loading on the passenger's pelvis and chest when used correctly, and that they protect the occupant especially against head injuries.

The back seat passenger had contusions at a longitudinal area approximately 6 cm wide on his lower chest and abdomen. He had also sustained internal injuries. These were most probably caused by the lap belt when the passenger slid as the aircraft was moving forwards and sidewards in inverted position. If the shoulder harness had been fastened, the load would have been distributed between three belt sections. Therefore the loading caused by the lap belt on the chest and abdomen would not have been so strong and the passenger would have sustained less severe injuries.

The worst injuries to the back seat passenger were caused by hits on the head and upper body, and his shinbone was broken as well. Probably he sustained the injuries when hitting the internal structures of the aircraft, since he was thrown away from his seat as the safety belt broke. He is also likely to have suffered injury from luggage falling over him, because the cabin luggage had not been secured.

If the shoulder harness had been fastened, the safety belt would not have broken. The passenger would have remained on his seat and would not have hit his head and upper body against the aircraft structures with such a force. The unsecured luggage probably fell over the area where the passenger was thrown from his seat; if he had remained on the seat, the luggage would not have caused injury to him.

The pilot-in-command was most severely injured in the head and upper body. The injuries were probably caused by hitting against the left cockpit sidewall, instrument panel and controls, as well as the upper edge of the windshield frame which had been deformed. His upper body was thrown forward and upward on impact. If his shoulder harness had been fastened, it would have restricted the upward movement and somewhat absorbed the side movement. Therefore some of the hits on the head and upper body would not have occurred and he would certainly have suffered less injury.

The safety belt of the operator’s representative, who weighed 93 kg and was sitting on the other crew seat with his shoulder harness appropriately fastened, had sustained the impact without breaking. His worst injuries were caused by a force directed on the chest and were mainly found on the left side. He probably suffered the injuries when hitting the right-side control stick.

The shoulder harness slowed down his upper body movement on the impact and reduced the load directed to the upper body and chest. The use of shoulder harness certainly helped to reduce his injuries. It is also highly probable that the shoulder harness restricted the upper body movement enough to prevent him from hitting his head against the instrument panel and thus protected him from head injuries.

According to the instructions in the aircraft and Aeroplane Flight Manual, the shoulder harness should have been worn for the entire flight on crew seats and during take-off and landing on the back seat.

The investigation commission did not consider it necessary to carry out a dynamic loading test on the belt assemblies, which the static test showed to be in compliance with the FAA-TSO-C22f strength requirements. The safety belt fittings in the seats and aircraft structures had sustained the impact without breaking. The investigation commission sees that the ruptures and deformations caused to the aircraft structures on impact do not give any reason to doubt their having been designed and constructed to meet the protection standards set in the applicable airworthiness requirements.

2.12 Accident flight

2.12.1 Pre-flight preparation

In an application sent to Murmansk during flight preparation, Turku (EFTU) and Ivalo (EFIV) were mentioned to be used as intermediate stops and for refuelling. In the flight plan actually filed, the stopover and refuelling aerodrome was changed to Oulu. As the route segments therefore became longer, the crew probably decided to refuel the tanks to the full amount. It is not clear who made the decision, but it can be assumed to have been the pilot-in-command.

According to the flight plan the endurance was 5 hours, which required the tanks to be filled up. The pilot-in-command was responsible for the airworthiness of the aircraft, including the correct take-off weight, and thus for ensuring correct loading and refuelling. As to refuelling, his responsibility was to determine how much and which type of fuel should be delivered.

It had been agreed in Oulu that the operator’s representative would go to the refuelling site and take care of duties related to refuelling. It could not be determined whether the fuel type was mentioned in this conversation. When the operator’s representative was interviewed after the accident and asked if the pilot-in-command told how much fuel should be taken, he answered ”No, it went without saying that the tanks were to be filled up.”

However, the fact that the fuel quantity ”went without saying” must have resulted from some kind of flight planning in which it was established how much fuel was needed. Obviously the pilot-in-command and the operator discussed about the planned route and where the stop should be made for refuelling. In this connection, they must have determined the endurance required to conduct the flight as planned and the amount of fuel needed. The fact that the tanks were filled up was probably well-thought-out and known to the pilot-in-command.

It is possible that the fuel type was not mentioned in the conversation between the pilot-in-command and the operator’s representative, who held a type rating for the accident aircraft, since it was considered self-evident.

It could not be found out whether the pilot-in-command checked the fuel type and quantity from the operator’s representative before the flight. The operator’s representative had kept the delivery receipt, and so the pilot-in-command did not read it. The operator and pilot-in-command may have discussed the matter and established that the refuelling had been carried out, but probably the pilot-in-command did not verify it from the delivery receipt. If he had checked the receipt, he would certainly have responded to the fact that the box next to JET A-1 had been ticked and noticed that according to the markings, JET A-1 had been delivered instead of AVGAS 100LL.

It came out during the investigation that the pilot-in-command had flown a check flight on the aircraft type on 31 May 1994. In this connection he had made the mass and balance calculations for the aircraft used on the check flight, using standard mass values of 170 lbs for the aircraft occupants. The calculations showed that there had been three persons on board and that the take-off mass with tanks full did not exceed the maximum certificated take-off mass.

According to the accident aircraft journey log book, the pilot-in-command had flown it before the reweighing carried out on 29 September 1993. At that time he probably had the records of the weighing carried out at the factory at his disposal. When familiarizing himself with the aircraft he may have understood that when there are three persons on board but no luggage and standard mass values are used, the tanks can be refuelled to the full amount without exceeding the certified mass and centre of gravity limits.

When using standard mass values of 170 lbs (77 kg) and data in accordance with the weighing records drawn up at the factory, the aircraft could be operated within the certified limits if there is no luggage.

The pilot-in-command had not flown the aircraft for a while, and it had been reweighed in the meantime. According to the new weighing records in the Aeroplane Flight Manual, the aircraft basic empty weight was 5001 lbs. A list of equipment installed and remaining in the aircraft during the weighing was not included. The AFM also contained the weighing certificate and equipment list for the weighing carried out at the factory, which indicated that the basic empty weight was 4893 lbs.

When the pilot-in-command resumed flying the aircraft, the AFM probably contained both the new weighing records and data from the earlier weighing. Whether he had noticed that the aircraft had been reweighed and its basic empty weight had increased by 108 lbs (49 kg) is not known.

If the pilot-in-command did not know that the aircraft had been reweighed and did not notice the new weighing documents in the AFM, he may have still made the mass and balance calculations based on the old weighing records. In addition, he may have used standard mass values for the aircraft occupants. Therefore he might have got the impression that the certified limits would not be exceeded with three persons on board without luggage even if the tanks were full. If he had weighed the luggage and taken account of the manuals, operating items and catering carried, he should have added at least 80 lbs (36,3 kg). Thus the calculations would have shown that the aircraft was overweight.

It seems probable that the pilot-in-command did not actually calculate the aircraft mass and centre of gravity when planning the flight from Bremerhaven to Murmansk, but used the data from the old weighing records. He concluded from his earlier experience that the certified limits would not be exceeded with the tanks full and three persons on board. This is supported by the fact that no fuel or mass calculations were found in the aircraft.

If the pilot-in-command had used the current weighing records contained in the AFM and the actual weighed masses for the aircraft occupants, luggage and other items carried on board, the calculated take-off weight would have been 7005 lbs (3178 kg) and the aircraft 230 lbs (104 kg) overweight. On the accident flight, the aircraft mass was further increased by the greater specific gravity of the incorrect fuel type, which caused a mass increment of 103 lbs (47 kg). Therefore the aircraft had 151 kg excess weight when departing Oulu, which significantly affected its performance.

The pilot-in-command visited meteo when the fuel company tanker car came to the aircraft. He was given information about the weather at the aerodrome of departure and on the planned route, and so he knew the weather conditions prevailing before the flight, such as cloud base, night conditions and visibility.

2.12.2 Chances for detecting the incorrect fuel type during pre-flight inspection and engine start

Due to the inclination of the wings, the remaining aviation gasoline was in the tank sections near the wing base. Because the aircraft was refuelled through the outboard filling orifices, the empty tank sections near the wing tip were first filled with jet fuel. Only some of the jet fuel was mixed with the aviation gasoline remaining in the lower tank sections during refuelling, but the mixing went on because of the specific gravity differences and movements.

The Aeroplane Flight Manual required a pre-flight inspection to be carried out. This inspection is made to ensure the airworthiness of the aircraft and includes for example a sump drain of the fuel tanks, in which a fuel sample is taken from the lowest parts of the fuel system. Whether these checks were made and by whom is not known, but in any case nothing unusual was found because no measures were taken to verify the fuel type.

The time elapsed after the refuelling until the walkaround check (if it was made) was so short that the fuel types had been only slightly intermixed because of the differences in their specific gravity alone. There was only clear, colourless petrol in the wing tip sections and only blue gasoline in the base sections. The central sections contained mixed fuel, the colour of which was light blue.

The purpose of the visual check of the fuel sample is to see that it does not contain water or any sediment. It was noted during the investigation that the vessels commonly used for taking fuel samples, including the one that was used in the accident aircraft, were so small that it was difficult to determine the fuel colour from such a quantity.

A test revealed that it was almost impossible to identify the jet fuel and aviation gasoline samples by their colour alone when they were presented separately in a small vessel, and even when they were compared side by side the colour difference was very slight. In a larger vessel the colour difference would be better exposed.

Although there was some colour difference between the fuel contained in different tank sections, it must have been very small. Under the circumstances, it has been almost impossible to identify the incorrect fuel type by the colour of a sample taken from the fuel tank sediment traps with the vessel used in the accident aircraft. The samples are usually not compared with each other, and so the slight difference in the colours of the samples taken from different tanks do not give an indication of an incorrect fuel type.

There was some pure gasoline left in the fuel manifolds and filters after the previous flight, and the engines started up normally. Therefore nothing indicated that the fuel delivered was incorrect.

2.12.3 Taxiing and test run

When departing for the accident flight, the crew asked for taxiing clearance 4 min 8 sec before take-off according to the time scale used in the air traffic control radio communication recordings, and started to taxi 3 min 17 sec before take-off according to the recorded radar data. The aircraft stopped at the take-off position at the end of runway 30 at 14.18.07 UTC according to the corrected time references in the recorded radar data and stated to be ready for take-off at 14.18.47, as indicated in the radio communication recordings. Having stood at the take-off position for 53 seconds, the aircraft took off at 14.19.00.

The aircraft did not stop during taxiing, and so the before take-off engine test run must have been made at the take-off position for runway 30. According to the recorded time scale, the test run must therefore have been carried out between the moment when the aircraft stopped at the take-off position (14.18.07) and when the crew reported ”ready for takeoff” (14.18.47), which leaves 40 seconds for the test run of both engines. The time used for the test run was short, which indicates that nothing unusual was detected. In case of any irregularity, a new test would certainly have been made and the time used would have been longer. On the other hand, some of the procedures may have been carried out during taxiing or the test run may have been only partial, which would explain the short time used for it.

The jet fuel delivered through the wing tip orifices had not yet been mixed with the aviation gasoline remaining in the lowest tank sections during the taxiing and test run. Therefore the engines were running normally on gasoline, or at least anything unusual was not noticed in their operation.

2.12.4 Navigational equipment and altimeter settings before take-off

The pilot-in-command probably set the navigational equipment according to the air traffic control clearance issued before take-off, but it could not be determined how.

The right-hand altimeter was calibrated in both millibars and in.Hg, whereas the left-hand altimeter only had in.Hg settings. An A5-sized plastic folder with approach charts for the route was found in the aircraft, and in one pocket there was an hPa - in.Hg conversion table. Whether it was used could not be found out.

After the accident, the setting of the altimeter on the pilot-in-command's side was 30,18 in.Hg. The right-side altimeter had the setting 1004 mb in accordance with the airport QNH hPa and the equivalent in.Hg value of 29,64. It could not be determined whether the pilot-in-command had set his altimeter incorrectly or if the setting had changed during the crash sequence or rescue operations.

The operator's representative could not remember what the left-hand altimeter setting was at take-off. However, he recalled that the right-hand altimeter had been set first and that the pilot-in-command had compared the indication of his own altimeter with it.

It can be assumed that the pilot-in-command set the QNH value in his own altimeter before take-off. He did not need to change the setting in flight, because they flew all the time below cloud and with visual reference to terrain without climbing to the en-route altitude. An incorrect setting could have resulted from a mistake in converting the given hPa value into in.Hg, and the pilot-in-command would have consequently set an incorrect value in his altimeter. However, the pilot-in-command would probably have noticed that the altimeter indication differed considerably from the aerodrome elevation and would certainly have detected the incorrect setting when comparing the indications with each other.

The investigation commission sees that the altimeter setting probably changed during the crash sequence or rescue operations.

2.12.5 Ensuring that the safety belts were fastened before take-off

According to the Aeroplane Flight Manual and the checklist used in the aircraft, the procedures to be followed before engine start include fastening lap belts and shoulder harnesses, as well as luggage securing. There were not any printed safety instructions for passengers in the aircraft, and the AFM specifies that when these are missing, the pilot-in-command should verbally brief the passengers about safety equipment, doors, emergency exits and emergency procedures in accordance with FAR Part 91. This FAR prescribes the pilot-in-command to ensure that all passengers know how to use the seat belts and safety harnesses.

It could not be determined for sure whether the pilot-in-command told about the safety equipment and instructions before take-off. It is not sure either if he asked the passengers to fasten the shoulder harnesses as well and ensured that they were actually fastened.

According to the AFM, shoulder harness should be worn during take-off and landing on passenger seats and at all times on pilot seats. Instructions about the use of safety belts and seat back positions were fastened to the cockpit and cabin side windows.

The back seat passenger did not necessarily know that his seat was equipped with a shoulder harness. When flying with large airliners, he may have understood that passenger seats were only equipped with lap belts. The shoulder harness had been wound inside the seat back so that only the part to be attached to the lap belt could be seen. It is possible that the passenger did not notice that there was a shoulder harness, since the visible belt section was in the upper part of the seat back behind his shoulder. Because a safety briefing was not given, he had left the shoulder harness unfastened.

If the pilot-in-command had given the safety briefing and properly ensured that the shoulder harnesses were fastened, he would certainly have fastened his own harness as well. The investigation commission considers that safety instructions were probably not given, although it would have been the pilot-in-command's responsibility.

2.12.6 Take-off, climb, rejection of climb, decision to return to the airport and forced landing

The accident aircraft was given route clearance to Murmansk on FL 160 and cleared to take off from runway 30 with a right turn to the route.

The take-off run and initial climb appear to have been uneventful. The change in aircraft configuration, landing gear retraction, seems to have occurred at the normal stage of flight after take-off. Nevertheless, the aircraft did not start the right turn but continued straight ahead.

According to the air traffic controller who monitored the take-off, there was nothing unusual except that the gradient of climb was rather low. The low gradient was probably due to the excess weight and engine troubles that occurred soon after take-off. Some of the cylinders may have started knocking, which reduced the engine thrust. The pilot-in-command probably noticed that the aircraft did not climb well and detected anomalies in the instrument indications, which led to the decision to fly straight ahead in the runway direction with visual reference to terrain. The direction was maintained with the help of an ADF tuned in the Laanila NDB beacon frequency and/or the heading bug set in the HSI. Autopilot may also have been used.

The knocking begun when the engines started running on a mixture of jet fuel and aviation gasoline already during take-off. The excess weight and engine troubles kept the gradient of climb lower and the airspeed slower than usual. It can be seen from the flight path and profile computed on the basis of recorded radar data that the aircraft drifted approximately 400 m right from the extended runway centreline at Laanila NDB, at 8,5 km from the estimated deviation point. This corresponds to the calculated sidewind drift.

Since the pilot-in-command had noticed that there was something wrong, he wanted to maintain ground visibility and avoid flying into the cloud.

According to the radar data, the climb rate gradually decreased after take-off and initial climb. The climb was rejected and the aircraft levelled off at approximately 1250 ft QNH. At this stage the pilot-in-command had certainly noticed the first problems in either engine, most probably in both engines. He detected anomalies in engine temperature indications and tried to find out their causes.

The pilot-in-command had probably never acquired any training for or experience from this kind of situation in which both engines simultaneously developed malfunctions that grew worse all the time. Therefore he had to focus entirely on the engine troubles, while paying less attention to controlling the aircraft. Maintaining the same heading, the aircraft flew past Laanila NDB to approximately 13 km from the initial deviation point, where it suddenly turned about 30° to the right. It had already been losing height before this change of course.

It can be assumed that the abrupt change of direction resulted from a sudden and considerable loss of engine power or from the pilot’s failure to control the aircraft while he was possibly trying to switch the cross-feed on.

In the detailed analysis of recorded radar data, the transponder signals showed that there were slight deviations at a distance of approximately 3,5 km before the 30° change of direction. These were all to the same side and can therefore have resulted from occasional power losses in the right engine. This would explain the right turn, particularly if the pilot had to control the aircraft manually after the autopilot had been disconnected due to the abrupt side movement. A hasty correction of the bank that had developed without the pilot noticing it may have caused the aircraft to turn to the other side. It seems logical that the right engine would have showed the first signs of malfunction, since the cowl flap actuator was stuck on that side and the right engine was running hotter.

Possibly the abrupt change of direction forced the pilot-in-command to focus on controlling the aircraft besides monitoring the abnormal engine temperature indications, and he steered the aircraft straight ahead in this new direction. Soon after the change of course, the air traffic control gave the departure time and a new radio frequency to the aircraft. The pilot-in-command replied swiftly by a brief acknowledgement, which was entirely different from his previous radio communications. This indicates that he was under pressure, concentrating on something else and not having time to speak.

During this straight section of flight he probably made the situation clear to himself and concluded that it would be wise to return to the airport. He decided to turn back and initiated a left turn, possibly using autopilot. He contacted Oulu ATC again, reporting that they were having some problems and wanted to return. He was immediately requested to call on final 12, which the pilot-in-command acknowledged. Approximately 10 seconds later the ATC asked if any emergency equipment was needed. The pilot-in-command’s reply was immediate and negative, but he sounded hesitant.

It is surprising that he refused, because even if the engines were running better at the time due to throttle adjustment, the pilot-in-command should have tried to maximize safety and accepted the use of emergency equipment. Actually the engines had not become any better during the turn and did not run properly. It can be seen from the recorded radar data that the aircraft was losing height all the time and the airspeed was deteriorating.

1 min 10 sec after the negative reply the air traffic control asked if the crew had the field in sight. The pilot-in-command confirmed this and added that their DME distance was 6 miles. 30 seconds later the pilot-in-command called mayday and told that both engines were stopping. After 15 seconds he gave another distress message, stating that they were about to crash.

The right engine was probably left running on reduced power already at an earlier stage, which caused the aircraft to lose height while the pilot tried to maintain the airspeed as high as possible under the circumstances. Just before the first distress message, the recorded radar data shows deviations that were more distinct than the earlier ones and could now be interpreted as serious malfunctions of the left engine, since they were to the opposite side.

As the left engine suffered more damage, the aircraft started losing height rapidly. Both engines lost more and more power, which led to a ground impact approximately 6,5 km short of runway 12 threshold. Judging from the impact marks, propeller damage and ruptures in their mounting parts, the engines were not running at the time of the impact.

Thrust increase made the knocking more intense and as the engines suffered internal damage, both engines gradually lost power and finally stopped almost simultaneously. Throttle levers were set at full power and remained in this position while the pilot-in-command focused on making the forced landing.

The situation developed rapidly so that a forced landing became imminent. The pilot-in-command called mayday stating that the engines had stopped. He had to make the decision about forced landing and choose the landing site very quickly. Because the terrain was covered with snow, he was able to discern the open fields and clear areas of forest since they were whiter than the surroundings, despite the fact that it was dark.

The pilot-in-command certainly saw the open field straight in front of the aircraft, as well as the clear area of forest closer by. He probably intended to land on the open field, but as the aircraft was losing height, he decided to head for the clear area of forest instead. Apparently the pilot-in-command did not notice the strip of taller trees at the edge of the area, and the aircraft hit them without reaching the intended landing site.

When interviewed after the accident, the operator’s representative told that he only remembered that the engines were not running well. He could not recall at which stage the engine problems first emerged and how they were manifested, nor could he tell which engine was first affected. He stated that at some stage after the engine troubles emerged, the pilot-in-command had said that it must have been refuelled with jet fuel. As to the action taken by the pilot-in-command, the operator's representative recalled that he had probably used the fuel cross-feed selection.

2.13 Airport equipment

Due to an equipment failure in Oulu ATC telephone call recording system, some of the calls had not been recorded. The system did not have any means to indicate a malfunction. In addition, the time references used in the radio and telephone communication recordings as well as in the radar data were found to be incorrect: they differed from each other and neither of them was in line with the actual timing.

This kind of deficiencies should absolutely be corrected. The recorded data and its correct timing are extremely important for accident investigation. If the data is only partly recorded or if the time references are inaccurate, the investigators may lose information that would be essential for determining what happened or draw false conclusions about the sequence of events.

3. FINDINGS AND CONCLUSIONS

3.1 Findings

The crew and the aircraft

1. The pilot-in-command held a valid Commercial Pilot Licence with ratings required for the flight.

2. Medicolegal examinations did not reveal anything that would have adversely affected the crew's performance.

3. The aircraft operator's representative, who had been marked as a crew member by the pilot-in-command, was not qualified to act as a crew member on the flight.

4. The aircraft had a valid registration certificate and certificate of airworthiness.

5. Fuel tank markings were not in accordance with airworthiness requirements. There was no indication of the fuel type used.

6. A modification had been made to the fuel tank filling orifices, in which they had been fitted with restrictors and smaller caps.

7. The restrictors had been installed incorrectly, and they were not properly locked in their places. The restrictor of the right wing outboard filling orifice came off when tested and it may have been out of its place when the aircraft was refuelled.

8. There were no markings on the location and use of the locking mechanism release button outside the door.

9. The right engine cowl flap actuator was out of order and stuck to the 50 % open position.

10. Both engines had stopped in flight as a result of damage to pistons, piston rings, cylinder walls and connecting rod bearing surfaces caused by knocking, frictional forces and disturbance of the engine working cycle.

Flight preparation

1. Mass and balance calculations were not made for the flight.

2. Navigational and fuel calculations were not made for the flight.

3. The aircraft had excess weight when taking off.

4. The pilot-in-command inquired about aviation gasoline refuelling possibilities along the route, but did not order the refuelling beforehand.

5. The pilot-in-command did not check the fuel type delivered before take-off.

6. It is probable that the pilot-in-command did not give any safety briefing before take-off and failed to check that the passengers' lap belts and shoulder harnesses were fastened.

7. Luggage and some equipment was loose in the cabin during flight, since the pilot-in-command had not attended to its securing.

Refuelling

1. The pilot-in-command contacted ATC by radio and told that refuelling was needed, but did not mention the fuel type or quantity.

2. The air traffic controller telephoned the fuel company, reported that the aircraft had asked for refuelling and stated that it would take jet fuel.

3. The serviceman was assigned a jet fuelling task by his foreman.

4. The aircraft operator's representative, who was present during refuelling, failed to mention the fuel type used.

5. The serviceman did not check the fuel type from the operator's representative before refuelling.

6. The serviceman failed to check the aircraft fuel type markings before refuelling.

7. The foreman visited the refuelling site but failed to notice that the fuel delivered was of the wrong type. He showed the jet fuel prices to the operator's representative from a price list written in Finnish.

8. The serviceman presented a sample of the fuel delivered to the operator's representative, who accepted it without noticing that the fuel type was incorrect.

9. The serviceman duly marked the fuel type as JET A-1 on the delivery receipt.

10. The operator's representative signed the delivery receipt and paid for the fuel in cash (DEM), but did not notice that the fuel type was incorrect.

Refuelling equipment

1. The tanker car was intended only for jet fuelling and equipped with correct and easily discernible fuel type labels.

2. The replenishment nozzle was equipped with a shaped extension which was larger in dimension than the restricted filling orifices for aviation gasoline.

However, the nozzle tip had been fitted with a Camlock coupling that was smaller than the extension and went into the reduced orifices.

Safety belts

1. The seats used by the aircraft occupants were equipped with both lap belts and shoulder harnesses, i.e. three-point seat belts.

2. The pilot-in-command’s and back seat passenger’s shoulder harnesses were not fastened.

3. The shoulder harness of the operator’s representative, who was sitting on the front seat, was fastened.

4. The aircraft and its Aeroplane Flight Manual contained appropriate instructions for the use of shoulder harnesses.

5. The light-metal attachment bracket of the back seat passenger’s right lap belt section broke in the accident.

6. The load capacity of the lap belts was in accordance with the applicable certification requirements.

Search and rescue operations

1. Search and rescue services were activated immediately after the crew reported an emergency and the operations were carried out in accordance with a pre-established plan.

2. The rescue operations were well co-ordinated.

3. The rescue crew could not open the aircraft door since they did not know how to use the opening mechanism due to insufficient markings.

4. The rescue crew did not know that there was an emergency exit in the aircraft.

5. The rescue crew did not know that the aircraft was equipped with an ELT transmitter. Therefore the ELT locator was not used and the transmitter was not switched off.

Regulations

1. No aviation regulation has been issued in Finland on the training of aircraft refuelling staff.

2. No aviation regulation has been issued in Finland on replenishment nozzle dimensions and markings.

3. No aviation regulation has been issued in Finland on filling orifice dimensions and markings.

4. Airworthiness directives providing for the installation of filling orifice restrictors and smaller caps have been published in Finland for some aircraft types. For the accident aircraft such directives do not exist in Finland, nor in its country of manufacture and registration.

Air traffic control equipment

1. There was a considerable time scale difference between the recorded radio communications and radar data. The recordings were not synchronized and they had not been compared with each other.

2. Some of Oulu ATC telephone calls had not been recorded due to an equipment failure. There was no failure indication in the system.

3.2 Cause of the accident

The accident was caused by incorrect refuelling. This was made possible by a series of human errors, which together with the fact that the technical defences failed, permitted the aircraft to be refuelled with Jet A-1 instead of Avgas 100LL. The incorrect fuel caused knocking, which resulted in engine damage and eventual stopping of both engines.

4. RECOMMENDATIONS

The Investigation Commission recommends that:

1. The Finnish Civil Aviation Administration should, in co-operation with fuel companies, work out a series of regulations on refuelling operations. These regulations should cover the training and qualifications of aircraft refuelling staff, requirements applicable to refuelling equipment and its condition as well as filling orifice dimensions, colour codes and their compatibility with refuelling devices.

2. The Finnish Civil Aviation Administration should, in co-operation with fuel companies, standardize the refuelling order forms and delivery receipts so that the field for the recipient's signature would be more distinct and located next to the indication of fuel type ordered and delivered.

3. The Finnish Civil Aviation Administration should make every effort to improve the harmonization of refuelling procedures, equipment and related markings at the international level.

4. The Finnish Civil Aviation Administration should further develop the radar data recording system so that a computer programme would be created to record the route coordinates obtained from all radar sources and to draw them immediately on a coordinate system based on road maps. By means of these maps, already used by rescue services, the rescue units could be guided to the accident site without delay and using the shortest possible route.

5. LIST OF APPENDICES

Appendices in the Investigation Report:

1. Photographs
2. Statement of the Finnish CAA on the Commission's recommendations

Other appendices (stored at the Accident Investigation Centre):

3. Preliminary investigation records
4. Records on medicolegal autopsy
5. Medical report on injuries sustained by the front seat passenger
6. Information obtained on the pilot-in-command's training
7. Records on the technical examination of the accident site
8. Cockpit examination records
9. Reports of ATS and rescue units; copies of Cospas/Sarsat alert messages obtained from the coastguard in Gulf of Finland
10. Analysis of Oulu airport radar recordings
11. Accident flight route drawing
12. Flight documents
13. Meteorological information
14. Recordings of radio and telephone communications
15. American Petroleum Institute Bulletin 1542 and corresponding fuel type decals
16. General Aviation Manufacturers Association Specification No. 3 and sample of fuel type decals in compliance with it
17. Service Bulletin No. 2045 Rev. III issued by the aircraft manufacturer on filling orifice restrictors, as well as documents on fuel tank filling orifice markings required for the aircraft type and ACs published on the issue by aviation authorities in the country of manufacture

18. Standards governing the dimensions and shape of aircraft fuel tank filling orifices and refuelling nozzles

19. Regulations and instructions on tanker car fuel nozzles, issued by the oil company for which the tanker car used to refuel the accident aircraft was manufactured

20. Reply of Shell to the inquiry about refuelling equipment

21. Aviation Regulations and Advisory Circulars published by the Finnish CAA on fuel types and refuelling

22. Copies of the Shell Airports Operations Manual (*Ilmailuhuollon toimintaohje*)

23. Analysis of samples taken from the accident aircraft fuel manifolds

24. Inspection records of the engines and propellers

25. Records on safety belt tensile test and certification requirements for safety belts

26. GPS inspection records from Trimble Navigation

27. Information provided by the manufacturer on markings required outside the aircraft door

28. Memorandum on discussions with aircraft operator company representatives

29. Documents and correspondence relating to the request for judicial assistance presented to the German Ministry of Justice

30. Reply of the Poison Information Centre *(Myrkytystietokeskus)* to the inquiry on medicaments found in the aircraft

31. Personal data

32. Photographs

33. Correspondence with various authorities

Having received the statement of the Finnish Civil Aviation Administration on the recommendations given in the draft investigation report on 15 November 1996, the Investigation Commission presented three of the recommendations on 3 February 1997 to fuel companies engaged in aircraft refuelling as follows:

1. The Investigation Commission recommends that the fuel companies should work out instructions on refuelling operations, covering the training and qualifications of aircraft refuelling staff as well as refuelling equipment and its condition, colour codes and compatibility with aircraft fuel tank filling orifices.

2. The Investigation Commission recommends that the fuel companies should standardize the refuelling order forms and delivery receipts so that the field for the recipient's signature would be more distinct and located next to the indication of fuel type ordered and delivered.

3. The Investigation Commission recommends that the fuel companies should make every effort to improve the harmonization of refuelling procedures, equipment and related markings at the international level.

The fuel companies replied on 18 February 1997:

As a result of their negotiations, the undersigned fuel companies will inform you as follows:

Every fuel company already has instructions on training and qualifications of refuelling staff as well as refuelling equipment markings and technical requirements.

The fuel companies are prepared to examine the possibilities of developing common qualification criteria for persons involved in aircraft refuelling.

The fuel companies are also prepared to examine the possibilities of introducing standardized, easily distinguished colour codes in the recipient's signature section of the delivery receipt.

The fuel companies are prepared to contribute to the international standardization of refuelling procedures, equipment and markings.

With regard to recommendation No. 4 and the Finnish CAA's statement, it came out in February 1997 that the CAA had in last November provided Helsinki-Vantaa airport with a system called **GLOBAL ENVIRONMENTAL MONITORING SYSTEM (GEMS)**. The system is mainly intended for aircraft noise monitoring, but it also entirely meets the Commission's recommendation: it produces real-time information in a coordinate system on computer screen, based on aircraft transponder responses to radar interrogations.

The draft investigation report was sent to German aviation authorities for comments in accordance with ICAO Annex 13 on 11 March 1997. In their reply dated 3 April 1997, the German authorities stated that they have no comments.

On 14 March 1997 the Commission sent the draft investigation report to NTSB (National Transportation Safety Board), USA. NTSB replied on 22 May 1997 that they had no comments on the report, whereas they saw that it would be advisable for the Investigation Commission to draft a recommendation for the US aviation authority, FAA (Federal Aviation Administration) concerning paragraphs 1.16.5.1 and 2.5.
First of the above mentioned paragraphs deals with the installation of filling orifice restrictors and the fact that the three locking tabs had not been pressed into their notches so as to lock the restrictor in place.
The other paragraph discusses the possibility of the restrictor coming off with the cap when it is opened. If this was considered to be possible, it would be advisable to make the above mentioned recommendation.

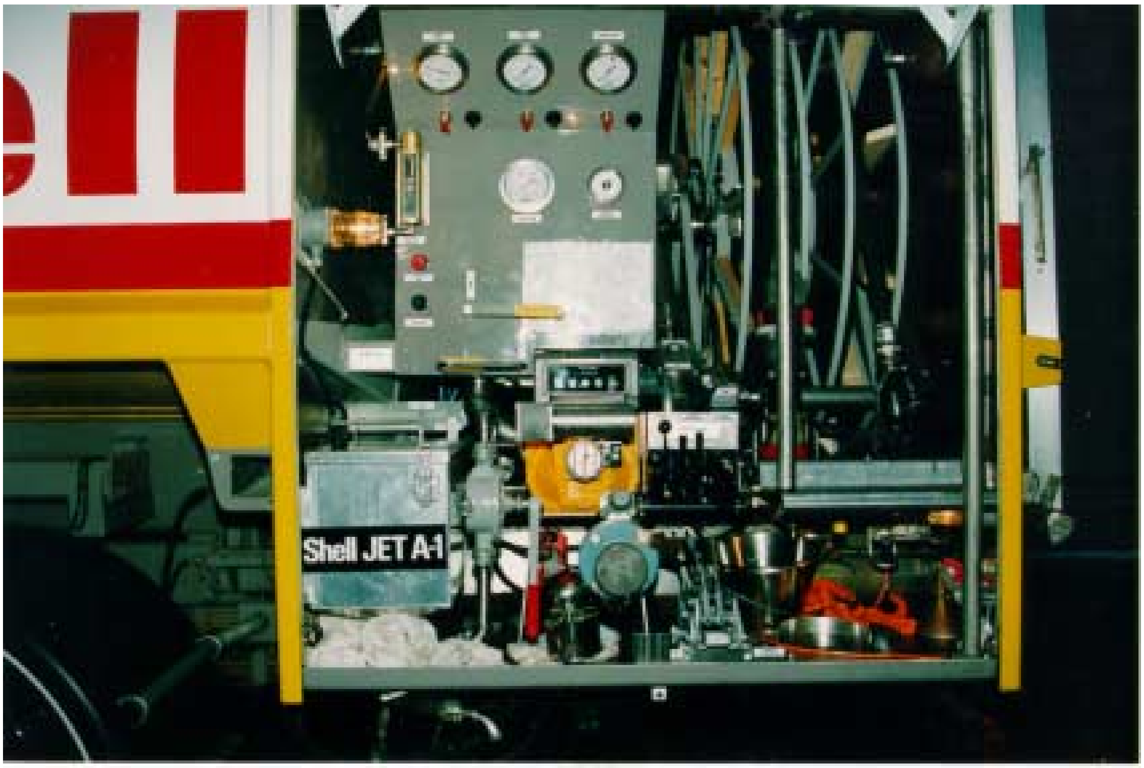
The Investigation Commission has sent a letter to the FAA, in which it explains the risk of incorrect installation described above and the resulting change in the filling orifice dimension.

Appendix No 1.

Fuel type markings on the Shell tanker car No. 8037

Markings on the left side

Markings inside the refuelling device box



Appendix No 1.

JET A-1 replenishment nozzle of the Shell tanker car No. 8037

Fitting of the Camlock coupling into the redused orifices intended for aviation gasoline

Appendix No 2.

ILMAILULAITOS
CIVIL AVIATION ADMINISTRATION
LENTOTURVALLISUUSHALLINTO
FLIGHT SAFETY AUTHORITY

Päivämäärä Date 15.11.1996

Dnro 6 / 01/ 96

Martin Blomqvist

07130 Anttila

Viite Ref Your request for statement on 14 October 1996

Asia Subject STATEMENT OF THE FINNISH CAA ON THE RECOMMENDATIONS GIVEN IN DRAFT INVESTIGATION REPORT, N911SG, 20 DECEMBER 1995, OULU

The Finnish Civil Aviation Administration issues the following statement on the Investigation Commission's recommendations, and informs that any necessary measures will be decided on separately.

RECOMMENDATION 1:

There is an existing Aviation Regulation and Advisory Circular on the subjects listed. A refueller's rating and too detailed regulations are not considered reasonable.

RECOMMENDATION 2:

Each fuel company has established its own forms, which are in international use. Altering them in Finland alone would cause problems.

RECOMMENDATION 3:

The investigation of this accident did not reveal any such new information, which would justify forcefully bringing up these questions again at international level.

RECOMMENDATION 4:

The Air Navigation Services department of CAA Finland has provided Flight Safety Authority with the following information concerning recommendation No. 4:

- In air search and rescue operations as well as general rescue operations, the coordination between different authorities and SAR units is assured by a so called SAR grid, the advantages of which are:
    - accuracy up to 50 m if needed
    - units can use charts in different scales
    - unambiguous and fit for use by different authorities
- In the future FATMI system, the data obtained from radar systems is recorded and it can be examined afterwards on a continuous basis. A selected radar image (individual 'square') can also be printed.

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- The SAR grid can be displayed on a FATMI screen; this feature is currently under development. FATMI system will be in operative use by 1998-1999.
- With the existing radar systems, the SAR grid can be displayed on screen only at Helsinki-Vantaa.
- The radar systems and coverage maintained by CAA Finland and the Finnish Air Force are already sufficient. Air search and rescue organisations are able to obtain real-time information from both systems when necessary.
- Existing terrain chart files cannot be integrated on radar screens, since they are not in vector form.

When planning and developing future chart databases and air navigation systems, the needs arising from air search and rescue operations will be taken into account.

Air Navigation Services department sees that the ANS and SAR developments currently in progress meet the requirements and obligations set for these services.

Director Kim Salonen
Flight Safety Authority

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