ISS 0803-3633

THE AIRCRAFT ACCIDENT INVESTIGATION BOARD/NORWAY (AAIB/N)

REP.: 01/96

REPORT ON THE HELICOPTER ACCIDENT AT ÅS, NORWAY, ON AUGUST 1, 1994, WITH BELL 206BIII JET RANGER, LN-OSL

SUBMITTED JANUARY 1996

REPORT ON THE HELICOPTER ACCIDENT AT ÅS, NORWAY, ON AUGUST 1, 1994, LN-OSL

Aircraft type:	Bell 206BIII Jet Ranger
Registration:	LN-OSL
Owner:	AS Helilift Oksenøyv. 12 1330 Oslo Lufthavn, Norway
User:	Same as owner
Crew/Pilot-in-Command:	1
Passengers:	1
Accident site:	Syverudveien, Ås, Norway 15°41'N 10°46'E
Time of accident:	1 August 1994, 11:53 hours

All times given in this report are local times, if not otherwise stated.

NOTIFICATION

The Aircraft Accident Investigation Board/Norway (AAIB) was informed of the accident at 12:10 hours by the Oslo Police Operations Department. An investigation team was despatched at 12:40 hours and arrived at Syverudveien, Ås, at 13:20 hours, where representatives from the AAIB/N were met by staff from Ås Police Station .

SUMMARY

On the morning of the accident the helicopter had flown to the Agricultural University of Norway (NLH) to carry out an annual check on the capacity of some fitted forest-spraying equipment. In addition to the Pilot-in-Command there was a

representative on board from the company that had hired AS Helilift to carry out the practical part of the forest spraying. Once the equipment had been tested and approved, a short reconnaissance flight of a nearby forested area was made. The Pilot-in-Command then set course for a return flight back to Oslo Airport Fornebu. When the helicopter was approx. 400 ft above the ground and climbing slightly, it suddenly went into an uncommanded right yaw (movement round the vertical axis). This was caused by a flaw in a bonded section of the tail rotor shaft, followed by stoppage of the tail rotor. It is then probable that the helicopter spun twice around its vertical axis at the same time as it was shaken by powerful vibrations. The Pilot-in Command (PIC) regained partial directional control by autorotating the helicopter. The helicopter continued to descend and the PIC was unable to reach an open clearing and was forced to make a controlled emergency landing in the forest. The helicopter came to rest on a forest path and suffered extensive damage. There was no outbreak of fire. The two on board were slightly injured.

1 FACTUAL INFORMATION

1.1 History of the flight

1.1.1 Helicopter LN-OSL took off from Oslo Airport, Fornebu, at 09:46 hours, and landed at the Agricultural University of Norway (NLH) near Ås at 10:00 hours. The visit to the NLH was for the purposes of conforming to the authorities' requirements for a check to be carried out on, and approval obtained for, the fluid discharge from the fitted spraying equipment before the forest was sprayed. The check was carried out at the NLH's Institute of Technology, and the helicopter was photographed during the test flight (see Appendix = Bilag 1).

1.1.2 The test flight was carried out at the NLH from 10:25 hours to 11:30 hours. The spray equipment was then approved, and LN-OSL started out on its return flight to Fornebu at 11:45 hours.

1.1.3 After take-off the helicopter circled once over an area of forest which belonged to the NLH so that the representative from the organization that had commissioned the job, who was a passenger on board, would be able to evaluate any damage which might be caused by dryness in connection with the impending spraying of the forest. Shortly afterwards it was decided that they should set course for Fornebu. When the helicopter made a left turn at a height of approx. 400 ft above ground level and at a speed of 40-50 kt a sudden, indeterminate noise was heard, which coincided with the helicopter going into an accellerating "yaw" to the right with a resultant powerful vibration. The helicopter then began spinning around its vertical axis. The vibration, which was so powerful that the Pilot-in-Command had difficulty reading the instruments, persisted as the helicopter spun around.

1.1.4 The Pilot-in-Command has stated that the helicopter probably rotated twice in a clockwise 360° spin. While the helicopter spun, the PIC reduced the blade angle on the main rotor by lowering the collective control and rolled of the throttle lever to idle at the same time as he pushed the cyclic control forward. He thus put the helicopter into an autorotation with slight forward speed, and thus regained directional control. The vibration stopped simultaneously. The helicopter had, however, lost so much altitude that the Pilot-in-Command had no choice but to land in the forest. The helicopter was flared at tree-top level, and was then lowered down between the trees, keeping its tail low.

1.1.5 The helicopter suffered extensive damage, but had an almost undamaged cabin. It came to rest on a forest path and lay on its right side. Once the Pilot-in-Command had turned off the fuel electrically and switched off the electrical power, he evacuated the helicopter through the broken glass of the front window. As the left-hand side passenger door was blocked by one of the spray booms, he had to free the door before the passenger could be helped out. They then both left the scene of the accident and walked to Syverudveien, which was approx. 100 m away from the accident site.

1.1.6 The Pilot-in-Command took his mobile telephone with him and used it to report the accident to, amongst others, Fornebu TWR, who raised the alarm, in accordance with instructions. Another helicopter - LN-OBD - was at that time situated above Slemmestad, approximately 23 km from the accident site. This helicopter was directed to the position of the accident and located the wreckage at 12:16 hrs. As time went by, the fire brigade and staff from the local police station, as well as medical staff, arrived at the scene.

1.2 Injuries to persons

1.2.1 The Pilot-in-Command was taken to Bærum Hospital and the passenger to Ski Hospital for examination. Neither of them appeared to have been harmed to any significant extent.

INJURIES	CREW	PASSENGERS	OTHERS
FATAL			
SERIOUS			
MINOR/NONE	1	1	

1.3 Damage to aircraft

1.3.1 The helicopter's vertical speed was controlled by the Pilot-in-Command down to tree-top level at which he stopped the decent by increasing the blade angle of the main rotor and then lowered the helicopter down into the trees, keeping its tail low. The helicopter's vertical speed was thus quite low when the rotor hit the trees. The rotor in this type of helicopter has a large mass, and thus a large amount of energy, when rotating. Most of the energy was used to cut through several large trees. While this was taking place the blades became deformed. The energy in the main rotating rotor was powerful enough to cause extensive damage both to the tail boom and to the tailrotor's drive system. In addition, the fuselage was damaged on impact with the ground. The damage must be assumed to be so extensive as to consider the helicopter to be a complete write-off.

1.4 Other damage

1.4.1 Several trees at the scene of the accident were damaged.

1.5 Personnel information

1.5.1 The Pilot-in-Command, male, aged 40, held a Class 3 (B) commercial pilot's licence for helicopters. The licence was issued on 8 December 1981, was last renewed on 27 September 1993, and was valid until 15 October 1994, on condition that the holder used corrective lenses. The licence was valid for helicopter types BO-105, Bell 206 and Hughes 269/300.

1.5.2 The Pilot-in-Command's total flying time on the day of the accident was 2,580 hours, 1,400 hours of which were on the Bell 206. The last Periodical Flight Training on this type of helicopter took place on 24 June 1994.

FLYING EXPERIENCE	TOTAL	ON TYPE
LAST 24 HOURS	1:27	1:27
LAST 3 DAYS	1:27	1:27
LAST 30 DAYS	5:12	4:03
LAST 90 DAYS	27:21	24:33

1.6 Aircraft information

1.6.1 Registration: LN-OSL

Manufacturer: Bell Helicopter Textron Inc. U.S.A.

Model: 206BIII

Type:	Jet Ranger
Serial No:	3430
Year of construction:	1981
Engine type:	Allison 250-C20B, gas turbine
Registration certificate:	No. 2205, issued on 3 June 1986
	NOTE: The registration certificate has been entered as No. 2005. However, the Civil Aircraft Register has shown this to be a printing error.
Certificate of airworthiness:	No. 2205, valid until 30 June 1995
Total flight hours:	3,284 hours

1.6.2 The helicopter's maintenance documentation shows that the helicopter was maintained in accordance both with current regulations and the company's approved maintenance programme.

1.6.3 The helicopter was fitted with Simplex 2700 spray equipment manufactured by Simplex Manufacturing Company, U.S.A. AS Helilift has confirmed to the AAIB/N that no maintenance routines have been established for this equipment.

1.6.4 Based on information supplied by the company about the helicopter's weight when empty (including spray equipment), calculations show that the helicopter's weight and balance were within permissible limits at the time the accident occurred.

1.6.5 At the time of the accident the fuel tank contained approx. 170 litres of Jet A-1.

1.7 Meteorological information

Weather conditions at Fornebu at 0800 UTC were as follows:

Light wind, clouds 1/8 CU at 4,000 ft, visibility over 10 km, temp./dew point 25°C/18°C, pressure 1,017 hPa.

1.8 Aids to navigation

Not applicable.

1.9 Communications

The Pilot-in-Command maintained normal radio contact with Fornebu TWR right up to the time of the accident.

1.10 Aerodrome information

Not applicable.

1.11 Flight recorders

Not installed. Not required.

1.12 Wreckage and impact information

1.12.1 The accident site

1.12.1.1 The accident took place in a thickly-wooded, hilly area approx. 2 km north of the Agricultural University of Norway (NLH) in Ås.

1.12.2 The wreckage

1.12.2.1 The fact that the helicopter was taken down into the trees, keeping its tail low, resulted in the main rotor starting to cut through some of the trees. One of the blades was bent pronouncedly downwards. The tail boom was bent slightly upwards, and the stabilisers in particular came into contact with the trees. This, in conjunction with the main rotor blade, which was bent downwards, resulted in the rotor cutting the tail boom at STA 291 (see Appendix 2). Yet another blade hit occurred at STA 265 (see Appendix 2), but the rotor did not then have enough energy to cut through the tailboom. The cut marks on the trees indicate that the helicopter fell to the right during this sequence. The right-hand spray boom was consequently bent upwards and was hit by the main rotor.

1.12.2.2 The fuselage hit rising ground along a forest road. Because the fuselage nose was in an elevated position at that time, the rear part of the fuselage and the front part of the tail boom absorbed the forces in the collision with the ground. This resulted in the passenger cabin itself, where both the pilot and the passenger sat, and which was lying on its right side, remaining to a large extent undamaged. The left-hand spray boom was folded over the cabin and partially blocked the passenger door on the left-hand side.

1.12.2.3 The gear box, mast and blades of the main rotor all remained attached to the helicopter. The gear box had been pushed forwards and down into the roof structure. This resulted in the front coupling section of the drive shaft between the engine and the rotor gear box separating into five pieces. The mast was bent over right under the rotor attachment, but was otherwise in one piece. The blades were damaged to rather different extents.

1.12.2.4 Approx. one metre of the end of the tail boom, which had been cut away by the main rotor, lay near the remains of the helicopter. Amongst the parts found on the cut-off section was the tail rotor. No rotation damage was found on the rotor, and both blades of the tail rotor had been statically bent in the direction of the tail fin/tail boom on contact with the trees (see Appendix 3).

1.12.2.5 The tail rotor drive system was severely damaged. The drive shaft between the engine and the tail rotor gear box, which consists of 8 steel and aluminium segments (see Appendix 2), was damaged partly by torsional forces and partly through direct truncation owing to main rotor hit and by crash forces when the fuselage and the remnants of the tail boom hit the ground. The first segment of the shaft was subjected to torsional forces which twisted the shaft off, indicating that the engine was in operation throughout the accident sequence. In addition to the damage mentioned, a loose bonding on shaft segment number four was discovered. This shaft consists of an aluminium tube and two bonded adapters. The adapters are coupling points to the next shaft segments. One of these adapters had worked its way loose from the tube and showed signs of overheating. The shaft tube had been pushed backwards and approx. 12.7 mm out of the adapter (see Appendix 4).

1.13 Medical and pathological information

Blood tests were carried out on the Pilot-in-Command. There were no medical conditions which might have had any bearing on the accident.

1.14 Fire

No fire broke out after the accident.

1.15 Survival aspects

The characteristics of the helicopter, as well as the Pilot-in-Command's - on the whole - correct course of action, resulted in the survival potential being assumed to have been good in relation to the accident sequence itself. However, there was a considerable fire risk owing to the fuel leak and high air temperature. The passenger in the back seat had to be helped out by the Pilot-in-Command owing to the fact that the left-hand side door was obstructed by the left-hand spray boom which was lying over the fuselage.

1.16 Test and research

1.16.1 Tests carried out at Bell Helicopter Textron, U.S.A.

1.16.1.1 The helicopter manufacturer quickly despatched two experts to Norway to assist in the investigations. It became clear at an early stage that it would be a great advantage to be able to carry out exhaustive metallurgical tests on the tail boom and the tail rotor drive shaft, as well as obtaining details relating to the loose bonding (see 1.12.2.5). Since this work is both time-consuming and requires special equipment, it was decided to send the remnants of the tail boom, tail rotor, and parts of the spray system to Bell Helicopter Field Investigation Laboratory for further tests. The AAIB/N was present during the tests, as was a representative from the National Transportation Safety Board (NTSB) who assisted in the preliminary phase. The main purpose of these tests was twofold:

- to establish, if possible, the physical and mechanical properties of the loose bonding mentioned in section 1.12.2.5.

- to evaluate whether the bonded connection could have been affected by external conditions which might be revealed through exhaustive testing of the tail rotor drive and control systems, the structure of the tail boom and the spray system.

1.16.1.2 The tests at the factory took approx. 14 days to complete. There were a number of experts at the factory during this period who were involved in the testing, but the main tests were carried out by the Field Investigation Laboratory which used a Scanning Electron Microscope (SEM) as part of its testing equipment.

1.16.1.3 After the tests at the above mentioned institution were completed, a report was compiled by the laboratory (Report No. 20694R-007). The report was sent in the first instance to the NTSB which concurred with the report and sent it on to the AAIB/N.

The conclusion reached by the report was that the bonding which held together the rear section of the drive shaft tube and the drive adapter for shaft segment no. 4 came loose in flight and caused the tube to rotate in the adapter, the result of which was that the tail rotor ceased to function. Under testing the adapter was split into two pieces so as to ensure that it could be loosened without affecting the adhesive surfaces. Traces of corrosion on the edge of, and approx. 20 mm inside, the adapter, were detected. The detection of corrosion inside the adapter indicates either that the bonding surface was never homogenous (insufficient application of adhesive) or that the bonding came loose at a time during operation of the helicopter. Three different areas (A, B and C) were detected on the section of the pipe which is normally bonded to the adapter (see Appendix 5). The three areas comprise the section of the pipe which was found pushed approx. 11.5 mm out of the adapter, and two areas which were hidden by the adapter. These areas suffered different types of damage:

Area A (whitish adhesive surface): After the adapter had come loose from the tube there was relative rotation between the adapter and the tube, which can be seen in the adhesive surface. After the tail boom hit the trees and was thereby compressed, the tube was pushed backwards and out of the adapter as it continued rotating. The reason why the adhesive was not more discoloured by the friction of the rotation in this area was that in the beginning the heat was diverted through the thickest section of the adapter and that the tube section later rotated outside the adapter.

Areas B and C: There was evidence here that the adhesive surface was discoloured to a light brown coating in area B and a dark brown coating in area C. The frictional heat in these areas affected the adhesive surface over a longer period of time than in area A (because the engine continued to drive the shaft), and the adapter became steadily thinner in this area (see Appendix 6). This meant that the frictional heat did not dissipate so easily, and that the temperature of the adhesive surface increased significantly and discoloured it. Another result of this was that it was impossible to find any trace of any failure mechanism in this section of the adhesive surface.

There was evidence in several places of voids in the adhesive surface on the section of the tube which protruded from the adapter and which had suffered only slight frictional damage. There was also an occurrence of cleavage fracture owing to overloading in the section of the adhesive surface which was homogenous. No evidence was found of progressive failure development. This section of the tube was also deformed by the tube jarring against the next shaft during the accident sequence.

1.16.1.4 Sharp impression marks were found in the metal on the sides of the adapter, at an angle of 90° to the adapter flanges (see Appendix 7). The laboratory has characterised these marks as "tool marks". In addition to this, soft impression marks were found on the surface of the same adapter (see Appendix 7). The report concludes that the soft impression marks were caused by the adapter coming into contact with the drive shaft cover during the accident sequence.

The laboratory tests were unable to produce evidence as to how the sharp "tool marks" on the sides of the adapter flanges had arisen, and were unable to connect these to the accident. The report was also unable to state the extent to which they were significant in the debonding.

1.16.1.5 The tests revealed no faults in either the tail boom or the remaining drive gear components of the tail rotor which might have had some connection with conditions which were important in the accident sequence. There was evidence that the damage to the tail rotor blades arose as a result of static overloading during the accident sequence. This overloading also occurred in the tail rotor hub static stops which were found to be bent.

1.16.1.6 *Sections of the Simplex 2700 spray system were examined as follows:*

A. Only one of the four turnbuckles which were fitted so as to hold the tank on to the fuselage was of the original type. The others might be classed as "boat standard". The barrel of the rear right-hand turnbuckle was screwed out so far that only approx. 4-5 threads were meshed with the end piece. The end piece had, moreover, been torn out of the barrel. The other non-original turnbuckles were also screwed out quite a long way. Two of the non-original turnbuckles had no indication holes to check the thread meshing in the end pieces. The holes for the pins connecting the turnbuckles to the mounting brackets in the fuselage and the tank were heavily worn and elongated.

B. The front right-hand mounting bracket, which was one of the points where the tank was attached to the helicopter, was found to be cracked. Closer inspection revealed that the bracket had come loose as a result of fatigue cracks and end fracture. The bracket was thus cracked prior to the residual fracture taking place during the accident.

C. One of the points at which the framework pipe of one of the spray booms was attached to the fuselage was found to be cracked. It could be evidenced that half the fracture occurred prior to the accident, based on the fact that the fracture surface was heavily corroded (rust). The residual fracture was due to overloading which occurred during the accident sequence.

1.16.2 The helicopter and the engine were, moreover, inspected at the AAIB/N's technical base at Kjeller. No faults were found which might have had any bearing on the way the accident developed. The bulbs in the warning lights were inspected with the aid of a magnifying glass. The only bulb which showed visible signs of change in its filament was the one for "Low Rotor RPM". The filament has been stretched, indicating that the light was on during the accident sequence. This accords with the fact that the main rotor steadily lost rotational speed when it "cut" its way through the trees.

1.17 Organisational and management information

1.17.1 <u>The company</u>

1.17.1.1 The company's name, AS Helilift, originally dates back to 1967. The company was not in operation for a period from the end of the 70's to the beginning of the 80's, and was then bought out by new owners. Since that time the company has primarily been involved in forestry flights (spraying of lime and manure), but has also been involved in film shooting and other ad hoc work. At the time of the accident the company was operating the following helicopters:

1 Bell 206L
1 Bell 206B
1 Eurocopter SA 350B-1

The company has a licence and permit to operate VFR helicopter flights. The permission comprises round-trip flights, parachute-drop flights, photo and commercial flights and surveillance flights.

The company's main base is at Oslo Airport, Fornebu, where it rents premises, which includes hangar space. The company has its own technical organisation with JAR 145 Approval No. CAA-N 030. Norwegian Air Ambulance (Norsk Luftambulanse) is contracted to monitor the quality requirements in JAR 145.65. There are (pr.date) four permanent employees in the company - a technical manager/ technician and three pilots, one of whom is the general manager and chief of operations. Over the last few years the company has logged approx. 1,500 flight hours a year.

1.17.2 Inspection by the Norwegian Civil Aviation Administration

1.17.2.1 The Norwegian Civil Aviation Administration's inspection of AS Helilift includes an annual inspection of both the technical and operational aspects of its activities. Physical inspection of aircraft may be carried out in such cases. The Certificate of Airworthiness is generally renewed for each aircraft on the basis of such continuous inspection and an application from the owner/user - in other words, without the aircraft necessarily being inspected by the Civil Aviation Administration (referred to as "Gransking" see 2.3). All renewals of LN-OSL's Certificate of Airworthiness subsequent to its initial issue were made based on "Gransking".

1.17.2.2 Maintenance programmes for each type of aircraft are to be approved by the Norwegian Civil Aviation Administration, as was the maintenance programme for the Bell 206B, which was used by AS Helilift and approved by the safety authorities.

1.18 Additional information

1.18.1 The helicopter manufacturer has informed the AAIB/N of other cases where a bonding in the drive shaft of the tail rotor on this type of helicopter has come loose in flight. None of the 5 reported cases of the same type as dealt with by this report were explained or could be explained. One of the reasons for it being difficult to explain is the fact that the over- heating which occurs when the bonding fails destroys any trace of evidence. In two cases where the shafts were inspected and tested in connection with conditions other than separation between adapter and tube, voids were found in the adhesive surface. Neither of these shafts failed when subjected under test to a torsional moment of such a magnitude as to deform the shaft tube itself. There was also evidence that it was possible to clearly see from a void the spreading of cracks in adhesive, which may indicate that it is possible to initiate fatigue in the adhesive itself.. There is no evidence to show to what extent such a development can go before a complete fracture occurs. It is thought that the initiation of such a development may occur, for example, through the tail rotor being subjected to a blade strike (where the tail boom comes into contact with an object during operation). With regard to construction requirements, up to 20% of the affected adhesive surface can include voids without this weakening the bonding.

In another case it was demonstrated that the shafts had been subjected to plastic media blasting, or something of that nature - a process whereby a surface is cleaned by pressure blasting a surface with small plastic particles (similar to sand blasting or glass blasting). This would have resulted in the thinnest section of the adapter becoming deformed in the area where it was bonded to the tube which, in turn, would have initiated a process which would have led to failure of the bonding (debonding).

1.18.2 The manufacturer of the helicopter has also informed the AAIB/N that they are conducting a design study on improvement to tail rotor drive system on the model 206. The study was initiated in August 1994 and is presently ongoing.

1.18.3 The helicopter was fitted with spray equipment designed for the liquid spraying of forest areas. The equipment was FAA-approved under Supplemental Type Certificate (STC) No. SH124NW. It was imported to Norway in 1978/79 and was used on other helicopters prior to AS Helilift purchasing the equipment and using it. Any approval of the equipment by the Norwegian Civil Aviation Administration was thus given prior to AS Helilift taking over the equipment. Close study of the Norwegian Civil Aviation Administration's technical documentation for this helicopter reveals no information on the STC in question.

1.18.4 An aerodynamic cowling, which should have been fitted in front of the spray system fluid tank, was not fitted at the time of the accident and had, according to the company, never been installed (see Appendix 8). The manufacturers of the equipment - Simplex Manufacturing Co., U.S.A. - have informed the AAIB/N that installation of the cowling is a required item.

1.18.5 The following restriction is found in the Flight Manual Supplement which applies to the Simplex 2700 when fitted to the helicopter:

> "Operation with the Simplex Jet Ranger II spray system installed is approved for Restricted Category Only. No persons other than the minimum required crew shall be carried during special purpose Restricted Category Operations."

1.18.6 The following wording appears in the chapter entitled "Tail Rotor Control Failure" in Section 3 of the Flight Manual, Emergency and Malfunction Procedures:

"Reduce throttle to flight idle. Immediately enter autorotation and maintain a minimum air speed of 58 mph (50 knots) during descent.

Note: Airflow around the vertical fin may permit controlled flight at low power levels and sufficient air speed when a suitable landing site is not available; however, touchdown shall be accomplished with the throttle in the fully-closed position."

During the preliminary investigations carried out at the scene of the accident, the AAIB/N found that the throttle was in the idle position.

1.18.7 Maintenance of the tail rotor drive shaft

1.18.7.1 The following relevant maintenance instructions for the tail rotor drive shaft are to be found in Bell Helicopter Maintenance Manual BHT-206B3-MM1:

100 hours: Check segmented drive shaft and Thomas coupling for condition and security. Check torque of Thomas coupling retention bolts/nuts and apply torque seal.

Conditional inspections - Sudden stoppage/acceleration main and tail rotor:

(This is for detailed inspections, which also include tail rotor shafts, after rapid acceleration or deceleration in the helicopter's drive system which is caused, for example, by contact between the main or tail rotor and an object, a sudden freewheeling clutch engagement, or a compressor stoppage).

1.18.8 The AAIB/N has studied the helicopter's historical documentation closely. The documentation gave no indication that the helicopter was subjected to any abnormal conditions from the time it was new until the day of the accident.

1.19 Useful or effective investigation techniques

No new methods.

2 ANALYSIS

2.1 Bell 206B Flight Manual - Emergency and malfunction procedures

The situation in which the Pilot-in-Command found himself when he lost directional control of the helicopter is described in Section 3 of the Bell 206B Flight Manual, Emergency and malfunction procedures, Tail rotor control failure, Complete loss of thrust. It reads as follows:

"Reduce throttle to flight idle, immediately enter autorotation and maintain a minimum air speed of 59 mph (50 knots) during descent."

Note: Airflow around the vertical fin may permit controlled flight at low power levels, and sufficient air speed when a suitable landing site is not available; however, touchdown shall be accomplished with the throttle in the fully-closed position."

The AAIB/N is of the opinion that the above-mentioned procedure is adequate for the situation when the power component of the tail rotor suddenly ceases in flight.

2.2 The reaction pattern of the Pilot-in-Command

When the Pilot-in-Command realised that he no longer had directional control over the helicopter, he immediately carried out the procedure described in paragraph 2.1 above. Autorotation requires a relatively significant drop in altitude. However, as the helicopter was at a altitude of no more than approx. 400 ft when directional control was lost, it was impossible for the Pilot-in-Command to reach open terrain. When the helicopter had descended to the height of the tree tops the Pilot-in-Command stopped the vertical movement by using the energy in the main rotor (increasing the blade angle) and then lowered the aircraft down into the forest. He did not, however, turn off the engine throttle, so the engine idled also after the helicopter came to rest. The engine stopped when the Pilot-in-Command turned off the electrically-operated main fuel cock. In the AAIB/N's opinion, the Pilot-in-Command carried out the emergency landing correctly and according to the procedure, except for the fact that he did not stop the engine at the right point in time by using the throttle. In the situation in question this might have created an additional dangerous situation, as the danger of fire was imminent, owing to the dryness of the forest floor and the high temperature. Fortunately no fire broke out.

2.3 Simplex 2700 Spray System

Tests on parts of the spray equipment, some of which were carried out at the Bell factory, have brought to light a number of deviations from acceptable standards of airworthiness. Non-original parts, worn attachment points, and cracks in the construction details were found, and an aerodynamic cowling which should have been fitted in front of the fluid tank was missing (see Appendix 8). This may indicate a situation which is not unfamiliar - i.e. that extra aircraft equipment is often not maintained to the same standards as the aircraft itself. In this case there were no maintenance instructions from the manufacturer of the equipment, and the company itself had not written any. In the opinion of the AAIB/N, this does not comply with the maintenance requirements specified in BSL B 3-2, in spite of the fact that it can seem unclear which paragraph(s) in the BSL in question apply to maintenance of STC equipment, etc.

Inspections in the company (audits) carried out by the CAA did not reveal this deficiency. This could, in this particulary case, have been caused by the fact that the Certificate of Airworthiness (C of A) for this aircraft for years has been renewed by the audit form "Gransking" (the word "Gransking" means that the C of A is renewed on the basis of the companys continuously maintenance program and not by direct inspection by the CAA, see 1.17.2.1). On the basis of earlier experiences, it is of the opinion of the AAIB/N that the safety authorities should require current documentation stating that all extra equipment used on a particular aircraft is approved and included in the maintenance programme.

The AAIB/N considers it to be unsatisfactory that the spray system fitted to this helicopter was not better maintained. There is no evidence, however, to show that the spray system had anything to do with the accident.

2.4 Conditions which may have affected the course of the accident and which require Conditional Inspections with reference to the Bell 206B Maintenance Manual

As mentioned in 1.18.7.1, conditions can occur during helicopter operation which require special inspections (Conditional Inspections). These conditions are described as "Sudden stoppage/acceleration main and tail rotor", and may have a bearing on the integrity of the rotor shaft.

The AAIB/N has studied the helicopter's history closely. There is no evidence to show that the helicopter has been the subject of any abnormal occurrences to do with its operation or maintenance which may have had a bearing on the course of the accident. There was no evidence either from the tests carried out at the factory of there being any fault in the drive system which might have had a bearing on the course of the accident. The engine was partially disassembled at the AAIB/N's workshop in Kjeller, and the compressor, amongst other things, was opened. No fault was found in the engine which could be connected with the accident.

2.5 The "tool marks" on the adapter

As indicated in paragraph 1.16.1.4 it was stated during testing at the factory that marks had been made on the sides of the adapter, at an angle of 90° in relation to the adapter flanges. The marks seemed not to be of recent date, and were thus not made during the accident. It was thus not possible to say when the marks were made. An important question was to what extent the making of the marks might have contributed to debonding of the adapter. In the opinion of the AAIB/N, the marks left were such that only a relatively small amount of force was required to imprint them in the metal on the adapter. There was no evidence in the section of the bonding material nearest the adapter flanges, which were undamaged by rotation, of any progressive failure development. There is thus no reason, in the opinion of the AAIB/N, to assume that the marks left contributed to the adapter coming loose.

There is reason to believe that the marks were made prior to the accident. It was not possible, however, to find out what caused them. Based on the assumption that the marks were made at some time during or prior to the last inspection they should have been discovered during the routine inspections carried out on the tail rotor shaft every 100 flight hours.

2.6 The vibration which occurred during the loss of directional control

The Pilot-in-Command explained that powerful vibrations shook the helicopter during the two 360° spins the helicopter went into after directional control was lost. These powerful vibrations stopped when the Pilot-in-Command put the helicopter into autorotation. It therefore seems natural to assume that the vibrations arose as a result of the helicopter spinning round. The vibrations were discussed with experts at the Bell factory and a representative from the Simplex factory in connection with the tests carried out at the Bell factory. Attempts were made to explain the vibrations both aerodynamically and in other ways. None of the experts had any experience of a similar situation in which a helicopter fitted with spray equipment with long spray booms span round owing to the fact that the tail rotor suddenly stopped working. A number of theories were discussed, but the experts were in agreement over the fact that any possible solutions were based more on speculation than technical explanations. Having taken this into account, the AAIB/N is thus of the opinion that it is impossible to offer any specific explanations for the vibrations.

2.7 Passenger on board the helicopter

The passenger sitting in the rear section of the cabin was wearing a safety belt. The original seat and back cushions had been removed and the passenger sat on a temporary cushion. A situation such as this may lead to a passenger suffering greater injuries than necessary in an accident because the normal cushions are there to absorb the kinetic energy to which the passenger is subjected. In this case the energy on collision with the ground was relatively small.

The FAA approved Flight Manual Supplement, which comes with the Simplex spray equipment fitted to the helicopter, reads as follows:

> "Operations with Simplex Jet Ranger II spray system installed is approved for Restricted Category Only. No persons other than the minimum required crew shall be carried during special-purpose Restricted Category Operations."

The expression "Restricted Category" is not found in Norwegian aviation regulations, and there is thus every reason to raise the question as to what extent the above-mentioned restriction is applicable to a Norwegian helicopter with a Norwegian certificate of airworthiness classified in the "normal" category, as is the case here. Information supplied by the Norwegian Civil Aviation Administration may indicate that when the safety authorities approve a supplement to a flight manual based on, for example, an STC, it also means that the wording of the supplement applies in all cases from the moment the equipment is fitted to the aircraft. The AAIB/N must thus assume that the passenger was, in this case, on board in contravention of the restriction in the flight manual.

2.8 Failure in the bonding ("debonding") on tail rotor shaft segment no. 4 - conclusion.

The direct cause of the helicopter accident may thus be ascribed to the debonding between the rear adapter and the drive shaft segment no. 4 tube. The direct cause of this could not be demonstrated on the basis of the tests carried out at the Bell factory laboratory. The tests revealed voids in sections of the adhesive bonding material which were not destroyed by overheating (the section of the pipe which protruded from the adapter). Cleavage fracture and cracking were also detected in the homogenous section of the adhesive surface. However, there was no evidence of a progressive spread of the cracking. Corrosion was also detected inside the adapter, which would indicate either that there were voids in the adhesive ever since the time of manufacture, or that separation between the adhesive surface and the metal surface had occurred over time. It was also noted in the laboratory report that there was no trace of adhesive on large sections of the inside surface of the adapter, and that adhesive remained solely on the shaft tube (adhesive debonding). No trace of any progressive spread of cracking could be seen. The adhesive in this area of the shaft tube could not be inspected owing to the fact that it was destroyed by frictional heat. It was thus impossible to determine directly which failure mechanism caused the debonding. It might be noted that it was also impossible in tests carried out by the Bell factory in the other cases mentioned in 1.18.1 to give an unambiguous answer as to why the bonding failed.

The maintenance instructions found in the Maintenance Manual for the tail rotor shaft seems to be adequate except in the case of a possible failure in one or more of the bonded connections. Should such a failure occur without the shaft segments being affected by extraneous conditions it seems possible that total failure can occur in the bonding without the indicated preventive maintenance catching the fault prior to failure. Ultrasound checking is a method used by some factories in their tests to reveal voids in bonded surfaces. This method, however, is, in the opinion of the AAIB/N, difficult to carry out in the normal maintenance of a tail rotor shaft.

The AAIB/N is of the opinion that it is not acceptable that elements of a rotor drive system of an aircraft have failure mechanisms which cannot be discovered by use of the manufacurers recommended maintanance program until total failure has occurred. It is thus the AAIB/N's opinion that the construction of the tail rotor shaft on this helicopter type should be studied more closely. It looks as if the Bell company itself is dealing with these consequences by carrying out a "design study" with the aim of making possible improvements in the construction.

3 CONCLUSIONS

a) The Pilot-in-Command was properly licensed and qualified to conduct the flight.

b) The helicopter was properly registered and certified. Maintenance of the aircraft was carried out in accordance with an approved maintenance programme based on current aviation regulations.

c) The helicopter was fitted with Simplex spraying equipment for forest spraying.

d) The maintenance programme for the aircraft did not include the fitted spray equipment. A number of irregularities were found with regard to its installation.

e) A bonded connection on a segment of the tail rotor shaft came loose in flight. This resulted in the tail rotor ceasing to operate and the Pilot-in-Command initially loosing directional control (Causal factor).

f) The Pilot-in-Command regained directional control by putting the helicopter into autorotation. He did not, however, manage to reach open terrain, and was forced to make an emergency landing in the forest.

g) A passenger was onboard in contravention of the restrictions specified in an STC supplement to the Flight Manual for the Simplex 2700.

h) No irregularities in the aircraft structure or systems were found which could have contributed to the tail rotor shaft segment coming loose.

i) During the preliminary investigations carried out at the scene of the accident, the AAIB/N found that the throttle was in idle posision.

j) The manufacturer of the helicopter informed the AAIB/N of other incidents/ accidents with the same causal factor.

k) The manufacturer of the helicopter has stated that they are evaluating modifications in the structure of the tail rotor shaft on this helicopter type.

4 SAFETY RECOMMENDATIONS

4.1 The Civil Aviation Administration is advised to evaluate whether the bonded driveshaft segments on Bell 206 helicopters are satisfactory in relation to airworthiness requirements.

4.2 The Civil Aviation Administration is advised to request AS Helilift to anjoin their practice to manage the configuration of their aircraft with special emphasis on modifications and equipment.

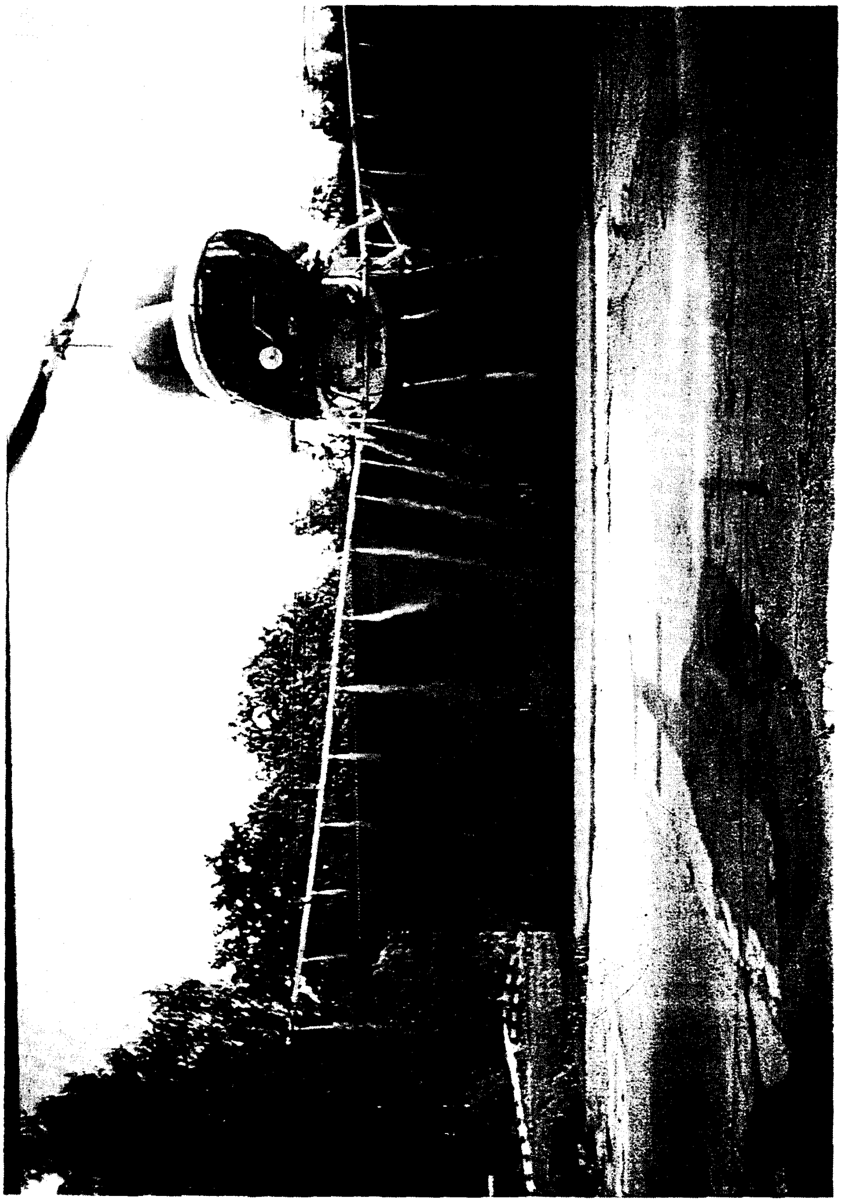
4.3 The Civil Aviation Administration is advised to evaluate whether it is appropriate to have current airworthiness status relating to equipment installed on commercial aircraft and not covered by the aircrafts type certificate.

5 APPENDICES

Appendix (Bilag) 1-8
Map of accident site
Abbreviations

THE AIRCRAFT ACCIDENT INVESTIGATION BOARD (AAIB/N)

Fornebu 19 January 1996



Bilag 1

Bilag 2

BHT-206B3

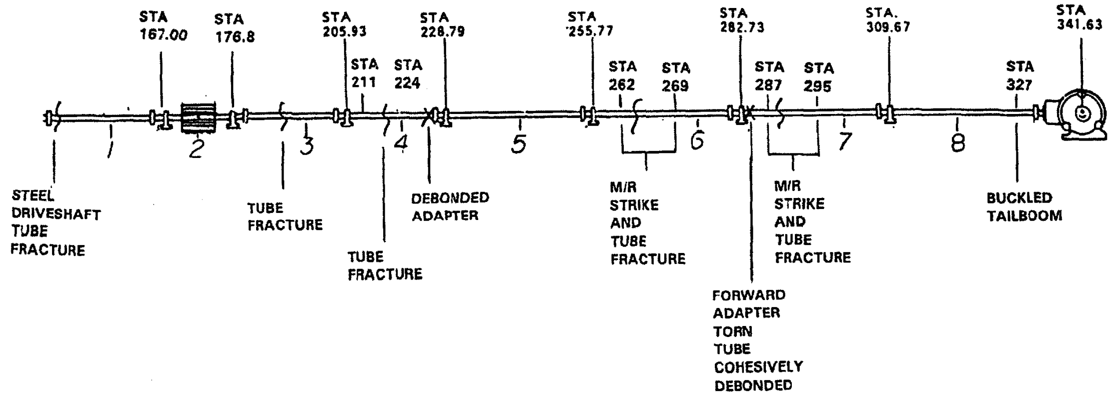
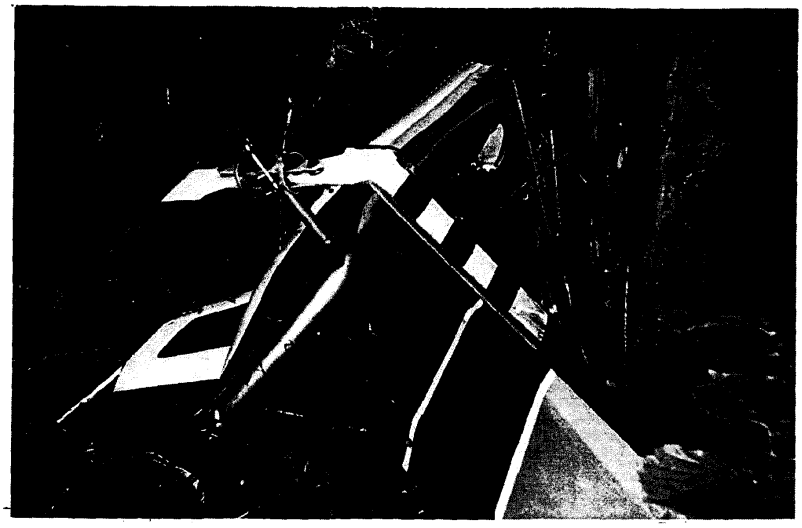
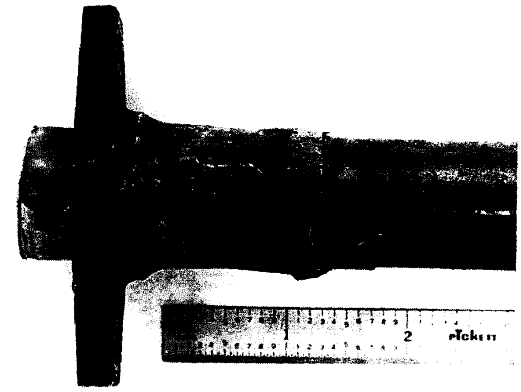


Illustration of tail rotor drive system and location of fractures and debonds

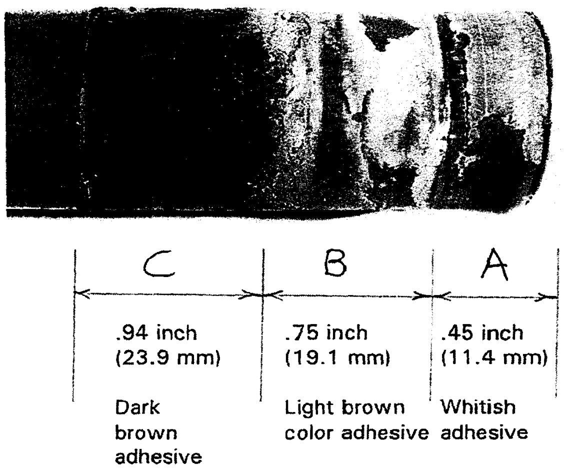


Bilag 3

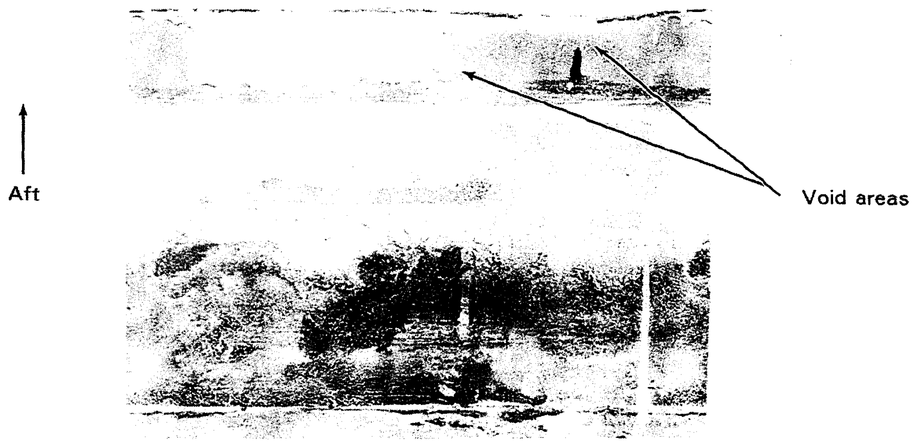


Bilag 4

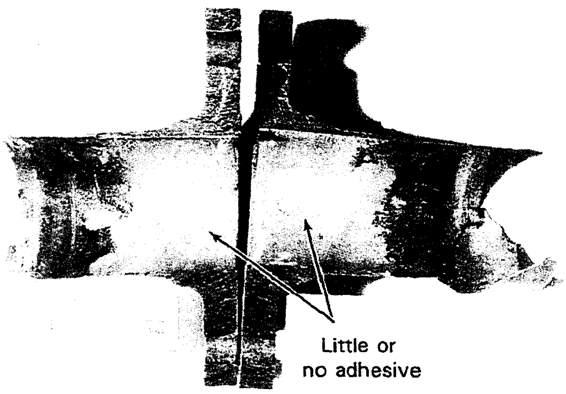
Figure 15
View of the debonded end of the #4 tail rotor driveshaft with the adapter removed.



Bilag 5



<u>Figure 17</u>
Peripheral camera view of debonded tube showing
a flat view of the debonded area.



Bilag 6

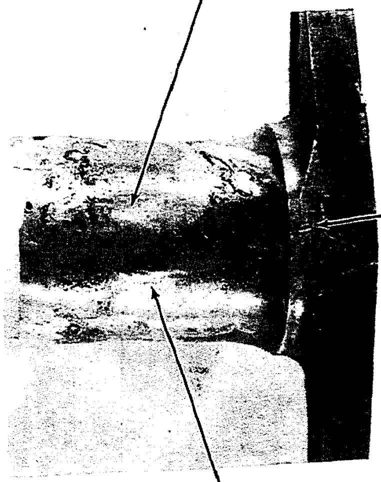


Figure 23
Side view of adapter showing the external damage along the tapered end. Also tool damage to rounded end 90° from flange.

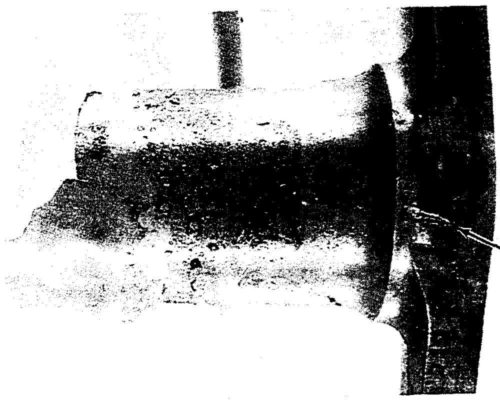


Figure 24
Opposite side view of adapter showing the tool damage.

Bilag 7

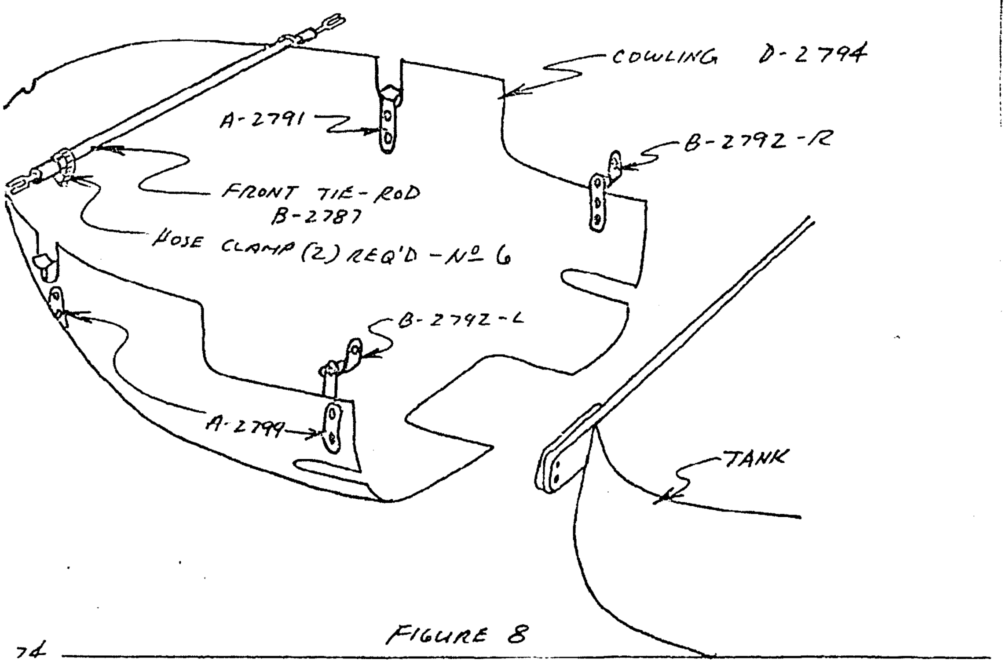
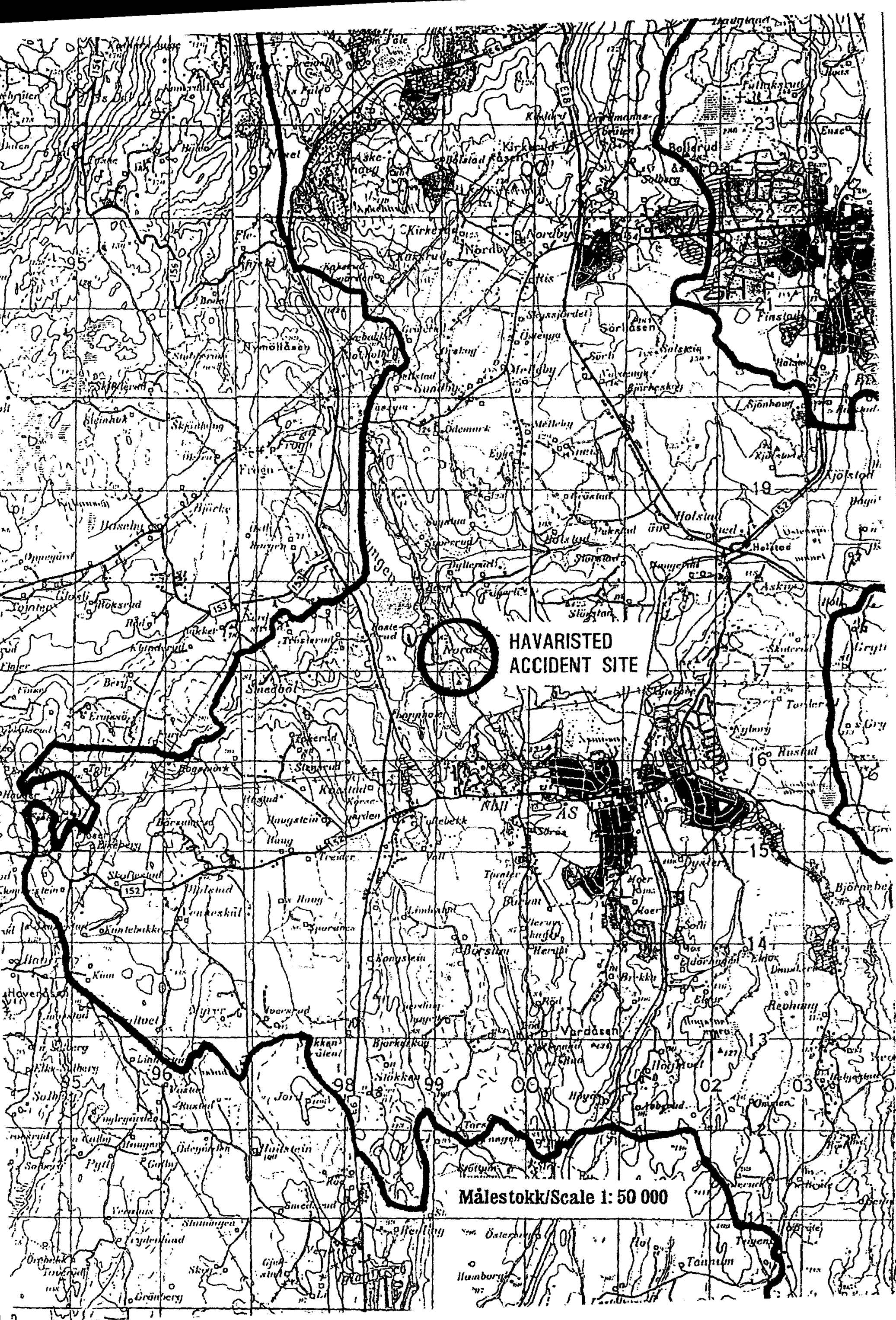


FIGURE 8

Bilag 8


HAVARISTED
ACCIDENT SITE
Målestokk/Scale 1: 50 000

FORKORTELSER

BSL	Bestemmelser for sivil luftfart
BSL B	Bestemmelser for sivil luftfart - flytekniske bestemmelser
CAA	Civil Aviation Authority
FAA	Federal Aviation Authority
ft	foot/feet , fot
HSL	Havarikommisjonen for sivil luftfart
JAR	Joint Aviation Requirement (felleseuropeiske luftfartsbestemmelser)
kt	knot (-s), knop
LV	Luftfartsverket
mm	millimeter
MPH	Miles pr. hour
NLH	Norges landbrukshøgskole
NTSB	National Transportation Safety Board (den amerikanske undersøkelsesmynd.)
PFT	Periodical Flight Training
STA	Station number (in inches from datum line) - en bestemt posisjon på skroget uttrykt i tommer fra datumlinjen
STC	Supplemental Type Certificate (et spesielt sertifikat for utstyr som kan monteres på et luftfartøy)
TWR	Kontrolltårn på flyplass (Tower)