FINLAND

Investigation report

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Translation of the Finnish original report

Landing gear malfunction of a HS 125-700B aircraft and landing at Helsinki-Vantaa airport on 3 September 1999

OH-JET

HS 125-700B

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Other investigation material is stored at the Accident Investigation Board, Finland.

ABBREVIATIONS

CVR	Cockpit Voice Recorder
DFDR	Digital Flight Data Recorder
EDS	Energy Dispersive X-ray analysis
MHz	Megahertz
SAR	Search And Rescue
SB	Service Bulletin
SEM	Scanning Electron Microscope
UTC	Co-ordinated universal time
VTT	Technical research center of Finland

SYNOPSIS

A serious incident occurred at Helsinki-Vantaa airport on 3 September 1999 at 18.40 local time, when a twin-engined HS 125-700B business jet made an emergency landing with the right main landing gear fully retracted. The aircraft was owned by Wihuri Ltd and operated by Jetflite Ltd. There were seven passengers and three crewmembers on board. The emergency landing was successful, and the aircraft was only slightly damaged considering the severity of the incident. After the aircraft came to a stop, the passengers and the crew exited calmly, assisted by firemen, and no one was injured. The landing gear malfunction was caused by a fracture of hydraulic cylinder lugs.

On 6 September 1999, the Accident Investigation Board, Finland (AIB) set up a commission to investigate the incident. Trouble-shooting coordinator (ret.) Heikki Tenhovuori was appointed investigator-in-charge. Airline pilot Harro Erofejeff from Finnair Oyj and Chief Air Accident Investigator Tero Lybeck from AIB were appointed members of the commission. In addition, two AIB's advisors were consulted: divisional fire officer Jari Hiltunen on the rescue operations and air traffic controller Ari Huhtala on ATC operations.

Mr. Lybeck had a preliminary interview with the crew immediately after the incident. The pilots were later interviewed again at the AIB on 16 and 21 September 1999. The rescue personnel was interviewed on 9 September 1999, 11 October 1999 and 16 March 2000 at Helsinki-Vantaa airport and at the premises of Vantaa municipal fire brigade.

The data from the flight data recorder (FDR) and cockpit voice recorder (CVR) was read out by Finnair Oyj technical department at Helsinki-Vantaa airport. The quality of FDR data was good, but the recorder had stopped at the final stage of final approach, as the crew switched the power off in accordance with emergency procedures. The CVR had not been working on the incident flight, since its drive belt had broken on the day before.

A test to determine the effect of runway foaming on friction coefficients was made at Tampere airport on 23 November 1999, on fire officer Hiltunen's initiative.

The fracture mechanism of the lug was examined by the Manufacturing Technology unit of the Technical Research Center of Finland (VTT). As the investigation commission found, at an early stage of the investigation, that the landing gear maintenance program had been inadequate for detecting the failure, it made a proposal for correcting the issue to the US Federal Aviation Administration (FAA) on 8 October 1999. The proposal was also sent for information to the US accident investigation authority, the National Transportation Safety Board (NTSB) and to the aircraft manufacturer, Raytheon Ltd. On 29 February 2000 the FAA reported having accepted the proposal.

The draft investigation report was sent for comments to the Civil Aviation Administration, Finland, on 21 March 2000. CAA Finland had no comments on the report. The investigation was closed on 19 April 2000.

1 FACTUAL INFORMATION

1.1 History of the flight

The business flight JEF 103 (HS 125-700B, OH-JET) operated by Jetflite Ltd departed for Turku from Gdansk airport, Poland, on 3 September 1999 at 13.20 UTC. The aircraft had a crew of three and seven passengers. The co-pilot was the pilot flying, and he was sitting on the left-hand seat.

As the pilots tried to extend the landing gear when approaching Turku, it appeared that the right main landing gear was not working. After several unsuccessful attempts to extend the gear both with the normal and alternative system, the crew concluded that the right main landing gear would not extend. When the aircraft flew past the control tower at Turku, the controllers confirmed that the right main landing gear was still in retracted position.

Except for the right main landing gear, the aircraft was operating normally. Because the left main landing gear and nose gear could be retracted and the hydraulic pressure remained normal, the pilots concluded that the hydraulic system was operative. They decided to fly the aircraft to Helsinki-Vantaa airport, as the rescue category was higher at Helsinki-Vantaa than in Turku and there was plenty of fuel remaining. Moreover, Turku airport had only one usable runway, which might have had to be closed for a long time after the emergency landing. The decision was also affected by the fact that Jetflite's technical services were situated at Helsinki-Vantaa, which was the company's home base.

The pilots reviewed the emergency landing procedures from the flight manuals and checklists for several times, and asked the flight attendant to prepare the passengers for an emergency landing. During the flight, the crew made sure that there were no loose items in the cockpit or cabin. The flight attendant placed all loose objects in the lavatory and checked that the route to the main door and emergency exit was unobstructed.

The pilots agreed that, after the aircraft would have come to a stop, the captain would go to the right overwing exit and open it. The pilots assumed that the aircraft might be so much inclined to the right that the left main door could not be used. In addition, they agreed that the co-pilot would open the main door and check the situation at that side. With this procedure, the aircraft could be evacuated to either side as necessary. The pilots asked the flight attendant to be seated in the cabin.

When the crew contacted the radar coordinator (COR) at Helsinki-Vantaa approach control, the controller asked them how long the aircraft could wait and what their fuel status was. The pilots stated that they would be able to wait for over an hour and that there was 2500 lb of fuel remaining. The pilots and the controller also discussed a possible overflight at Helsinki-Vantaa before landing. Thereafter the COR controller handed the aircraft over to the arrival controller (ARR) frequency.

The ARR radar controller asked if the pilots would like to make an overflight or to land straight away, and the pilots replied that they would first fly over runway 15. The controller then reported vectoring the aircraft for an ILS approach to runway 15 and asked whether the pilots would accept making a visual approach again to runway 15 after go-around, to which the pilots agreed. The controller also asked the pilots if they would like the runway to be foamed. The pilots answered yes, and the controller told that foam would be applied after the intersection of runways 22 and 15 to the south, so that runway 22 could still be used.

The aircraft had to hold for 35 minutes at Helsinki-Vantaa before it was issued an approach clearance. During the hold, the pilots tried to extend the landing gear with both the normal and alternative system, but the right main landing gear remained retracted.

With the aerodrome control's permission, the company technical staff drove to taxiway Y, holding position Y2, to see if the other main landing gear was up when the aircraft flew past the control tower. The controllers also informed the pilots that company technical staff was watching the overflight. After the overflight, both the tower controllers and the technical staff reported that the right main landing gear was fully retracted. The technical staff then asked the controllers for a permission to leave one person at the grass area near Y2 to watch the landing. The controllers gave the permission, but reminded that the person would be there at his own risk.

The pilots decided to make an emergency landing on the nose gear and left main gear. They extended the gear using the normal procedure, because with the alternative system the landing gear doors would have been left open and damaged on landing.

At the final stage of final approach, the flight attendant told the passengers to brace for an emergency landing. The approach was conducted at an approximate speed of 145 knots, until the pilot started to slow down closer to the threshold. According to the co-pilot, the aircraft was already depressurized and the generators and main power were switched off just before landing. Main power was switched off at 150 ft, when the airspeed was 136 knots and decreasing. As the co-pilot retarded the throttles to idle thrust immediately before touchdown, the captain closed the low and high pressure shutoff valves.

The co-pilot told that, at the moment of touchdown, he tried to particularly concentrate on landing the aircraft smoothly, so that it would not fall down. The left main landing gear touched down first, about 200 m from the beginning of the foamed area. The right wing came down on the runway about 700 m from touchdown, when there was approximately 200 m of foamed area remaining. The aircraft remained well aligned with the runway. It came to rest at the right edge of the runway after a landing run of about 1150 m, sliding about 250 m beyond the foamed area. According to the co-pilot the landing run was really smooth, and the aircraft had no tendency to turn while sliding on the foam. It turned towards the right edge of the runway only after the speed had significantly decreased.

After the aircraft came to a stop, the firemen covered it with foam. The captain went to the overwing exit and started to open it, but noticed that extinguishing foam was spraying inside the aircraft through the exit door. He therefore closed the exit door but did not lock it. The co-pilot opened the main door and asked the firemen whether the aircraft was on fire. As the firemen told that there was no fire, the crew decided that the passengers should be evacuated calmly to avoid them slipping. The passengers exited through the main door, assisted by the crew and the firemen. No one was injured and the aircraft sustained only very slight damage.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	0	0	0
Serious	0	0	0
None	3	7	0

1.3 Damage to aircraft

The aircraft sustained only minor damage on landing. The right wing tip, outer wing flap trailing edge, hinge fitting and aileron were damaged. There was a skid mark on the left main gear outer tire, but the tire was otherwise intact. The damage mainly consisted of abrasions and skid marks, which were very small considering the severity of the incident.

1.4 Other damage

There was no other damage.

1.5 Personnel information

The pilots and the flight attendant held valid qualifications and met the requirements specified in Jetflite Operations Manual, part A (section 5, Qualification Requirements). The pilots' duty times and rest periods were within the limitations set in Operations Manual, part A (section 7, Flight time and duty time limitations), both for the planned and the actual flight.

Captain:

Captain:	Male, 52 years
License:	Airline transport pilot license, valid 12.8.1999 – 1.3.2000
Type rating:	Valid
Check flights:	29.5.1998, 26.11.1998 and 21.5.1999, CL-600 simulator

Flight experience	Last 24 hours	Last 30 days	Last 90 days	Total
All types	4 h	62 h	170 h	6995 h
On type	4 h	26 h	82 h	1500 h

The captain was the monitoring pilot on the incident flight. He also was Jetflite Ltd's quality manager.

Co-pilot:

Co-pilot:	Male, 57 years
License:	Airline transport pilot license, valid 3.5.1999 – 21.10.1999
Type rating:	Valid
Check flights:	29.7.1998 Beech 400 Beechjet, 17.2.1999 Beech 400 Beechjet, 1.5.1999 HS 125-700B simulator.

Flight experience	Last 24 hours	Last 30 days	Last 90 days	Total
All types	5 h	28 h	134 h	11754 h
On type	7 h	27 h	117 h	1200 h

The co-pilot was the pilot flying on the incident flight. He worked for Jetflite Ltd as a freelance pilot.

Cabin crew:

Flight attendant:	Female, 31 years
Safety training:	Madrid 6.5.1999 MD-80, MD-83, MD-87 and B-767-300
In Jetflite Ltd:	Emergency instructions given by pilots before flights on HS 125-700B, Dassault Falcon 20 and Canadair CL-600 Challenger

The flight attendant worked for Jetflite Ltd as a freelancer. She had previously been working as a flight attendant for the Spanish airline Spannair.

1.6 Aircraft

The aircraft was a twin-engined business jet with a passenger configuration of 8 seats.

Type and model:	HS 125-700B
Manufacturer:	British Aerospace
Registration:	OH-JET
Owner:	Wihuri Ltd
Operator:	Jetflite Ltd
Maximum takeoff weight:	11567 kg
Serial number:	257136
Year of manufacture:	1981
Flight hours:	7529 h
Landings:	4698

The aircraft was airworthy before the incident, and it had been maintained in accordance with current maintenance requirements (Hawker Raytheon Corporate Jets 125 series 700, Aircraft maintenance schedule, Rev. 2, March –97).

The previous heavy maintenance to the aircraft, including the actions required at 600, 1200 and 2400-hour checks and 12-month inspection, had been performed by Duncan Aviation, USA. By that time, the aircraft had accumulated 7263 flight hours and 4563 landings. The failed hydraulic cylinder lug is required to be visually inspected at the 600-hour check, without removing the component. No indication of failure was detected during the maintenance. The aircraft had flown 265 hours and made 135 landings after the maintenance.

Daily inspections as well as the 150 and 300-hour checks had been performed by Jetflite Ltd.

Mass and balance were within allowable limits. The aircraft used JET A1 fuel.

1.7 Weather

When the aircraft was issued a landing clearance to runway 15 at 15.37 UTC, the crew received the following wind information:

230°/13 knots, maximum 17, minimum 10.

Current weather (arrival information)

At 1420 UTC: wind 230° 12 knots, variable between 200°-280°, visibility 10 km, clouds BKN 1800 ft, temperature + 20 °C, dew point + 16 °C, QNH 1020, temporarily clouds BKN 1500 ft

At 1450 UTC: wind 230° 14 knots, visibility 10 km, clouds FEW 1500 ft, BKN 1700 ft, temperature + 19 °C, dew point + 16 °C, QNH 1020, becoming: visibility 8 km, clouds BKN 1500 ft

At 1520 UTC: wind 240° 16 knots, visibility 10 km, clouds FEW 1300 ft, SCT 1500 ft, BKN 1700 ft, temperature + 19 °C, dew point + 16 °C, QNH 1020, becoming: visibility 8 km, clouds BKN 1300 ft

At 1550 UTC: wind 240° 15 knots, visibility 10 km, clouds BKN 1300 ft, BKN 1700 ft, temperature + 19 °C, dew point + 16 °C, QNH 1020, temporarily visibility 8 km

Forecasts (EFHK TAF)

At 1100 UTC: valid from 12 to 21, wind 210° 15 knots, visibility over 10 km, clouds BKN 2500 ft.

1.8 Aids to navigation

All navigational aids were operating normally.

1.9 Radio communications

Radio communications during the flight were normal. Radio contact was lost when the crew switched the power off during final approach.

1.10 Aerodrome information

The aircraft landed at Helsinki-Vantaa airport, runway 15, which is 2900 m long and 60 m wide. The coordinates of the aerodrome reference point are 601902N and 0245748E. Elevation is 167 ft above mean sea level. The airport rescue category is Cat 8.

1.11 Flight recorders

The aircraft was equipped with a Fairchild Model F 800 digital flight data recorder (DFDR), p/n 17 M 900-251, s/n 2023. The recorder was removed from the aircraft and read out by Finnair avionics department. The DFDR recorded seven parameters, and it had been operating normally. The device had ceased to function during the final approach, at about 150 ft above the aerodrome, when the pilots switched the main power off.

The aircraft also had a Fairchild Model A 100 cockpit voice recorder (CVR), p/n 93 A 100-10, s/n 6592. The recorder was removed from the aircraft and read out by Finnair avionics department. The quality of recording was sufficient, but the recording saved was not that of the incident flight. When the tape was listened, it appeared that the recorder had stopped on the previous flight soon after departure from Helsinki, due to a drive belt failure. The malfunction could have been detected when testing the device before the flight. The pilots assumed that they either had forgot to test the recorder or had failed to notice the malfunction during the test.

1.12 Examination of the accident site and the aircraft

Helsinki-Vantaa runway 15 was foamed at the pilots' request. The width of the foamed area varied between 20 and 40 m. Foam was applied from the intersection of taxiway Z, about 650 m from the threshold of runway 15, to halfway between taxiways YF and YJ. The total length of the foamed area was about 1100 m.

The aircraft touched down on the foamed area, about 1300 m from runway 15 threshold (about 200 m from the beginning of the foamed area). The landing run was slightly to the left of runway centerline, so that the left main gear moved on dry asphalt and the nose gear was on the left edge of the foamed area. The track left by the outer hinge fitting of the right wing flap began 50 m after the foamed area and 200 m before the aircraft came to a stop, 8 m left of the runway centerline. Thereafter the aircraft turned right and stopped at the right edge of the runway. The aircraft slid about 250 m beyond the foamed area.

1.13 Medical tests

The police made a breath analyzer (Alcometer) test to the captain and co-pilot after the landing. Both tests showed 0 ‰. Other medical tests were not made.

1.14 Fire

At the final stage of the landing run, after the aircraft had passed the foamed area, the right wing produced some sparks described as "fireballs" when it skidded on the runway. However, there was no fire.

1.15 Survival aspects and rescue operations

1.15.1 Readiness

On the day of the accident, the regular fire and rescue services of the Finnish Civil Aviation Administration at Helsinki-Vantaa airport were on standby in the composition of 0+1+5 (0 fire officers, 1 sub-officer, 5 firemen). One fireman was assigned to the dispatch center, and the sub-officer took charge of the main fire station command vehicle (V-30). The rapid intervention vehicle (V-341) of the satellite station was manned by one fireman. Three firemen were assigned to the major foam vehicles of the main fire station, two of them to V-342 and one to V-343.

The airport fire brigade actually set off in the composition of 1+0+4, as the sub-officer was acting in fire officer duties as the airport rescue commander in command vehicle V-30, and one fireman was assigned to the dispatch center. One fireman assigned to make the hose arrangement was missing from the operational shift load.

Moreover, the fire fighting vehicle V-33 of Vantaa municipal fire brigade was called to the accident site and located at the CAA main fire station.

1.15.2 Airport rescue category

The rescue category of Helsinki-Vantaa airport is Cat 8. This means that there are three fire trucks, the minimum shift load of rescue personnel is six and the operational shift load is 1+1+4.

1.15.3 Alerting the rescue services

The control tower alerted the airport fire and rescue services at 17.44. At the same time, the alert was relayed to Helsinki emergency dispatch center by an automatic fire indicator. Helsinki dispatch center alerted the municipal rescue units in accordance with an established plan of operation.

The airport rescue units gave a dispatch notice at 17.44 and were in position by 17.46. The first unit from Vantaa municipal fire brigade (VP-3) started off at 17.45, and the first rescue unit (V-33) was in position by 17.47. More units were alerted in accordance with the plan of operation established by Vantaa fire brigade, and their number was sufficient for the situation.

The control tower changed the alert status into aircraft accident at 18.23. Consequently, Helsinki emergency dispatch center alerted additional rescue units as required by its internal instructions. The incident mobilized a significant number of rescue units.

1.15.4 Preparations and runway foaming

At 17.44, the control tower informed the rescue units that Jetflite's aircraft would land at Helsinki-Vantaa and its landing gear would not extend. The rescue units were waiting for further information on standby for about five minutes. The control tower then reported that the aircraft would probably land on runway 22 at about 18.00, and that there were ten persons and 3000 lb of Jet A 1 fuel on board.

At 17.54 the controller told the rescue units that the aircraft would land on runway 15, whichafter the units moved to new standby posts. At 17.58 the controller informed that the amount of fuel on board was 1370 kg. Immediately thereafter he told that the pilots had requested runway 15 to be foamed south of taxiway Z, and asked the rescue units to start foaming. The major foam vehicle V-343 started spreading the foam at 18.00.

While the other units were preparing for the emergency landing, the rescue commander (VP-3) requested additional rescue units to be sent to the airport and guided them to the SAR (Search and Rescue) gathering area. The controller used a mobile phone to inform the rescue commander that the alert status had been raised to aircraft accident. At 18.23, the commander reported to the emergency dispatch center that the situation would be treated as an aircraft accident, the location of which is known, and that any further alerts would be made accordingly.

The rescue commander told the airport rescue units to change over to the fire channel and to operate in sector one. V-30 supervised the runway foaming and gave instructions

to the foaming units. Runway 15 was foamed between holding positions Y and J, on a distance of about 1100 m. The foaming operation was completed at 18.33.

The aircraft flew over runway 15 at 18.35. The tower controllers and the crew of Mediheli rescue helicopter watched the overflight to check the landing gear position. At 18.36 Mediheli crew reported to the rescue commander that the landing gear was retracted. The airport rescue commander (V-30) was watching the overflight at the beginning of the foamed area and specified that the left main gear was down and the right one up. In addition, he stated that the aircraft might veer to the right towards the terminal building during the landing run.

At 18.39 the rescue commander asked the tower to take care of fuel trucks located in the maneuvering area near the runway. The controllers acknowledged the message and requested that some free unit would handle the issue. The airport rescue commander told that the police had been charged with clearing the maneuvering area in front of the terminal building. The rescue commander then reported that the aircraft was about to land.

1.15.5 Rescue operations after the emergency landing

When the aircraft passed the rescue units (V-30, V-33, V-341 and V-342) during final approach, the units immediately started to follow the aircraft. Also the rescue helicopters H-501 and Mediheli went after the aircraft. Mediheli reported that the aircraft's wing was skidding on the ground and producing small sparks, but there was no fire. The aircraft slid about 250 m beyond the foamed area before coming to a stop.

While the aircraft was still moving, the airport rescue commander (V-30) ordered that it should be covered with extinguishing foam. Rescue unit V-342 foamed the underside and the fuselage of the aircraft after it had stopped. The captain opened the right over-wing exit, but closed it again without locking it when the foam spray hit the door and foam was sprayed inside the aircraft. Units V-30 and V-341 continued the foaming. The aircraft did not catch fire and the risk of fire had now been eliminated.

The co-pilot opened the aircraft's main door, and the airport rescue commander came to the door. The co-pilot asked the commander if the aircraft was on fire. As there was no fire, the passengers exited the aircraft calmly, assisted by the crew and the firemen. The firemen examined the aircraft and stated that no fuel leaks were found. Rescue units V-11 and V-15 were preparing for smoke diving.

Mediheli and H-501 helicopters landed near the aircraft. Mediheli doctor checked that no one had been injured, whichafter Mediheli departed for another emergency mission with the rescue commander's permission. The H-501 helicopter also left, having received a permission from the rescue commander. One ambulance was left near the aircraft.

1.15.6 Division of tasks (Operational sectors)

The accident site was divided into operational sectors, each of which was charged with a specific task.

Sector 1 (Fire fighting) was assigned to protect the aircraft fuselage from flames, extinguish the fire, prevent the aircraft from catching fire by covering the underside and the fuselage with extinguishing foam, and to safeguard passenger evacuation. The sector was headed by the airport rescue commander (V-30).

Sector 2 (Rescue) was responsible for ensuring that the passengers and crew could safely exit or be rescued from the aircraft. The sector was headed by the sub-officer of rescue unit V-11 (VP-11).

Sector 3 (Medical) was in charge of medical assistance to patients. There was no actual need to set up this sector, as the doctor of Mediheli rescue helicopter, who headed the medical sector, found that no one had been injured.

Sector 4 (Ambulance) was planned to transport any injured persons to hospital, as well as to make sure that transport capacity was sufficient and reasonably used. There were 6 ambulances and one emergency medical service helicopter on standby at the airport.

Sector 5 (Logistics) was mainly in charge of logistics and supplies. At the beginning of the rescue operation, it was also responsible for opening sectors 3 and 4.

Sectors 4 and 5 were headed by the leader of rescue unit V-21 of Vantaa municipal fire brigade (VP-21). The units for these sectors were on standby but not in use. One ambulance was ordered to be located next to the aircraft.

1.15.7 Communications

In operative communications, one fire channel and the CAA airport vehicle frequency were used. Rescue operations management also communicated by mobile phones.

1.15.8 Movement of rescue units in airport maneuvering area

The airport's own rescue units moved in the maneuvering area with the control tower's permission. The units used Helsinki-Vantaa airport vehicle frequency (121,90 MHz). The municipal rescue units proceeded to their standby posts next to runway 15 after having been instructed to go there.

1.15.9 Gathering areas

At the initial stage of the operation, when the runway to be used was not known, the municipal rescue units assembled at the SAR gathering area. After the landing runway was reported, rescue units were instructed to proceed to the front of the cargo terminal.

1.15.10 Management of the rescue operation

During the whole operation, the rescue services were commanded by the divisional fire officer on duty at Vantaa municipal fire brigade (VP-3). The deputy chief of Vantaa municipal fire brigade (VP-2) contacted Helsinki fire brigade (HP-2) at an early stage of the operation, and it was agreed that the H-501 helicopter, one rescue unit and two ambulances would be sent to the airport from Helsinki. For several times during the rescue operation, VP-2 communicated with VP-3, HP-2, Helsinki rescue commander and the provincial rescue inspector using a GSM telephone.

A command center was not set up in the premises reserved for it at the airport air raid shelter, since the aircraft was small and the number of passengers low. At 18.26, VP-2 called VP-3 with his mobile phone and reported that he was in the duty room of the airport fire brigade and would not move to the command center. The rescue inspector had agreed, also by mobile phone, that he would meet VP-2 at the premises of airport rescue service. VP-2 checked from the control tower that there were no VIP passengers on the aircraft. VP-2 supervised the actions of the site rescue commander (VP-3).

1.15.11 Other units participating in the rescue operation

The police authorities were operating at the accident site as separate units, in contact with the site rescue commander. Airline personnel came to the site voluntarily, using the airport vehicle Parking 2. CAA Finland was represented by two FOLLOW ME units and Parking 2. A rescue inspector from the State Provincial Office of Southern Finland was also present.

1.16 Tests and research

The preliminary examination of the aircraft was made on 5 September 1999 in Finnair hangar 7 at Helsinki-Vantaa airport. After the preliminary examination, the aircraft was transferred to Jetflite Ltd's hangar for more detailed inspection and repair. The inspection revealed that the lugs at the lower end of the right main landing gear hydraulic cylinder had fractured, which allowed the cylinder to move freely. For this reason, the landing gear would not extend. No hydraulic leaks or other damage was found in the area.

1.16.1 Operation of the hydraulic cylinder and landing gear lock

Besides functioning as the landing gear retracting cylinder, the hydraulic cylinder was the actuator for the gear up and down lock. At the end of gear movement, the side stay levers reach the overcenter and are locked by an uplocking roll. Thereafter the levers remain locked in the extended or retracted position without hydraulic pressure. During flight, after the gear doors have been closed, the hydraulic cylinder is unpressurized. In gear extended position, the cylinder is always pressurized when there is hydraulic pressure in the system, which causes tensile stress to the cylinder lugs.

The alternative manual system uses the same hydraulic cylinder to extend the landing gear. HS 125-700B aircraft is not equipped with a mechanic opening system for the gear up-lock.

1.16.2 Cylinder specifications

The right main landing gear hydraulic cylinder (p/n 48503/2, s/n LK 0777, dated 4/1980) had been installed on 1 May 1980 when the aircraft was manufactured. By the time of the incident flight, the aircraft had accumulated 4698 landings, while the cylinder overhaul cycle is 5000 landings. The fractured lug was at the cylinder head (Air 11506, XQC 0116, Cone 25808).

1.16.3 General history and maintenance requirements for the cylinder

Fractures in cylinder lugs had occurred in the 80's already. Two Service Bulletins, SB 32-A197, 29 Sept 1983 and SB 32-199, 10 Feb 1984 were published to correct the issue. Both bulletins required the cylinder lugs to be visually inspected for cracks without removing the component. After the actions in SB 32-199 had been carried out, the lug was required to be checked at the intervals of 300 flight hours, in connection with A-checks. When the maintenance schedule was changed in 1993, the inspection interval became 600 flight hours. The manufacturing process has gone through three modifications to improve its reliability. The latest model has been available since August 1986, but the investigation commission has not received any information about its reliability.

1.5.1980	The aircraft was manufactured and the cylinder installed
29.3.1983	SB 32-A197
10.2.1984	SB 32-199 (inspection required at 300 flight hour intervals)
1985	SB 32-311 (recommendation to change the cylinder lug into an improved model, available 8/1986, in connection with cylinder overhaul; not changed in OH-JET)
1987	The aircraft was acquired by Jetflite Ltd
1993	Change in maintenance schedule (inspection required at 600 flight hour intervals)
1997	Landing gear overhaul and replacement of gear (hydraulic cylinders were not changed)
3.3.1999	Aircraft 600 h/1200 h/2400 h/12 month inspections made in USA
3.9.1999	Landing gear malfunction (total flight hours 7529 h, 4698 landings)

1.16.4 Technical inspection of the lug material and fracture

The material and fracture mechanism of the hydraulic cylinder lugs were examined by Technical Research Center of Finland (VTT), Manufacturing Technology department. The complete inspection report is available in English at the AIB, Finland.

The chemical composition of the lug material was analyzed with an optical emission spectrometer. The material was found to meet the requirements specified for aluminum alloy 2014-T6.

To examine the fracture surfaces, the components were photographed. The failed lugs were marked with numbers 1 and 2, and the fracture surfaces with codes 1a, 1b, 2a and 2b. Each fracture surface consisted of two different areas: the area adjacent to the lug hole had a very fibrous appearance, whereas the area bordered by the outer surface of the lug was irregular and uneven (see Appendix 1). The approximate cross-sectional portions of the fibrous areas in fracture surfaces were as follows: surface 1a ~ 50 %, 1b ~ 90 %, 2a ~ 25 %, 2b ~ 25 %. The fracture surfaces were then examined more closely with a scanning electron microscope (SEM) and an optical microscope. The impurities on the inner surface of the lug hole were determined by the EDS method (Energy Dispersive X-ray analysis).

Examination of the fracture surfaces with a scanning electron microscope showed that the fibrous area (the area adjacent to the hole) was mainly grain boundary fracture caused by stress corrosion, while the uneven area bordered to the outer surface had an appearance typical of a ductile fracture, resulting from overloading. When a 10-fold magnification was used, corrosion pits and numerous cracks could be seen on the inner surface of the lug hole. The grain boundary fractures caused by stress corrosion had originated at the inner surface of the lug, gradually reducing the undamaged cross-section of the lug. Stress corrosion is accelerated by moisture in the air and chlorides (e.g. marine climate). However, when the lug was inspected from outside, no indication of deformation or crack could be found. The age of cracks caused by stress corrosion could not be determined, but they have probably originated for a long time past, even years ago.

1.16.5 Conclusions on the fracture mechanism

Every time the landing gear is extended and always when the gear is down and hydraulic pressure is on, the hydraulic cylinder lugs are under tensile stress.

The first fracture had occurred on surface 1b of lug No. 1 (90% of stress corrosion cracking and 10% of ductile fracture caused by metal overloading). Surface 1b may have fractured entirely during the previous flight already. The fracture surface is not easily detected when the hydraulic cylinder is in place.

When the crew tried to extend the landing gear on the incident flight, the load needed to open the gear up-lock caused lug No. 1 to break. As the other lug was also deteriorated (25% of stress corrosion cracking on both fracture surfaces), it did not bear the unequal torsional load, but broke before the gear up-lock opened. Thereafter the cylinder head moved freely, and the gear up-lock could not be opened with the normal or alternative system.

2 ANALYSIS

2.1 Correcting the deficiencies in landing gear maintenance program

The landing gear malfunction was caused by fractures in hydraulic cylinder lugs, which had originated on the inner surface of the lugs. The fractures resulted from stress corrosion.

According to the current maintenance schedule, the component was required to be inspected at 600-hour intervals (Hawker 125 Series 700 aircraft maintenance schedule: 600 hour inspection, Item 320020). The component is inspected visually from the outside, from a distance not greater than an arm's length. However, the procedure was inadequate for detecting this fracture before the component finally broke.

During the investigation, on 8 November 1999, the investigation commission made a suggestion to the US aviation authority, FAA, for correcting the above mentioned deficiency in the maintenance program. The commission suggested the inspection procedure to be made more thorough, so that all surfaces of the lugs would be checked. Moreover, the commission recommended that the inspection schedule should be based on calendar time as well as on the number of landings, and that special attention should be paid to the older lugs, p/n 48503-2 and 48503-3.

By a letter dated 29 February 2000, the FAA replied that it accepted the proposals made by the investigation commission.

The investigation commission is of the opinion that the hydraulic cylinder should be taken out and the bearing bushing removed in the inspection, which would allow any corrosion pits and cracks on the inner surface to be detected using e.g. 10-fold magnification.

2.2 Crew actions

The flight had been prepared in accordance with Jetflite's Operations Manual, section 8, which covers all necessary issues including the flight plan, notams, weather, loading and fuel calculations.

The crew noticed the right main landing gear malfunction when they tried to extend the gear when approaching Turku. As the gear could not be extended, the crew decided to fly the aircraft to Helsinki instead of Turku, which was a wise decision for many reasons. First, there were two usable runways at Helsinki-Vantaa. The airport rescue category was also higher at Helsinki-Vantaa (Cat 8) than in Turku (Cat 6; Cat 7 on request). Weather was good in Helsinki, considering both visibility and ceiling. Moreover, flying to Helsinki gave plenty of time to prepare for an emergency landing and to burn excess fuel. The decision was also affected by the fact that the company's home base and technical services were located at Helsinki-Vantaa.

During the emergency landing, the crew followed the HS-125/700A check list compiled by Flight Safety International, which had been approved to be inserted in the company Operations Manual, part B, paragraph 3.2.5.8. They complied with the check list ”Landing with gear in abnormal positions”, except for item 5 (page E-27, July 1993). Item 5 of the check list states that the landing mass should be lowest possible, flaps in normal position and the landing speed as low as possible.

The crew could have flown somewhat longer to consume fuel and thus reduce the landing mass. However, they decided to land soon after runway foaming was completed, because they wanted to land before dusk.

In this case, the crew accepted runway 15 for landing as suggested by the controller, although wind had been reported as 230–240 degrees 13–14 knots. According to the wind information, the crew could have landed on runway 22 with lower groundspeed, which would have made the landing run somewhat shorter. The wind information given to the pilots immediately before landing was 230 degrees 13 knots, maximum 17 knots, minimum 10 knots.

The co-pilot, who was flying the aircraft, stated after the landing that he had flown the approach with slightly too much speed. According to the flight data recorder, the final approach was flown at a speed of approximately 145 knots, until the pilot started to reduce speed closer to the threshold. When the pilots switched the main power off at about 150 ft above the runway, the speed was recorded as 136 knots and decreasing. In accordance with the landing speed chart, the approach speed with the landing mass in question would have been 120 knots and the speed at threshold 109 knots. The aircraft touched down on the left main gear at about 200 m from the beginning of the foamed area. It remained well aligned with the runway. The aircraft came to a stop at the right edge of the runway after a landing run of 1150 m, sliding about 250 m beyond the foamed area.

The co-pilot estimated that the touchdown was late because he was tempted to make sure that he would reach the foamed area. He also stated that he particularly wanted to land the aircraft smoothly, so that it would not fall down on the right wing uncontrollably. The emergency check list also emphasizes that the wing must be let down on the runway smoothly and controllably.

The emergency landing succeeded well, except that the aircraft slid about 250 m beyond the foamed area. The right wing did not touch the runway until after 700 m of landing run, and therefore only 200 m of the foamed area was actually utilized. Factors that contributed to the aircraft sliding beyond the foamed runway area were the considerable overspeed in approach and the fact that the runway with headwind component was not used.

After the end of the foamed area, the right wing produced some sparks like ”fireballs” when it skidded on the runway. However, the aircraft did not catch fire and the firemen covered it with foam immediately after it came to a stop. No one was injured, and the aircraft was very slightly damaged considering the severity of the incident.

2.3 Rescue operations

2.3.1 Alerting the rescue services

Aerodrome control first alerted the rescue services of a risk of an aircraft accident, as instructed. When the controllers later changed the status into an aircraft accident, Helsinki emergency dispatch center started alerting rescue services as required in a major aircraft accident situation.

The alarm system at Helsinki emergency dispatch center had recently been updated so that in a case where a previous alert of a risk of an aircraft accident was changed into an actual accident situation, the system did not take account of rescue equipment already sent to the accident site as a result of the initial alert. For this reason, both the rescue services required by the risk of an aircraft accident and those required by a major aircraft accident were sent to the airport. Whenever rescue services are alerted of an aircraft accident, the equipment needed in case of a major aircraft accident are sent to the site. The alert therefore mobilized a considerable number of rescue units.

2.3.2 Preparations and runway foaming

At the beginning of the operation, the rescue units took their positions in a routine-like and smooth manner. When the aerodrome control asked the runway to be foamed, this was a situation for which the rescue units had not been prepared. However, the foaming operation was started without delay. The runway was foamed on a distance of about 1100 m, which took 33 minutes. The foaming took rather long, because the foaming devices had to be refilled at the fire station and foaming units had to work in turns. With this procedure, it could be ensured that there would be enough extinguishing foam available even in case the aircraft would have landed before the foaming was finished. Airport rescue units must also be prepared for any other aircraft incidents or accidents at all times.

Runway foaming is currently not included in basic operational plans of airport fire and rescue services, since it has largely been abandoned as the fire vehicles and extinguishing foams have improved. The main principle is to reach the target quickly and get the fire rapidly under control. This procedure saves water and foam, and makes sure that the aircraft can be effectively extinguished and protected.

The control tower reported to the airport rescue commander that there was 3000 lbs of Jet A1 fuel on board, and offered to give the amount in kilograms as well. However, the rescue services usually measure the amount of dangerous substances in liters.

2.3.3 Survival aspects and rescue operations

While the aircraft was approaching the airport for landing, the rescue units were in position and ready to follow the aircraft. When the aircraft landed, the units went immediately after it while it was still moving. The first layer of foam was sprayed 13 seconds after the

aircraft came to a stop, to protect its fuselage and underside. The next two foaming units came after 16 seconds and started protective foaming immediately. The extinguishing units reached the aircraft quickly and the foaming was rapidly completed.

As there was no fire, the passengers and the crew exited the aircraft calmly, assisted by the firemen. The situation was under control and the rescue crew was sufficient, but the evacuated passengers were not immediately guided to a safe distance from the aircraft and they were allowed to take photographs near the aircraft.

2.3.4 Radio communications

Radio communications were handled quite well, and the frequencies in use were not jammed. When the rescue units changed over from the airport vehicle frequency to the fire channel, radio communications were conducted on both frequencies for a while. There were busy radio communications at times between the Parking 2 vehicle and aerodrome control, while company personnel was transported around the area. The communications revealed that the air traffic controllers did not know which radio channel should be used to contact some of the units.

2.3.5 Movement of rescue units in airport maneuvering area

The rescue units moved in the airport maneuvering area in accordance with the applicable instructions. However, the rescue commanders had to watch over airport service vehicles, which created a safety hazard by gathering to watch the events. The rescue units needed to consider this as well when preparing for the operation.

2.3.6 Management of the rescue operation

The rescue operation was commanded by the divisional fire officer on duty at Vantaa municipal fire brigade (VP-3). The deputy chief of Vantaa fire brigade estimated that there was no need to set up an operational command center, as the aircraft was rather small and there were not many passengers (accident category 2B).

There appeared to be some confusion in the communications between the helicopters, the site rescue commander and the controllers, e.g. when discussing where the helicopters would be positioned during the operation.

The radio communications revealed that the site rescue commander initially thought that the left main landing gear was up. However, the misunderstanding was soon corrected, and the commander was then able to consider that the aircraft might slide towards the terminal and the nearby taxiway and apron, where there was vehicle traffic all the time. The rescue commander of the airport fire brigade informed the police about this risk. The police officers tried to clear the area, but could not stop all vehicle traffic within the danger zone.

At the final stages of a rescue operation, the rescue workers must also seek to prevent any further damage and, together with the police authorities, make sure that bystanders

are not allowed to enter the accident site. In this case, company personnel was allowed to move around the aircraft after the accident and examine it with the crew. Moreover, the airport manager brought along a child, who was walking in the accident area and watching the aircraft. There were several authorities at the site who should have interfered and made sure that procedures appropriate for an aircraft accident situation were complied with.

2.4 Test to determine the effect of runway foaming on friction coefficient

On 23 November 1999 at 9.30, a test to determine the effects of runway foaming was made at Tampere-Pirkkala airport, at fire officer Hiltunen's initiative. Temperature was –0 °C and wind southerly, 4 m/s. The foam was sprayed by the Finnish CAA's major foam vehicle T842. A full tank of water (9000 l) was used, mixed with 1100 l of the most effective film foam Afrofilm AFFF in a solution of less than 3 %.

The test began with checking the spread angles of the monitor and the driving line of the vehicle in relation to the taxiway centerline. The taxiway to be foamed was 20 m wide. The driving line was to the right of centerline, so that a 10 m wide area left of the centerline was sprayed with foam, when the monitor was directed 30º to the left in full-down position. The foam monitor was adjusted for wide foam jet. As the wind was from south, the driving direction was from west to east. The spraying pressure was about 7 bar and the speed of driving approximately 20 km/h. The driver of the foaming vehicle was working alone. Forward visibility could be maintained by keeping the windscreen wipers on all the time.

The area covered was 10 m wide and the thickness of foam layer about 3–5 cm. Foaming of a 800 m long section of the taxiway took 2 min 30 sec. 9000 liters of water and 350 l of foam was used. The consumption of foam liquid was slightly higher than usual, because some extra liquid accidentally got into the water tank when water was added at the end of the test.

After the foaming was completed, the braking action on the foamed area was measured with a friction measuring device. The friction coefficients on all measured areas were good (0.40 or higher). Another measurement was made after 30 minutes, and the friction coefficients had further improved by then. After the test, the foamed area was cleaned and inspected.

The test showed that foaming does not significantly impair runway friction characteristics.

3 CONCLUSIONS

3.1 Findings

1. The crew had valid licenses and appropriate ratings for the flight.
2. The aircraft had a valid certificate of airworthiness.
3. There were three crewmembers and seven passengers on board.
4. The right main landing gear could not be extended when the aircraft was approaching Turku. The gear did not extend with the alternative system either.
5. The crew decided to fly the aircraft to Helsinki-Vantaa, which allowed them to burn some more fuel. Furthermore, there were two runways in use at Helsinki-Vantaa, and an emergency landing on the other runway would not have caused the whole airport to be closed. The airport rescue category was higher at Helsinki-Vantaa than in Turku. Helsinki-Vantaa was also the company's home base, where its technical services were located.
6. At Helsinki-Vantaa, the crew accepted to use runway 15, although the emergency procedures required the aircraft to be landed with minimum speed. According to the information provided to the crew, wind was 230–240 degrees 13–14 knots.
7. The crew tried to extend the landing gear with both the normal and alternative system still at Helsinki-Vantaa, but without success.
8. When the air traffic controller asked the pilots whether they would like the runway to be foamed, they answered yes. The foamed area was about 1100 m long, between 20 and 40 m wide, and started at the intersection of taxiway Z.
9. The pilots prepared for the emergency landing by reviewing the relevant emergency procedures during the flight from Turku to Helsinki-Vantaa. They asked the flight attendant to prepare the passengers for an emergency landing. All loose items in the cabin were stowed at the lavatory.
10. The passengers and the flight attendant were in an emergency landing position.
11. Approach speed was about 25 knots too high.
12. The aircraft touched down approximately 1300 m from the threshold of runway 15, about 200 m after the beginning of the foamed area.
13. During the landing run, the nose wheel moved along the left edge of the foamed area and the left main gear was on dry asphalt.
14. The pilot let the right wing fall smoothly down on the runway after a landing run of about 700 m, when there was about 200 m of foamed area remaining.
15. As the right wing touched the runway, the aircraft soon started to veer to the right. It came to rest on its left main gear, right wing and nose wheel at the right edge of the runway, after sliding about 250 m beyond the foamed area.

16. Only 200 m of the foamed area was actually utilized. When the aircraft slid beyond the foam, the right wing produced some sparks like ”fireballs” as it skidded on the runway.

17. The aircraft was covered with extinguishing foam. As there was no fire, the crew and the firemen evacuated the passengers calmly to avoid them slipping. However, the passengers were not guided to a safe distance from the aircraft.

18. The aircraft was only very slightly damaged considering the severity of the incident, and there were no injuries to persons.

19. The right main landing gear malfunction was caused by a fracture of hydraulic cylinder lugs. Since the alternative landing gear extension system uses the same hydraulic cylinder and there was no mechanical system, the gear could not be extended.

20. The fracture could not have been detected by complying with aircraft maintenance program requirements. While the investigation was still in progress, the investigation commission made a suggestion to the US aviation authority (FAA) for improving the maintenance program, which was accepted.

21. The fireman assigned to make the hose arrangement was missing from the operational shift load of Helsinki-Vantaa airport fire and rescue services.

22. When the air traffic controller asked the pilots if they wanted the runway to be foamed, they answered yes. The foamed runway area was 1100 m long and 20–40 m wide. The foaming took rather long, 33 minutes.

23. The site rescue commander was the divisional fire officer on duty at Vantaa municipal fire brigade.

24. The rescue commanders had to watch over service vehicles moving in the airport maneuvering area, because they created a safety hazard by gathering to watch the events.

25. Air traffic controllers did not know how long the runway foaming would take.

26. Runway foaming is currently not included in basic operational plans of airport fire and rescue services, since it has largely been abandoned as the fire vehicles and extinguishing foams have improved. The main principle is to reach the target quickly and get the fire rapidly under control.

27. The air traffic controller did not know at first which radio channel the site rescue commander was using, but had to find out about it.

28. There were some deficiencies in the guidance given to helicopters during the preparations and the rescue operation.

29. Unauthorized persons were allowed to come near the accident aircraft soon after it had stopped.

3.2 Probable cause

The incident was caused by a fracture of hydraulic cylinder lugs in the right main landing gear. Because of an inadequate maintenance program, the fracture could not be detected before the component finally broke.

4 RECOMMENDATIONS

1. The Civil Aviation Administration, Finland, should make sure that the operational shift load of Helsinki-Vantaa airport fire and rescue services is achieved in all shifts.

2. The Civil Aviation Administration, Finland, should determine the benefits and drawbacks of runway foaming. If the CAA decides to use runway foaming, instructions and training on the associated procedures should be given to rescue personnel, air traffic controllers and pilots.

3. The Civil Aviation Administration, Finland, should make sure that the training for drivers of vehicles moving at the apron and in maneuvering areas emphasizes the fact that gathering to watch the events in an aircraft accident situation may significantly hamper the rescue operations.

Helsinki, 19 April 2000

Heikki Tenhovuori

Harro Erofejeff Tero Lybeck

APPENDICES

1. Photographs
    - Picture 1. Final location of the aircraft and end of the foamed area
    - Picture 2. Fractured hydraulic cylinder lug
    - Picture 3. Magnification of the fracture surface

REFERENCE MATERIAL

The following investigation material is stored at the AIB, Finland:

1. Decision of the Accident Investigation Board No. B 4/1999 L
2. Pilot's incident report in accordance with Aviation Regulation GEN M1-4
3. Records on crew interviews
4. Transcripts of radio communications by ATC and rescue personnel
5. Extracts from ATC log
6. Research report (No. VAL 24-992590) by the Technical Research Center of Finland (VTT) on the fractured hydraulic cylinder lugs (in English)
7. Service bulletins, maintenance requirements and checklists for the aircraft
8. Correspondence related to the investigation
9. Weather information at the time of the incident
10. Flight data recorder read-out
11. Records on the foaming test made at Tampere-Pirkkala airport
12. Samples of operative instructions for rescue personnel
13. Photographs, report, and drawing of the accident site made by the police
14. Statement of the Finnish Civil Aviation Administration, Flight Safety Authority, on the draft investigation report
15. Photographs.


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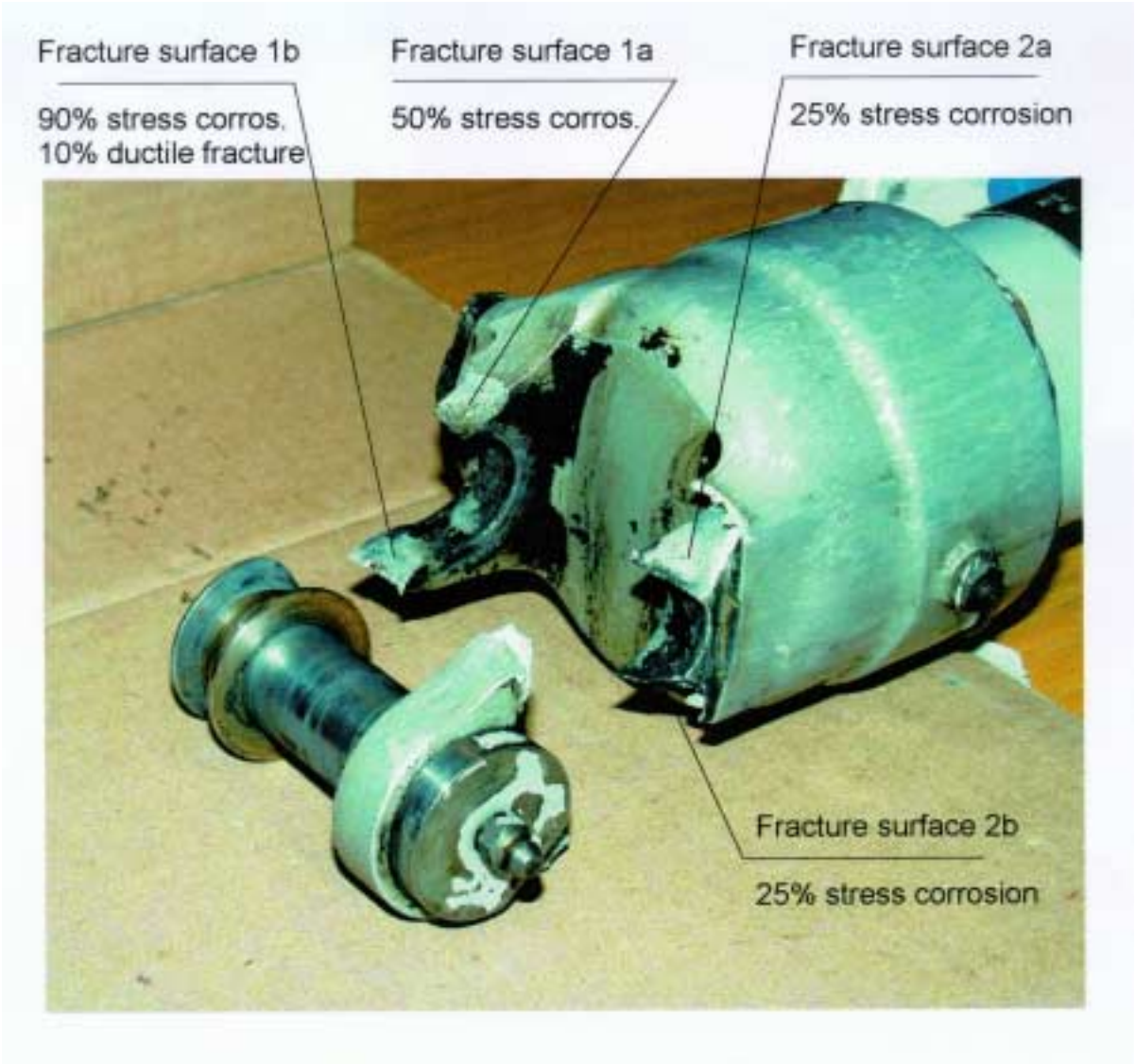
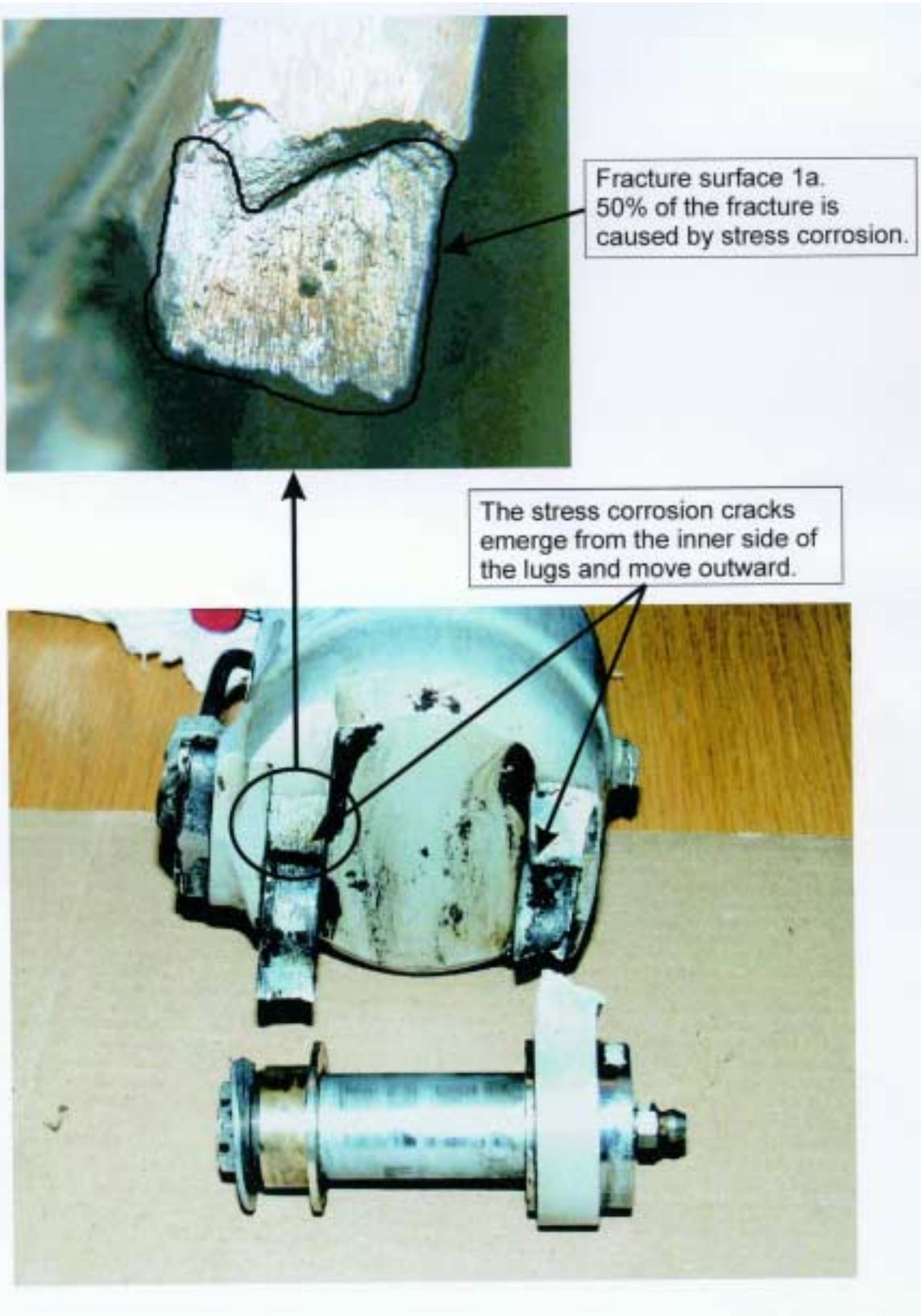
V3


Fracture surface 1b
90% stress corros.
10% ductile fracture
Fracture surface 1a
50% stress corros.
Fracture surface 2a
25% stress corrosion
Fracture surface 2b
25% stress corrosion


Fracture surface 1a.
50% of the fracture is caused by stress corrosion.
The stress corrosion cracks emerge from the inner side of the lugs and move outward.