Statens
Havarikommisjon
for Transport

SL Report 2007/23

REPORT ON THE AIRCRAFT ACCIDENT AT BODØ AIRPORT ON 4 DECEMBER 2003 INVOLVING DORNIER DO 228-202 LN-HTA, OPERATED BY KATO AIRLINE AS

This report has been translated into English and published by the AIBN to facilitate access by international readers. As accurate as the translation might be, the original Norwegian text takes precedence as the report of reference.

June 2007

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AIR ACCIDENT REPORT

Type of aircraft:	Dornier DO 228-202
Registration:	LN-HTA
Owner:	Kato Airline AS
Operator:	As owner
Accident site:	Bodø airport (ENBO), threshold of runway 25 (67°16’2’’N 014°24’0’’E)
Date and time:	Thursday 4 December 2003, time 0909

All times given in this report are in local time (UTC + 1) unless otherwise stated.

NOTIFICATION

On Thursday, 4 December 2003 at time 0915, the Head of Air Traffic Control at Bodø control tower telephoned the duty Inspector of accidents at the Accident Investigation Board Norway[1] to notify about the accident. The notification stated that a Dornier 228 belonging to Kato Airline had chrashed just east of the threshold of runway 25 at Bodø Airport, and that the status with regard to the four people onboard was unclear. Shortly after, the AIBN received similar notification from the Police's operation centre and from Kato Airline.

Because of poor weather conditions in Bodø and the fact that east part of the runway were closed, it was for a time uncertain whether the AIBN’s scheduled flight would be able to land at Bodø airport. The AIBN managed to turn out with three Inspectors of accidents, who arrived at the accident site at time 1450 on the same day.

SUMMARY

Kato Airline flight KAT603, an aircraft of the type Dornier 228-202 with registration LN-HTA, was to fly a regular scheduled flight from Røst airport (ENRS) to Bodø airport (ENBO). There were two passengers and two pilots on board.

There was a strong westerly wind, and when the plane approached Bodø extensive lightning activity developed quickly. The aircraft was struck by a very powerful lightning. The lightning struck the aircraft’s nose area and passed to the tail. Boundings between the fuselage and tail surface and a wire between the tail surface and the elevator were burned off. A powerful electric energy passed through the elevator rod in the tail section. A rodend came loose, resulting in a breach in the controlrod. Thus the only connection between the control column in the cockpit and the elevator was lost. This aircraft type has electric pitchtrim which adjusts the tail surface angle of attack and after a period the pilots regained limited control of the aircraft’s nose position by using this.

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[1] The AIBN’s Norwegian name was Havarikommisjonen for sivil luftfart og jernbane (HSLB) prior to 1 September 2005.

When the lightning struck the aircraft, the pilots were blinded for approximately 30 seconds. They lost control of the aircraft for a period and the aircraft came very close to stalling. The pilots declared an emergency.

The aircraft's remaining systems were intact and the pilots succeeded in bringing the plane in for landing. During the first landing attempt the airspeed was somewhat high. The aircraft hit the ground in an approximate three-point position and bounced into the air. The pilots concluded that the landing was uncontrollable because the elevator was not working. The landing was aborted and the aircraft circled for a new attempt. Wind conditions were difficult and the next attempt was also unstable in terms of height and speed. At short final the aircraft nosed down and the pilots barely managed to flare a little before the aircraft hit the ground. The point of impact was a few metres before the runway and the aircraft slid onto the runway.

Emergency services quickly arrived at the scene. The two pilots were seriously injured while both passengers suffered only minor physical injuries. No fuel leakage or fire occurred. The aircraft was written off.

There is reason to believe that the total amount of energy in the lightning exceeded the values of the construction specifications. The investigation has uncovered that up to 30% of the wiring in essential boundings in the tail may have been defective before lightning struck. Other relevant safety issues that are discussed in the report are the need for increased focus on maintenance and the optimum use of airborne weather radars. The investigation has further uncovered a need for better presentation of information from ground-based weather radars by the air traffic control service.

The Accident Investigation Board Norway issues three safety recommendations in this report.

1. FACTUAL INFORMATION

1.1 History of the flight

1.1.1 The crew checked in at the company's base at Narvik Framnes Airport (ENNK) on the morning of 4 December. Thereafter, they flew the following routes:

KAT601: Narvik to Bodø, departure at time 0615, landing at time 0705.

KAT602: Bodø to Røst (ENRS), departure at time 0735, landing at time 0800.

1.1.2 The flight from Narvik to Bodø and onward to Røst was without incident.

1.1.3 Seven passengers were booked on the flight from Røst to Bodø. Because of the poor weather conditions and strong winds, a married couple with three children elected not to make the journey. After a short stay, KAT603 took off from Røst at time 0825, with four people onboard - two male passengers, the Commander and First Officer. The First Officer was the Pilot Flying (PF).

1.1.4 At time 0828, the crew of KAT603 contacted Bodø Approach (119.700 MHz). Bodø Approach confirmed radar contact and instructed the crew to fly at 6,000 ft and follow a heading of 090° which would enable them to make a subsequent approach to ILS 25 using radar vectoring. The crew then obtained automatic terminal information services (ATIS) for Bodø Airport.

1.1.5 The first part of the flight progressed without problems and with less turbulence than expected. Bodø soon came into sight. Because there was a strong wind from the west, runway 25 was in use for landing. Ahead of them, and over the mainland, was a wall of clouds. In the space of a very short time, severe lightning activity developed in the area north to south of Bodø. In the subsequent period, several flights in the area decided, either on their own initiative or based on thunderstorm activity reports from the air traffic control service, to fly round the active cells containing heavy precipitation/intense lightning activity.

1.1.6 At time 0836, WIF803 (DHC-8 from Widerøes Flyveselskap) was nearing its approach to Bodø Airport from the east. The crew had registered a high intensity of precipitation in the area of the Ilstad locator (IL) on their weather radar. They were reluctant to fly through the precipitation cells and asked the air traffic control service if any other aircraft had flown through the area. They were told that there had been no other flights east of the location during the past half hour. The air traffic control service then cleared WIF803 to begin its ILS 25 approach. WIF803 was above Valnesfjord at that time. A little later, the air traffic control service informed WIF803 that another option would be to set a course west of the airport and make an ILS 07 approach, followed by visual circling for landing on runway 25. They added that, as visibility was poor, this was not a favourable alternative. Meanwhile, cumulonimbus clouds (CB) had amassed in the Landegofjorden area (see map, figure 1) and to the south of Fugløya. The crew of WIF803 therefore elected to continue their approach from the east. At time 0838, WIF803 reported it was established on ILS 25.

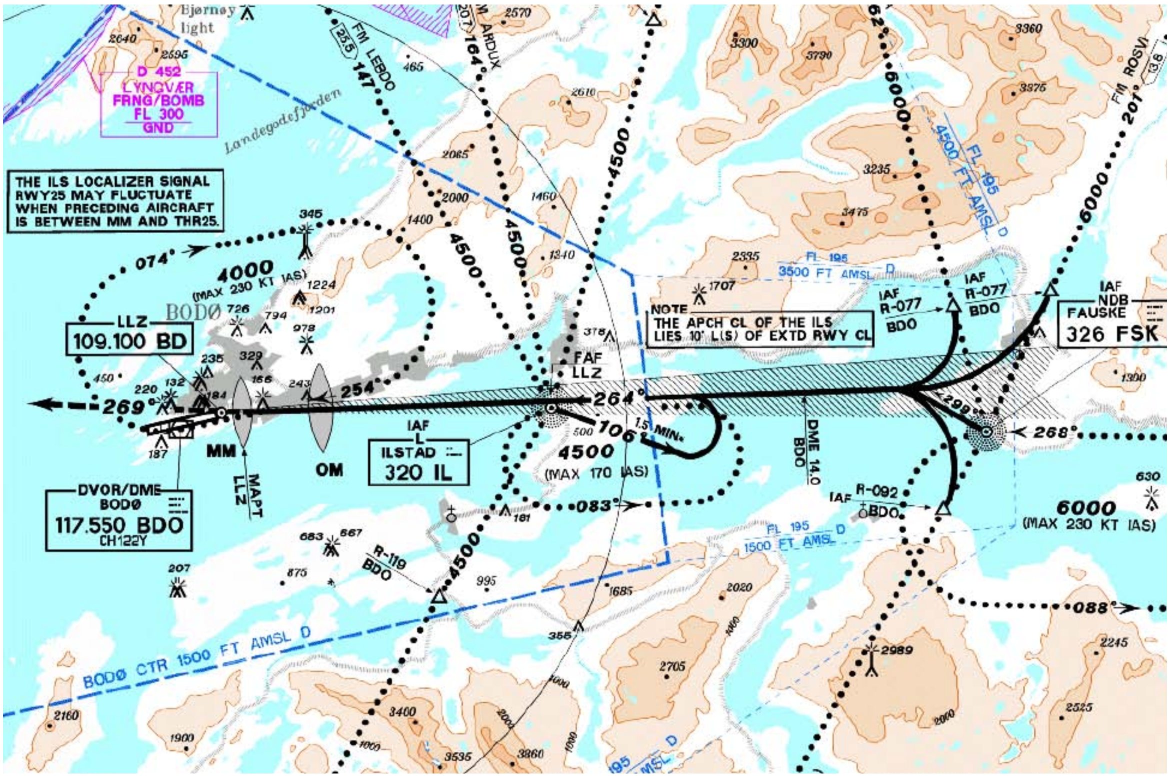


Figure 1: Section of approach map ILS 25 to Bodø

1.1.7 At time 0839, while WIF803 was approximately 3 NM east of Ilstad (IL) (see figure 1), at an altitude of 3,500 – 4,000 ft, the crew informed Bodø Approach that they had sustained a powerful lighting strike and did not advise other Dash 8 aircraft to fly through the same showers. The commander of WIF803 subsequently told the AIBN that in all the 19 years he had flown in the Bodø area, he had never experienced such a rapid build-up of intense lightning activity. He described the situation as like turning on a switch. As a result of the lightning strike, the Widerøes aircraft remained in the workshop for a week for damage repair.

1.1.8 Bodø Approach immediately informed KAT603 of the warning from WIF803. The crew of KAT603 then asked about the possibility of an ILS 07 approach followed by circling to runway 25. After coordination between Bodø Approach and Bodø TWR, which was able to visually check the position of the showers, KAT603 was informed that the showers were heading north-east. The crew were given the choice of waiting in the Fauske area or setting a westerly course and then making an approach from west to east. KAT603 asked to make an approach from the west. There were extensive showers in the Bodø area at the time and the crew were asked what it would be like to fly back to the west. The crew stated that they had visual contact with the airport on the flight from Røst to Bodø and that a return the same way should be ok, but that there were quite intense showers where they were. At time 0841, KAT603 had passed north of Bodø Airport and was now northeast of the airport. To position it for the approach from the west, KAT603 was sent a radar heading of 270º, continuing at a cruising altitude of 6,000 ft. In the period 0842-0843, there was frequent communication between the crew and Bodø Approach. They communicated about the positions of showers in the area, changes in the weather, the possibility of flying round the showers and their assessment of the best course to follow. The crew decided to continue to the ILS to runway 25. At time 0843, the pilots discussed the fact that the aircraft’s weather radar was completely unusable. Despite the obviously powerful cells in the area, the weather radar was not displaying any red colours. At the same time, the aircraft encountered heavy turbulence.

1.1.9 At time 0844, KAT603 sustained a very powerful lightning strike on its nose area. Both pilots were completely blinded. It was 30 seconds before their vision gradually began to return. The crew informed Bodø Approach about what had occurred. The aircraft's flight data recorder showed that when the aircraft was hit by lightning, the airspeed was 168 KIAS, the altitude 5,900 ft and the heading 225º. At that time, the aircraft was approximately 10 NM east of Bodø Airport.

1.1.10 The sequence of events after the lightning strike was as follows:

- 0-45 seconds: The aircraft slowly lost altitude, descending from 5,900 ft to 5,600 ft. Airspeed varied between 145 and 165 KIAS.
- 10-40 seconds: The pilots realized that the elevator was not working normally.
- 40 seconds: The pilots wondered if something had happened to the elevator and decided to increase engine power.
- 45 seconds: The aircraft began a rapid climb, eventually reaching a rate of climb as high as 4,000 ft/min, with a rapidly decreasing airspeed as a result.

- 70 seconds: The pilots registered that the airspeed was decreasing rapidly and discussed how they could get the aircraft down again.

- 80 seconds: The aircraft was close to stalling. The airspeed had fallen to its lowest value of 66 KIAS and the aircraft had stopped climbing at an altitude of 7,800 ft. (Vmc single engine = 81 KIAS)

- 90 seconds: Control of the aircraft was transferred from the First Officer to the Commander.

1.1.11 Engine power and trim were used to increase the airspeed to safe level. The aircraft continued its unwanted climb to 9,000 ft.

1.1.12 For a period, Bodø Approach did not interrupt the pilots, only later asking them to report when they were ready to start their approach.

1.1.13 At time 0846, the airport was hit by lightning and lost all its electrical equipment for a short while until the emergency backup power started and they were able to use the emergency equipment. There were no reports of this posing any problem to the air traffic control service.

1.1.14 At time 0846, Bodø Approach, which had then seen KAT603 diverge from the cleared altitude, commented that there was no other air traffic in the area and that they were free to climb and fly as they wished for the moment. At time 0847, the crew called and said they were at flight level (FL) 090 on a compass heading of 010º. Bodø Approach acknowledged receipt of the message and reiterated that they were free to operate as they deemed necessary. At time 0848, the crew reported that they were experiencing problems with the elevator and were having to apply electric elevator trim to control the aircraft's altitude. Exchanges over the next few minutes concerned updated information about the showers in the area and planning of the best way of making the landing approach. The crew were told that wind at the airport was 230º and 25-32 kt.

1.1.15 At time 0850, the crew declared an emergency, as a result of the problems with the elevator, and gave information on how many passengers were onboard and how they were seated in the cabin. Receipt of the message was confirmed by the air traffic control service. At time 0851, the air traffic control service issued a warning in accordance with the warning plan (see section 1.15.1). The tape recording reveals that the air traffic controllers were expecting the aircraft to crash. Because of new showers moving into the area, the subsequent period was marked by hectic activity, with the air traffic control service constantly evaluating how they could best advise the crew to fly. The preferable situation was to bring the aircraft into visual flying conditions if possible, but it was not certain that this was feasible, due to low clouds and reduced visibility in the showers. From a position over Landegodefjorden, heading and altitude clearances were given for the approach to runway 25.

1.1.16 The crew gradually gained experience in keeping control of the aircraft. Because the elevator trim had an incremental effect, each change of engine power meant that the trim had to be re-adjusted. The strong wind at altitude and high terrain created turbulence and made stabilization of the aircraft even more challenging. The aircraft's other systems appeared to be intact after the lightning strike. At time 0901 descending to 2,500 ft, the crew gained sight of the airport from a distance of 7 NM and received clearance to land on runway 25. The passengers were kept informed of the problems with the elevator. They were told to expect a hard landing and instructed to tighten their seat belts.

1.1.17 At time 0904, when the aircraft was on short final, the current wind was reported as 230º 25 kt. The Commander decided to land with flaps in position 1. He was flying the aircraft and asked the First Officer to make all the required changes to engine power. As the aircraft was at approximately 700 ft, its ground proximity warning system issued an alarm that the aircraft was below the electronic glide path. The pilots tried to keep the aircraft as stable as possible. From approximately 100 ft the aircraft flew with a very low sink rate over the runway, before suddenly descending. When the aircraft met the runway outside taxiway “D” (about the middle of the runway), its airspeed was a little too high (110 KIAS) and it landed in a three-point position. It was a hard landing and the aircraft immediately bounced high into the air. Faced with this situation and with the elevator out of action, the Commander felt justified to abort the landing.

1.1.18 The air traffic controllers in the tower witnessed the aborted landing and the subsequent go-around. They have told the AIBN that they thought the aircraft would crash because it had a very high nose attitude. The airspeed during the climb was approximately 110 KIAS, varying from 101 to 120 KIAS. The crew then circled to make a new left landing circuit and approach to runway 25.

1.1.19 The aircraft was established on short final again 1 minute and 55 seconds before landing (the accident). The approach was considerably flatter that the standard 3.5º for runway 25 at Bodø. The Commander wanted to place the aircraft at a lower approach angle than on the first landing approach and to land some way onto the runway. The Commander was aiming to minimize any need for a change in pitch and trim, and to achieve the best possible landing down in one of the oscillations on the aircraft’s flight path (approach angle). The air traffic controller reported a wind of 230º 27 kt. From 30-10 seconds before impact, the airspeed varied between 99 and 123 KIAS. In the last 10 seconds, the airspeed fell from 123 KIAS to the flight data recorder’s last registered speed of 101 KIAS. The nose attitude was too low, but the Commander managed to flare a little before the aircraft hit the ground virtually flat, 22 metres short of the asphalt at the eastern end of the runway (see section 1.12 for details). The aircraft’s flight data recorder registered up to 8.4 G on impact. The aircraft’s landing gear broke off, its belly was forced up and the wing pressed down into the cabin. The aircraft slid for 78 metres before stopping on the runway. No fuel leakage or fire occurred.

1.1.20 The powerful impact rendered both pilots unconscious for a short period. When they came round, the rescue services were outside the window. The pilots evacuated the aircraft through the left cockpit door, while the two passengers evacuated it at the front through the right emergency exit in the cabin. The fire fighters sprayed the aircraft with foam. The passengers and pilots were taken to Nordland Hospital in Bodø.

1.2 Injuries to persons

Table 1: Injuries to persons

Injuries	Crew	Passengers	Other
Fatal			
Serious	2		
Minor/none		2	

1.2.1 The Commander's main injuries were moderate compression injuries/fractures to the back. Because of the extent of his injuries and the fact that he was admitted to hospital for more than 48 hours, he has been categorized under serious injuries.

1.2.2 The First Officer suffered minor compression in the back, as well as wounds and cuts. Because he was admitted to hospital for more than 48 hours, he too has been categorized under serious injuries.

1.2.3 After being examined by a doctor, the two male passengers were discharged from hospital and are therefore categorized under minor injuries.

1.3 Damage to aircraft

The aircraft was a total loss (see section 1.12 for details).

1.4 Other damage

There was minor damage to the runway and the terrain in front of the runway.

1.5 Personnel information

1.5.1 Commander

1.5.1.1 The Commander, male, 49 years of age, began his flying career in 1984 by training as a commercial pilot and going on to work as a pilot in the USA. In 1988 he returned to Norway and worked at Norving as a First Officer on DO 228s, later working as Commander on this and other aircraft types. He also had a short period on DO 228s in Sweden. Between 1993 and 1998, he was a pilot with Air Stord, flying Beech 100/200s and later DO 328s. He then flew DO 328s for a company in Italy for 2.5 years until the company went into liquidation. He was unemployed for a period, eventually returning to his original profession as an electrician. In May 2003, he took up employment with Kato Airline, flying DO 228s. During his relatively short period of employment with Kato Airline he was made redundant on two occasions. He was given three months' notice on 1 October 2003, and was actually serving his period of notice when the accident occurred. He had approximately 700 hours of on-type flying experience on Dornier 228s, half of these as Commander.

1.5.1.2 Certificates: Norwegian B/CPL (national) from 26 July 1994 and ATPL (A) (national) from 26 June 1998 (valid until 25 March 2008).

1.5.1.3 Ratings: First Officer's DO 228 type rating from 19 November 1992. Commander's DO 228 type rating from 26 March 1998. His most recent DO 228 proficiency check (PC) was conducted on 1 December 2003 (four days before the accident) and was valid until 30 November 2004. His type rating certificate was subject to the restriction of flying the aircraft type in a multi-pilot concept.

1.5.1.4 Previous ratings: IR (A), SEP (land), MEP (land), BE90/99/100/200 and DO 328.

1.5.1.5 Medical certificates: His Class 1 medical certificate was last renewed on 19 November 2003 (valid until 7 May 2004) and is subject to a VNL clause (must carry reading glasses).

Table 2: Flying experience

Flying experience	All types	On type
Last 24 hours	6	6
Last 3 days	11	11
Last 30 days	12	12
Last 90 days	34	34
Total	6 400	700

1.5.1.6 All the Commander's DO 228 instruction, training and proficiency checks were undertaken on the aircraft. The Commander did not have previous training in the LANDING WITH ELEVATOR INOP emergency procedure, as it is difficult to provide this type of training without a simulator.

1.5.1.7 The Commander had previously received training in flying with an inoperative elevator in a Dornier 328 simulator. He believes that this training helped him on LN-HTA.

1.5.1.8 The Commander has told the AIBN that he felt well rested and fit for flying on the day in question.

1.5.2 First Officer

1.5.2.1 The First Officer, male, 35 years of age, began his flying career in 1991 by training as a commercial pilot and going on to work as a pilot in the USA for a few years. Between 1992 and 1994, he took a degree in organization and administration at Bodø University College. He then worked for 2 years at the Meteorological Institute in Bodø and on Blindern. He served as a pilot inspector with the Norwegian Civil Aviation Authority during the period 2000-2003 specializing in supervision of pilot training. At the same time he was a flight instructor at Oslo Flyveklubb. The First Officer started his employment with Kato Airline in January 2003. For the first six months, he was based at Værnes, mainly flying the company's Trondheim-Brønnøysund route. From August 2003, he was stationed in Narvik, mainly flying the route between Narvik, Bodø and Røst.

1.5.2.2 Certificates: Norwegian CPL (A) (national) from 22 October 1999 and CPL (A) (JAR-FCL) from 31 January 2003 (valid until 31 January 2008).

1.5.2.3 Ratings: IR (A) siden 22. oktober 1999. First Officer's DO 228 type rating acquired in a skill test (ST) on 31 January 2003 (valid until 31 January 2004). His type rating certificate was subject to the restriction of flying as First Officer.

1.5.2.4 Previous type ratings: SEP (land), IK/3, FI (A) and FE.

1.5.2.5 Medical certificates: His Class 1 medical certificate was renewed four days before the accident on 1 December 2003 (valid until 28 November 2004), with no restrictive clauses.

Table 3: Flying experience

Flying experience	All types	On type
Last 24 hours	3	3
Last 3 days	3	3
Last 30 days	35	35
Last 90 days	110	110
Total	1 450	260

1.5.2.6 All the First Officer’s DO 228 instruction, training and proficiency checks were undertaken on the aircraft. The First Officer did not have previous training in the LANDING WITH ELEVATOR INOP emergency procedure, as it is difficult to provide this type of training without a simulator.

1.5.2.7 The First Officer has told the AIBN that he felt well rested and fit for flying on the day in question.

1.6 Aircraft information

1.6.1 <u>General</u>

Manufacturer:	Dornier Luftfahrt GmbH (Germany)
Type of aircraft:	DO 228-202
Serial number:	8127
Year of construction:	1987
Nationality and Registration:	LN-HTA
Owner:	Kato Airline AS
Airworthiness certificate:	Valid until 30 June 2004
Type certification number:	FAA A16EU
Certification class:	FAR 135A, FAR 23, SFAR 41C
Accumulated flying time:	11,069 hours
Flying time since last inspection:	55 hours (since 300-hour inspection)
Engines:	2 Garret TPE 331-5-2520
Fuel:	JET A-1
Maximum take-off mass:	6,200 kg.
Actual take-off mass:	4,738 kg.
Centre of gravity:	23 % MAC (17.5-40% certified limit)

1.6.1.1 The Dornier 228 was entered in the Norwegian Aircraft Register when Norving began using the aircraft type in 1982.

1.6.1.2 The aircraft has an unpressurized cabin and is therefore mainly flown at altitudes below 10,000 ft where there is no need for use of oxygen. The aircraft type is constructed mainly of aluminium. The same applies to its horizontal stabilizer. The elevator has an aluminium framework covered with fabric.

1.6.1.3 Flight control (in both pilot positions) and the aircraft's elevator are connected by means of a series of rods (see figure 2).

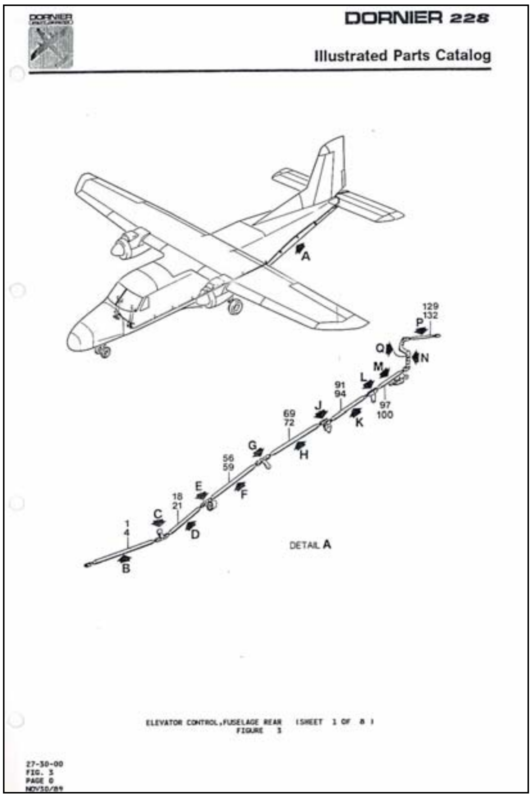


Figure 2: Diagram showing the rods which transfer power from elevator control to the elevator.

1.6.1.4 The Dornier 228 is constructed in such a way that the aircraft's electric trim moves the horizontal stabilizer up and down. The elevator is mounted behind the movable horizontal stabilizer. This means it is possible to maintain some control over the aircraft's pitch, even with an inoperative elevator.

1.6.1.5 The aircraft was equipped for instrument flight and had VOR, ADF, DME, ILS, GPS, transponder, radio altimeter, GPWS and weather radar installed**.**

1.6.2 <u>Weather radar (airborne)</u>

1.6.2.1 JAR-OPS 1.670 states that aircraft of this size must be equipped with airborne weather radar equipment when being operated at night or in instrument meteorological conditions in areas where potentially hazardous weather conditions, regarded as detectable with airborne radar, may be expected to exist along the route.

1.6.2.2 Section 8.3.8 of the Appendix to JAR-OPS 1.1045 states that an operator shall ensure that the operations manual (OM) contains a description of the procedure for operating in adverse and potentially hazardous atmospheric conditions. Section 8 in part A of Kato Airline’s OM contains guidelines on general operating procedures for the company's pilots when an aircraft is close to or in areas with thunderstorm activity. The guidelines indicate that where possible, an effort should be made to avoid heavier showers. In this case, some of the guidelines were relevant, others not. The operations manual has a table with guidelines on not flying closer than 5-10 NM to the most active cells. The company’s manual states that if the weather radar is not working, heavy showers (CB) should be avoided (min. distance 10 NM). The manual also recommends switching the cockpit lighting on full and using the sun visor to minimize the effect of dazzling lightning.

1.6.2.3 As stated in section 1.1.8, the pilots reported that the weather radar did not show a red alarm during the minute prior to the aircraft flying into cells with heavy precipitation and being hit by lightning. Consequently, the AIBN has examined the maintenance of the aircraft's weather radar. A weather radar transmitter/receiver antenna (type designation KA126, serial number 50585) and an indicator (type designation KI244, serial number 60616) were installed on board. After undergoing repair and bench testing, both were issued with “JAA FORM ONE" “JAR 145.50 Release to Service” forms by Aerotechnic Vertriebs und Service GmbH (Germany) on 16 May 2001.

1.6.2.4 Shortly afterwards, a work order shows that the transmitter/receiver antenna (KA126 s.no. 50585) and indicator (p.no. KI244 s.no. 60616) were removed from LN-HTA on 5 June 2001 for the following reason: WXR – Frequency out of tolerance. The following corrective action was described: *“KA126 and KI266 removed for repair, repair too expensive, after repair reinstalled and tested acc. AMM Chpt. 34-62-30 and test report ZE-0-004, ok”*.

1.6.2.5 The next entry in the technical log which the AIBN has at its disposal was on 10 June 2003, describing the weather radar as “WX radar only shows green”. Technicians acknowledged receipt of the statement the case was scheduled to be dealt with on job order WO 03-106. According to the copy of work order 03-106, the indicator (KI126 s.no. 50585) was installed onboard LN-HTA on 18 June 2003.

1.6.2.6 The AIBN’s findings after the accident show that the weather radar had the following settings:

- Function (mode): MAP (Options: OFF, STBY, TEST, WX or MAP)
- Range: 40 NM (Options: 10, 20, 40, 80 or 160 NM)
- Tilt: +3.5º (variable adjustment between -12 º and +12 º)
- Gain: Automatic (Options: Automatic or variable gain)
- Stabilizer: ON (Options: OFF or ON)

1.6.2.7 Weather radar operates according to the echo principle and emits electro-magnetic pulses. When the pulses encounter precipitation cells, ground or other objects, some of the pulses are reflected and represented on the indicator in different colours, sizes, contours, directions and distances. The electro-magnetic pulses from the transmitter will vary in Pulse Repetition Frequency (PRF) depending on how the radar is adjusted. Most indicators present the weather in the following colours: Black, green, yellow, red and magenta. Weak return signals are indicated by green, while maximum return signals are magenta. Reflectivity depends on the precipitation intensity in the cells. Weather radar does not detect lightning, turbulence or static electricity.

1.6.3 Elevator

Section 3 (Emergency and Abnormal Procedures) of Dornier 228 Pilot's Operating Handbook contains the following procedure for LANDING WITH ELEVATOR INOPERATIVE:

"With an inoperative elevator it has been proven that the airplane can be safely landed by use of horizontal stabilizer trim and/or power adjustment for pitch control. To prepare for a landing approach proceed as follows:

1. Flaps - UP or 1

WARNING

Do not extend the flaps beyond position 1 as airplane may become marginal with forward center of gravity.

2. Approach Speed - V_{REF} + 5 kts

3. Fly a shallow, power on approach

4. For landing flare use horizontal stabilizer trim and engine power as necessary

WARNING

With forward center of gravity and flaps position UP, horizontal stabilizer trim will not be sufficient for the landing flare. Adding approx. 15% torque per engine for the flare will result in sufficient pitch up moment to break a normal sink rate.

NOTE

Adding power will induce a pitch up moment.

Reducing power will induce a pitch down moment."

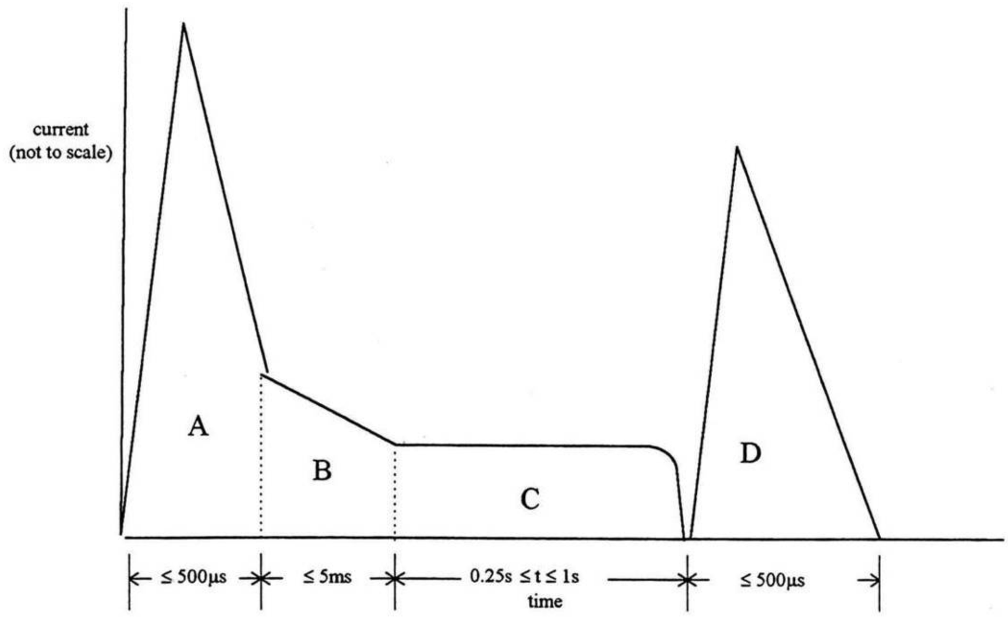
1.6.4 Certification requirements for protection against lightning

1.6.4.1 Certification requirements with regard to resistance to lightning are very general. For example, the following requirements are described in "FAR Part 23 Airworthiness Standards: Normal, Utility, Acrobatic, and Commuter Category Airplanes, section 23.867:

"(a) The airplane must be protected against catastrophic effects from lightning.
(b) For metallic components, compliance with paragraph (a) of this section may be shown by--

(1) Bonding the components properly to the airframe; or
(2) Designing the components so that a strike will not endanger the airplane."

1.6.4.2 In order to increase knowledge and obtain a common understanding of construction requirements, European aircraft manufacturers and certification authorities have joined forces to form EUROCAE. The organization is divided into sub-groups, with Working Group 31 (WG31) specializing in protection against lightning and associated certification requirements. The working group has developed standards and test models which when used satisfy the requirements of FAR 23.867. For example the working group has also developed negative lightning flash, positive lightning flash and intra-cloud flash models. Based on this work, standard models have been produced to test the effects of lightning (see figure 3). Similarly, a map of lightning strike zones on aircraft has been produced**.**



COMPONENT A (First Return Stroke)

Peak Amplitude	:	200kA (± 10%)
Action Integral	:	$2 \times 10^6 A^2s$ (± 20%) (in 500µs)
Time Duration	:	≤ 500µs

COMPONENT B (Intermediate Current)

Max. Charge Transfer	:	10 Coulombs (± 10%)
Average Amplitude	:	2kA (± 20%)
Time Duration	:	≤ 5ms

COMPONENT C (Continuing Current)

Amplitude	:	200 - 800A
Charge Transfer	:	200 Coulombs (± 20%)
Time Duration	:	0.25 to 1 s

COMPONENT D (Subsequent Return Stroke)

Peak Amplitude	:	100kA (± 10%)
Action Integral	:	$0.25 \times 10^6 A^2s$ (± 20%) (in 500µs)
Time Duration	:	≤ 500µs

Figure 3: Model for testing direct effects of a lightning strike

1.6.5 Maintenance requirements for bondings

1.6.5.1 The aircraft's maintenance manuals contain inspection descriptions of some of the bondings onboard, although the bondings between the fuselage and the tail surfaces are not described. Consequently, those particular bondings are only subject to general area inspections.

1.6.5.2 The US Federal Aviation Administration (FAA) has published a book entitled "Aircraft Inspection, Repair & Alternations, Acceptable Methods, Techniques, and Practice AC 43.13-1B/2A". The book has been accepted as a standard reference document in Norway and is used in the training of aircraft mechanics/technicians. The following quotations are taken from Chapter 11-188 "Bonding Inspection":

> *"c. Bonding connections should be secure and free from corrosion.*
>
> *d. Bonding jumpers should be installed in such a manner as not to interfere in any way with the operation of movable components of the aircraft.*
>
> -----------------
>
> *h. Bonds must be installed to ensure that the structure and equipment are electrically stable and free from hazards of lightning, static discharge, electrical shock, etc.*
>
> ----------------
>
> *i. Use of bonding testers is strongly recommended."*

1.6.5.3 Chapter 11-193 "Lightning Protection Bonding" describes methods of protecting the aircraft against lightning strikes. The chapter gives construction advice on how to protect control surfaces and flight controls, but does not mention maintenance of bondings.

1.7 Meteorological information

1.7.1 The Meteorological Institute (MWO) in Tromsø is responsible for issuing meteorological information at Bodø Airport. The Meteorological Officer at Bodø Airport received weather observations and issued METARs The airport was fitted with equipment for presenting satellite cloud images.

At time 0739 UTC: Lightning strike sustained by WIF803.

At time 0744 UTC (dark): Lightning strike sustained by KAT603.

At time 0809 UTC (beginning of dawn): KAT603 crash.

1.7.2 TAF:

ENBO 040615 23030G45KT 9999 –SHRA FEW012 BKN025 TEMPO 0609 21020KT TEMPO 0615 4000 SHRA TS SCT006 BKN012CB BECMG 0609 23040G55KT BECMG 0912 29045G60KT=

ENBO 040918 23040G55KT 9999 –SHRA FEW012CB BKN025 TEMPO 0912 21030G45KT 4000 TSRAGR SCT006 BKN012CB BECMG 0911 29045G60KT TEMPO 1218 0500 +TSSNGR VV004=

1.7.3 METAR:

ENBO 040650Z 22031G41KT 9999 –SHRA FEW015 BKN030 07/03 Q0988 TEMPO 4000 SHRA BKN012=

COR ENBO 040720Z 22030G49KT 8000 SHRAGS TS BKN015CB 07/03 Q0987 BECMG 23040G55KT TEMPO 4000 TSRAGS SCT006 BKN012CB=

ENBO 040750Z 22023G33KT 8000 –SHRAGS TS SCT012CB SCT025 03/M03 Q0986 BECMG 23040G55KT TEMPO 4000 TSRAGS SCT006 BKN012CB=

ENBO 040820Z 22030KT 6000 VCSH SCT012CB SCT025 07/04 Q0985 BECMG 23040G55KT TEMPO 4000 TSRAGS SCT006 BKN012CB=

ENBO 040850Z 24034G48KT 9000 VCSH SCT012CB SCT020 05/04 Q0984 TEMPO 23045G60KT 4000 TSRAGS SCT006 BKN012CB=

The duty air traffic controller in the tower has said that approximately 5-10 minutes before KAT603 landed for the first time, the wind was much stronger than during the landing. In addition, the ground wind was up to 60 kt a few minutes after the final landing (the crash). This shows the wind force was much more adverse than during the two landings.

1.7.4 SIGMET:

ENMI 040353

ENBD SIGMET 02 VALID 040400/040800 ENVN –
NORWAY FIR N OF N6500 AND W OF E02500 LOC SEV TURB FCST BLW FL080. NC.=

ENMI 040757

ENBD SIGMET 03 VALID 040800/041200 ENVN –
NORWAY FIR N OF N6500 LOC SEV TURB FCST BLW FL080. NC.=

1.7.5 ADDITIONAL INFORMATION:

WS WARNING ENBO VALID 040830/041030 ENVN-
WS OBS AND FCST AT ENBO. WS AT SHORT FINAL. WIND SFC W 23045KT, WIND SFC E 23020KT.=

1.7.6 The Meteorological Institute has provided the following information about weather conditions around Bodø Airport on 4 December 2003 during the relevant time frame.

"….

The information is based observations from Bodø Airport and nearby stations, analysed weather charts, satellite images and a lightning registration program.

A cold front passed over Bodø Airport at time 0600 UTC, which was the product of a storm centre to the immediate northwest of Lofoten. The storm centre was moving in a north-easterly direction. The cold front was followed by precipitation cells, cumulonimbus (CB), with showers, hail and thunder. At time 0744 UTC, these reached the area around Bodø Airport. At time 0745 UTC, a south-westerly wind of 23 knots with gusts of 33 knots was observed at Bodø Airport (ENBO). Visibility in the thunder, rain and hail was 8,000 m, cloud height was 1,200-2,500 ft and the temperature was 3 degrees C.

The wind in the area was therefore south-westerly. The maximum wind force between time 0600 and 0900 UTC was 39 knots for Bodø (ENBO), 43 knots for Røst (ENRS) and 46 knots for Myken Lighthouse to the southwest of Bodø. The strongest gust in Bodø was 62 knots. The wind at 5,000 ft was around 240 degrees and 60 knots. A SIGMET about locally strong turbulence (LOC SEV TURB) below 8,000 ft north of 65 degrees north and west of 25 degrees east was issued."

1.7.7 The Meteorological Institute issued the following written response to the question about energy in the thunder activity:

"We are unable to provide additional information about the energy in particular lightning strikes as we do not measure the voltage in the electrical field. However, based on the number of registrations, there was severe lightning activity between time 0600 and 0900 UTC, particularly around Bodø Airport. Satellite images also show that the precipitation cells were powerful, with a large vertical extent. Further intensification of the precipitation cells with increased electric voltage may have occurred when vertical air currents in them increased in strength due to rising caused by the strong wind to the coastal mountains.

1.7.8 The temperature at 6,000 ft was approximately -5 ºC.

1.8 Aids to navigation

The aircraft was given radar vectoring for the remainder of the flight until the approach. Despite the lightning strike, the aircraft's gyro system (heading gyro), pitot-static instruments (altimeter/airspeed indicator) and ILS seems to have functioned normally.

1.9 Communications

1.9.1 There was normal two-way VHF radio communication between the crew of LN-HTA and the air traffic control service. At the time of the lightning strike, KAT603 was in two-way contact with Bodø Approach on frequency 119.700 MHz Before landing, an aircraft will normally be handed over to Bodø Tower on frequency 118.100 MHz. However, in view of the situation, the air traffic control service decided to let KAT603 remain on frequency 119.700 MHz for the remainder of the flight. The air traffic control service coordinated internal arrangements so that Bodø Approach and Bodø Tower both operated on frequency 119.700 MHz.

1.9.2 According to Regelverk for lufttrafikktjeneste (RFL) chapter 15, section 1.1.3, the recommended procedure in an emergency situation is to avoid asking an aircraft crew to change radio frequency wherever possible.

1.10 Aerodrome information

1.10.1 General:

1.10.1.1 Bodø Airport is owned by the Norwegian Air Force and is open to military and civil IFR/VFR traffic around the clock. Avinor provides airport safety/security services and operates the civil part of the airport.

1.10.1.2 Runway 25 is equipped with an instrument landing system (ILS). ILS 25 and the approach light are at an angle of 10º (offset) in relation to the direction of the runway. The runway is equipped with a visual glide path (PAPI) of 3.5º. The landing distance available (LDA) for runway 25 is 2,794 metres. The width of the runway is 45 metres, while the total width of the runway and shoulders is 54 metres. Threshold 25 is 39 ft above sea level.

1.10.1.3 The air traffic control service at Bodø Tower (TWR) and Bodø Approach (APP) use Bodø terminal radar (TAR).

1.10.1.4 The fire and rescue services at the airport were in category 6 and the service was standing by.

1.10.1.5 Ambulances had been ordered and were standing by prior to the aircraft landing.

1.10.2 Presentation of weather on radar display.

1.10.2.1 The Meteorological Institute, Avinor and the Norwegian Public Roads Administration have joined forces on the development and operation of weather radar in Norway. At present, the network is not nationwide. The Meteorological Institute (http://met.no/met/met_lex/v_a/varradar/index.html) says that the development of a nationwide weather radar network is a priority task. A total of 27 weather radars in Sweden, Finland and Norway have overlapping coverage areas. These countries have agreements on the exchange of radar data.

1.10.2.2 A new weather radar to cover the Nordland area was being developed at Røst when the accident occurred. The weather radar at Røst was operational from June 2004.

1.10.2.3 In Bodø TWR/APP, the NARDS radar display system shows raw video from Bodø terminal radar (TAR). The quality of this information with a view to radar vectoring aircraft round poor weather is not the best, according to the air traffic control service. The quality of weather information deteriorated after the last primary surveillance radar (PSR) upgrade and does not correspond well with what the pilots experience or see on their weather radar.

1.10.2.4 The NOVA radar display in Bodø TWR also shows raw video from Bodø terminal radar. This is installed in the desk next to the Radar and Automatic Dependence Surveillance (Radar and ADS Display System RaADS) to ensure that TWR air traffic controllers have weather information.

1.10.2.5 RaADS does not show raw video or weather information.

1.10.2.6 When the scheduled installation of the Norwegian Air Traffic Control System (NATCON) in Bodø is completed, the system will show synthetic information about the weather. This will take the form of symbols indicating that the radar processing system has received information that there is a certain intensity of precipitation of (low or high).

1.10.2.7 Although the weather radar chain is partly funded by Avinor, the air traffic control services do not receive data directly from the weather radars. So, for example, Bodø TWR/APP does not receive radar data directly from the weather radar at Røst. This means they have to get information from the Internet with a 15-minute delay, and the air traffic controller is not able to see the computer which is connected to the Internet. The air traffic control service finds this situation unsatisfactory.

1.11 Flight recorders

1.11.1 Flight data recorder:

1.11.1.1 LN-HTA was equipped with a flight data recorder (FDR) as prescribed in the equipment requirements of BSL JAR-OPS 1. The flight data recorder was manufactured by Sundstrand (model name UFDR Digital Flight Data Recorder, part number N 980-4100-FMUS and serial number 2049).

1.11.1.2 The flight data recorder was taken to the Air Accidents Investigation Branch (AAIB) at Farnborough, UK, for data retrieval. The flight data recorder did not have any external physical damage, but an internal fault necessitated removal of its memory module to another flight data recorder of the same make. The data was downloaded from the FDR was of a high quality.

1.11.1.3 The flight data recorder had the following registered parameters:

- Altitude
- Airspeed
- Heading
- G-load
- Outside air temperature
- VHF keying
- Manual activation of the Event button

1.11.1.4 Data from the flight data recorder played an important part in analysing the aircraft's movements.

1.11.2 Voice recorder

LN-HTA was equipped with a cockpit voice recorder (CVR) as prescribed in the equipment requirements of BSL JAR-OPS 1. The cockpit voice recorder was manufactured by Sundstrand (model name AV 557D, part number 980-6019-001 and serial number 205). The voice recorder was taken to the Air Accidents Investigation Branch (AAIB) at Farnborough, UK, for data retrieval. The requirements state that the CVR must be capable of retaining information recorded during the last 30 minutes of its operation. The CVR must record voice communication and audio signals received from the Commander and First Officer's speakers/microphones and the aural environment of the cockpit area. The AIBN was able to retrieve recordings from the last 45 minutes (11 minutes before the lightning strike and the 34 minutes thereafter until the crash). The information retrieved from the cockpit voice recorder played an important part in identifying the sequence of events during the flight.

1.12 Wreckage and impact information

1.12.1 The accident site

1.12.1.1 The first point of impact was virtually an extension of the runway's centreline, 22 metres short of the asphalt of runway 25. The terrain before the runway was even and covered with grass. The aircraft slid 56 metres onto the runway before stopping. The airspeed on impact was 101 KIAS, corresponding to a groundspeed of approximately 78 kt, which decelerated over a total length of 78 metres.

1.12.1.2 The aircraft came to rest a little to the right of the runway's centreline, with its nose 13 metres from the runway's longitudinal edge.

1.12.2 The aircraft wreckage

1.12.2.1 The aircraft's flight data recorder registered up to 8.4 G on impact. The landing was so forceful that the aircraft's nose wheel leg broke off and both main landing gears were pushed in, then twisted back and came loose. The force of impact pushed the aircraft's wing so far down into the cabin that the propellers on both engines were badly bent after contact with the ground. In addition, the whole of the aircraft's underside was compressed, particularly at the front. (See figures 4 and 5). This forced up the floor of the cockpit by about 20 cm, resulting in somewhat restricted legroom. Powerful vertical forces were transferred to the pilots and passengers via all the seats. These forces were most powerful in the front part of the aircraft, resulting in injuries to the pilots' back, buttocks area and neck.

1.12.2.2 The aircraft had a seating configuration of 19 passenger seats – 2 to the left and 2 to the right of the central aisle. The two passengers were seated on the second row on the right and the third row on the left. In the front part of the cabin (rows 1-4), the height to the ceiling was substantially reduced (from the normal 155 cm down to 70 cm), as a result of the front part of the wing section being forced down into the cabin. From row 5 back there was little damage to the cabin.

1.12.2.3 On the morning of 5 December, the aircraft was moved to one of the Norwegian Armed Forces' shelters for closer examination. It was then discovered that there was a break in the elevator control rod in the end that was connected to the elevator. The right elevator was missing approximately half of its fabric covering. About half of the carbon fibre cover on the end was also missing, including the elevator's outer static discharger (see figure 6). The outer right corner of the elevator's aluminium structure was also burnt off. With the help of an ohmmeter, a break in the electric connection between the elevator and the fuselage was discovered. Closer examination revealed several breaks in the bonding connections between the elevator and the fuselage (see figures 8 and 10). Almost the entire bonding on the outer bonding connection to the right elevator was missing. In addition, both nails holding the bracket to the bonding had melted leaving the bracket loose in the space between the elevator and the horizontal tail surface (see page 2 of Report by Norwegian Armed Forces, appendix B). It was also discovered that there was no electric connection between the horizontal tail surface and the fuselage. The reason for this was found to be that the tail surface was fixed by means of bearings with Teflon coating. Consequently, the horizontal tail surfaces became electrically isolated from the fuselage when the bonding connections broke.

1.12.2.4 It was decided to remove the right elevator, the broken rod and the bondings between the fuselage and the horizontal tail surface for closer examination. During the dismantling of the elevator, damage to one of the four bolts holding the two halves of the right elevator together was also discovered. The bolt which also holds the corner where the elevator rod was fixed had gradually melted.

Figure 4: The wreckage (photo taken by armed forces)

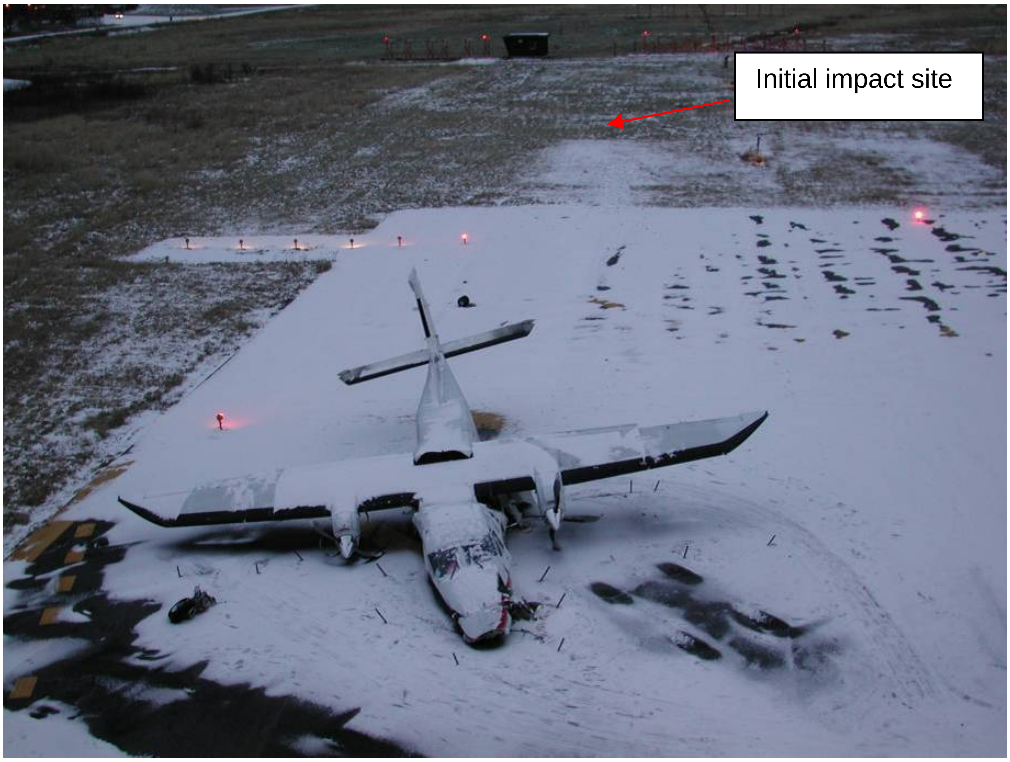


Figure 5: The wreckage (photo taken the day after the accident)

Figure 6: Damage to the right elevator (photo taken by armed forces)

Figure 7: Broken elevator transfer rod

Figure 8: Burnt bonding

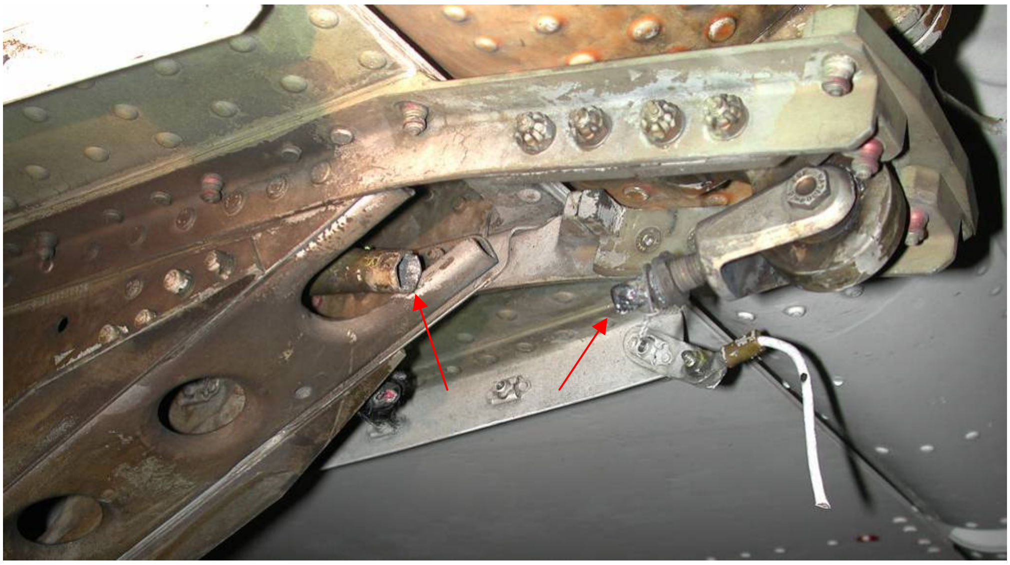


Figure 9: Broken rod transfer between cockpit and elevator

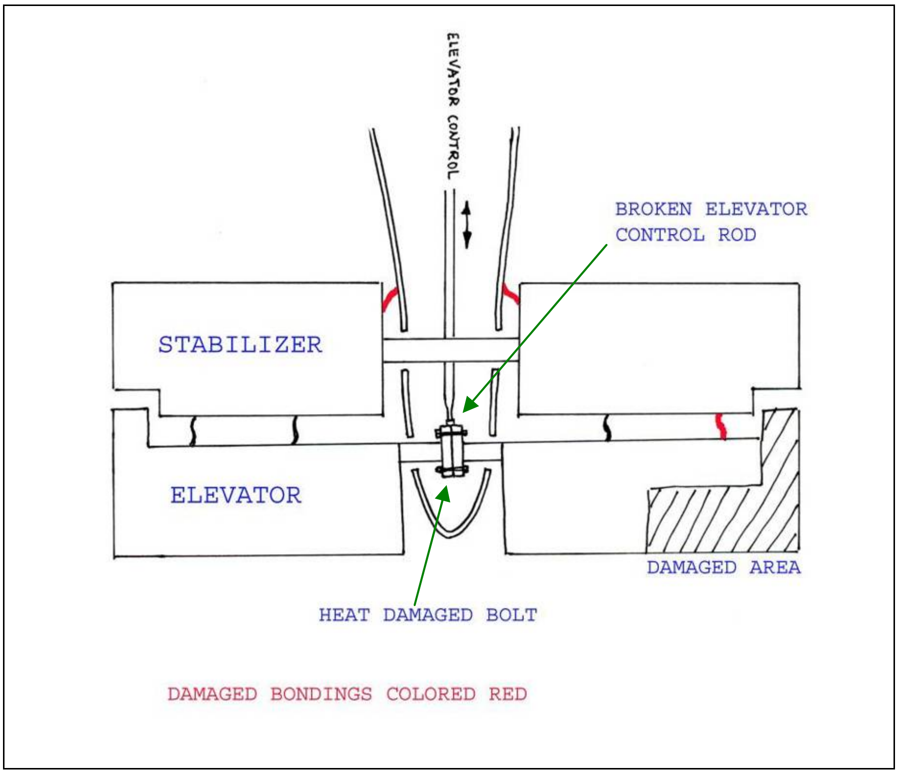


Figure 10: Diagram showing damaged bondings

1.12.2.5 The aircraft was examined in order to identify the site of the lightning strike if possible. The only sign was two small marks high on the nose on the left (see figure 11). A small area (2 x 6 mm) in the left baggage door had melted in front of the handle. A nail head in the left pitot tube had melted in a similar way.

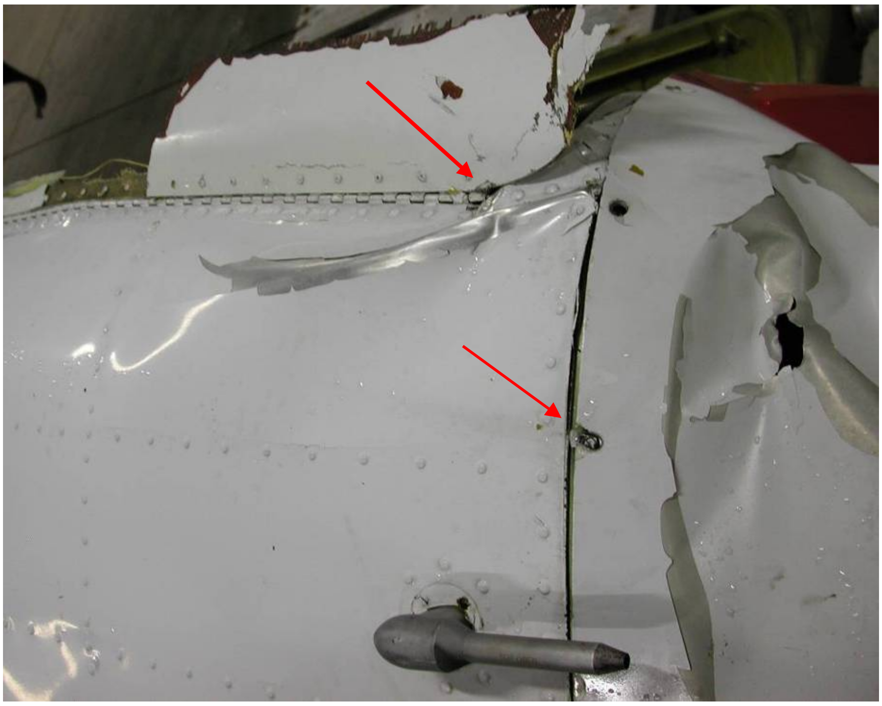


Figure 11: Photo of the aircraft's nose. Front of the aircraft is to the right. The red arrows show the impact points.

1.12.2.6 No damage from the lightning strike was found inside the aircraft. After a period, the aircraft was released and sold for scrap. Members of Working Group WG31 were later asked to perform destructive tests on equivalent rods to the elevator rod which failed. A representative of the company which bought the wreckage of LN-HTA unscrewed and handed over the available rods from the cockpit area. In this context, it was discovered that several bolts and bearings in the elevator mechanism had suffered heat damage when the current passed through. However, the AIBN has not investigated this further.

1.13 Medical and pathological information

The crew were routinely tested for drugs and alcohol. The tests were negative.

1.14 Fire

No fire occurred.

1.15 Survival aspects

1.15.1 Twenty five minutes before the crash, the crew notified the air traffic control service that the aircraft had sustained a powerful lightning strike and they were having problems controlling the aircraft’s elevator. Nineteen minutes before the crash, the crew declared an emergency. In accordance with standard procedures, the air traffic control service immediately issued warnings in the following order: Air Force 330 Squadron with Sea King rescue helicopter, Joint Rescue Coordination Centre, North Norway (HRS), fire and rescue services at the airport, AMK-sentralen (Hospital Emergency Centre, 113), Wing OPS (Air Force, Bodø), MIL SKV (Air Force, Bodø), Police, Head of Air Traffic Control, Head of Department of Air Traffic Control (LTT), Widerøe, Airport Services (LHT) and Kato Airline.

1.15.2 When the accident occurred, new warnings were issued.

1.15.3 After the crew declared an emergency, the warning issued by the air traffic control service put 11 men and 4 fire engines at the airport’s fire and rescue services on standby. These were dispatched to the accident site when the accident became a reality.

1.15.4 Bodo Fire Service also turned out, with 10 men, 1 fire engine and one water tender.

1.15.5 The ambulance service dispatched 4 ambulances to the scene.

1.15.6 The police turned out with a large number personnel and vehicles.

1.15.7 No fuel leakage occurred. The aircraft was quickly covered with foam.

1.15.8 The front of the cabin had been forced up towards the ceiling and the two passengers had to crawl to the nearest emergency exit. There was torn metal in several places, which could have caused injuries to those onboard.

Figure 12: Compressed cabin (photo taken by armed forces) *Figure 13: Front of the cabin.*

1.16 Tests and research

1.16.1 General

In order to obtain better knowledge on lightning strikes on aircraft, the AIBN contacted Saab AerotechTelub AB in Sweden. Several persons became involved in the question of what could have happened to LN-HTA. One of these was Leif Andersson, who in his capacity as Saab's representative in EUROCAE Working Group 31 (see section 1.6.4.2) brought information about the accident to a broad specialist environment.

1.16.2 The elevator rod

The strength of the current which passed through the aluminium elevator rod melted one end of the thread part in the actual rod. The end parts, which are coated with high alloy steel, withstood the loads. In order to calculate the strength of the current which passed through the rod, it was decided to measure the electrical resistance in the intact end. However, the first measurements also revealed that the apparently undamaged end had suffered damage to the thread part and the counter nut had loosened. After the thread part was cleaned and the counter nut retightened, the electrical resistance was measured at 0.7 - 1 mΩ (milliohm). Aerotech Telub's calculations showed that the thread part in question could have melted during loads from an A pulse (see figure 3).

1.16.3 The bondings

1.16.3.1 Both bondings between the horizontal tail surfaces and the fuselage were found to be broken in two. To ascertain the condition of the bondings before the aircraft was hit by lightning, parts of the two bondings were sent to the Armed Forces' laboratory services at Kjeller for analysis. A bracket from the outer bonding connection from the right elevator was also analysed with the bondings. The results were documented in "Technical Report no. 04012.03" (see appendix B). The report's conclusion was as follows:

"Based on the investigations carried out, the following conclusions have been reached:

The bondings we received had reduced conductivity as a result of mechanical wear (worn conducting wires) and considerable corrosion.

It is highly likely that the bondings burned off due to an electrical overload resulting from the lightning strike. The observed damage is consistent with observations made during experiments conducted by FOLAT/EMC and the Kraftforsyning laboratory."

According to the aircraft's construction specifications, the bondings in question must have a cross section of 13 mm^2. Personnel from Aerotech Telub confirmed that this cross section could handle the current pulses specified by WG31. Measurements indicate that the bondings originally had the specified cross section.

1.17 Organizational and management information

The airline was originally established as Kato Air in the early part of 1995 and has been operating charter and freight flights, aerial photography and seismological surveys since 1995. The airline subsequently changed its name to Kato Airline, but continues to be marketed as Kato Air. For a year starting in December 1998, the company operated the scheduled route between Evenes, Tromsø and Bodø.

The company received JAR-OPS 1 approval in April 2002.

In autumn 2002, Kato Airline was granted a permit to operate the public service obligation routes Røst-Bodø and Narvik-Bodø routes with effect from April 2003.

The company has its administrative, operational and technical main base at Harstad/Narvik Airport Evenes. It also has a secondary base at Bodø Airport.

Kato Airline operated two DO 228s – one stationed at Narvik/Harstad and the other at Trondheim. The company's scheduled routes included Trondheim and Brønnøysund. In addition, the company operated two Cessna Caravans (C-208) and owned one Piper Seneca (PA 34-220T).

The company is not an approved training organization for type ratings (TRTO). When appointing a pilot without a DO 228 type rating, Kato Airline takes advantage of the option in JAR-FCL enabling it to seek authorization from the Norwegian Civil Aviation Authority to arrange an approved course for the aircraft type.

1.18 Additional information

1.18.1 <u>General information on lightning strikes on aircraft</u>

1.18.1.1 Lightning is categorized into three main groups:

- Positive lightning. Positive electric charges are discharged from clouds to the ground. This type of lightning is normally the most powerful of the three groups. The initial current may be moderate, although the periods with high currents are relatively long.

- Negative lightning. Negative electric charges are discharged from clouds to the ground. The initial current may be one or more very powerful pulses of short duration. There then follows a middle low-current phase before the lightning finishes with more powerful pulses. Because the pulses are short (< 10 ms), the total amount of energy is less than with positive lightning.

- Intra-cloud lightning. Electric charges are transferred between clouds. The initial and final phases consist of a number of pulses of very short duration. Pulses in the middle phase vary in frequency and current strength.

1.18.1.2 Lightning follows an ionized channel. When the voltage field (V/m) in such a channel is sufficiently high, a discharge occurs (lightning) The voltage field in an ionized channel can be several thousand volts per cm. An aircraft entering an ionized channel may short-circuit parts of the channel, significantly increasing the chances of discharge. This means that large aircraft are more likely to discharge lightning because they can short-circuit a greater voltage potential. The atmosphere's electrical resistance is much greater than the resistance in an aircraft. Consequently, lightning may be considered a constant current generator, with the current passing through the aircraft remaining constant regardless of the materials in the aircraft structure.

1.18.1.3 An aircraft's movements in the air may lead to electric charging of the aircraft. This type of charging often happens in cold dry air containing snow. It is normally strongest at high airspeeds and on rotor blades on helicopters. The voltage field increases around protruding and pointed objects. To reduce an aircraft's voltage charging, most aircraft are equipped with static dischargers (corona dischargers) on the wing tips, tail surfaces and similar areas. To reduce radio interference, the dischargers consist of carbon with high electric resistance. If a powerfully charged aircraft enters areas containing high voltage fields (around 50 KV/m), triggered lightning may occur. Cloud-to-ground lightning is at its most powerful when it hits the ground, as the energy is normally concentrated in one point on the ground. Higher up, the energy is divided into a number of branches. This means the greatest damage is likely to occur when an aircraft is hit by positive lightning at low altitude.

1.18.1.4 Aircraft are most likely to be hit on the nose, engine/propeller or wing tips. Lightning normally passes back out a large distance from its point of impact, i.e. the opposite wing tip, the tail or rotor blades. Primary damage comprises overheating, explosion[2] and powerful magentic fields. Secondary effects are largely caused by induction, and can often be problematic during intra-cloud lightning, as a result of the very high frequency of the current pulses. Experience has shown that the greatest damage occurs when lightning leaves the aircraft. If a cable or object is burnt away during an initial pulse, subsequent pulses may follow the same ionized path. However, if the subsequent pulses come a long time later, they may find new paths. An aircraft may have several points of impact - along the aircraft's back, for example. This phenomenon is referred to as swept stroke lightning and occurs because the aircraft is moving forward at the same time as the lightning is pulsing. Each point of impact may be difficult to detect, as there is often minimal damage to nail heads and similar objects.

1.18.1.5 Air accidents caused by lightning strokes are relatively rare. There is normally only minimal mechanical damage and interference to aviation equipment. The following list describes some serious incidents:

[2] Explosions occur when heat causes materials to assume gas form in a narrow or an enclosed space.

- 19 February 1971. A Beechcraft B90 was hit by lightning in Jackson, Michigan, USA. The aircraft suffered extensive damage to the left wing tip, tail surfaces and one propeller. Melted metal and splitting of non-metal components both inside and outside the aircraft.

- 1980. A Piper PA 46 was hit by lightning near Milwaukee, Wisconsin, USA. The glass -fibre wing tips were broken off and parts of the wing structure were deformed by overpressure. It is assumed that the effect of the lightning exceeded the certification requirements.

- 22 December 1983. A military Nimrod surveillance flight was hit by lightning over the Atlantic to the west of Northern Ireland. Particular damage to the radar and MAD Boom in the tail.

- 4 February 1986. An AS 332 in the vicinity of La Coruna in Spain lost a third of the rotor tip on a main rotor blade due to lightning. The blade tips were modified in 2000 to improve their lightning resistance.

- 19 January 1995. An AS 332 which was 120 NM east of Aberdeen in the North Sea experienced major vibrations due to lightning. The vibrations caused the tail rotor gear box to fall off.

- 29 February 1996. An AS 332 suffered major damage to its main rotor after being hit by lightning in the North Sea. All the main rotor blades were extensively damaged and a third of one blade tip was lost.

- 12 December 1997. An AS 332 suffered major damage to its main rotor after being hit by lightning in the North Sea. All the main rotor blades were extensively damaged and approximately 40% of two opposite blade tips was lost.

- 17 April 1999. An ASK 21 glider flying in Bedfordshire in the UK was totally damaged by pressure inside the wings after being hit by lightning, which caused partial melting of the rods to the ailerons. The two people onboard were able to parachute to safety. There are no special requirements to protect gliders from lightning, although it is assumed that the effect of the lighting exceeded the general certification requirements.

1.18.2 Airworthiness directive

Based on the AIBN's investigations and preliminary findings, the Norwegian Civil Aviation Authority issued the following airworthiness directive on 20 December 2003.

Luftfartstilsynet
Postboks 8050 Dep., 0031 Oslo
Besøksadresse:
Rådhusgata 2, 0031 Oslo
Telefon : 23 31 78 00
Telefax : 23 31 79 95
e-post: postmottak@caa.dep.no

LUFTDYKTIGHETSPÅBUD (LDP)

MOTORDREVNE LUFTFARTØY

DORNIER - 69

Med hjemmel i lov av 11. juni 1993 nr. 101 om luftfart, § 15-4 jf. § 4-1 og det vedtak om delegering av myndighet til Luftfartstilsynet av 10. desember 1999 nr. 1273.

2003-085 KONTROLL AV BONDING JUMPERS

Påbudet gjelder:

Alle Dornier Do 228 modeller på norsk register.

Påbudet omfatter:

For å sikre at strøm ledes ut av flykroppen som tiltenkt, skal det utføres kontroll av følgende bonding jumpers:

2 stk bonding jumpers på venstre del av høyderoret i overgangen mellom stabilisator og høyderor. Tilsvarende på høyderorets høyre del.
I tillegg skal bonding jumpers mellom stabilisator og skrog på hver side av skroget ved stabilisatorens opplagring mot skroget kontrolleres.

Følgende kontroll skal utføres:

1. Sikre at innfesting av bonding jumpers er fri for fett og smuss og kontroller at bonding jumpers er hele (ikke fliset) og er festet forsvarlig.

2. Dersom bonding jumpers er fliset eller på annen måte i ustand skal disse erstattes med nye av godkjent type.

Tid for utførelse:

Innen 2003-12-31.

Referanse:

TOL

Gyldighetsdato:

2003-12-20

MERK! For at angjeldende flymateriell skal være luftdyktig må påbudet være utført til rett tid og notat om utførelsen

LUFTDYKTIGHETSPÅBUD

Courtesy translation:

Subject: Control of bonding jumpers

Effectivity:

All Dornier Do 228 models on the Norwegian register.

Reason:

This Airworthiness Directive (AD) is issued following an accident in severe weather conditions. The elevator control rod broke from the eye bolt attaching the control rod to the elevator attach fitting as a consequence of high electric current caused by a lightning strike.

Bonding jumpers involved:

- Each two bonding jumpers connecting the LH and RH elevator to the stabilizer.
- The two bonding jumpers on the horizontal stabilizer bearing fitting connected to the fuselage.

Mandatory actions:

1. Ensure that the attachment of the bonding jumpers as described above are clean and without grease and/or dirt and control that the bonding jumpers are intact (not splintery) and correctly attached ref. MM chapter 23-61-00.
2. If the bonding jumpers are splintery or in other ways are incorrect they should be replaced by new approved bonding jumpers.

Compliance time:

Within 2003-12-31.

Effective date:

Upon receipt.

Reference:

TOL

Figure 14: Airworthiness directive

1.18.3 Information provided by the Norwegian Civil Aviation Authority

1.18.3.1 In response to a request by the AIBN, the Norwegian Civil Aviation Authority has provided information about other registered incidents involving lightning strikes on Dornier 228s. The following list is taken from a Nordic database of reported incidents:

- 16 September 1986, DO 228-100, LN-HPE, Norving. During enroute, the aircraft sustained a lightning strike, which resulted in a generator fault and necessitated manual extention of the aircraft's landing gear.

- 21 May 1995, DO 228, SE-KVV flying from Stockholm Arlanda (ESSA) to Mora (ESKM). The aircraft was struck by lightning. The aircraft suffered only minor damage.

- 4 May 2003, Kato Airline, DO 228-200, LN-BER. A lightning strike shortly after take-off resulted in minor damage to the wing tip, ADF antennas and weather radar.

1.18.3.2 The Norwegian Civil Aviation Authority stated that the same database contained only one registered accident in connection with a lightning strike on an aircraft (fixed wing).

- 8 September 2000, Coast Air, ATR-42-320, LN-FAO south of Florø (ENFL). The aircraft aborted its approach to Florø, and during the climb to Bergen experienced strong turbulence, being hit by lightning twice. The lightning caused structural damage on the leading edge of the right and left elevators. The AIBN's investigations after the accident are described in RAP 90/2000:

1.18.3.3 In addition, a pilot who previously flew this aircraft type has also contacted the AIBN and provided the following statement.

- On one occasion in the period 1985-89, a Norving DO 228 was hit by lightning on its approach to Kirkenes (ENKR). Both the aircraft's ADG navigation instruments became defective.

1.18.4 Lightning registration

1.18.4.1 SINTEF Energiforskning AS (SINTEF Energy Research) and Statnett SF collaborate on lightning registration. The lightning registration system, which gives the position and data relating to lightning strokes, is owned and operated by Statnett. SINTEF is responsible for services regarding distribution of lightning data. They have amassed years of experience in thunderstorm problems relating to electrical systems, analyses of lightning stresses, design and selection of lightning protection etc.

1.18.4.2 The following information is taken from the SINTEF Energy Research website:

1.18.4.3 A certain temperature and level of humidity in the atmosphere (i.e. a certain amount of energy and dynamics) produces lightning activity.

1.18.4.4 SINTEF describes 2003 as a record year, with over 200,000 strokes registered in Norway.

1.18.4.5 SINTEF has produced and placed on its website a map showing registered lightning in the Bodø area on the morning of 4 December 2003. The map shows, for example, that there were as many as 45 lightning strokes in the selected area (red circle) at the time highlighted in the table.

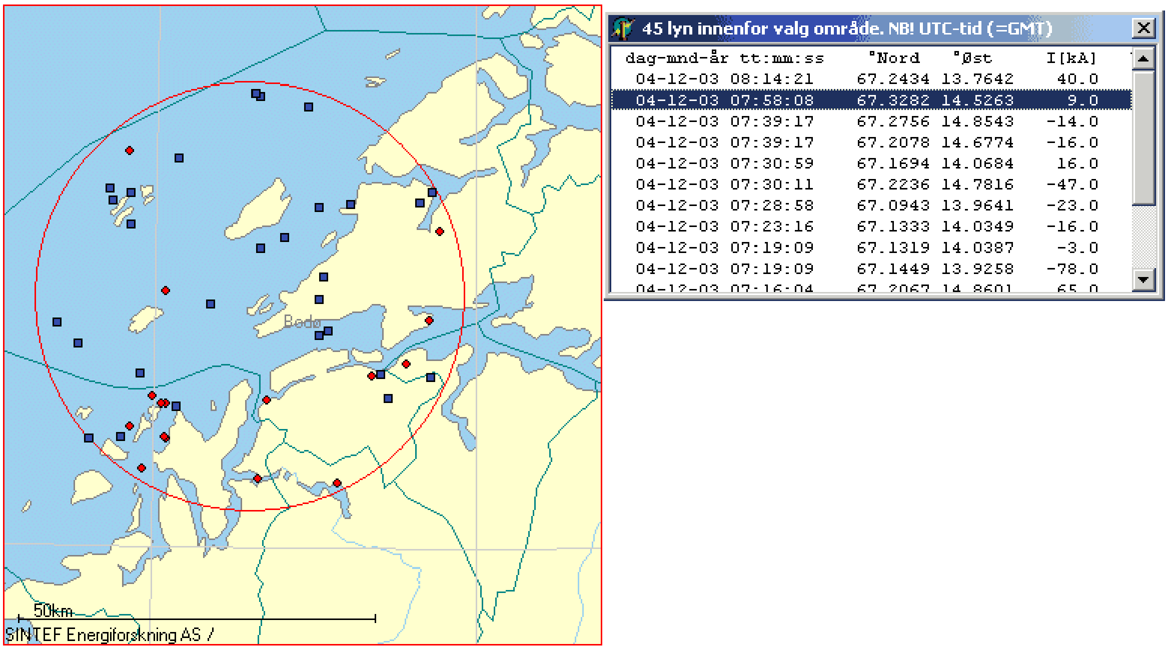


Figure 15: SINTEF Energy Research map showing registered lightning in Bodø area on 4 December 2003

1.18.4.6 Source: http://www.sintef.no/upload/Energiforskning/LYN/Bodø_04-12-2003.gif

1.18.4.7 SINTEF has reported on the aircraft accident to Kato Airline in the article:

http://www.nfo.no/nyinfo/Main/Tidligere_artikler/2003/04.12.03_Flyulykke_i_BOO.htm (original source: Online version of Avisa Nordland newspaper)

1.18.5 Kato Airline’s internal investigations

Kato Airline initiated an internal commission of inquiry after the accident. The following are extracts from the commission’s technical recommendations:

1. Annual/1,200-hour inspection of the general condition of all bonding connections.

2. Measure the resistance of all connections to the nearest part.

3. Measure the resistance of all static wicks to the nearest bonding connection.

4. Ensure a double ground plane between stabilizer and fuselage.

1.18.6 The pilots

The Norwegian Airline Pilots Association put forward both the Commander and the First Officer as candidates for the Polaris Award presented by the International Federation of Airline Pilots Associations (IFALPA) for exceptional airmanship. The Polaris Award is the highest professional airmanship recognition that can be bestowed on a commercial pilot by colleagues across the world. The IFALPA presented both pilots of KAT603 with the Polaris Award at its annual conference in South Africa in April 2005.

1.19 Useful or effective investigation techniques

The AIBN has used information provided by the aircraft's flight data recorder and cockpit voice recorder, airport radar and air traffic control audio recordings to produce an animation. The animation covers the start of the aircraft's journey at Røst Airport right up to the accident at Bodø. The animation has proved very useful in giving an overview of the aircraft's route, airspeed and altitude and an understanding of the crew's decisions.

2. ANALYSIS

2.1 Weather conditions

2.1.1 A warning about thunderstorms and strong wind at Bodø Airport had been issued for the period containing the scheduled landing for KAT603. The crew had flown in and out of Bodø on the same morning without experiencing any major problems. It is the AIBN's opinion that weather conditions were acceptable for flying a DO 228 into Bodø on the morning in question.

2.1.2 The above opinion is contingent on the aircraft's weather radar functioning correctly**.**

2.2 Weather radar (airborne)

2.2.1 As described in section 1.6.2.3-1.6.2.5, there had been several problems with the aircraft's weather radar. The AIBN has studied documentation it received on the technical history of the aircraft's weather radar. On 10 June 2003, it was stated that the aircraft's weather radar was only indicating a green colour.

2.2.2 The crew found that the weather radar was not displaying the expected colours immediately before the aircraft was struck by lightning. At that time, the crew had recently experienced powerful precipitation cells in the area which would clearly have presented a red or magenta colour. With reference to the statement on June 2003 and the crew's experience on the day of the accident, the AIBN takes this as a sign that the weather radar was not functioning correctly.

2.2.3 The AIBN repeats that if an aircraft has systems which are not operative, this must be noted in the aircraft's technical log and actioned by authorized personnel within a defined time frame. In accordance with the company's minimum equipment list (MEL), the flight would not have been allowed to take off if it had been known that the weather radar was not functioning correctly, as warnings of thunderstorm activity along the route had been issued. Please see the JAR-OPS 1 regulations described in sections 1.6.2.1 and 1.6.2.2.

2.2.4 On the other hand, if a crew finds the weather radar is no longer working normally after take-off, the MEL regulations cease to apply, and the company's operations manual is used instead. The Kato Airline's operations manual states that, in such a situation, thunder cells should be avoided (min. distance 10 NM).

2.2.5 After the crash, LN-HTA's weather radar was found to be in MAP mode, with the range selector set at 40 NM. The crew are unable to remember the weather radar's setting when the lightning strike occurred. However, the crew had tried to turn the radar off and on a few times, in an attempt to get it to give more meaningful presentations. A weather radar system requires about 45 seconds warm-up time in STBY to allow the magnetron to warm up before the selector is switched to TEST, WX or MAP. Once the weather radar is in the OFF position, the warm-up time is the same, even if the radar has recently been on. On examining the cockpit voice recorder, the AIBN was unable to hear the crew referring to the presentations they saw on the weather radar display after the lightning strike or talking about changing its settings. Precipitation cells will appear on a weather radar which is in MAP mode and set at a range of 40 NM, but not as clearly as in WX mode with a shorter range setting. The AIBN has established that the weather radar did not indicate the thunder showers in the area, and believes that this was as a result of a technical fault in the equipment. It was not possible to test the weather radar after the crash, as some parts of the system were broken.

2.2.6 It is AIBN's opinion that weather radar should be used continuously on flights involving a risk of thunder activity, in order to give indications of areas to be avoided. Crews should use the weather radar well in advance of flying into potentially hazardous areas, so they have plenty time to check that the weather radar is working correctly and that the settings are optimal.

2.2.7 The cockpit voice recorder has revealed that the first time the crew of KAT603 commented that the weather radar was not giving the expected indications was about 30 seconds before the aircraft was hit by lightning.

2.2.8 The AIBN believes that pilots should be provided with better training in the functioning and use of weather radar. For example, training should be given in selecting the correct mode (WX or MAP), the optimal range (short or long), tilt and transmitter strength (automatic or variable). It is also important to be able to interpret the presentations, in terms of colour, size and contour of precipitation cells. Technical and operational personnel must know how to test weather radar and which test indication verifies that the weather radar is functioning correctly. A safety recommendation in this connection is being prepared.

2.3 The crew's handling of the emergency situation

2.3.1 It is the AIBN's opinion that the Commander and First Officer cooperated well. Up to the time when the thunder activity began, the crew were actively involved in obtaining an overview to enable them to assess the best way of avoiding the worst weather.

2.3.2 The First Officer was flying the aircraft from Røst and shortly after the lightning strike he discovered that the elevator was not working. The Commander also checked how the controls felt. He too found that the elevator was not working, but that it was possible to change the nose attitude to a limited extent using the aircraft's elevator trim. When the aircraft was making its sudden climb later, it quickly lost airspeed and came close to stalling. The crew's cooperation reflected the fact that they were in a critical situation and making every effort to find how to fly the aircraft with the elevator inoperative. It is the AIBN's opinion that, with the elevator not working, it would have been difficult to regain control if the aircraft had stalled.

2.3.3 The AIBN believes that the Commander was correct to take over the control of the aircraft at this point. However, it placed him in a situation in which much of his mental capacity was directed towards flying. Although the manufacturer has demonstrated that a Dornier 228 can be flown with an inoperative elevator, this was not a situation in which the crew of KAT603 had received training. The AIBN considers that the combination of a very strong wind, turbulence, clouds, thunder activity and an inoperative elevator made flying the aircraft a very demanding task.

2.3.4 The AIBN commends the crew for declaring an emergency. On a global basis, many pilots are reluctant to declare a MAYDAY. This can result in an absence of assistance and important information failing to get through.

2.3.5 The crew's cooperation was gradually affected by their difficult situation and high mental load. Emergency checklists were not consulted, which would have given the crew important information. The Commander has cited tough mental and physical work pressure as the reason for his failure to use the checklist, as well as the fact that he was familiar with its contents. The emergency checklist for LANDING WITH ELEVATOR INOPERATIVE (see 1.6.3) would have told them that the landing must be made with flaps in position 0 or 1 and would have given them information on the correct approach speed, approach angle and the optimal engine setting. It would also have provided information on the effect a change in engine power would have on the aircraft's nose pitch.

2.3.6 With a strong headwind and a long runway, there would not have been a danger of overshooting the runway. The AIBN therefore supports the Commander's decision to aim for a point some way onto the runway.

2.3.7 Everything considered, the AIBN believes that the pilots managed to perform their tasks well under very difficult conditions. Consequently, the AIBN believes the pilots deserved their IFALPA exceptional airmanship awards.

2.4 Air traffic control service

2.4.1 It is the AIBN's opinion that air traffic control provided good services in helping the pilots to avoid the most active precipitation cells based on the aids they had at their disposal.

2.4.2 When KAT603 was hit by lightning and the aircraft was no longer maintaining its assigned altitude, the air traffic control service was quick to ascertain that the crew were in a stress situation. The air traffic control service gave the crew necessary assistance in the form of regular tactical assessments relating to the approach, but did not overload them by interfering unnecessarily.

2.4.3 As soon as the crew declared an emergency, warnings were issued to all relevant parties.

2.4.4 The loss of power at the airport was brief and no problems were reported.

2.4.5 The Head of Air Traffic Control has stated that in his opinion the approach controller and tower controller coordinated well in a difficult situation. The AIBN supports this opinion.

2.4.6 The AIBN considers it a paradox that the Avinor have been and are involved in supporting the development and operation of weather radars in Norway, but do not themselves have the technology to use the data in the air traffic control service's radar displays. The AIBN believes that the present solution, whereby weather radar data is presented via the Internet with a delay of 15 minutes, is not satisfactory for air traffic control use. The AIBN also considers it essential that updated data on the position of powerful precipitation cells be shown directly on radar displays, to enable the air traffic control service to offer this information and to avoid radar vectoring aircraft into potentially hazardous flying conditions. The AIBN believes that technical solutions should be identified as soon as possible to allow radar displays used by the air traffic control service to show integrated information from the weather radars. A safety recommendation in this connection is being prepared.

2.5 Airport service

2.5.1 The AIBN has decided against conducting a more detailed investigation of the rescue work other than to communicate its impression that the airport service made a very good contribution. The teams were alerted well in advance of the aircraft's approach to the airport. The emergency services and equipment arrived quickly at the scene and made an active contribution.

2.5.2 The airport service made a good contribution by securing the aircraft after the crash, as the wind was very strong at times and there was a danger of the aircraft moving.

2.6 The lightning strike

2.6.1 Based on an altitude of 5,900 ft, the AIBN assumes that LN-HTA was hit by intra-cloud lightning. The AIBN also assumes that the aircraft was hit in the nose on the left-hand baggage door. Because of the damage in the crash, it has not been possible to rule out several points of impact, but it is not unlikely that the energy was distributed between the two observed points. The AIBN believes that the current followed these paths along the aircraft:

- From the aircraft's nose along the fuselage back to the tail. Then through the bondings from the fuselage, over to the horizontal tail surface and on through the bondings to the elevator's right side.

- From the aircraft's nose into the elevator rods in the cockpit area. This means that the current followed the elevator rod back along the aircraft and across to the right elevator.

2.6.2 It is not possible to determine whether the current followed these two paths in parallel or whether one pulse followed one path and a subsequent pulse used the other. However, AerotechTelub AB's calculations give reason to assume that the total amount of energy in the lightning exceeded the values in the model produced by EUROCAE WG31 (see section 1.6.4.2). There is no sign that the end of the elevator rod had not been sufficiently tightened or that insufficient threads in the adjustable end were in contact with the rod.

2.6.3 The lightning left the aircraft via the tip of the right elevator. The lightning presumably left via the outer static discharger initially. The sudden heat expansion inside the elevator tore the fabric and damaged the carbon fibre cover on the very outside of the elevator.

2.7 Bondings

2.7.1 There is reason to believe that the condition of the bondings was not satisfactory before the aircraft was hit by lightning. Tests conducted by the Armed Forces' laboratory services indicate that approximately 30% of the wires in the bonding marked as A may have been damaged before the aircraft was hit. In addition, examination of the bondings revealed considerable corrosion of the wires. This would have a negative effect on the mechanical properties and the conductivity of the bondings.

2.7.2 It is not possible to calculate the energy in the lightning which hit LN-HTA. Also, the condition of the bondings before the lightning strike cannot be established with any certainty. Consequently, it is not possible to calculate whether the end part of the elevator rod would have held had the aircraft been equipped with new bondings. However, there is reason to assume that the strength of the current passing through the elevator rod would have been reduced if the bondings had had better conductivity.

2.7.3 The maintenance requirements issued by Dornier Luftfahrt GmbH are not specific with regard to the condition of the aircraft's bondings. An aircraft techician must therefore apply generally accepted inspection criteria. These criteria require the technician to focus on good electrical contact between terminal and component, and inspect for secure mounting and termination corrosion. It is also important to ensure that the bondings do not come into conflict with movable components, so that unobstructed operation of the flight controls, for example, is not affected. Measuring a bonding's resistance gives a good picture of its conductivity for low currents, but does not indicate its capacity to conduct several hundred amperes of current. A splintered bonding with corroded wires may ostensibly be airworthy in accordance with key inspection parameters. Nevertheless, such a bonding may have considerably reduced capacity to conduct high currents.

2.7.4 The accident to LN-HTA has shown that the conductivity of the bondings was put to the test when the lightning struck. It is not possible to fit aircraft with bondings that are able to conduct all the currents from every single lightning strike. However, it is important to inspect the bondings regularly and replace corroded and splintered wires with new ones.

2.7.5 The AIBN has noted that the Norwegian Civil Aviation Authority has issued Airworthiness Directive (AD) no. 2003-085. This requires a one-off inspection of the aircraft type's bonding jumpers. This appears to have dealt with the necessary checking of the relevant bondings in the short term. However, the AD does not require any subsequent checks. See also the inspections recommended by Kato Airline's internal inquiry. It is the AIBN's opinion that maintenance of key components in connection with the capacity to withstand lightning should be considered as a separate item, which is not the case in AD 2003-085, and has therefore made a recommendation to this effect.

3. CONCLUSIONS

3.1 Findings

3.1.1 The aircraft

a) The aircraft was registered according to regulations and had a valid airworthiness certificate.

b) Nothing was discovered to indicate that the aircraft was not maintained in accordance with approved inspection procedures

c) Rod between the cockpit and elevator were not required to function as bondings

d) The transfer rod to the elevator was broken when the lightning travelled through the aircraft. This made it no longer possible to control the elevator

e) It was possible to use electric trim to control the aircraft's horizontal stabilizer and therefore, to a certain extent, the aircraft's pitch

f) According to the aircraft crew, the aircraft's weather radar did not indicate the precipitation cells. This is an indication that the weather radar was not functioning correctly.

3.1.2 The crew

a) The crew held the necessary rating certificates and had undergone mandatory periodic training/checks

b) The aircraft's weather radar was found in MAP mode and set at a range of 40 NM after the crash. This indicates that the crew had had insufficient training in the use of weather radar

c) The crew had not received training in flying with an inoperative elevator

d) The crew did not use emergency check lists

e) Crew cooperation was gradually affected by the fact that both pilots were at the limits of their mental capacity

f) Overall, the crew handled the situation which had arisen well

3.1.3 Air traffic control service

a) The air traffic control service was active in obtaining an overview of the areas which had strong precipitation cells and communicating this information to aircraft in the area

b) Ground weather radar was not available when the accident occurred.

3.1.4 Airport service

a) The rescue services were dispatched immediately and made an active contribution.

3.1.5 Weather conditions

a) There were a large number of strong precipitation cells in the area.

3.2 Significant investigation results

a) The air traffic control service did not have equipment for integrated weather presentation on the radar display

b) The aircraft's weather radar did not indicate precipitation cells and was therefore not functioning correctly

c) Up to 30% of the wires on individual bondings between the fuselage, horizontal stabilizer and elevator may have been broken before the lightning struck

d) The aircraft was hit by lightning containing a very large amount of energy. The aircraft's bondings were not able to conduct the electric energy from the lightning and the transfer rod from the cockpit to the elevator was broken

e) As a result of the reduced control of the aircraft's pitch and difficult wind conditions, the sink rate was not sufficiently stabilized on short final. The crew were unable to prevent the aircraft from hitting the ground.

4. SAFETY RECOMMENDATIONS

The following safety recommendations were made by the Accident Investigation Board[3]:

Safety Recommendation SL no. 2007/22T:

A functional airborne weather radar system and optimal use of such a system are important in localizing precipitation cells and thereby avoiding flying into areas with hazardous flying conditions. The AIBN recommends that the Norwegian Civil Aviation Authority and Kato Airline assess the best way of focusing on maintenance of airborne weather radars and training in their optimal use.

Safety Recommendation SL no. 2007/23T:

Presentation of weather on the air traffic control service's radar displays is important in avoiding aircraft being radar vectored into areas with hazardous flying conditions. The AIBN recommends that Avinor assess integrated presentation of information from weather radars on the air traffic control service's radar displays.

Safety Recommendation SL no. 2007/24T:

Up to 30% of the wires on individual bondings between the fuselage, horizontal stabilizer and elevator may have been broken before the lightning struck. For example, the maintenance requirements issued by Dornier Luftfahrt GmbH are not specific with regard to the condition of the aircraft's bondings. The AIBN therefore recommends that the Norwegian Civil Aviation Authority consider issuing additional maintenance requirements for aircraft type DO 228 with regard to the capacity to withstand lightning.

Accident Investigation Board Norway

Lillestrøm, 29 June 2007

[3] The Ministry of Transport and Communications forwards safety recommendations to the Norwegian Civil Aviation Authority and/or other involved ministries for evaluation and monitoring, see Norwegian Regulations regarding public investigations of accidents and incidents in civil aviation, § 17.

ABBREVIATIONS

AOC	Air Operator Certificate
AMK-sentral	Hospital Emergency Center
APP	Approach
ATPL (A)	Airline Transport Pilot License (Aeroplane)
CPL (A)	Commercial Pilot License (Aeroplane)
CVR	Cockpit Voice Recorder
DFDR	Digital Flight Data Recorder
DME	Distance Measuring Equipment
FAA	Federal Aviation Authority
FAR	Federal Aviation Requirements
FE	Flight Examiner
FI (A)	Flight Instructor (Aeroplane)
FDR	Flight Data Recorder
G	Gravity
GPS	Ground Positioning System
GPWS	Ground Proximity Warning System
hPa	Hectopascal
IAS	Indicated Air Speed
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IR (A)	Instrument Rating (Aeroplane)
ISA	Internasjonal Standard Atmosphere
JAA	Joint Aviation Authorities
JAR	Joint Aviation Requirements
JAR-FCL	Joint Aviation Requirements-Flight Crew Licensing
JAR-OPS	Joint Aviation Requirements-Operations
KIAS	Knots Indicated Airspeed
kt	knots
LDA	Landing Distance Available
LHT	Department of Aiport Services
LTT	Department of Air Traffic Control
MEP	Multi Engine Piston
METAR	Actual weather observations
MWO	Meteorological Watch Office

NATCON	Norwegian Air Traffic Control System
NM	Nautical Miles
NORDRAD	Nordic Weather Radar Network
NTSB	National Transportation Safety Board
OM	Operations Manual
PC	Proficiency Check
PSR	Primary Surveillance Radar
QNH	Altimeter setting, adjusted to show 0 when at sea level
RaADS	Radar and Automatic Dependence Surveillance
RWY	Runway
SEP	Single Engine Piston
SIGMET	Significant Weather
ST	Skill Test
STBY	Stand-by
TAF	Terminal Area Forecast
TAR	Terminal Area Radar
TWR	Tower
UTC	Co-ordinated Universal Time
VFR	Visual Flight Rules
VHF	Very High Frequency
V_{MC}	Minimum control speed
V_{ref}	Reference speed
V_s	Stalling speed
WX	Weatherr

Forsvarets laboratorietjeneste

FLO/LHK

Analytisk Laboratorium

Kjemi og materialteknologi

Teknisk Rapport

Oppdragsgiver	Oppdragsgivers referanse
HSLB v/	
Gjenpart	

Tittel

Undersøkelse av jordingskabler

Rapportnr	Ordrenr	Antall sider/vedlegg
040112.03		9
Dato for mottak av oppdrag	**Jobbnr**	**Dato for utgivelse**
2003-12-08	M-03-272	2004-01-27
Utført av		**Sjef VLA**
Overing I.M. Kulbotten Senioring Ø. Frigaard		Senioring T A Gustavsen

Sammendrag

FOLAT, kjemi og materialteknologi, mottok deler av jordingskabler etter lynnedslag. Det var ønskelig å fastlå hvorvidt kablene hadde røket som følge av lynnedslaget, eller om kablene hadde vært utsatt for mekanisk slitasje. Det ble utført fraktografi i SEM samt metallografiske undersøkelser.

I tillegg ble det utført forsøk for å se på mulige forløp ved overbelastning av lederne.

Konklusjon

På bakgrunn av utførte undersøkelser konkluderes følgende:

De mottatte jordingskablene har hatt redusert ledningsevne som følge av mekanisk slitasje (brukkne ledertråder) samt betydelige korrosjonsangrep.

Kablene har høyst sannsynlig røket som følge av overbelastning ved lynnedsalget. De observerte skadene er forenlig med observasjoner som ble gjort ved forsøk utført ved FOLAT/EMC og Kraftforsyningslaboratoriet.

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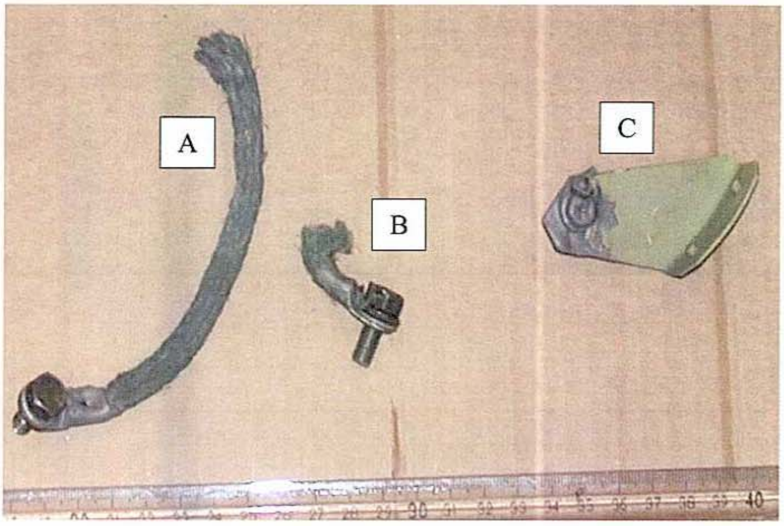
1 Innledning

FOLAT, kjemi og materialteknologi, mottok deler av jordingskabler etter lynnedslag. Det var ønskelig å fastlå hvorvidt kablene hadde røket som følge av lynnedslaget, eller om kablene hadde vært utsatt for mekanisk slitasje. Det ble utført fraktografi i SEM samt metallografiske undersøkelser.

I tillegg ble det utført forsøk for å se på mulige forløp ved overbelastning av lederne.

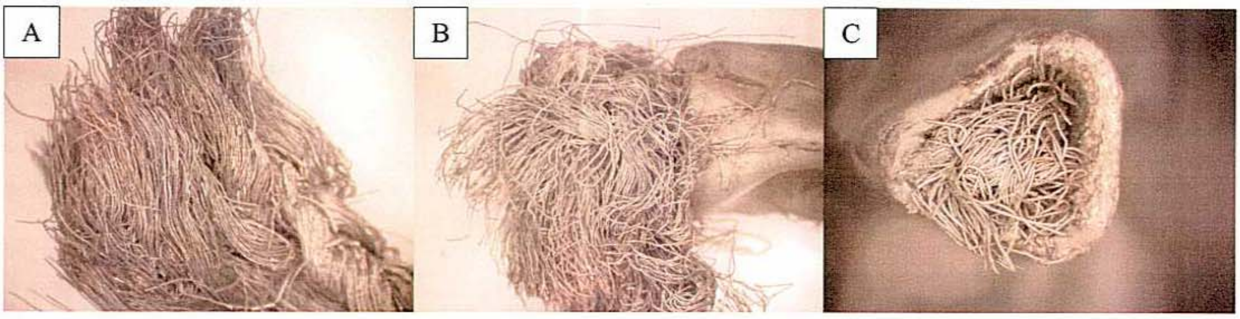


Figur 1 Oversiktsbilde av jordingskabler mottatt for undersøkelse, merket A, B og C.

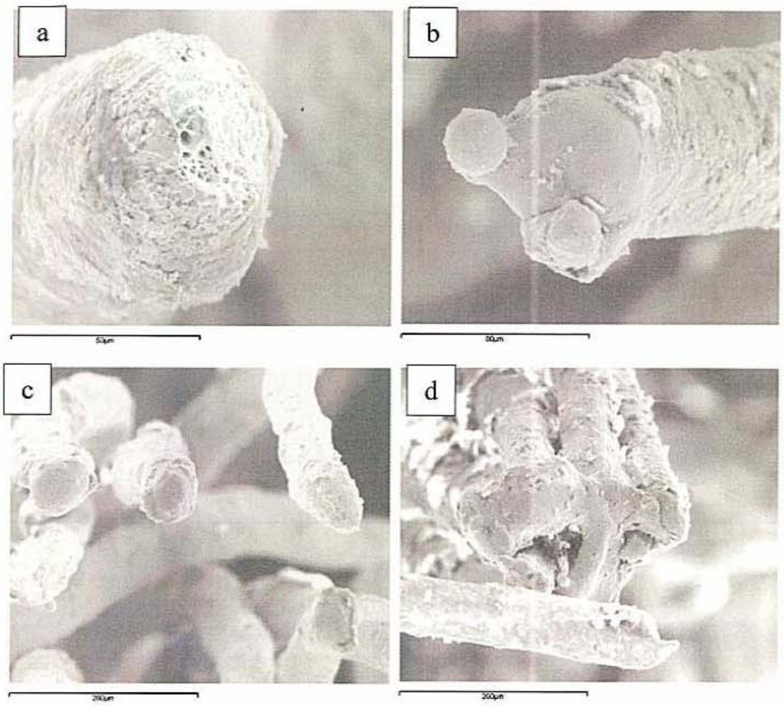
2 Fraktografi

Noen karakteristiske bilder av bruddflatene på de ulike kablene ref. Figur 1 og Figur 2 er vist hhv. i Figur 3, Figur 4 og Figur 5. Gjennomgående kunne trådene deles inn i fire hovedgrupper: tråder med dimpler i bruddoverflaten, tråder med glatt overflate med liten/ingen innsnevring mot bruddflaten, tråder med innsnevring uten åpenbare dimpler, og tråder med smelteperler. Det var kun mulig å observere åpenbar smelting av noen få tråder på kabel A, se bilde b og d i Figur 4.

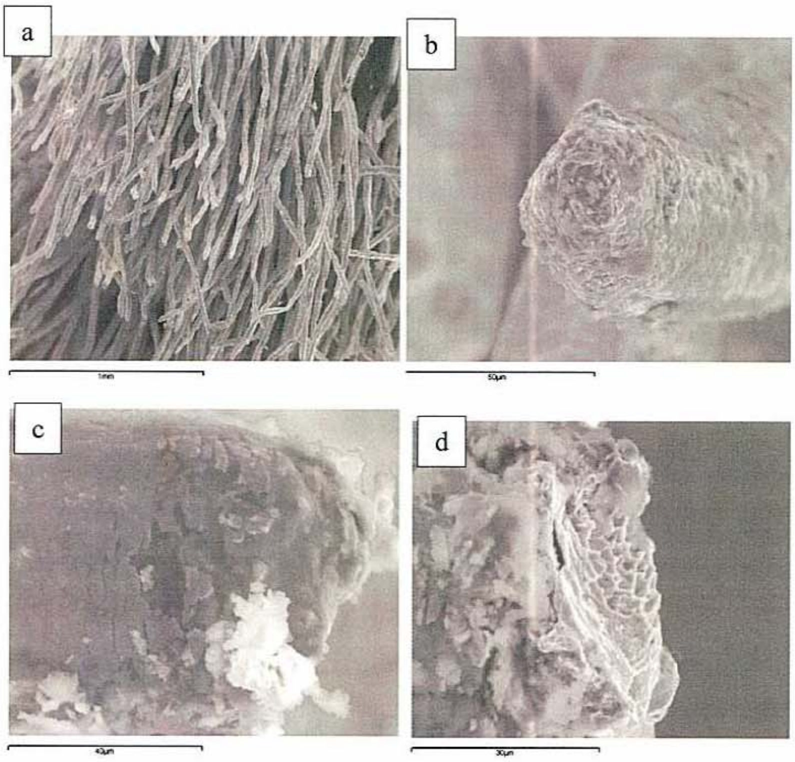
Det må også nevnes at fordi trådene var betydelig deformert, ref Figur 4a og Figur 5a var det vanskelig å få vurdert et tilstrekkelig antall bruddflater få å kunne gi en relevant statistisk vurdering av fordelingen til de ulike hovedgruppene.



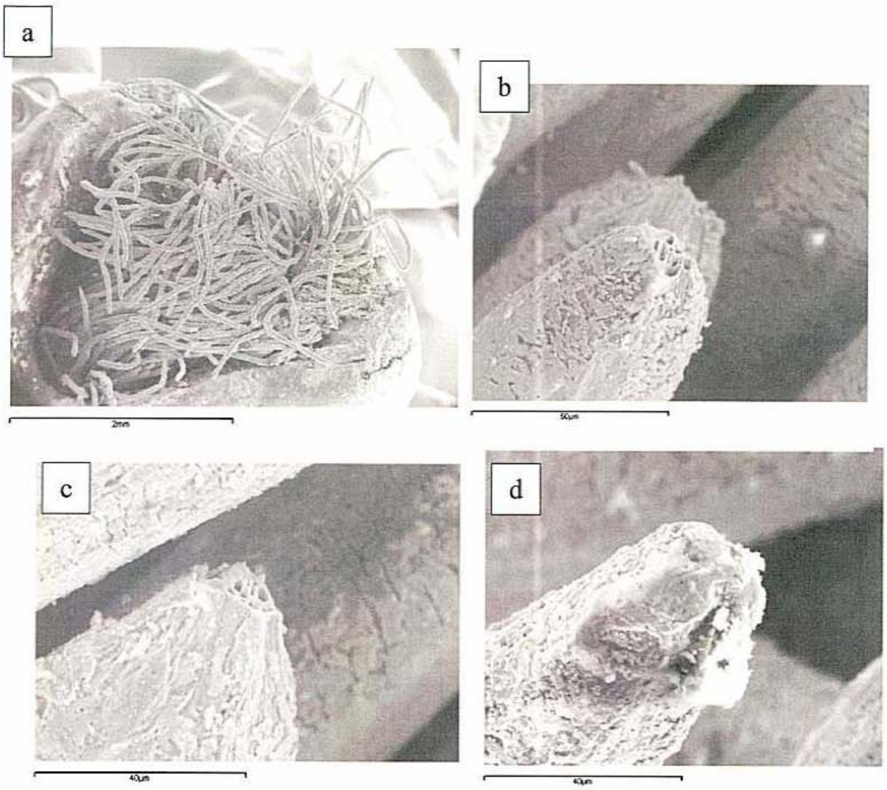
Figur 2 Bilder tatt i stereomikroskop av de ulike kablene vist i Figur 1 (merket tilsvarende).



Figur 3 a: Tråd med dimpler i bruddflaten, b: Tråd med smelteperler, c: Oversiktbilde av tråder med glatt overflate, d: Sammensmeltede tråder. (Leder i Figur 2A).



Figur 4 a: Oversiktsbilde av tråder, b: Tråd med innsnevring ut mot bruddflaten uten dimpler. b: tråd med glatt og oksidert bruddflate, d: tråd med dimpler i bruddflaten. (Leder i Figur 2B).

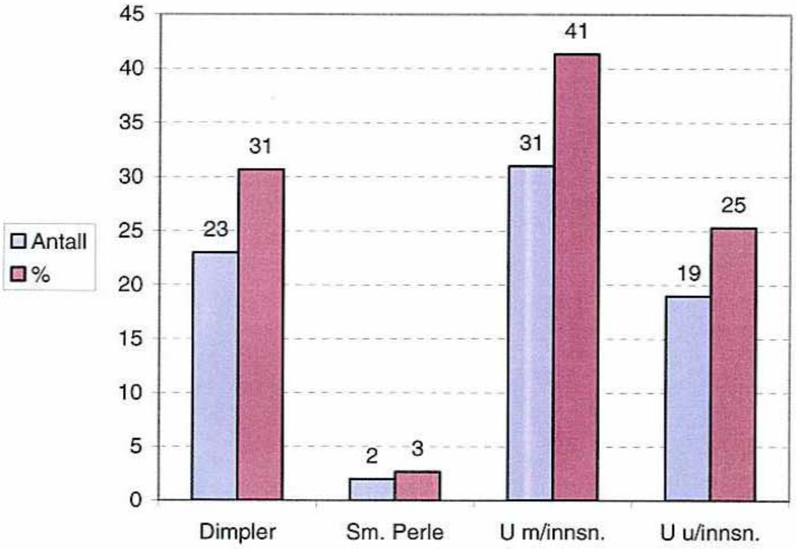


Figur 5 a: Oversiktsbilde av tråder, b: Tråd med dimpler i bruddflaten, c: Tråd med dimpler i bruddflaten, d: tråd med innsnevring ut mot bruddflaten uten dimpler. (Leder i Figur 2C).

Kabelen merket A i Figur 1 ble valgt for å forsøke å gi et anslag på hvordan fordelingen mellom de ulike brudd typene var. Kabelen ble flettet opp, og fire prøver ble tatt ut, vist i Figur 6. Totalt 75 tråder ble undersøkt og delt inn i fire grupper: Dimpler: bruddflater med dimpler, Sm.Perle: bruddflater med smelteperler, U m/innsn.: Uidentifisert bruddflate med innsnevring og U u/innsn.: Uidentifisert uten innsnevring.

Fordelingen er vist grafisk i Figur 7.

Figur 6 Oversiktsbilde av prøver tatt ut fra kabel merket A i Figur 1 for vurdering av bruddflater.

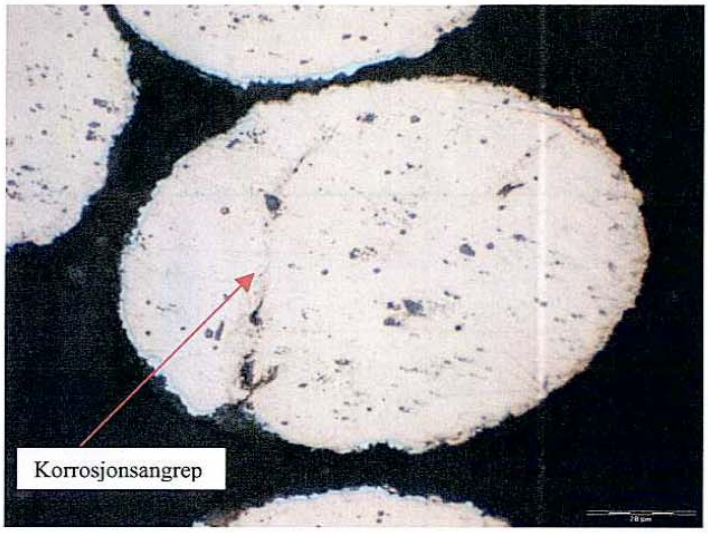


Figur 7 Grafisk presentasjon av fordeling (antall og prosentvis) av ulike bruddtyper. Totalt ble 75 tråder undersøkt.

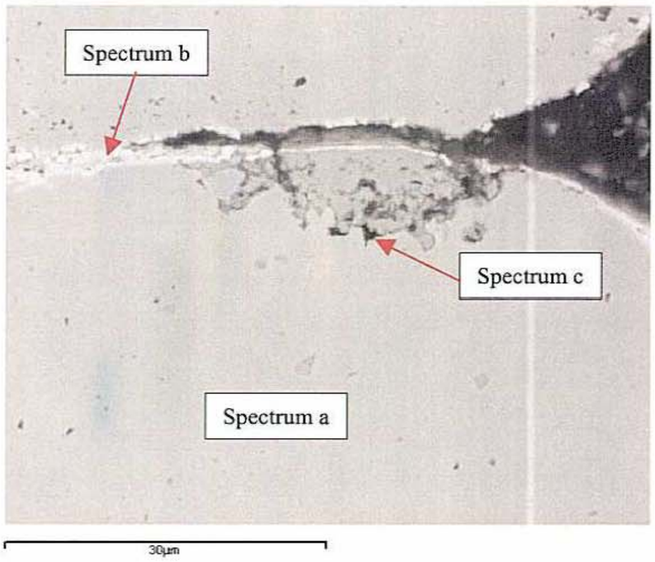
3 Metallografisk undersøkelse

For å få et bilde av trådenes beskaffenhet og oppbygning ble det laget tverrslipp gjennom tråder, disse ble undersøkt i lysmikroskop samt i SEM med EDS.

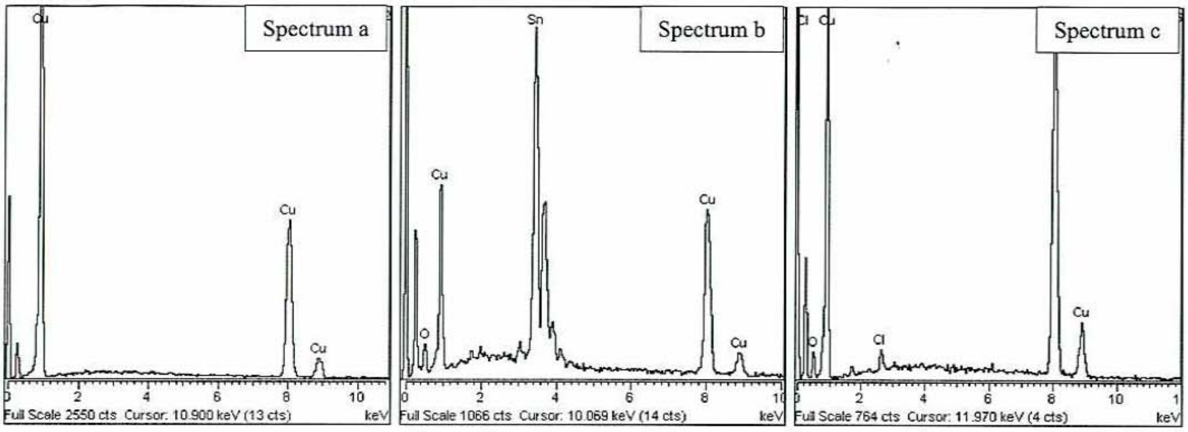
Figur 8 viser et bilde tatt i lysmikroskop gjennom et tverrsnitt av en tråd, bildet er representativt for lederne, og viser tydelig korrosjonsangrep. En tilsvarende tråd med tydelig pitting ble undersøkt med EDS i SEM, se hhv Figur 9 og Figur 10. Det fremgår av bildene at tråden består av rent kobber med et tynt tinnbelegg, spekteret fra roten av korrosjonsangrepet påviser klor.



Figur 8 Bilde av tverrslip gjennom en leder tråd med tydelig korrosjonsangrep.



Figur 9 Bilde av tverrslip gjennom tråd med korrosjonsangrep. Bildet er merket med områdene for EDS spektrene vist i Figur 10.



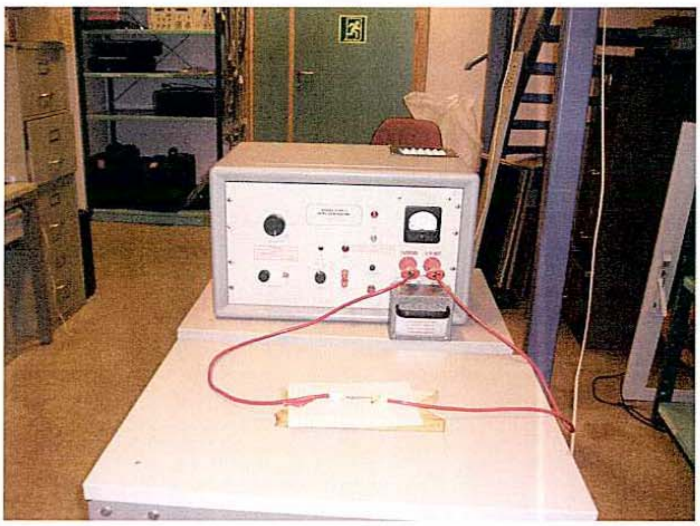
Figur 10 EDS spektre fra områdene avmerket i Figur 9. Spectrum a viser grunnmaterialet i tråden; kobber. Spectrum b viser belegg på tråden; tinn, Spectrum c viser forekomst av klor i korrosjonsgropen.

4 Avbrenningsforsøk

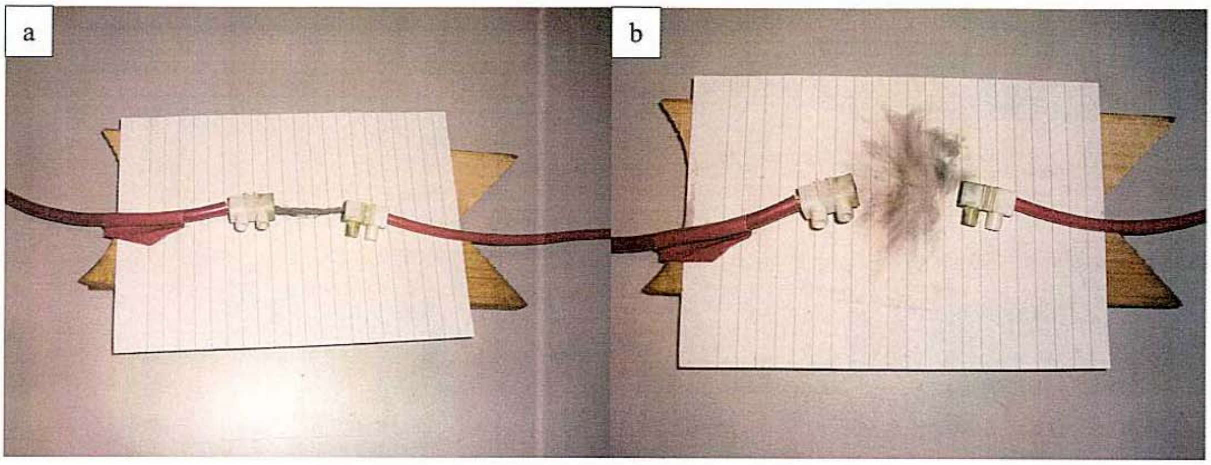
På grunn av stor usikkerhet angående forløpet ved overbelastning av lynavlederne, ble det utført forsøk der deler av lynavleder merket A i Figur 1 ble overbelastet som vist i Figur 11 og Figur 12. Forsøkene ble utført ved FOLAT/EMC og Kraftforsyningslaboratoriet av Overing. O.M. Øystad.

Lynavleder A (se Figur 1) ble flettet opp, og bunter med tråder ble utsatt for belastninger mellom 1500 og 2000 V. Forsøkene avdekket to forløp: i enkelte tilfeller ble lederen svidd av og delt i to, i de fleste tilfellene ble lederen pulverisert som vist i Figur 12b.

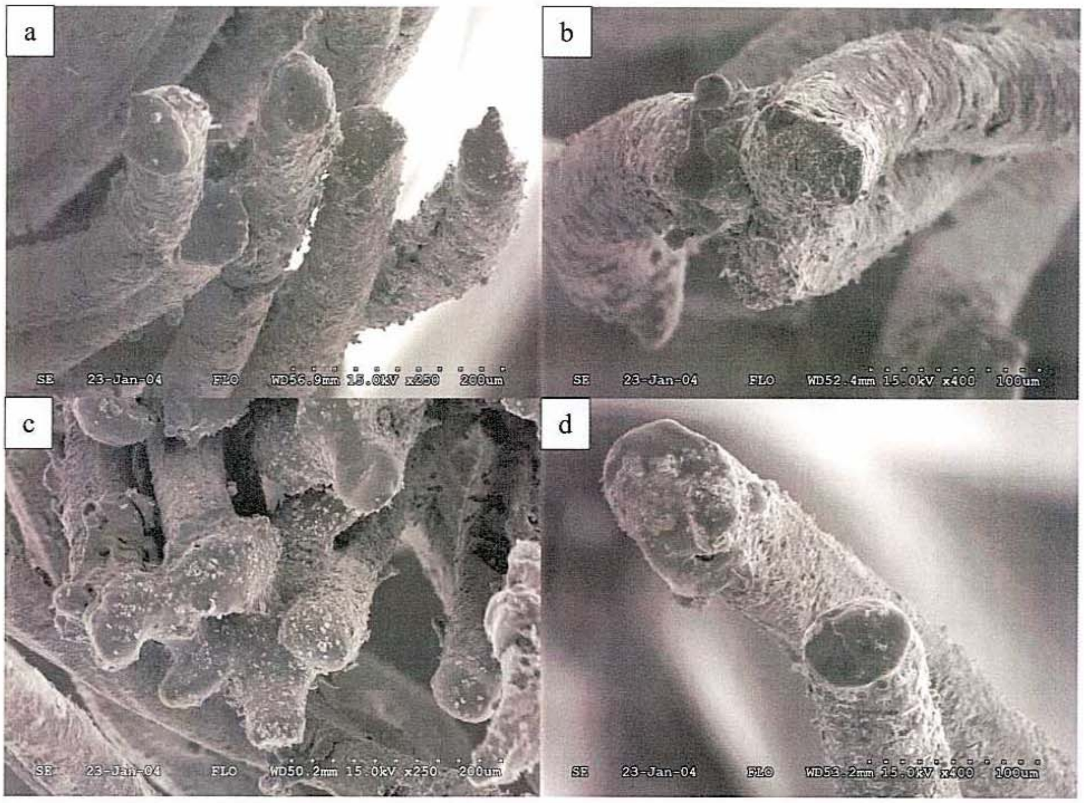
Bruddflaten på to prøver der trådene ble svidd av ble undersøkt i SEM for sammenlikning med resultatene fra lederne undersøkt tidligere. Representative bilder av trådene er vist i Figur 13. Resultatene viser en noe større tendens til sammensmelting sammenliknet med observasjonene ovenfor, det kunne heller ikke observeres bruddflater med dimpler.



Figur 11 Oversiktsbilde av forsøksoppsett (Spike Generator "model 7399-2").



Figur 12 Oversiktsbilde av tråd før og etter belasting ved 2000V.



Figur 13a-d Representative bilder i SEM av tråder etter avbrenningsforsøk, belastning 2000V.

5 Diskusjon

På bakgrunn av de utførte undersøkelsene er det åpenbart at det kan stilles spørsmål ved jordingskablenes beskaffenhet. De metallografiske slipene viser betydelig korrosjonsangrep, i tillegg er det påvist klor sammen med korrosjonsproduktene hvilket viser at jordingskablene har vært utsatt for et korrosivt miljø. Undersøkelse i SEM påviser også flere bruddflater med dimpler hvilket er forenlig med mekanisk slitasje. Det må her nevnes at den observerte korrosjonen vil påvirke både ledningsevne samt mekaniske egenskaper til trådene.

Når det gjelder sprøsmålet om i hvor stor grad lederne var avslitt før lynnedslaget så er det vår vurdering at inntil 30% av trådene kan ha vært brukkne før nedslaget for jordingskabel merket A i Figur 1. Dette på bakgrunn av det store antall bruddflater med dimpler og tråder med innsnevring.

I forhold til kablene merket B og C så er det vanskelig å gi et tilsvarende anslag da det viste seg å være begrensende muligheter i å få et tilstrekkelig statistisk grunnlag.

Forsøkene utført ved FOLAT/EMC og Kraftforsyningslaboratoriet påviser et skadeforløp forenlig med de observasjoner som er gjort på de mottatte jordingskablene. Der lederne har enten blitt svidd av eller pulverisert. I de tilfellene der kabelen var svidd av kunne det observeres kobberfarge på deler av lederne, trolig på grunn av smelting av det ytre tinnbelegget som har et betydelig lavere smeltepunkt sammenliknet med kobber, hhv. 232 og 1083°C. Tilsvarende observasjoner kunne gjøres på de mottatte kablene, se Figur 2, hvilket indikerer at disse også er blitt brent av.

I forhold til tendensen til sammensmelting av ledertrådene ved avbrenning så vil dette avhenge av avkjølingsforholdene rundt lederne. Det må derfor avklares i hvor stor grad lederne utsettes for luftstrømmer før relevansen i forhold til forsøkene vurderes.

6 Konklusjon

På bakgrunn av utførte undersøkelser konkluderes følgende:

De mottatte jordingskablene har hatt redusert ledningsevne som følge av mekanisk slitasje (brukkne ledertråder) samt betydelige korrosjonsangrep.

Kablene har høyst sannsynlig røket som følge av elektrisk-overbelastning ved lynnedsalget. De observerte skadene er forenlig med observasjoner som ble gjort ved forsøk utført ved FOLAT/EMC og Kraftforsyningslaboratoriet.